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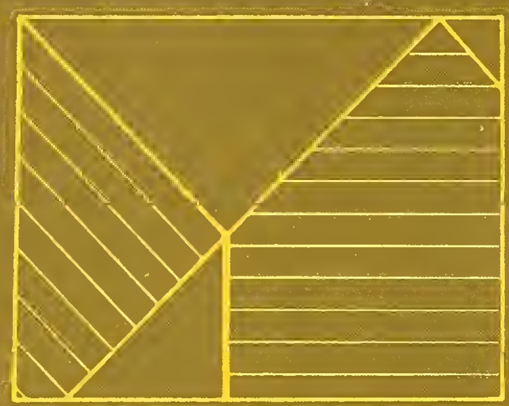

Research and Innovation in the Building Regulatory Process

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards[1] was established by an act of Congress March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau consists of the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Institute for Computer Sciences and Technology, the Office for Information Programs, and the Office of Experimental Technology Incentives Program.

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Office of Standard Reference Data — Office of Information Activities — Office of Technical Publications — Library — Office of International Standards — Office of International Relations.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.

[2] Located at Boulder, Colorado 80302.

Research and Innovation in the Building Regulatory Process

Proceedings of the First
NBS/NCSBCS Joint Conference

Held in Providence, Rhode Island
on September 21-22, 1976, in conjunction
with the Ninth Annual Meeting of the
National Conference of States on Building
Codes and Standards (NCSBCS), Inc.

Patrick W. Cooke, Editor

Office of Building Standards and Codes Services
Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
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PREFACE

The National Conference of States on Building Codes and Standards (NCSBCS) and the National Bureau of Standards worked together to conduct the first major national Conference on research and innovation in the building regulatory process. The conference was held on September 21-22, 1976, in conjunction with the Ninth Annual Meeting of NCSBCS in Providence, Rhode Island.

The purpose of the conference was to provide a forum for a variety of different researchers from industry, universities, and governments to review what is known so as to assist in the establishment of a systematic understanding of the Nation's building regulatory processes and for building officials and administrators to obtain information of innovative practices among building regulatory agencies. The conference was an occasion for the building community and the research community to better acquaint themselves with the entire field of building regulatory research particularly as it is practiced in a variety of settings. It is hoped that through the interaction between meaningful research findings and practical application of innovations, significant understanding and improved effectiveness of the building regulatory process through public policy will evolve.

The Proceedings represent the twenty-six papers presented at the various technical sessions and include the opening remarks and Keynote Address as well as a summary of a panel discussion on the future of building regulatory research. The program for the conduct of the Conference corresponds to the Table of Contents of these Proceedings.

ACKNOWLEDGEMENTS

The editor gratefully acknowledges the cooperation and assistance of the following NCSBCS State Delegates and members of the NBS Staff who served as moderators for the technical sessions.

NCSBCS Delegates

Mr. Charles J. Dinezio (Massachusetts)
Mr. James M. Hicks, Jr. (California)
Mr. Trevor Jacobson (Oregon)
Mr. C. Sutton Mullen (Virginia)

NBS Staff

Dr. Francis T. Ventre, Scientific Assistant to the Director, Institute for Applied Technology
Mr. Robert J. Kapsch, Office of Building Standards and Codes Services
Mr. Charles T. Mahaffey, Office of Building Standards and Codes Services
Mr. James H. Pielert, Office of Building Standards and Codes Services

Also assisting in the successful conduct of the Conference and the publication of the Proceedings were Ms. Sandra A. Berry and Mr. Robert M. Eisenhard of the NBS Office of Building Standards and Codes Services.

CONTENTS

SI Conversion Units

In view of present accepted practice in this technological area, U.S. customary units of measurements have been used throughout this report. It should be noted that the U.S. is a signatory to the General Conference on Weights and Measures which gave official status to the metric SI system of units in 1960. Conversion factors for units in this report are:

	Customary Unit	International (SI), UNIT	Conversion Approximate
Length	inch (in)	meter (m)[a]	1 in=0.0254m*
	foot (ft)	meter (m)	1 ft=0.3048m*
Force	pound (lbf)	newton (N)	1 lbf=4.448N
	kilogram (kgf)	newton (N)	1 kgf=9.807N
Pressure Stress	pound per square inch (psi)	newton/meter^2	1 psi=6895N/m^2
	Kip per square inch (ksi)	newton/meter^2	1 ksi=6895x10^{6}N/m^2
Energy	inch-pound (in-lbf)	joule (J)	1 in-lbf=0.1130 J
	foot-pound (ft-lbf)	joule (J)	1 ft-lbf=1.3558 J
Torque or Bending Moment	pound-inch (lbf-in)	newton-meter (N-m)	1 lbf-in=0.1130 N-m
	pound-foot (lbf-ft)	newton-meter (N-m)	1 lbf-ft=1.3558 N-m
Weight or Mass	pound (lbf)	kilogram (kg)	1 lb=0.4536 kg
Unit Weight	pound per cubic foot (pcf)	kilogram per cubic meter (kg/m^3)	1 pcf=16.018 kg/m^3
Velocity	foot per second (ft/sec)	meter per second (m/s)	1 fps=0.3048 m/s
Acceleration	foot per second per second (ft/sec^2)	meter per second per second (m/s^2)	1 ft/sec^2=0.3048 m/s^2

[a]Meter may be subdivided. A centimeter (cm) is 1/100 m and a millimeter (mm) is 1/1000 m.

*Exact

ABSTRACT

The First NBS/NCSBCS Joint Conference on Research and Innovation in the Building Regulatory Process was held in Providence, Rhode Island on September 21-22, 1976. The proceedings of the Joint Conference include the opening remarks, the Keynote Address, the technical papers presented at each session, and a summary of a panel discussion on the future of building regulatory research. The subject matter covered in the papers includes -

- New Alternatives, Environmental Research and the Building Regulatory Process
- Energy Conservation, Solar Energy and Building Standards
- Coping with Building Innovations and Environmental Considerations
- Issues in Building Regulation and Administration
- Organization and Structure of Building Regulations
- Information Processing and the Building Regulatory Process
- Impact, Economics and Metrication of Building Regulation
- Preservation, Rehabilitation and the Building Regulatory Process

Key Words: Administrative procedures; buildings; building codes; building regulations; economic impacts; environmental considerations; innovative practices; regulatory research; standards development.

OPENING REMARKS

by

Glen R. Swenson
President of NCSBCS, Inc.

President Swenson opened the session by welcoming attendees to the NBS/NCSBCS Joint Conference on Research and Innovation in the Building Regulatory Process.

Most of you here are familiar with the relationship of mutual support and cooperation between the National Conference of States on Building Codes and Standards (NCSBCS) and the National Bureau of Standards (NBS).

Since the inception of NCSBCS in 1967, NBS has proven to be a tower of strength and has been a great help.

In the last few years, it is fair to say much credit should be given to Mr. James G. Gross and the excellent staff of the National Bureau of Standards for the elimination of concerns that existed at one time, and for the development of a compatible and harmonious relationship between the two organizations.

Recently, there was a development which created another organization which, in my opinion, is a natural ally of NCSBCS, and which is deserving of complete NCSBCS support. I say this because, as you know, NCSBCS has among its goals and objectives the promotion of voluntary cooperation among all those involved in the building regulatory process.

This is a very compatible goal insofar as this new organization is concerned. I am not introducing the keynote speaker -- I am introducing Mr. James G. Gross.

One of the reasons that Jim Gross has been able to work so effectively with NCSBCS and others is the fact that Jim came to the Federal Government from the private sector and he understands the problems which we all face from both sides of the fence.

Mr. Gross' history includes working with many organizations in the private sector. Prior to joining NBS in May 1971, Mr. Gross was Director of Engineering and Research for Precast Systems, Inc. Prior to that he served as Director of Engineering and Technology for the Structural Clay Products Institute.

Since joining NBS, Mr. Gross was Chief of the Office of Housing Technology and now has served for two years as Chief of the Office of Building Standards and Codes Services. He earned a degree as an architectural engineer and is a registered professional engineer.

I hope by the time this week is over, I have the opportunity to express our gratitude to Jim Gross for what he has done and for the work done by the excellent staff of NBS.

For now, it will suffice to say we are pleased to cooperate with NBS in sponsoring this Joint Conference.

INTRODUCTION TO NBS/NCSBCS JOINT CONFERENCE

by

James G. Gross, Chief
Office of Building Standards
and Codes Services

Thank you President Swenson.

It is a pleasure for me to introduce this joint NBS/NCSBCS conference, which I anticipate will be a rewarding experience for each of us.

This conference is the outgrowth of "Innovations in Building Regulatory Agency Management and Procedures," a workshop held in Santa Fe, New Mexico, in conjunction with the NCSBCS 8th Annual Meeting. This first workshop had only six speakers. It was the brainchild of Francis Ventre, who was Assistant Chief of the Office of Building Standards and Codes Services at that time. Dr. Ventre will be the moderator for the panel discussion this evening.

I also want to recognize Pat Cooke, Program Manager for Research and Technical Studies in the Office of Building Standards and Codes Services. Pat has provided the leadership and much of the leg work in putting this conference together.

The building regulatory process of the United States is under attack by consumers, the public and Congress. The U.S. has limited information on the workings and effectiveness of the building regulatory process and we have a variety of approaches to building regulation.

We have statewide and local programs based on model codes--programs based on State-developed codes and local efforts based on locally-developed codes and regulations. Under each of these approaches, out-of-date and up-to-date building codes are used, upon which the regulatory process depends.

While we have a variety of programs, we have very little information on the costs and benefits of such programs and their overall effectiveness. Added to the problems of nonuniformity of regulations, we have jurisdictions where enforcement is well carried out and other jurisdictions where there are no enforcement efforts.

Let us, for a minute, consider the case of an owner of a new single-family dwelling. There are large areas in the United States where there are no building regulations applied or enforced which are applicable to these dwellings. There are other areas where regulations of single-family dwellings are rigorously enforced. Do the people living in areas where regulations exist and are enforced benefit more than those people living in areas where there are no regulations or where the regulations are not enforced? Where there are no regulations, do the people benefit because they do not have to bear the cost of regulation; or, in areas where there are enforced regulations, do the people benefit because of improved life safety, health, or other improved performance attributes? We simply do not know the answers to these questions.

We, in the United States of America, lack a system of building regulation. Today's conference program uses the word "processes." This is probably an apt descript--certainly we do not have a building regulatory system, in the strict sense, in that the processes used in the United States lack the system characteristics of compatibility, harmony, and the fitting of the various parts and processes.

Nevertheless, it is my view that the building official and his Bible--the building code--are unjustifiably maligned and are unfairly blamed for many of the social and economic problems of the country, even when the problems do not emanate from the quality of buildings which serve the Nation's citizens. Also, I want to point out, on the positive side, that U.S. citizens enjoy better housing at a lower relative cost than do the people of most, if not all, other nations.

Building regulatory knowledge and understanding is a pressing national need. An understanding of both the need for regulation and the products and processes in place is required in order to improve and develop an effective building regulatory system. It is to this end that this conference is dedicated.

The objectives of this conference relate to the sharing of solutions to problems of building regulatory administration and to identification of needs in order to stimulate research and innovation which is required to fill the gaps. I am impressed by the breadth of the subject matter to be shared. For example, we have process research, including innovations with computers and other aids, environmental research and regulations, opportunities of metric conversion, rehabilitation, standards' needs, energy conservation, costs, and regulatory administration.

Let me share some thoughts that I have in regard to trends in the regulatory field!

- Individual States are assuming greater responsibility and authority for building regulation as is provided for by the Constitution of the United States under the police power of individual States. Over twenty States have statewide regulatory programs, and a number of additional States have studies underway to determine the possible desirability of statewide programs.

- There is an increasing reliance of model building codes, with only a few States now preparing a statewide code that is not patterned after one of the major model codes.

- Model codes themselves are becoming harmonious! Work of the Model Codes Standardization Council (MCSC) on uniform format, definitions, types, and classes of construction contributes to uniformity and encourages reciprocity between regulatory jurisdictions. The Board for the Coordination of the Model Codes (BCMC) has been developing and studying recommendations on the technical content of the model codes, including egress, energy, and fire resistance, in order to develop uniform technical requirements.

- Through the NCSBCS organization, there is a movement toward reciprocity between States. An example is the acceptance of the One- and Two-Family Dwelling Code, which is widely used as a basis for reciprocity in industrialized housing.

- Education and training programs for professionalizing the building official are being developed by the National Academy of Code Administration (NACA).

- Federal involvement in building regulation is increasing; e.g., the mandatory national mobile homes standard and its enforcement by the Department of Housing and Urban Development, and recent legislation requiring the development of national performance standards for energy conservation.

- Increasing interest in standards and regulations based on the performance concept.

- The development and application of the voluntary conversion to the metric system of measurement. This will offer an opportunity for rationalization, increased uniformity, and general improvement of building standards and codes.

One of the most recent and important developments in the regulatory area is the establishment of the National Institute of Building Sciences (NIBS).

I now want to introduce the Chairman of the NIBS Board of Directors, Mr. Otis Mader, to give us a progress report. Mr. Mader is Vice President of Alcoa. A 1940 architectural graduate of Ohio State University, he entered the U.S. Navy Reserve with ship construction duties and attained the rank of lieutenant commander. He joined Alcoa's sales development division in 1946 and became head of the architectural section in 1947. In 1951, Mr. Mader was named assistant manger of architectural sales. Three years later, he became affiliated with The Stolle Corporation, Sidney, Ohio, as vice president in charge of automotive and architectural sales. Returning to Alcoa in 1961 as manager of building products sales, he became manager of product development (1964), president of Alcoa Building Products, Inc. (1966), and president of Alcoa Properties, Inc., a subsidiary which manages Alcoa's nationwide real estate developments, in 1969. In 1970, he became president of Alcoa Building Industries, a new division of Alcoa designed to consolidate management and planning of all Alcoa's activities in real estate, building products, land development, construction and housing. The same year, he was elected an Alcoa vice president and continued as president of Aloca Building Industries until taking over corporate marketing responsibilities in 1974. Mr. Mader is a director of the Producers' Council and a member of the Producers' Advisory Committee, the Building Research Advisory Board and the Advisory Committee of the Center for Building Technology in the National Bureau of Standards. He also is chairman of the Producers' Advisory Board of the Joint Center for Urban Studies, at MIT/Harvard. In April 1976, Mr. Mader was nominated by President Ford to serve as the first chairman and organizer of the National Institute of Building Sciences, a nongovernmental activity authorized by Congress to devote its efforts to technological progress and an improved sense of order in the field of building codes and standards.

KEYNOTE ADDRESS

The National Institute of Building Sciences--A Progress Report

by

Otis M. Mader
Chairman of the Board of Directors
National Institute of Building Sciences

Before I begin I want to tell you that I am not singly representing NIBS today. Other members of the National Institute of Building Sciences (NIBS) Board of Directors are present. They are Jasper Hawkins, Joseph Newman, Bob Schmitt and Glen R. Swenson.

More formally I can start my presentation.

Ladies and gentlemen of NCSBCS, BOCA, NACA, SBCC, HUD, CABO and other alphabeted organizations, I represent the National Institute of Building Sciences, NIBS, still another addition to the world of title abbreviations.

I want to speak to you today on EOPO - "Eternal Optimism Pays Off."

In 1969 I felt that the National Institute of Building Sciences would probably come formally into existence in 1971. But, of course, it didn't. So in 1971, I was sure that Congressman Moorhead and Senator Javits would be able to make it happen in 1973. Wrong again. Finally, with 1974 legislation enacted to create NIBS I was convinced that wrapping up the details and putting NIBS into existence would only be a matter of months. It was - about 20 of them.

Such a track record and timing was enough to turn a man to pessimism, even me. And I must admit that my confidence in the eventual success of NIBS was severely shaken when I learned who the White House had nominated as the first Chairman.

Fortunately, my optimism was resuscitated when I reviewed the list of Directors the White House nominated to serve with me. And believe me, when I called them together for the first time, my optimism reached new heights. I found them broadly representative of the whole building community, totally committed to the concept of NIBS, highly competent in their specific areas of involvement in the building community, and most important, completely unselfish in the time they are willing to devote to launching NIBS on a sound and meaningful course. I just hope that I can keep up with them. They travel fast.

So NIBS has finally been born. There has been strong support as you know from the building community for NIBS all along the seven-year path of creation. Understandably, there is today a healthy impatience in that community to see NIBS describe its role and "have at it." There is also, at this early time, divergency of understanding of the mission of NIBS - and that divergency has undoubtedly created concerns in some groups as to what NIBS is going to do for them. Indeed some groups may be concerned as to whether NIBS may do something to them. I can say today that NIBS is basically interested in doing something with the various sectors of the building community.

The Directors of NIBS and I share the impatience; and being totally normal, we find divergent opinions among ourselves on describing our mission and organizing to fulfill that mission. So we are determined to subvert our own impatience to the strong concern of carefully and thoughtfully deciding who we are and what we are - and indeed what we are not. The whole building community must have input to those decisions and that means we will have to take time for appropriate communication. We are not only going to learn to walk before we learn to run, we are determined to learn to crawl before trying to walk.

My mission today as I understand from Glen is to review briefly for you the history of NIBS and then to tell you how we are doing in our crawling lessons.

A little history might help. In the late 1960's the Douglas Commission was appointed to study urban problems within broad parameters and also to deal with certain specifics - one of which was to investigate whether the then existing proliferation and divergence of building codes and standards was a restraint to development and utilization of new technology that might improve the building process.

In brief, the Commission reported that the building community was highly populated, economically vital to the nation, but also highly fragmented. Similarly, over 8000 Federal, State and local code administering authorities existed, and there was substantial non-uniformity between them, as well as a lack of a system in existence to permit constant updating of codes and standards. The situation was believed to be a restraint to technological progress. The Commission recommended creation of a National Institute that could lead, encourage, and assist the building community to develop, understand, accept, and implement new building technologies.

Most segments of the building community supported the need for such an activity, but only if it could be accomplished without moving toward Federal codes, standards and regulations for private construction.

Congressman Bill Moorhead and Senator Jacob Javits authorized bills that would create a "non-governmental" National Institute of Building Standards and then through a long frustrating period, the bills were delayed, tabled, returned to Committee, and caught by adjournments. Finally, a modified version creating a non-governmental National Institute of Building Sciences (certainly a broader title) was included as part of the 1974 Housing Act and became law with the President's signature.

The White House at that time requested HUD to develop recommended nominees to the Board of Directors of NIBS, and HUD in turn petitioned the National Academy of Science to screen and to submit substantial lists of people whose capabilities might be of interest to HUD for recommendation to the White House.

The burdensome process culminated with announcement of the White House nominees in May of this year. Senate confirmation under Senator Proxmire's Committee hearings were held in June, and the swearing-in ceremony was conducted July 9. There was a unique question as to whether the Directors should be sworn in since NIBS was to be a non-governmental institute. However, since Federal "seed money" would be received by NIBS at its outset, it was decided that the Directors should be sworn to office. Another sign that in this life, philosophy often has to defer to the fiscal responsibility of the situation!

Some of you have perhaps read those portions of the 1974 Housing Act that relate to authorizing NIBS. For those of you who have not, let me warn you that legislative prose is not known for its ability to excite or to enthrall!

Let me give you my Layman's interpretation of the basics of the Act that created NIBS.

In the Act, Congress deplores the lack of an authoritative national source for collecting, evaluating and disseminating advisory information on building science and technology that is related to achieving nationally-acceptable or nationally-compatible standards in the building industry. It sees that lack as an obstacle to technological and economic improvement of the building process with time.

The Act recognizes the contributions toward uniformity made by the model codes, but also acknowledges the problem of keeping those model codes technologically updated.

The Act proposes the National Institute of Building Sciences as the "single authoritative nationally recognized institution to provide for the evaluation of new technology and to facilitate introduction of such innovations and their acceptance at the Federal, State and local levels."

Please understand that the term "authoritative" in the Act is in no way used in a regulatory sense. "Authoritative" describes the image of NIBS when, by the demonstration of its competence, it has gained the confidence and participation of the clients it serves - which is the overall building community. That means the builders, the developers and the construction managers - the architects and the engineers - the lenders - the product manufacturers and the building trades of labor - the public officials administering codes and standards, Federal, State and local. And, finally, it also means the consumer, and he could be anyone from a homeowner to the Federal Government.

The legislation does not propose that NIBS shall organize and staff to become technologically all things to all people. In fact, it specifically directs NIBS to encourage and to utilize the capabilities of existing private and public entities that are currently engaged in building research and technological activities across the country.

The Academies - Research Council -- National Academy of Sciences - National Academy of Engineering - National Research Council --is named as an advisor along with other such knowledgeable organizations to assist during the start-up period of NIBS.

Organizationally there can be 15 to 21 Directors initially appointed by the President with a majority to be appointed as members in the public interest, Architects and engineers, public officials and consumer groups are considered as members in the public interest. Currently we have eighteen Directors with nine being public interest appointees. It is my understanding that the White House intends to fill the remaining three vacancies with public interest members placing the majority at 12 to 9. Frankly, I intend my own participation to be in the public interest as much as any other member, but technically I don't qualify by Congressional specifications.

The first chairman is appointed by the President and serves for one year from date of incorporation. Thereafter, he is elected by the Board of Directors as are all other officers.

The Board of Directors will at an early date be served by a full-time paid staff headed by a President reporting to the Board. The paid staff will contain the administrative, technological, and professional competence to carry on the day-to-day activities of NIBS within the policies and programs outlined by the Board of Directors.

So far, then, we have a working board and as I have described we will soon have a full-time central staff. Joe Newman heads the committee to search out candidates for President. But if NIBS is meant to serve the building community, it must have constant access to the input and advice from all sectors of the building community which, as you know, is highly populated but loosely knit. The communication device in the NIBS organization which will link NIBS to the building community is known as the Consultative Council.

While I earlier threw a few darts at legislative language, in the case of the Consultative Council, I feel the language is clear and concise so let me read directly from the Act:

> "The Institute shall establish - with the advice and assistance of the Academies-Research Council and other agencies and organizations which are knowledgeable in the field of building technology - a Consultative Council, membership in which shall be available to representatives of all appropriate private trade, professional, and labor organizations; private and public standards, code, and testing bodies; public regulatory

agencies; and consumer groups so as to insure a direct line of communication between such groups and the Institute and a vehicle for representative hearings on matters before the Institute."

When the Council is organized we will have the overall "non-governmental" organization as Congress visualized it. The Board of Directors, representative of the public and private building community, at the top to set NIBS policies and programs - the paid staff which will report to the Board, to organize and carry out the programs - and the Consultative Council to serve both the staff and the Board as a vast resource of technological advice and know-how and as a communication network to speed the effective utilization of new technology.

The task for NIBS has always seemed enormous to me but not all impracticable. I do not feel, however, that the enormity automatically requires the growth of a huge organization. To the contrary, I think NIBS needs to adopt a rigid principle of demonstrating how much can be done with little. Many of us criticize bureaucratic growth as inefficient and costly. If we really believe that a non-governmental activity can avoid it, NIBS is an opportunity to make that point in spades. I think the Board of Directors shares this attitude with me.

To some degree, Congress addressed that point by directing that NIBS should accomplish its responsibilities by assigning and delegating tasks and activities to the maximum extent practicable to existing organizations in the community with the technical competence to make meaningful contributions.

Now let me quickly review for you where the NIBS Board is today in our efforts to define who we are and what we are. The Board held a two-day orientation meeting concurrent with the swearing-in ceremony to get a fast start. Shortly thereafter seven basic committee groups were established to examine and to recommend to the Board policy positions in critical areas of the organizing process. These assignments were mission, staff activities, budget, liaison, incorporation, data collection and dissemination, and formation of the Consultative Council.

At its first meeting the Board decided to meet monthly into 1977 until NIBS was effectively on stream and operating. To date we have held three such meetings plus appropriate Committee meetings necessary to feed times for decision to the Board of Directors meetings.

In some areas we are moving rapidly. As of September 8 we are chartered as a non-profit corporation in Washington, D.C. appropriately equipped with articles of incorporation and bylaws. We have established temporary quarters in the Joseph Henry Building in Washington, D.C. and we have a phone number and letterhead to prove we are in business. We have established the specifications for the experience and competence we need for the full-time paid staff. We are now filtering through the building community to search out appropriate candidates.

We are now operating on a temporary budget funded by a $140,000 grant from HUD which will sustain NIBS for a few months until we can achieve appropriation of funds originally authorized by Congress.

In that regard, we have prepared and are now submitting to the Office of Management and Budget (OMB) a five-year budget in support of the 10 million dollars authorized by Congress as seed money and in support of another 10 million dollars of financial resources that NIBS believes it can develop to become self-sustaining as Congress has directed. Since the budget is a 38-page document, I am not going to try to summarize it here today.

In fulfilling our needs for liaison work, we have established firm contact with many of the public agencies who will wish to fund projects with NIBS in a consultant role or as the management organization for accomplishment. A good example is the role that NIBS is expected to play in the orderly implementation of conservation standards required in the recent energy legislation.

In the building community itself we are beginning a program of communication in many forms, one of which is this opportunity to talk to NCSBCS here today. In such communication we have two aims - to tell you who we are and to solicit your input as to where we should go. NCSBCS input to NIBS, of course, should represent no problem since Glen Swenson is a hard working member of our Board and I might add he has had 100 percent attendance at our meetings.

Some other high priority goals of our organizational period are being approached with much sensitivity and very careful deliberation. One of those in the description of our mission, the delineation of responsibilities making up the mission, as well as the strategies required to fulfill the responsibilities. The Mission Committee has spent many hours compiling countless pages of laundry lists of things NIBS should do and, of equal importance, list of things NIBS should <u>not</u> try to do. While we are well into the task, we are weeks, perhaps months away, from a complete and detailed statement which we would consider a thoughtful enough document to submit to the building community for its reactions and suggestions. The task of mission description is too important to be hurried, so hurry we will not.

However, since some abbreviated form of mission statement was required for inclusion in our budget submissions, I think you might like me to read it to you.

The mission of the National Institute of Building Sciences is to improve the built environment and foster more effective use of the nation's building resources by stimulating development of needed scientific and technical knowledge and by ensuring that existing and yet to be formulated construction technologies are rapidly introduced into and accepted by the building community. The Institute therefore will pursue activities and administer programs that:

- Ensure the Institute's acceptance as the nationally recognized source of information needed to encourage the adoption of beneficial procedures and practices in the field of building technology, particularly in relation to the development and use of national performance criteria and standards for building codes, and

- Stimulate the creation of mechanisms that faster closer interrelationships among all segments of the building community and promote clear understanding and acceptance of the Institute as a motivating and coordinating force.

Public agencies, private organizations, and educational institutions will be utilized by the Institute to conduct research, develop performance standards, and establish criteria for the testing, evaluation, and prequalification of all those elements that are inextricably a part of the building process and that affect its safety, cost, quality, and efficiency as well as the institute's acceptance by consumers.

To accomplish its mission, the Institute initially will employ eight strategies--it will:

1. Establish the Institute as the authoritative national source of information on building science and technology, performance criteria and standards, and the building process.

2. Identify areas in need of investigation and special study; formulate a building research agenda for the nation; define the significant issues related to innovation; and stimulate and administer research programs in various public agencies, private organizations, and educational institutions.

3. Develop a system that permits the formulation, promulgation, and maintenance of nationally recognized building performance criteria and standards and other related technical provisions.

4. Create a national system for the evaluation and prequalification of existing and new building technologies.

5. Establish and maintain a Building Regulation Information Program by assembling data and information on existing codes, standards, and other provisions related to the building process; analyzing all material; creating a data bank; and generating multiple routes of access.

6. Develop mechanisms to demonstrate, at all levels of public and private interest, how the building code process can be coordinated to become a system that consolidates the building community, supports those being regulated, and better serves the consumer.

7. Develop methods for introducing the scientific and technological innovations and performance criteria and standards the institute promulgates to regulatory officials at the local, State, and Federal levels and for facilitating their acceptance by these officials.

8. Pursue those initiatives that will permit the institute to become financially self-sustaining.

Each of these strategies will be implemented by a series of activities and programs. Activities involve direct action by the Institute, the Consultative Council, or the Institute's staff. Programs are those studies, investigations, and research efforts supporting the Institute's mission that are to be carried out under contract by various public agencies, private organizations, and educational institutions.

Augmenting that abbreviated statement of missions let me give you a few philosophical beliefs that we keep in mind as we further consider our mission.

NIBS is meant to serve all segments of the building community even though it was created by an addition to the Housing Act of 1974. NIBS can and will, however, prioritize its efforts toward those areas where it can demonstrate the earliest realized benefits and where its services appear to be in the greatest demand.

NIBS will not write codes but will be a vast technological resource for those who do.

NIBS will apply its influence and resources toward more rapid development and acceptance of performance criteria vs. prescriptive criteria.

NIBS intends to make it practicable for the system of codes and standards to be constantly updated from a technological standpoint.

NIBS will not assume responsibility for solving the sociological problems related to construction, but it must be sensitive to the social consequences of technological decisions.

NIBS will not involve itself in the business processes of construction except for how they encourage and react to development and acceptance of new technology.

We believe that NIBS can only become what the building community wants it to be. The many community segments are not only its clients but will be indeed a part of NIBS through participation in the Consultative Council.

Those philosophies bring me to the second major area of organization where NIBS is moving slowly in order to tap the ideas of those hundreds or perhaps thousands of organization where NIBS is moving slowly in order to tap the ideas of those hundreds or perhaps thousands of organizations of the entire building community who will want to participate as members of the Consultative Council. That group will be a vast advisory and technological resource to NIBS and must be organized in such a way that its resources are available quickly, conveniently, and through an organizational concept that will encourage concensus and minimize interface frictions. That concept will probably include hearings on various matters and projects that are completely open to those building community segments that are most affected by the matter under discussion and best qualified to make a contribution toward technological progress.

The NIBS Board of Directors will continue to be the source of policy and programs within which the NIBS full-time staff will operate. The Consultative Council in turn must be firmly linked to NIBS and its staff in order to contribute thinking on its policies and technological know how to its programs. Once a progressive program in NIBS has been successfully pursued, the results must be promulgated and implemented throughout the building community, and principally by the organized efforts of the Consultative Council. It is my personal belief and I think it is shared by the Board that NCSBCS and the model codes will be very effective components of the Consultative Council in their ability to implement technological progress quickly and with a sense of order and uniformity.

The third and last area in which we will travel carefully is the task of setting up a system to collect and disseminate technological data as they relate to codes and standards. This task also involves a possible system that by retrieval can tell an inquirer at any specific location what codes and regulations are applicable to a specific building use at that location.

There really seems no limit to the sphere of technological development to which NIBS can make a contribution if the basic fuels can be provided. There are 3 fuels--the first fuel is funding, sizeable but not huge, and eventually on a self-sustaining independent basis. The second is the human energy necessary to keep pushing forward. The third, and extremely important, is to gain and to hold the confidence and the participation of the entire building community through a necessarily complicated organizing process period.

In closing I can say the NIBS Directors have become strong enough and with feet big enough to take a firm stance and stay in balance, but our feet are not big enough or holy enough to walk on water! We will need to share a lot of boats in the days ahead to cross our river. We hope we can share yours.

INCENTIVES AND CONSTRAINTS IN BUILDING AND THE REGULATORY PROCESS

by

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This paper discusses three specific ways to improve the balance between incentives and constraints in the building regulatory process:

1. Reorganizing and controlling the building process with the aim of making the interests of individual participants more congruent.

2. Offering tax incentives at the federal level that would distinguish between those parts of a building which reflect a common objective such as health and safety and those which respond to the wishes of a particular client.

3. Developing federal legislation that prohibits, on the basis of restrictive trade practice, the establishment of arbitrary local code restrictions, particularly those measures which inhibit the national marketing of highly factored building components or sub-assemblies.

Key Words: Alternatives; building codes; building process; constraints; costs; incentives; regulation.

THE STATUS QUO

General

Building, as an activity, takes a prominent place in the economy of the United States. The capital invested every year in privately-owned buildings absorbs approximately half of all private funds invested. This investment pattern is reinforced by taxation laws, particularly depreciation and interest payment exemptions.

It is evident that the enormous volume of building which takes place each year has to be controlled or regulated to ensure basic standards of public safety, health and sanitary conditions. Most of our lives are spent in or around buildings. The need for public safeguards and their enforcement locally through police power is beyond question.

Since these safeguards are by necessity enforced by imposed controls, they naturally form part of the overall constraint system that surrounds and influences the process of building. In addition, they are a major determinant in the quality of the end product. Because of its direct effect on the incentives and constraints, the regulatory process affects not only the quality of construction by maintaining certain standards; it also directly affects costs and thereby the total volume of construction.

Due to the size of the building industry, the total amount of money involved annually is staggering. The building regulatory process absorbs a considerable amount of this money, a fact that is well documented elsewhere.[1] Estimates of the exact amount vary but in each case it is a considerable percentage of construction costs.

This paper starts by examining the present system of building in this country; it then continues by suggesting ways to alter the system. The aim throughout is not to subvert the original purpose of the regulatory process, but to suggest more efficient alternatives. The speculative suggestions have inherent economic advantages which might offset the possible difficulties associated with their implementation.

Building: A System of Incentives and Constraints

Building as a process is highly fragmented. There are, however, three sequential and discernable phases: inception and planning; execution or construction; and marketing and

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[1] The increased costs due to the building regulatory process that are reported in the literature vary widely from 3 1/2 to 21 percent of initial construction costs. See: A Study of Local Building Codes and their Administration in the Southeast Michigan Six County Region, Public Building Service, 1966; Reports Relative to the Development, Administration and Enforcement of Building and Housing Codes, Department of Community Affairs, Massachusetts, 1970; and Building the American City, The Report of the National Commission of Urban Problems, 1968.

maintenance. Each phase is surrounded by a complex web of economic motivations and government-imposed controls (see Figure 1). Key incentives and constraints can be broken down into:

(1) The incentives present in building in the private sector as it occurs within the current context (Section 1.3);

(2) The incentives provided by the federal government in changing the context and therefore the character and the degree of motivation for specific building and occupancy types (Section 1.4);

(3) The constraint and regulatory system within which all building efforts have to take place in an effort to safeguard the public interest (Section 1.5).

The Private Sector: Incentives for Building

There are numerous ways of being involved in the process of building. The various participants in a building venture, however, seldom relate to the process in the same manner. The pecuniary rewards for their respective involvement vary both as to type and amount.

There are basically three kinds of involvement in the process of construction. First, there is a group whose primary objective is entrepreneurial. This group includes the developer, the owner and the investor. The second group are interested in the activity of building. They profit by building as a process and are paid for their respective contributions. This group includes architects, engineers, builders and suppliers. The third group consists of agents or brokers. Their interest is attached to a specific transaction, and their portion, therefore, is contingent on the successful completion of a transaction (see Figure 2).

Generally, the instigators of a specific building process are primarily interested in the entrepreneurial aspect. Their main concern is the potential for return on an investment. The regulatory process affects this group the most directly, since a toughening up or slackening of minimum code requirements has a bearing on the expense of building. On the other hand, as will be discussed shortly, it is also this group that benefits most by the incentives provided by the federal government, e.g., tax shelters.

Rarely are the interests and aims of the various participants completely congruent or even mutually supportive. A typical building venture, for example, is not usually an exercise in altruism, i.e., producing the highest quality product for the most reasonable cost. On the contrary, the interests of most participants in a typical project are widely divergent. The client or building owner, on his part, wants a high quality product for a minimum price (i.e., the most for the least). The architect and other professionals, who have a moral and ethical obligation to look after the interests of the client, are also interested in a high quality product. The architect's fee, however, is usually a percentage of the total cost of the building (i.e., the most for the most). Where, then, is his incentive for holding costs down? At best, it is his wish to uphold professional standards or his hopes of getting future jobs. A contractor constructing a building has virtually no incentives at all to create a high quality product other than pride or reputation. Indeed, doing so will typically reduce his primary incentive for erecting buildings in the first place--that of making a profit from the process. In general, the contractor wants to do the minimum amount of work for the greatest amount of money without violating his contractual objectives (i.e., the least for the most). The incentives of developers, lawyers, brokers, etc., for involvement are mainly monetary. These participants, therefore, have a limited vested interest in the quality of the building. The more a project costs, the higher is the return on invested money and services. Given this general picture, it is extraordinary that anything of quality ever gets built in current practice as a result of investment by the private sector.

Current practice thus does not make much attempt to align interests of participants. In fact, the contractual agreements between the various parties often create a conflict between their professional role vis-a-vis others and the formula by which their reward is established. Making the vested interests of all participants more convergent would streamline the building process. This in turn would foster a climate in which the constraint system would not primarily serve the function of protecting one from the other. Instead, building regulations and constraints could be reduced selectively as a result. A specific proposal for doing just this is discussed later in this paper.

Government Incentives as a Context for Building

The overall context of a system of incentives as described above is strongly influenced by the federal government, the body primarily responsible for the formulation, maintenance and encouragement of common objectives. Quite importantly, the federal government has the power to offer incentives to encourage activities that are perceived as being in the common good. Indeed, the federal government has a history of providing specific incentives geared to foster those activities which are considered to be of national importance in achieving social, political or economic goals.

The primary mechanism through which the federal government has major control over the inception or removal of incentives to encourage an activity is taxation. The tax structure of this country is indeed a reflection of its implicit national priorities. For instance, the desire to maintain a high level of productivity generally has been regarded as important on a national scale. Certain types of structures such as manufacturing buildings are thereby allowed a higher rate of depreciation than are other types of buildings. This is a reflection of the value that we the public place on the activities housed in a building of this type. How a building can be depreciated, of course, strongly affects its desirability as an investment opportunity, particularly as a tax shelter. The federal government also supports the building efforts of so-called nonprofit organizations, such as many private universities, by giving them tax-exempt status and thereby supplying indirect aid. It is the prerogative of the federal government to decide periodically which building activities are offered incentives through the mechanism of taxation.

Constraints to Building: Codes and Regulations

Constraints to the building process in the form of regulations and codes were developed over time to protect the public. Most of them came about due to a specific instance of accident or failure. Their main objective is to regulate and ensure common minimal standards of health and safety. There are two basic types of regulatory instruments. One is a performance code which sets minimum standards for the initial performance of all aspects of a structure. The other is a specification code which prescribes specific materials and methods. This distinction is, of course, an oversimplification, since most regulations contain a measure of both approaches. The intent here is not to argue the relative merits of either approach, but to note how each affects the building process.

Performance codes usually rely on test data which are developed and accepted nationally (e.g., American Society of Testing Materials and the Underwriters' Laboratories). These codes in no way preclude or impede the possibility for new developments and solutions to existing problems. Testing of new materials and methods creates national precedents and therefore renders testing for each specific application superfluous. However, it should be noted that performance codes are not primarily concerned about the life span of a product or process, but rather its initial performance and safety. By and large, these codes are open to innovation and are primarily attractive to professionals engaged in building.

Specification codes define specific materials and methods by which buildings can be rendered acceptable for occupancy. If specific projects are at variance with the code, the onus is on the particular project developer to produce test data acceptable to a local regulatory agency which has the power to grant a variance. This procedure has to be repeated at the occasion of every specific project until the code is changed. Local control and the preservation of regional trade practices are more impermeable to change in a specification type code than to a performance code. By and large, specification codes tend to be favored by individuals engaged in building who received their training in the field rather than obtaining professional degrees. They usually have a limited enthusiasm for a multiplicity of possible solutions; they are instead interested in the promulgation of the tried and tested.

By prescribing specific methods and materials of construction, specification codes may also protect the interests of certain characteristic participant groups in the building industry rather than act in the interest of all. Union and labor groups clearly have a vested interest in some items in a typical specification code. An example might be the resistance to plumbing systems which technically need no venting, thus substantially reducing the amount of plumbing work required on a site.

It is not generally in the public interest to support sections of the code that are responsive to anything other than issues of health and safety. The fact that regulations backed by vested interest groups can be incorporated into a publicly propagated document enforced by the police power of the state attests to the political power of some special interest groups. It lends credence to the notion that building and the constraints surrounding it are manifestations of a political and economic system.

SUGGESTIONS FOR IMPROVEMENT

Reorganization and Control of the Building Process

> First proposal: Reorganizing and controlling the building process with the aim of making the interests of individual participants more congruent.

As discussed previously, the relationships among participants in the building process is primarily adversative. The nonconvergent interests of each of the various participants involved almost insures this.

However, one can conjecture that this is not the only model which can result in buildings. Alternatives can exist which involve the aligning of interests in a more direct way.

In current practice, a building is built as the result of a contractual relationship between owner and contractor. The architect is typically an agent of the owner and works for fee (1) to prepare plans and contract documents that form the basis of the agreement between the owner and contractor; (2) to assure that the building is designed within the limitations imposed by building regulations and zoning requirements; and (3) to administer the contract by periodically inspecting progress in construction and to authorize payments to the contractor. Other professionals, such as the engineers, are usually hired by the architect as his consultants. (Figure 3 diagrams the contractual relationships involved.)

A contractor is selected on the basis of sealed bid proposals with low bidder taking all. He is contracted to build what is specified and in no way has a vested interest in the quality of the final product.

There also is another model for the construction process in this country: the so-called design-build firms. In this model, a client contracts with a firm to design and build a building for a specified cost. (Figure 4 diagrams the contractual relationships involved in this model.) In this case, the architect is placed in an entrepreneurial position and thereby has no vested interest in acting as an agent for the owner in assuring and safeguarding the quality of the end product. His interests are coincident with the contracting side of the organization.

A substantially different model that could be adopted is as follows: The primary contract for the building would be made between the client and the architect rather than between the client and the general contractor as is typically done now. In the proposed model there would be no general contractor. Instead, the architect would be primarily responsible for the quality and price of the proposed building. The architect would not develop full working drawings but only preliminary plans and documents. He would then hire a series of subcontractors, each having the necessary engineering expertise to prepare detailed plans and drawings. The subcontractor would, of course, be responsible for his parts of the construction and be paid on a negotiated contract basis as authorized. The architect would provide a superintendent for the job whose function would be to coordinate subcontractors and authorize payments. The relationship between the architect and the subcontractors would be that of fellow professionals. Figure 5 diagrams the general contractual relationships that are proposed. Figure 6 diagrams the contractual relationships involved for each subcontractor doing a subassembly.

The above model is, of course, quite different from our current one. Besides eliminating the general contractor, it also postulates the existence of subcontractors, e.g., for mechanical services, with complete design and build capabilities. In this country, subcontractors rarely have or need these capabilities. The proposed model combines the roles in a way that makes the interests of the designers and builders identical and therefore encourages more cooperation in a nonadversative context. This is not to be confused with a design-build firm which does not primarily sell professional services, but rather a product for a price. The motivation is therefore quite different.

The whole model is based on the premise that the more the building process is founded on relationships among professional groups, the less adversative it will be. Similarly, it is hypothesized that the more a professional has a vested interest in the quality and buildability of his designs, the better the quality of the resultant whole will be. It should be reemphasized that the architect is responsible for the quality of the end product. He also hires subcontractors. Subcontractors not having a history of designing and producing buildable designs of quality would not be competitive. The architect would find himself in an analogous situation with respect to clients.

The proposed reorganization of the building process would have a marked effect on the building regulatory structure. This could happen in two ways. The first is a common interest in technical innovation, even on the part of subcontractors. This is now mostly the concern of architects and engineers. This prediction is based on the condition that the subcontracts would be in fact a coalition of professionally trained and state licensed individuals who design components and organize their installation. If several of these coalitions are competing to be hired by the architect for the job, there is a definite incentive to explore the benefits of technical innovation in order to produce a higher quality at a given cost in order to gain a competitive edge. Both the designers and the craftsmen would therefore have the same vested interest in finding ways of improving the process of building. Commensurate with this would be a desire not to be constrained by building regulations that specify detailed methods and the exact character of components. In our current system, this incentive is largely not present. Rather, groups tend to provide the same solution for the least expenditure, no matter what its efficiency or viability. The proposed reorganization of the building process is based on the converse premise, i.e., a variable design to meet specified cost goals. This concept has proven effective in other contexts such as the aerospace industry.[2] Given the proposed system, the participants in the building process would have a vested interest in reducing constraints, or in converting them into a format which allows for maximum innovation. It is quite possible that this system would create a climate which would foster innovation and improvement in the whole building regulatory structure.

There is yet another way in which the building regulatory process could be affected: the inspection and approval process currently used would be streamlined. In the current process, a professional architect prepares working drawings and specifications (as contract documents). He then submits them for review and approval by building departments (often consisting primarily of individuals with an extensive field knowledge of the methods and techniques not often with a background in any of the theoretical disciplines, e.g., structural engineering). During construction there are periodical inspections and approvals of the installation of specific subcomponents. This process works, but is more cumbersome than need be. In the model proposed above, it is possible to streamline the whole process. Since all of the participants involved would be professionals licensed by the state, it is reasonable to assume that none of the participants would construct anything not meeting minimum safety and health standards. The incentive is clear. Their licenses could be revoked for willful violations. The professional and the state would therefore not be in conflict. In present practice, the contractor has no real interest in conforming to regulations since this domain is really the province of the professional, who is legally liable. This method opens the possibility of reducing building costs by

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[2] McCarthy, J. F. and S. J. Novak, "Design to Cost and Life-cycle Costing in the Aerospace Industry," <u>Industrialization Forum</u>, vol. 6, no. 3-4, 1975, pp. 37-52.

potentially cutting down lead time.

In summary, reorganizing the building process to make the vested interests of the building participants more convergent would improve the quality of building and foster a climate for innovations and improvements in the building regulatory process.

Tax Incentives in Building

> Second proposal: Offering tax incentives at the federal level that would distinguish between those parts of a building which reflect a common objective such as health and/or safety and those which respond to the wishes of a particular client.

As previously discussed, there is a close relationship between taxation and the rate of building. It is the prerogative of the federal government to decide which building activities are offered incentives through this mechanism. It is proposed that tax incentives should be offered only to those activities that clearly represent a common interest of the people (who pay the tax).

Offering special incentives for certain building types, e.g., manufacturing buildings, is a form of subsidy to encourage the activities contained in the buildings, not the activity of building itself. As a consequence, the vested interests of many participants in the building process are also subsidized by the public, since no distinction is made between interests representing the common good and those of special vested interest groups.

It is suggested that any additional tax incentives be clearly focused. For instance, it would be possible to have a differential depreciation rate for those aspects of a building which contribute to its safety (e.g., sprinklers in buildings where not required by law).

What this means is that the costing of a building should be done in a way which allows a distinction to be made between those elements which directly contribute to the market-related aspects of the building or those which contribute to safety and health standards. This could even include such items as the structure's connective tissues (such as its egress system) and energy-saving devices. It can be argued that all other aspects of a building benefit particularly the owner of the building because they respond to market conditions and have little to do with public interest. This bias in the tax shelter system would favor the construction of more structures which exceed minimum standards as set out by law. This procedure would, of course, be difficult to implement, but it focuses on one of the major incentives to make regulations more responsive to our collective concerns.

Incentives for a Delivery Process on a National Scale

Third proposal: Developing federal legislation that prohibits, on the basis of restrictive trade practice, the establishment of arbitrary local code restrictions, particularly those measures which inhibit the national marketing of highly factored building components or sub-assemblies.

A way of increasing the general health of the building industry nationally is to improve the production and delivery process of buildings. This can be achieved through the development on the federal level of premium or rebate systems for highly factored nationally marketed products, on the condition that they are made according to criteria established at the federal level. Producers designing and marketing products meeting federally established standards could then be given a tax incentive for doing so. Producers designing and producing products responding only to local codes would not. Standards established nationally would preferably be performance-oriented.

This is not a plea for additional incentives to further the development of specific industrialized building systems or components. Only when the entire production and delivery system is revamped on a national scale can buildings become products in the sense used in other branches of industry. This does not necessarily imply immediate technological innovation, but would provide a climate for innovation to occur over time. There is the possibility that, once a system of this type were instituted, it would logically lead to the use of federal power to eliminate restrictive trade practices as enforced and promulgated by local codes. This would open up local markets to national manufacturers rather than letting them function as enclaves protected by local regulations.

CONCLUSIONS

It is fair to say that the regulatory process, because it maintains certain standards, does in fact cost money: public money. The process mainly aims, however, to safeguard the interests of the public by controlling the quality of building. This aim is not at issue. However, the more stringent the regulatory process, the more it costs. As building costs are affected, so are the returns on investments. The total quantity of buildings built is correspondly affected.

A careful balance should be maintained between the incentives and constraints surrounding the building process. Without this balance it is probable that more and more building must become a public charge, for better or worse. Historically, building, particularly housing, was a most profitable undertaking. Usurious profits resulted from the construction of overcrowded substandard firetraps. As a result of the Industrial Revolution and the population influx, the demand for housing seemed insatiable. The second half of the 19th century saw the rise of building regulations in an effort to achieve a modicum of health and safety. By the turn of the century, building codes and regulations started to assure reasonable minimum standards. However, it made the lower end of the rental market no longer profitable enough to attract investors in sufficient numbers. Tax incentives had to be introduced in an effort to attract private investment capital to the construction of buildings which would otherwise be but marginal investments. Despite the introduction of this incentive system, the constraints of building regulations made housing for the lowest economic denominator too marginal for private investment. This kind of housing thus became a public charge; hence, the emergence of public housing. Whether this whole course of events was for the better, worse can be argued. It is possible, however, that better quality housing might have been built without its becoming a public charge if the incentives for building and the constraints imposed by the government that mitigate against it were kept more in proportion.

If we assume that the balance between the incentives to build and the constraints imposed by the regulatory process are to be kept in proportion, then any new regulations or changes in existing regulations which can result in additional expenditures should be coupled with the appropriate additional incentives (such as tax benefits). The reasoning is that building as an investment has to compete with all other types of investments for available capital. Since regulations have as their basic purpose the protection of the public, it can be argued that the public in turn should reward the owner of a building for including those measures. The degree to which these tax and other financial accommodations have to be made should be flexible enough to adjust the average rate of return on investment to those present in non-building sectors of the economy.

The regulatory process does work. Very few buildings fail as a whole or in the part to the point that they endanger lives. The three suggestions contained in the lines above are meant to reinforce the idea of a strong and healthy regulating process by making the procedure as common-sensical as possible and by always assuring that the regulatory process is a manifestation of the public will. The regulatory process should therefore be on a continuing basis responsive and accountable to the public, the people it serves.

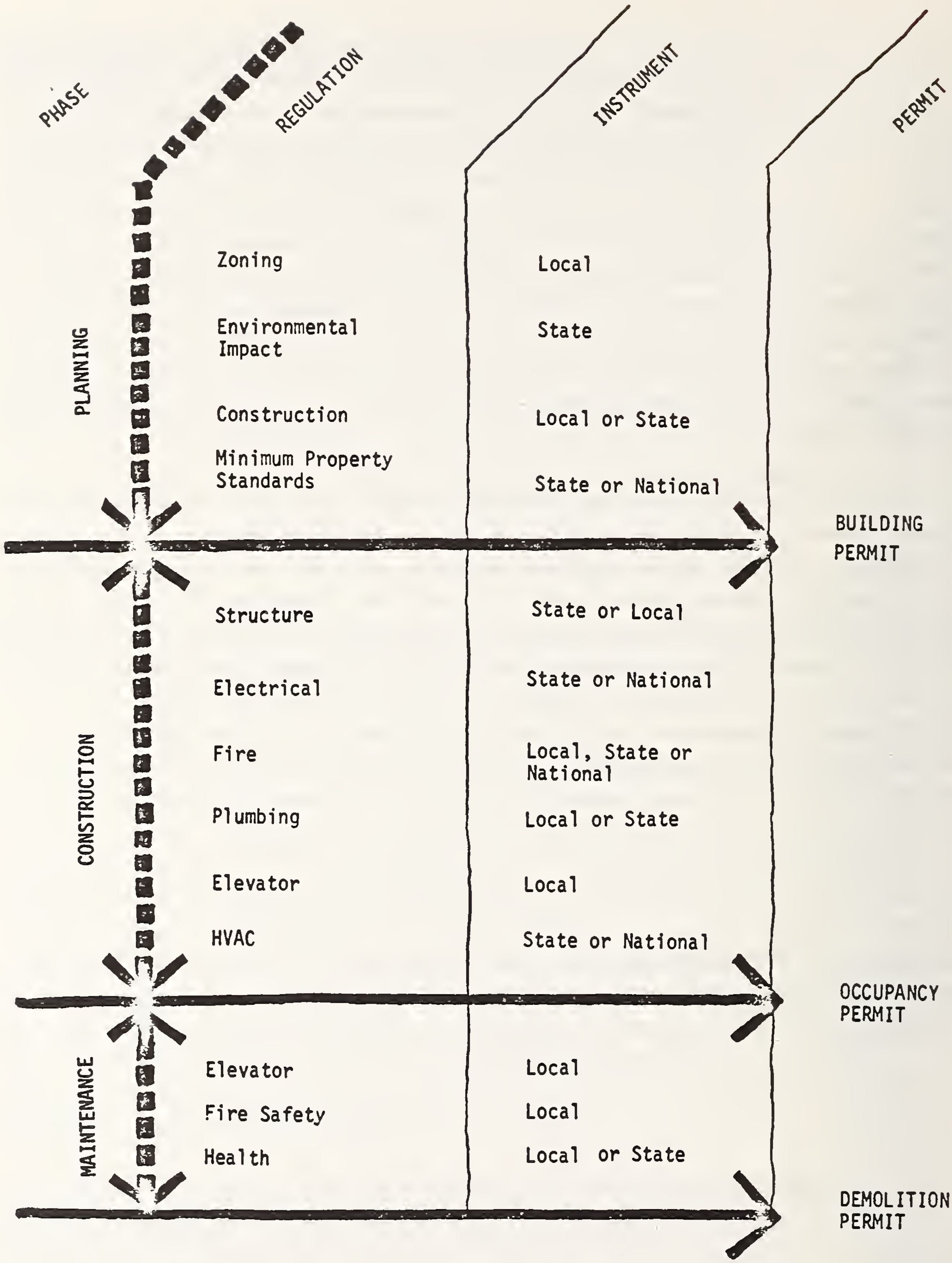

Figure 1. The Regulatory Process

MOTIVATION	PARTICIPANT	RENUMERATION
ENTREPRENEURIAL	Owner Developer Investor	Return on Investment
PROCESS	Architect Engineer Lawyer Title Companies Contractor Subcontractor	Fee for Service
AGENT OR BROKER	Real Estate Broker Distributor	Contingent Fee

Figure 2. Participants and Motivations in the Building Process

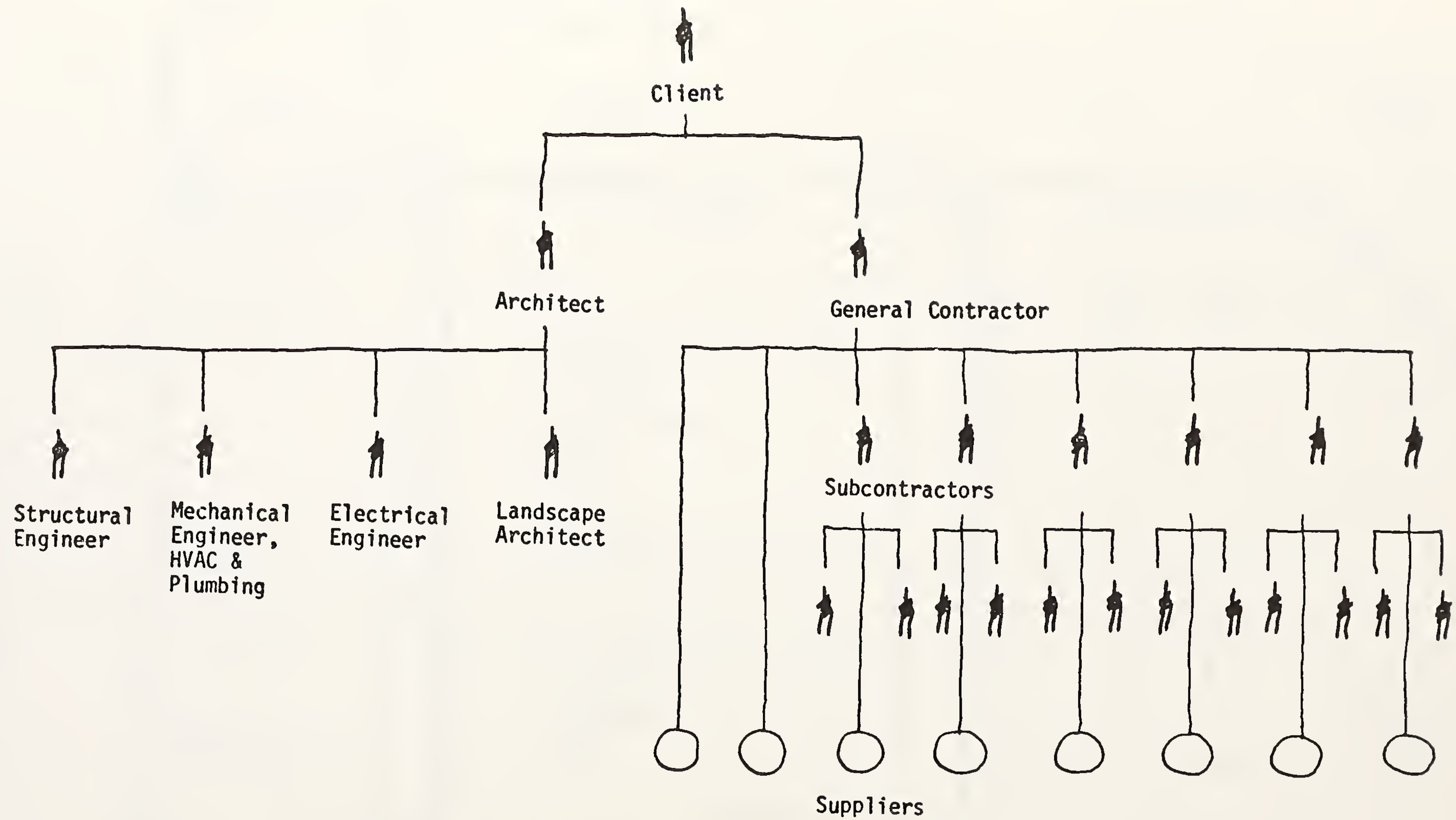

Figure 3. Diagram of Contractural Relationships - Present Practice

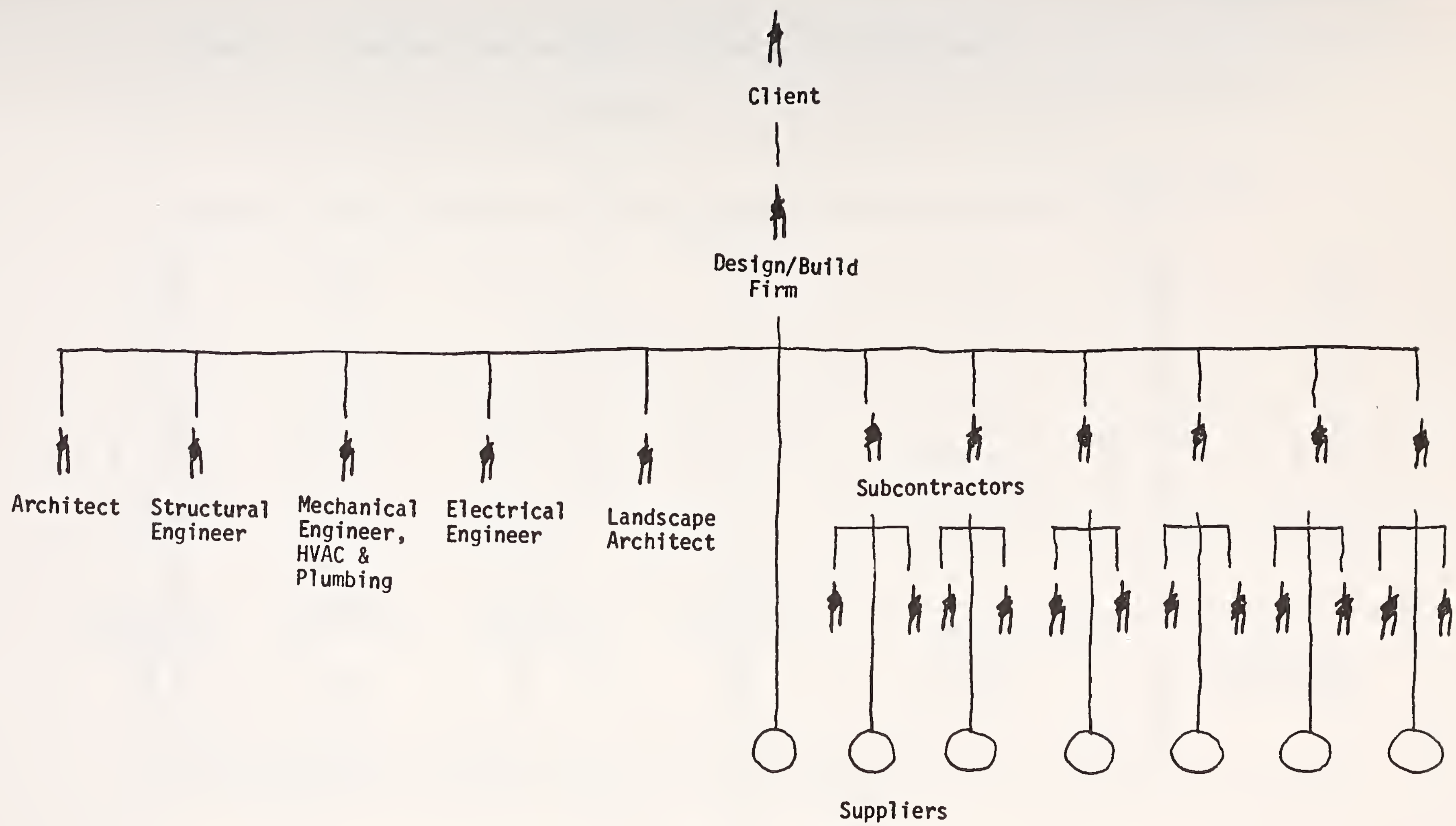

Figure 4. Diagram of Contractural Relationships - Design/Build Package

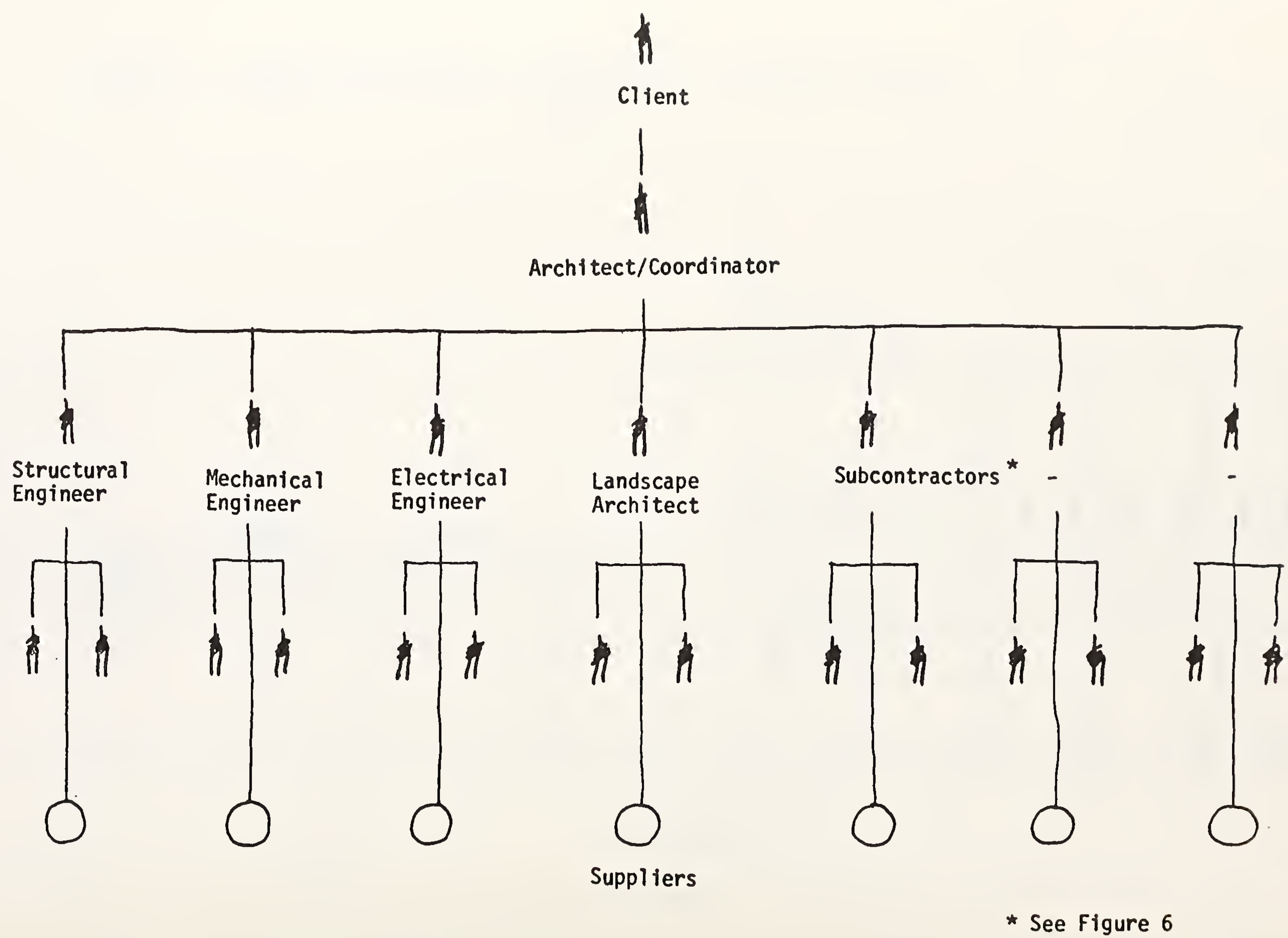

Figure 5. Diagram of Contractural Relationships - Proposed Model

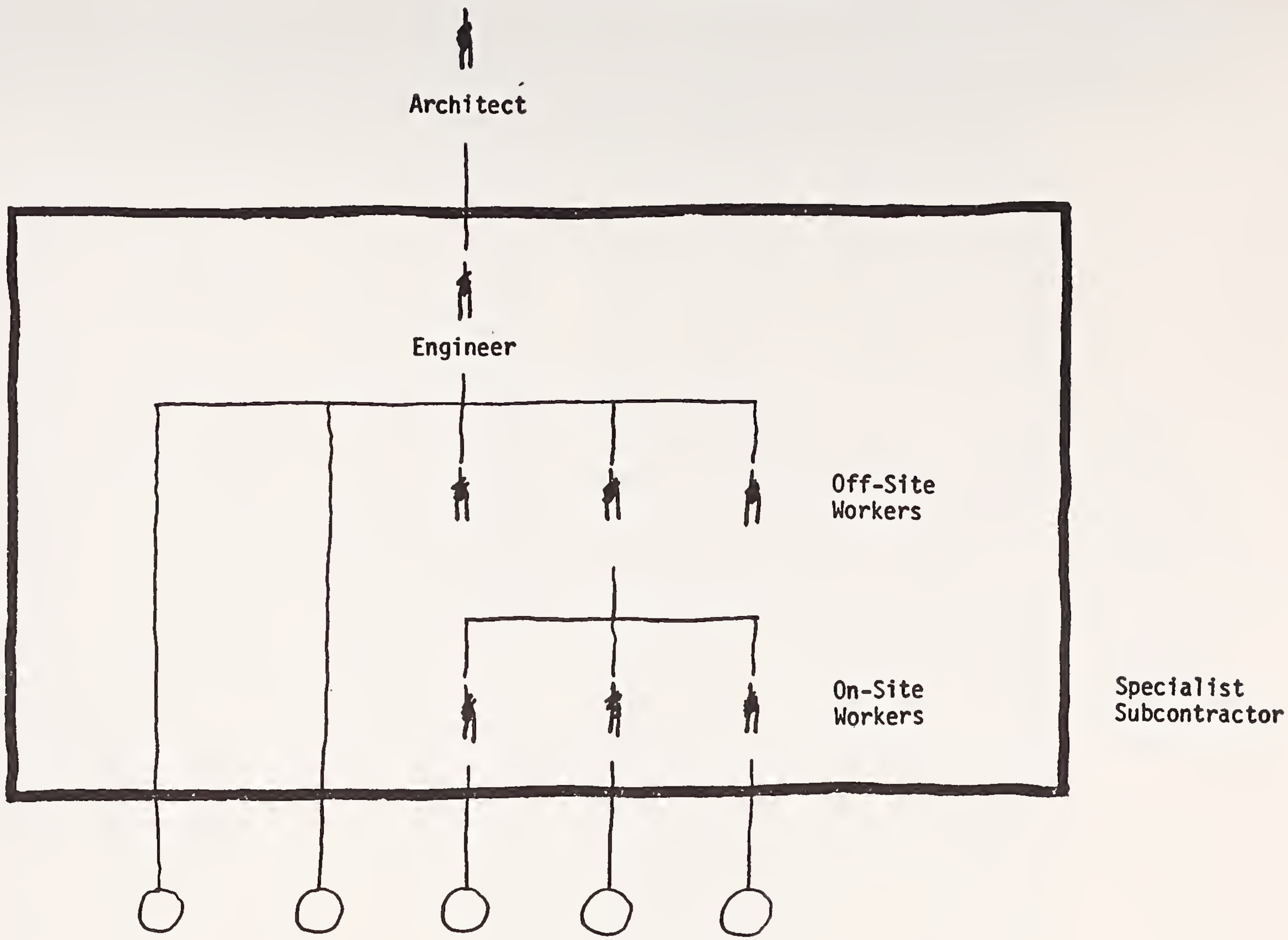

Figure 6. Diagram of Contractual Relationships for Each Subassembly in Proposed Model

HOW ENVIRONMENTAL RESEARCH MAY AFFECT THE TECHNICAL PROVISIONS AND ENFORCEMENT OF REGULATIONS

by

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Two case studies illustrate the consequences of knowledge voids on the technical provisions and enforcement of regulations. The first case deals with legal decisions about the reasonableness (and, by implication, the scientific justification for) certain health provisions of a model housing code adopted by a local government. The second case focuses on a situation in which enforcement of the Life Safety Code could have resulted in the forced relocation of institutionalized elderly. In this situation, code enforcement (leading to forced relocation) could have contributed to more deaths than non-enforcement of this fire safety code. The application of environmental research to solve the problem posed by this situation is described. Problems of obtaining and applying environmental research, with regard to policy decisions such as building regulations, are noted.

Key words: Codes and standards; environmental studies; fire safety; health dangers; research needs.

INTRODUCTION

This article, "How Environmental Research May Affect the Technical Provisions and Enforcement of Regulations" might be subtitled "Some Egregious Examples of the Consequences of Regulatory Enforcement Under Conditions of Knowledge Voids."[1] The expression "knowledge void" describes the absence of needed research and theory. Practically speaking, the expression also describes an inadequate familiarity with, understanding of and/or search for available, applicable knowledge.[2] The examples appear as two case studies. The first case deals with adjudicative attacks on certain health provisions of a model housing code that had been adopted by a local government. In addition to the legal issue of whether the provisions in question fell within or beyond what the housing code could legally require, there was the associated, though implicit, issue of the scientific justification for these provisions. That is, was there an empirical relationship between the provisions for human health and occupant well-being, the goal of health provisions? The second case study focuses on the consequences of implementing fire safety code provisions. Because of the very special conditions of implementation, human lives were at stake if the code <u>was</u> enforced <u>and</u> if it was <u>not</u> enforced. This unusual situation became the occasion for the application of relevant environmental research. How this research came to bear on this situation, and the subsequent history of the use of this research, offer important insights into the role of environmental research in building regulation and into the nature of the research enterprise itself. With respect to the two meanings of "knowledge void" noted above, the first meaning (void as absence of theory) applies to the first case study; the second meaning (void as inadequate familiarity) applies to the second case study.

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[1]I wish to thank my colleagues at the National Bureau of Standards, especially Robert Wehrli and Stephen Weber, for their helpful comments on earlier drafts of this article. And my most special thanks to John Archea whose insights and efforts shaped the project upon which this article is based.

[2]The expression "knowledge void" is the writer's response to a discussion of this issue by Ferguson (1974).

The cases were selected to illustrate the need for knowledge-based codes (Ferguson, 1974): codes whose provisions can be justified and documented in terms of cumulative, systematic study and theoretical understanding of the physical and human requirements to which the provisions pertain. It follows that knowledge-based codes could make decision makers and users of our built environments less likely to be victims of knowledge voids, voids resulting from currently less relevant historical knowledge (tradition) or inadequate research or observation. It is assumed that accumulating knowledge and improved explanations would be systematically considered during code development and revision.

The case studies share two characteristics: they demonstrate the potential importance of research on the relationship between the built environment and human behavior, and they deal with either human health or safety. The reason for emphasizing each of these characteristics should be made explicit.

The current knowledge base about the built environment is uneven. It is uneven because the built environment has tended to be studied and analyzed in terms of engineering disciplines rather than in terms of behavioral science and health disciplines. As a consequence, the knowledge voids and the need for knowledge are greater with regard to behavioral knowledge.

Since health and safety (like other environmental attributes) are as much behavioral as they are engineering issues, and since the government is required to protect the health and safety of citizens -- and does this, in part, through building regulations -- the case studies deal specifically with building-related health and safety issues.

CASE STUDY 1. A MODEL HOUSING CODE IN THE COURTROOM: WHAT IS A "REASONABLE" PROVISION FOR THE PROTECTION OF HEALTH?

Introduction

The history of code enforcement in the United States has been marked by legal attacks against housing codes or ordinances on the grounds that they did not fall within the public interest in health or safety. For example, the Tenement House Act of 1867 of the State of New York was the first United States legislation which addressed the issue of housing and health. There were three additional major legislative enactments between 1867 and the turn of the century. The first major challenge was in 1895, when a court upheld an ordinance requiring a water supply on each floor of a tenement house [Health Department vs. Rector of Trinity Church, 145, N.Y. 32, 39 N.E. 833 (1895)] (City of Jacksonville, 1974). There have been recent legal attacks on housing code provisions. The case of Safer v. City of Jacksonville (Florida) has been called "probably the best known of the recent litigation against a housing code" (City of Jacksonville, 1974, p. 2). This legal case is the basis of this case study.[3]

Before turning to the facts of the court case, it is well to point out that the law is characterized by making normative decisions about specific circumstances. Therefore, to aid in the consideration of the legal cases, questions raised by or implied by them will be stated. By addressing these questions to the details of the court cases and to the surrounding circumstances, the cases may be better appreciated.

1. Would scientific knowledge be persuasive in a court if it were introduced in support of a housing code provision? How persuasive would it be if those opposed to a provision also had their own expert witnesses attack the quality and/or relevance of the scientific knowledge?

2. What circumstances could result in a challenge to the legal reasonableness of specific housing code provisions?

3. Would it make a difference if a legal challenge were addressed to regulations concerning new construction rather than existing housing?

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[3]The description of the Safer case is found in Safer v. City of Jacksonville, 237 So. 2d, 8 (1st D. CA., 1970). Background material and the descriptions of the consequent cases were provided by Mr. J. R. Bartley, Chief, Codes Enforcement and Rehabilitation Division, Department of Housing and Urban Development, City of Jacksonville, Florida. Mr. Bartley's continued interest and help are sincerely appreciated. Portions of this case study are reported in Margulis (1975).

4. Suppose a tenant were faced with forced relocation if their housing remained in violation of a housing code or with increased rent if the cost of correcting the violations were passed on to the tenants by the owner. Suppose the tenants were low-income families and either of these outcomes represented a more serious hardship than the existing violations. Whose interests should receive a higher priority: the public interest in correcting the violations or declaring the housing unfit for habitation or the tenant's interest in keeping his rent at its current level (rather than have it raised to pay for the improvements)?

The Safer Case

The key details of the Safer case are as follows. The City of Jacksonville charged the Safers (to be called "the landlords") with 70 violations of the housing code. The housing code in question is the Jacksonville Housing Code. It is based on a model code, The Southern Standard Housing Code, developed by the Southern Building Code Congress. It was adopted, by Jacksonville, in order to meet a U.S. Department of Housing and Urban Development requirement for obtaining federal urban renewal funding. The Southern Standard Housing Code was selected because it was considered more lenient than others.

The City asserted that the 70 violations had to be corrected or the housing would be declared unfit for habitation and the households vacated. Since the estimated cost of repairs was $20,000 and the housing (eight dwellings in a low-income area) was only worth $40,000, the landlords appealed to the City for relief. The administrative appeal failed; the landlords went to court. The code and its enabling legislation were challenged and the landlords asked that the regulations not be enforced for to do so would constitute a hardship. This case was dismissed as without a legal basis. The dismissal was appealed, reversed, and sent back to the Circuit Court for trial.

The City and the landlords agreed that the trial would be by jury. The jury would decide, for each alleged violation, whether the situation did violate the code and whether the violation affected the health and safety of the tenants (renters). The jury decided that for 50 of the alleged violations, either violations did not exist or, if they did, they did not jeopardize the health and safety of the tenants. Of the remaining 20, each violated the code and jeopardized the tenants' health or safety but 19 had already been corrected. The landlords subsequently corrected the remaining one violation (for less than $30).

The Circuit Court also considered the challenge by the landlords to the validity of the enabling legislation behind the code, the code provisions involved in the case, and the City's right to enforce the housing code. Each was affirmed by the Court.

A fourth trial arose (in 1970), on an appeal by the landlords, because the City continued to charge the landlords with the 50 violations that the jury had decided were either not violations or did not jeopardize the health and safety of tenants. (The author does not know the City's reason for this course of action.) The landlords wanted protection against the City's action and, in addition, the landlords again raised a challenge against the code and its enabling legislation.

The District Court of Appeal accepted the case and decided that the enabling legislation was valid but that some code provisions were not. Two provisions were rejected as falling beyond the enabling legislation on the grounds that they were not demonstrably related to the health or safety of tenants.[4] One of these provisions required each dwelling unit to contain a sink, lavatory, tub or shower connected with an adequate supply of potable hot water and the other provision required each habitable room to contain at least two wall-type convenience electrical outlets or one such outlet and one ceiling-type electrical fixture. The Safers' dwellings did not have potable

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[4]It appears that the Court of Appeal's ruling on the validity of the two provisions was a general one and not restricted to the facts of the case under consideration.

hot water supplied to the sink and tub or shower and some did not contain a lavatory. They all contained sinks and tubs or showers. Furthermore, all rooms contained at least one electrical outlet or fixture but not all of them contained the two the code required.

The Court's reasons for rejecting the provisions are provided by this excerpt from the opinion of one of the judges. It is reproduced without comment.

> The primary question posed for consideration is whether the requirements that every rental unit contain a lavatory, convenience electrical outlets in each room, and a continuous supply of potable hot water are reasonably required in order to protect the health, safety or welfare of the tenants occupying these units. To hold in the affirmative would do violence to the history of our country, in the early years of which hearty citizens were reared and grew to maturity under living conditions which included bathing in a bowl supplied by a water pitcher placed upon a washstand in the bedroom, and under which all hot water used by the family was heated in a kettle, pot, or tub on the kitchen stove. Research fails to reveal any substantial number of instances in which living under these conditions adversely affected the health, safety or morals of our forbears, or indeed many of the older generation living today. The paternalistic trend in government is gradually forcing a surrender of the living conditions commonplace in the "good old days" for more modern concepts of living which frequently are influenced more by aesthetic considerations than those relating to health, safety or welfare. To require the installation of lavatories, hot water heaters and convenience electrical outlets in all of the low rent dwelling units owned by appellants would not only be unreasonable but constitute a confiscation of appellants' property without compensation contrary to basic constitutional rights. The cost of compliance bears no reasonable relationship to the objects to be attained. (Safer, p. 13)

The District Court of Appeal also returned (remanded) the case to the Circuit Court and directed a decision of injunctive relief for the landlords.

The City, it appeared, appealed the ruling of the Court of Appeal but the Florida Supreme Court would not consider the Safer case for a variety of technical legal reasons.

Thus, the provision of potable hot water, of lavatories, and of convenience electrical outlets in low-cost rental housing in Jacksonville, Florida was no longer necessary.

Subsequent Court Tests

Having failed to obtain an appeal, the City nevertheless continued to enforce the illegal provisions of the City's housing code in order to provoke a legal challenge. The City wanted to get another day in court. The challenge was joined in the case of Christian, et al. v. City of Jacksonville. The City of Jacksonville was ready. During 1973 the City had contacted some 200 experts and, based on these contacts, secured 12 expert witnesses -- sanitary engineers, epidemiologists, and medical doctors (often public health professionals) --to support their case. This was part of the search, by Mr. J. R. Bartley of the Codes Enforcement and Rehabilitation Division, Department of Housing and Urban Development, City of Jacksonville (See Note 3), to obtain research and/or legal precedents to support the argument that the provisions of their housing code, such as the provisions rejected by the District Court of Appeal, are in fact necessary to protect the health and safety of tenants and, therefore, are a proper requirement of a housing code.

The case of Christian, et al. v. City of Jacksonville proved to be a disappointment. One hour before the trial was to begin, the plaintiff dropped the case. Thus, the charges were dismissed and the original decision of Safer still stood. However, there was to be one more legal challenge, Stallings v. City of Jacksonville. It, too, addressed (to all intents and purposes) the three provisions that were at issue in Safer: potable, continuous hot water, lavatory, and convenience electrical outlets. In September 1974, the case went to trial. According to Mr. Bartley, the plaintiff was so overwhelmed by the list of experts that would argue for the City, that the Stallings' lawyers refused to argue the Safer issues. In turn, the judge refused to prohibit the City from enforcing the rejected code provisions. The trial proceeded on less important issues, such as rodent extermination, screen doors, etc. The City won on all points.

As of July 1976, code provisions requiring hot water, a lavatory, and convenience electrical outlets are illegal but enforced in Jacksonville.

Implications and Conclusions

Mr. Bartley was aware of the great expense of getting his expert witnesses ready for trials. Therefore he decided to do the necessary research in-house with the part-time help of a graduate student. A considerable amount of data was collected which could be used to defend specific provisions. With his evidence assembled and reviewed, however, Mr. Bartley agreed with the researchers and with his assistant that most available longitudinal studies concerning the relationship between health and housing were inconclusive. That is, there was a lack of substantive research and established data that could be used to demonstrate the reasonableness of a housing code's provisions in a court of law. In this regard, Mr. Bartley (personal communication, August 30, 1976) has recently suggested the creation of "a central data bank" where research and data relevant to housing code provisions could be maintained and updated for use by municipalities and states (with state-wide codes) throughout the nation.

The issue posed by Safer and the subsequent cases has additional implications. In the absence of research with legal significance, continuing litigation against code provisions could weaken existing housing codes. Weak or unenforceable codes could prevent improvements of the quality of life and could obstruct the goal of the Federal Housing Act of 1949 to provide "a decent home and suitable living environment for every American family." This means that research on environment and behavior has a necessary role, whether it is for code development, for supporting adopted codes that are in litigation, and even for helping to define the individual's view of quality of life and of decent housing.

In sum, the questions raised at the start of this case study suggest the following. There are bases for legal challenges to housing code provisions and there are questions about the persuasiveness of available scientific knowledge because of unfortunate knowledge voids. There have been attacks on new construction regulations and on provisions about existing housing. There are important considerations which pit the public interest in the design, construction, and management of the built environment against the interests and resources of the owner, on one hand, and the tenant, on the other.

CASE STUDY 2. REGULATION, RESEARCH AND THE RESCUE OF PERSONS: FIRE SAFETY VS. THE FORCED RELOCATION OF THE INSTITUTIONALIZED ELDERLY[5]

Introduction

Although the first U.S. legislation addressing health and housing appeared in 1867, written laws concerning safety and housing appeared as early as 1189, in London. The laws of 1189 addressed the problem of fire safety and the spread of fire (Ferguson, 1974). Thus, fire safety, as a matter of public policy, has an 800-year history.

Fire Safety vs. the Forced Relocation of the Elderly

The second case study involves the consequences of the adoption and enforcement of the National Fire Protection Association's (NFPA) Life Safety Code, (NFPA 101-1967), a fire safety code, in which a risk to life and a potential knowledge void came to bear upon each other. The risk to life was directly attributable to but was an unforseen consequence of implementing and enforcing the Life Safety Code. The case study also demonstrates the importance of gaining access to information that would fill a knowledge void, in this instance, information about environment and behavior. (To reinforce Mr. Bartley's contention about the Safer case, the present case study demonstrates the usefulness of persuasive research findings in court cases.) Nevertheless, it must be explicitly stated that the consequences of enforcing the Life Safety Code and of the environmental research were unusual and special. Thus, after presenting the case study, the unusual and special aspects of this case study will be discussed. Moreover, lessons learned from the environmental research will be presented.

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[5]The descriptive material in this section, unless otherwise noted, is from one or more of a series of related presentations of this case study (Archea, 1976; Archea and Margulis, 1976; Margulis, 1975). I would like to thank Mr. Richard Hoke, Office for the Aging, Department of Public Welfare, State of Pennsylvania, for providing additional details. I would also like to thank Mr. Bertram Vogel, Center for Fire Research, National Bureau of Standards, for clarifying certain aspects of the regulatory process that pertain to this case.

The impetus for this case study is provided by Public Law 92-603 (signed in October 1972), an amendment to the Social Security Act covering Medicaid payments, which gave the Federal government greater control over environmental and medical aspects of nursing homes and other facilities for the care of the elderly. This law led the U.S. Department of Health, Education and Welfare (HEW) to establish the Life Safety Code (NFPA 101-1967) as a basis for certifying nursing homes whose elderly occupants were covered by Medicaid. That is, nursing homes and other facilities for the care of elderly whose owners wanted to obtain Federal Medicaid payments for their elderly occupants would have to have their buildings comply with the Life Safety Code.[6] However, the enforcement of the Life Safety Code resulted in the decertification of those nursing homes that failed to comply with the Life Safety Code and, as a consequence, a need to transfer patients. At the same time other regulations affecting the medical classification of patients also created a need for transfers. As a consequence, plans for the forced relocation of many elderly were made. The problem was particularly critical in Pennsylvania, where an estimated 2,000 to 6,000 persons, from a population of between 60,000 and 65,000, would have had to be moved.

About this time, research (to be called the "Michigan study") by Dr. Norman Bourestom and Dr. Leon Pastalan, Institute of Gerontology, University of Michigan had documented increases of up to 100 percent in the mortality rate for elderly persons subjected to forced transfers from one institutional setting to another. The Michigan study also suggested that even the expectation of a move was fatal to some elderly persons.

What the Michigan study meant for Pennsylvania was that if 2,000 elderly persons were subjected to a forced relocation without prior preparation, this could increase the number of deaths within this group by 250 to 450 deaths above the expected number of 540 deaths. By contrast, only 16 persons, from

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[6] The enforcement of the Life Safety Code preempted local fire codes which, in general, are reported to be less stringent than the Life Safety Code. (B. Vogel, personal communication, February 1977.)

among all of the institutionalized elderly in Pennsylvania (between 60,000-65,000 elderly persons), were known to have died in nursing home fires in Pennsylvania in 1972, the year before the plan to have a mass relocation of the elderly.

It must be emphasized that the comparison reported in the last paragraph involves two atypical events. That is, a mass relocation and an unusually high number of fire-related deaths are both uncommon events in Pennsylvania. Although there were 16 fire-related deaths in Pennsylvania among the institutionalized elderly in 1972, in the several years before and after 1972 the annual number of fire deaths has been low, typically zero deaths. When fire deaths have occurred, typically a nursing home fire, resulting in a number of fire-related deaths, has been implicated. As for group or mass relocations of the institutionalized elderly, they have been truly rare. Rather, relocations have been individual matters in Pennsylvania.

This comparison of atypical events reinforces the conclusion that the potential cost in human life is greater from a forced relocation of the elderly without prior preparation in order to avoid a fire-related death than from leaving these people where they were and having them run the risk of a fire-related death in a nursing home which has been classified as structurally substandard from the fire safety point of view. However, the comparison itself is not the issue. Rather the central issue remains the potentially lethal consequences of a mass relocation of the institutionalized elderly. Put another way, the health and safety of the institutionalized elderly are important with respect to both fire safety and the consequences of a relocation. However, in this particular situation, actuarial figures suggest that a mass relocation was a relatively more important problem than fire safety.

Forced Relocation: Filling A Knowledge Void

If there must be forced relocation, what could be done? As early as 1967 it could have been learned that a properly implemented program which prepared the elderly for such a relocation attenuated the lethal effects of such moves (see Kasl, 1974, pp. 214-215, for a summary of the studies). Moreover, the Michigan study had tested programs to prepare the elderly for relocation. One of the programs involved gradually familiarizing the patients with their new environment in the months preceding the scheduled move. Like the earlier studies (reviewed by Kasl, 1974), the Michigan study also found that this preparation program reduced the lethal consequences of the forced relocation. (This is the program to which we shall refer subsequently.)

Thus, information that could fill a seeming knowledge void was available. Fortunately, Pennsylvania's newly appointed Commissioner on Aging had been a student and later a colleague of Dr. Pastalan at the Institute of Gerontology. Thus, when the Commissioner on Aging was consulted about patient transfer in May 1973 by the responsible State agency, he recognized the problem and eventually got Dr. Pastalan to adapt the Michigan relocation program for the Pennsylvania situation. Dr. Pastalan's preparation program for Pennsylvania was adopted in October 1974 by the State agency responsible for carrying out the transfers. (This adoption was two months before the first publication of the Michigan study in a technical journal.)

In the months following the adoption of the relocation preparation program, relocations began and the preparation program was implemented. Dr. Pastalan evaluated the efficacy of the preparation program based on study of the elderly who had been relocated through July 1975. He found only 300 to 400 elderly persons had been relocated during this period and not the 2,000 to 6,000 persons that were projected. (In fact, the total number of relocations through July 1976 is estimated at 600 to 700 persons. The preparation program, of course, continues to be implemented.) The difference between the actual and projected number of relocations was the result of an underestimate of the time it would take to process decisions to close institutions for the elderly. Although the central issue remains the same, the magnitude of the consequence of mass relocation may seem greater based on the original estimates.

Computing mortality figures for comparable periods of time, Dr. Pastalan found that the death rate in Pennsylvania's general nursing home population was 27 percent. This is similar to the figure (28%) for the U.S. nursing home population. Presumably, the mortality rate for the relocated group, if they had not been moved (other factors equal), would have been 27 percent. Judging from the Michigan studies, under conditions of forced relocation without preparation, the rate could have nearly doubled! However, as a result of the prior preparation familiarization program, the mortality rate in the relocated group was only 22 percent (Institute of Gerontology, 1976). (Earlier studies report similar findings; see Kasl, 1974, p. 215.) The training program not only counteracted the potentially lethal consequences of forced relocation but it also may have had additional healthful consequences. That is, the mortality figures are lower for the relocated group than for the general nursing home population.

The conclusion is inescapable: a knowledge void could have risked lives; and a knowledge-based policy decision saved lives. If it had been necessary to wait for the technical publication of the Michigan study before action could have been taken, lives would have been lost.[7]

Other Impacts of the Michigan Study

The impact of the Michigan study does not end here. These findings found their way, usually informally and by word-of-mouth and sometime fortuitously, to others who were faced with individual or collective forced relocation problems involving institutionalized elderly. Rather than spell out the details of each of these, there will be a summary of the direct results of the Michigan study to date. 1) The Michigan study findings and recommendations have served as the basis for court decisions in seven civil rights cases in five states. These cases have determined that institutions must grant their elderly occupants who are faced with forced relocation with

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[7]Of interest, the review by Kasl, published in July of 1974, does not cite the Michigan study. True, the first publication of the Michigan studies in a technical journal was in the Winter of 1974. Nevertheless, research reports were issued starting in the Spring of 1972 and the final report to the sponsor (NIMH) was issued by the Michigan researchers in April 1974. There was also a brief presentation of the research findings in the proceedings of EDRA 4 in 1973. However, this comment must be put into context. Kasl's review was quite broad, covering six categories (of which forced relocation was only one), and his literature review was comprehensive.

access to a preparation program prior to the relocation. 2) Guidelines based on the Michigan study findings have been developed for use by public interest lawyers handling such cases and by social workers who become involved with such situations. 3) Regulations requiring a preparation program, based on the Michigan research, to protect the institutionalized elderly have been adopted by one state and are being drafted by two others. 4) Memoranda urging all states to adopt such preparation programs have been issued by two federal agencies (other than the one funding the original Michigan research). 5) Eleven bills to require a preparation program, like the Michigan example, for all elderly transfer cases covered by federal assistance (i.e., Medicaid) have been introduced in the United States Congress. The legislation is directed at overcoming the problem created by PL 92-603 stemming from the enforcement of the Life Safety Code. It is important to note that all of these actions are the <u>direct</u> results of the Michigan research, and to particularly note that most of these actions were initiated <u>before</u> the major reports on this research were published in a technical journal.

Special and Unusual Aspects of the Case

At the start of this case study, special and unusual aspects of this case study were mentioned. First, the special aspect: failure of nursing homes and other facilities for the institutionalized elderly to meet the fire safety provisions of the Life Safety Code, required to be enforced by HEW under PL 92-603, was the basis for decertifying some nursing homes and for patient reclassification in others. Both resulted in forced relocation because the owners of the nursing homes would not rehabilitate their homes to comply with the structural requirements of the Code. This is the special aspect of the case study through which the enforcement of the Life Safety Code potentially generated lethal consequences. Second, the unusual aspect: the Michigan study was useful prior to its appearance in the open literature (as a journal article). Usefulness was the avowed aim of the study, not publication. This aim was the unusual aspect of the case to those familiar with the emphasis on publication which is part of the approach of "basic researchers" toward research.

Lessons to Be Learned

Why was the Michigan study useful? There are lessons to be learned from the Michigan study which can be applied by other environmental researchers who want their work to be useful.

First, the Michigan study findings were stated in terms of actual numbers of deaths associated with each type of transfer and with each version of the Michigan preparation program. Thus the data were readily understood by persons not trained in the behavioral sciences or in the special problems of the aged.

Second, the researchers advocated positive intervention (i.e., preparation programs). Their primary commitment was to the elderly, not to research as such. They focused on the consequences of decisions of the kind made by nursing home administrators and government officials. This focus permitted members of the policy community who were sensitive to the problem of forced relocation to identify the correspondence between specific research findings and specific programmatic alternatives.

Third, the timing of the study was right. The Michigan study researchers were sensitive both to the needs of the institutionalized elderly and to the impending threat of a critical relocation problem brought about by new federal regulations. They shared the commitments of those in the policy community who might be able to make use of their findings. Put another way, they sensed an impending national need and responded to it.

It has been noted that Dr. Pastalan's preparation program was adopted by the State of Pennsylvania two months before the first publication of the Michigan study findings in a technical journal. Prior to that publication, the dissemination of the Michigan study results, by the investigators and others who received them, was through less formal channels: the Michigan investigators sent project reports to the sponsor, made presentations at professional conventions, and made direct mailings of the results to potentially interested persons. In addition, others who received the results distributed the results through publication in a legal clearinghouse newsletter, federal agency memoranda, and word-of-mouth exchanges, often based on fortuitious meetings. In short, for results to be useful, there may have to be active participation by the investigators and others in the distribution of information to those who might need it.

Of importance, the major impacts of the Michigan study findings were made prior to the publication of the findings in a technical journal. Clearly, publication is a legitimate objective for the researcher. However, the usefulness of the Michigan study results did not suffer because of problems typically associated with publication in technical journals, such as publication lag (the time between submission of an article and its eventual publication) and the use of technical jargon. This was because the major impacts of the research had occurred prior to the formal publication of the Michigan study.

CONCLUSIONS

The case studies argue for knowledge-based codes: codes whose technical provisions (with respect to their development and subsequent updating) and whose enforcement can be justified and documented in terms of the systematic study and understanding of applicable, relevant events or phenomena and their implications. This thesis is predicated on the assumption that knowledge reduces risk to both decision-makers who create and manage the built environment and to users of the built environment. It is recognized that our knowledge about the environment is uneven and that knowledge voids exist. The case studies addressed some consequences, actual and potential, of these knowledge voids. In turn, it was shown that knowledge either improved or could have improved decisions by informing persons about what should be done (e.g., what provisions should be part of a housing code) and what should not be done (e.g., not allowing forced relocation without prior preparation for the move).

This thesis has a number of implications. First, systematic understanding means going beyond traditional disciplinary approaches. The physical, social, behavioral, economic, and legal aspects of events and phenomena must be considered jointly. Second, there are knowledge voids. We cannot always be assured that professionals with the foresight of Dr. Bourestom and Dr. Pastalan will have done the requisite research. The circumstances required for researchers to convince potential sponsors or for sponsors to convince potential researchers to do the research which is needed to reduce knowledge voids represent critical but unresolved problems. Third, the research community must be sensitive to the requirements of those who use their products. The lessons learned from the Michigan study must be kept firmly in mind. Last, the regulatory community must be open to the consequences of accepting a knowledge-based approach to regulation.

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INTERIOR ARCHITECTURE BY CONSENT DECREE AND COURT ORDER

by

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Mental hospital patients, mental retardates, handicapped people and prisoners in jails are suing various governmental authorities saying, among many other things, that the physical interior environments of these institutions do not meet their needs. Consent decrees and court orders in 16 leading cases are examined. The question is raised as to the origin of the very specific standards in several of the cases. The long-range suitability of these standards is questioned and contrasted with more humane, less specific approaches to the same concerns in Sweden and Canada. The need for further research to establish more useful determinations of the effects of the immediate physical environment on human well-being and behavior is pointed out. The problems of the designer in meeting the special needs of these four types of plaintiffs are also examined.

Key words: Court orders; human behavior; institutional occupancies; interior design; physical environment; standards; regulation; research.

INTRODUCTION

Working as interior design consultants in mental hospitals and in mental retardation sites in three states, we are gaining a growing conviction that mental patients are being hurt, not helped in terms of the design of the settings where they are sent for treatment, nor can they fend for themselves in influencing these designs.

Patients have participated with us in the designing process, but before that can happen fruitfully, the patients must want to do so and invite the designer's help instead of having the designer's services imposed upon him. This involves enlisting the help and participation of the staff first. Then the designer can talk with the staff and patients, interpret and evaluate his combined findings and finally present the evolved design to whomever the powers may be - in a manner that helps the patients get what they want and need.

As for the powers that be - pay for the designer and the physical improvements comes from remote places, like a state board of mental health and mental retardation, but the patient is the user and his needs and wants are paramount; the patient is the user client, the real client; the board or whatever is the paying client.

However, this is not only a matter of separation between the paying client and the user client; it is also a matter of the necessity for the designer to fend for patients who by the very nature of their difficulties as well as because of frequently very heavy drug treatments are just not in any condition to respond, to project, to demand, to evaluate, in short to fend for themselves. Therefore, the designer must be the patient's design agent, his intercessor, his advocate.

Actually, this kind of advocacy design is necessary in varying degrees in many situations where the paying client is not the user client and where in varying degrees the user client cannot fend for himself.

CLIENT TAXONOMY

Without the benefit of massive psychometric studies, the following is not absolutely accurate, but the continuum of user clients who need the most design advocacy might start off with the mental patient and the mental retardates; next would come seriously ill general hospital patients, and perhaps rehabilitation subjects. The list would proceed through the residents of convalescent homes and various other forms of housing for the elderly to prisons, public housing, kindergartens, grade schools, junior high schools, high schools, boarding schools, colleges, universities, factories, offices, laboratories to executive offices and the homes of wealthy clients who need no design advocacy at all.

This need does not solely depend on the distance between the paying client and the user client; it also depends on the user client's ability to cope. As the above list proceeds, ability to cope increases - really on two scales - one is based on the ability of the user client to conceptualize and express his real needs and wants (and be listened to); the second scale is based on how much control is exercised by others upon the immediate environment of the particular user client.

GRAND TOUR EGO TRIP

It is our own belief that architectural and interior designers have been slow to understand on their own these needs for design advocacy; the grand tour ego trip attitude of the typical interior or architectural designer is diametrically opposed to design advocacy. Architectural and interior designers are too accustomed to telling clients (both paying and using) what they can have - they're not accustomed to - or even geared up for making detailed investigations to determine client needs and wants.

However, pressure from a new direction is creating a situation where designers may be forced to consider design advocacy as a way of life - or - to put it another way: If they don't consider it, Federal courts may accomplish the same result as if they had.

What's happening now in a surprisingly wide variety of settings is that INTERIOR AND ARCHITECTURAL DESIGN IS BEING ACCOMPLISHED BY FEDERAL CONSENT DECREES AND COURT ORDERS.

WYATT

Perhaps the most important landmark court order and consent decree yet promulgated occurred as the result of a case in a Federal District Court in Alabama, known progressively as Wyatt v. Stickney, Wyatt v. Aderholt and Wyatt v. Hardin. (344 Fed. Supp. 373 - while the case was in progress, a succession of changes of Alabama Mental Health Commissioners changed the name of the defendant in the case.)

Basically what happened was that a patient at Bryce Hospital, Tuscaloosa sued the Alabama Mental Health Commissioner in what later became a class action - saying that patients there had not received proper treatment and that Bryce did not have a proper physical environment for patients. This case was later enlarged to include patients at Searcy Hospital (another Alabama State Mental Hospital) and patients at Partlow State School and Hospital for the Mentally Retarded.

After a protracted series of hearings and orders, the Court issued a final order and decree to force improvements in the physical facilities, the numbers and quality of staff and the patients treatment programs.

The following are some excerpts from it affecting interior architecture: "The Court found defendants' treatment program was deficient in (that) .... It failed to provide (1) a humane psychological and physical environment...." More specifically, the Court found ... the absence of any semblance of privacy.... The physical facilities at Bryce were overcrowded and plagued by fire and other hazards...."

AMICUS CURIAE

Friends of the Court were called in to give expert counsel to help set standards for improving Bryce, Searcy and Partlow. These friends included the United States of America, the American Orthopsychiatric Association, the American Psychological Association, the American Civil Liberties Union, and the American Association on Mental Deficiency. The Court stated in the order and decree that they "have performed exemplary service for which this Court is indeed grateful." You will note that no physical design agents, no architects or interior designers (or their professional associations) were friends of this Court in this case.

MINIMUMS

Before getting to the specific physical environmental standards set up by the Court, it should be emphasized that these are just minimums, as the Court strongly pointed out, and it should also be emphasized that a Court-appointed Human Rights Committee was set up at Bryce plus a separate one at Searcy to monitor the State's compliance with the order and decree. The State of Alabama was also required by the Court to find and fund as a consultant a Ph.D. psychologist at Bryce to help the Human Rights Committee in its work; this psychologist is now a full time consultant to the Bryce Human Rights Committee.

It is also noteworthy that the Court did not appoint a Master, as it might in a bankruptcy case, to run the affairs of the hospitals; however, the Court said, "Nevertheless, defendants, as well as other parties and amicus in this case, are placed on notice that unless defendants do comply satisfactorily with this Order, the Court will be obligated to appoint a Master." (We shall find that actually happened in a similar case in Ohio.)

The implications of this statement are clear and the Court further strengthened its stand by saying that "...a failure by defendants to comply with this decree cannot be justified by a lack of operating funds," emphasizing the obligation of the State of Alabama to provide "suitable treatment for the mentally ill."

The Court further strengthened this with a statement that the importance of "how the Legislature and Mental Health Board respond to the revelations of this litigation is the very preservation of human life and dignity. Not only are the lives of the patients currently confined at Bryce and Searcy at stake, but also at issue are the well-being and security of every citizen of Alabama."

ORDER AND DECREE

Appendix A of the Court's Order and Decree is 14 legal size pages long; here are some excerpts which specifically affect the interior environment and its design:

"II. Humane Psychological and Physical Environment

1. Patients have a right to privacy and dignity..." After mentioning the Patient's rights to telephone communication and other matters in 2 through 14, Appendix A continues:

"15. Patients have a right to be outdoors at regular and frequent intervals, in the absence of medical considerations..."

"17. The institution shall provide, with adequate supervision, suitable opportunities for the patient's interaction with members of the opposite sex..."

"19. Physical Facilities - A patient has a right to a humane psychological and physical environment within the hospital facilities. These facilities shall be designed to afford patients with comfort and safety, promote dignity and assure privacy. The facilities shall be designed to make a positive contribution to the efficient attainment of the treatment goals of the hospital.

A. Resident Unit - The number of patients in a multi-patient room shall not exceed six persons. There shall be allocated a minimum of 80 square feet of floor space per patient in a multi-patient room. Screens or curtains shall be provided to ensure privacy within the resident unit. Single rooms shall have a minimum of 100 square feet of floor space. Each patient will be furnished with a comfortable bed with adequate changes of linen, a closet or locker for his personal belongings, a chair and a bedside table.

B. Toilets and lavatories - There will be one toilet provided for each eight patients and one lavatory for each six patients. A lavatory will be provided with each toilet facility. The toilets will be installed in separate stalls to ensure privacy, will be clean and free of odor, and will be equipped with appropriate safety devices for the physically handicapped.

C. Showers - There will be one tub or shower for each 15 patients. If a central bathing area is provided, each shower area will be divided by curtains to ensure privacy. Showers and tubs will be equipped with adequate safety accessories.

D. Day room - The minimum day room area shall be 40 square feet per patient. Day rooms will be attractive and adequately furnished with reading lamps, tables, chairs, television and other recreational facilities. They will be conveniently located to patients' bedrooms and shall have outside windows. There shall be at least one day room area on each bedroom floor in a multi-story hospital. Areas used for corridor traffic cannot be counted as day room space; nor can a chapel with fixed pews be counted as a day room area.

E. Dining facilities - The minimum dining room area shall be ten square feet per patient. The dining room shall be separate from the kitchen and will be furnished with comfortable chairs and tables with hard, washable surfaces..."

Other provisions of the Order and Decree provide for "an established routine maintenance and repair program" so that "the physical plant shall be kept in a continuous state of good repair....adequate heating, air conditioning and ventilation systems" to remove steam and odors and keep air temperatures between a maximum of 83 degrees and a minimum of 68 degrees F. Required temperatures for hot water are set at 110 degrees at the fixture for patient use and 180 degrees at the equipment for mechanical dishwashing and laundry use.

The Court also decreed that "The physical facilities must meet all fire and safety standards established by the state and locality. In addition, the hospital shall meet such provisions of the Life Safety Code of the National Fire Protection Association (21st edition, 1967) as are applicable to hospitals...The hospital shall meet all standards established by the state for general hospitals, insofar as they are relevant to psychiatric facilities."

WHENCE COMETH?

The first obvious question that comes to the designer's mind as he reads these very detailed and specific standards set by the Court is: "Where did they come from?" (especially those definite square feet minimums and those temperatures).

Well, here is a clue: A recent use of similar but not all identical figures (with great impact) can be found in the Federal Register for Thursday, January 17, 1974, Vol. 39, #12, Part II, Department of Health, Education and Welfare, Social and Rehabilitation Service, Medical Assistance Program, Intermediate Care Facility Services, 249.12, Standards for Intermediate Care Facilities and 249.13, Standards for Intermediate Care Facilities in Institutions for the Mentally Retarded or Persons with related Conditions.

These two sections contain similar water temperatures as standards; the "friends of the court" probably dug these out and incorporated them in their briefs - whence they came to be part of the Court Order and Decree.

Probably these sections of the Federal Register were influenced by the standards of the Joint Committee on the Accreditation of Hospitals also. However, there is another source which seems likely, too: "Standards for Psychiatric Facilities," promulgated by the American Psychiatric Association (a friend of the friends of the court?) in 1969. This document specifies a minimum 80 square feet of floor space in single rooms and 70 square feet of floor space per patient in multiple patient rooms; this is slightly less than the minimums in the Wyatt decision. The prescribed square footage in day rooms and the ratios of toilets, lavatories and showers to the numbers of patients are identical to those in the Wyatt decision.

All of which is just fine - there have been some standards set, and these may be as good as any - for a start and as minimums, that is. What's worrisome about this, though, is that once definite square footage standards become part of a landmark court order like this, these standards tend to become rigidly emplaced in the system, and from then on, nobody questions their validity.

MORE CASES

Meanwhile, there are literally more than a dozen similar cases in various stages of progress around the country, and many of them are citing this case as a precedent in their place to improve mental hospital conditions and conditions in sites for the treatment of the mentally retarded. As we shall see the Order and Decree in one case copies almost word for word the above quoted sections of the Order and Decree in the Wyatt case.

NO EXPERIMENTAL OR BEHAVIORAL BASIS

No one has publicly challenged these standards in terms of their use in mental institutions and, especially referring to the square feet standards for patient rooms, the most comprehensive search of the literature available does not show any experimental or behaviora basis for these figures.[1]

[1] "A Bibliography of Materials Useful for Changes in Mental Hospitals: Architecture, Institutional Settings and Health," Exchange Bibliographies #463, 464, 465, 533 and 534 by ARC/Architecture/Research/Construction, ARC Research Division, Cleveland State Hospital. Published by the Council of Planning Librarians, P.O. Box 229, Monticello, Illinois 61856, 1973, 1974. The authors were members of the team which researched and annotated the 544 pages of bibliography.

Obviously, behavioral research is called for either to validate these standards or to find other standards needed. However, now that these very definite standards have become part of the law by consent decree and court order the tendency will be for everybody to accept them as faits accompli without even any attempts as creative interpretation.

They will be ignored as a research opportunity, which in our opinion, they certainly are; these standards desperately call for evaluation of their effectiveness on a wide-spread scale, since the influence of them seems so pervasive.

Incidentally, the British Department of the Environment seems to agree; in a report issued in June, 1976, "The Value of Standards for the External Residential Environment," by George Woodford, Kirstine Williams and Nancy Hill, the statement is made that "Unfortunately, it is all too easy for a standard, simply because it is a standard, to become a formula at which thought stops." DOE is recommending "housing environment indices" saying that "the quality of a housing environment depends on much more than can be assessed by reference to quantities."

MENTALLY RETARDED

There's another landmark case in the field, this time concerning a facility for the mentally retarded where, although the standards are not quite so detailed as they are in the Wyatt Order and Decree, the meaning for designers is just as clear.

This case is Ricci v. Greenblatt, Civil Action #72-469-T, U.S. Dist. Ct., Massachusetts; it too became a class action suit and November 12, 1973, a consent decree was entered that turned into $2.6 million worth of capital outlays to improve Belchertown State School, Belchertown, Mass. This consent decree starts off with:

> "For the purpose of providing the mentally retarded residents at the Belchertown State School with their immediate Constitutional rights and further in consideration of their rights to health, safety, and a suitable living environment:
>
> 1. Physical Plant - The defendants agree to request of the Legislature an appropriation of $2.6 million in capital outlay funds for the renovation and improvement of various buildings, including furnishings and equipment..."

Though Ricci v. Greenblatt repeats some of the numerical standards found in Wyatt, there is great emphasis on the use of adjectives to describe the court-ordered environment such as "appropriate," "personalized," "comfortable," "attractive," and "homelike." One statement in the Decree is particularly worth quoting, "The design, repair and renovation of activity rooms shall provide suitable accommodations to promote physical and mental health, and optimal sensory-motor, cognitive, affective and social development, and to encourage movement from dependent to independent and inter-dependent functioning together with provisions for the enjoyable use of leisure time..."

THEY GOT THE MONEY

The $2.6 million was appropriated by the Massachusetts Legislature; the Consent Decree is being implemented.

OTHER CASES CONCERNING THE MENTALLY RETARDED

There have been quite a few more court cases where Court Orders and Consent Decrees have affected the interior architecture of mental health and mental retardation facilities. Here are some of the better known ones:

1. New York State Association for Retarded Children v. Carey (formerly v. Rockefeller) 357 Fed. Supp. 752.

This is known as the "Willowbrook" case, since it concerns a New York state facility for the mentally retarded, Willowbrook State School. Though a landmark case in many respects, especially in that it directs the reduction of the population at Willowbrook and the moving of patients to intermediate facilities, there seems to be little in the Consent Decree that directly affects interior architecture except a provision that "no more than eight residents can live or sleep on a unit," and another ordering "immediate and continuing repair of all inoperable toilets."

2. U.S. v. Michael K. Shorter (Crim. #67724-23, Superior Ct., D.C.) The November 13, 1974, decision in this case found that "facilities designed for the treatment of the mentally <u>ill</u> are <u>not</u> generally <u>suitable</u> for the treatment of the mentally <u>retarded</u>." (underlining ours) Though the differences are not specified in the decision, it does indicate a high degree of architectural sensitivity to the specific needs of patients, a sensitivity which unfortunately is not shared by some interior designers and architects.

3. Welsch v. Likins, 373 Fed. Supp. 485. This, too was a class action similar to Wyatt v. Hardin; here the Court ordered "extensive alterations to the facility's (mental hospital) physical plant, air conditioning in non-ambulatory units, carpeting in all residential and program areas, removal of bars and limitations on the use of underground tunnels for transporting residents."

4. Davis v. Watkins, 384 Fed. Supp. 1196. In this Ohio case, the Court <u>did</u> appoint a Special Master (as the Alabama Court had threatened to do in Wyatt) to run Lima State Hospital. Though there are some minor differences between this Order and that in Wyatt, the same square footage figures appear and this Order closely follows the format of the

Wyatt Order and Decree - in places, word for word.[1]

THE HANDICAPPED ALSO SUE

Another type of Court Order and Consent Decree is being handed down which fundamentally concerns the rights of handicapped persons to use public buildings and facilities.

Three recent cases include:

1. Urban League (also the Paralyzed Veterans of America, the National Paraplegic Foundation and others) v. Washington Area Metropolitan Transit Authority (WMATA). Civil Action #776-72 U.S. Dist. Ct., D.C. The plaintiffs wanted to be sure that they as handicapped persons would be able to use the Metro subway system when it is built and asked for elevators to be available for people who cannot use stairs. The court issued a mandatory injunction on October 9, 1973, saying that WMATA cannot commercially operate the Metro until handicapped persons are able to use it.

2. Disabled in Action of Baltimore, et al., v. Hughes, et al. Civil Action #74-1069-HM U.S. Dist. Ct., Maryland. This was a class action filed on behalf of all elderly and handicapped persons who were being denied access to mass transit vehicles in the Baltimore metropolitan area. The case was settled by a memorandum of understanding which included the agreement that 205 buses would be bought in accordance with specifications which would make them accessible to the elderly and handicapped just behind the driver and that 10 buses would be bought that could be used by people in wheel chairs.

3. Friedman v. County of Cuyahoga, Case #895961, Court of Common Pleas (Ohio) Friedman, a lawyer confined to a wheelchair by injuries suffered in a car accident, could not enter Cuyahoga County Buildings, including the Administrative Building and the Courthouse. He and others sued to be allowed access to these buildings. A Consent Decree ordered the installation of "ramps, a bell or other signalling device, or other appropriate means to assure ingress and egress by physically handicapped persons to certain public buildings."

PRISONS, TOO

Another area of legal activity affecting interior architecture design has been a number of court cases involving interior conditions in jails and prisons, especially as they produce overcrowding.

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[1] A decision affecting a facility for the mentally retarded should be handed down soon in Rone, et al., v. Fireman, et al. a suit filed against Hawthornden State Hospital (Ohio), Civil Action #75-355A in the U. S. Dist. Ct., Northeast Ohio. The case does involve the interior architectural environment.

One of the landmark decisions is Costello v. Wainwright, 397 Fed. Supp. 20. The Court said, (among many other things) "In summary, the overwhelming evidence is that there is a direct and immediate correlation between severe overcrowding, as now exists in the Florida Prison System, and the deprivation of minimally adequate health care. In addition, it appears that severe overcrowding endangers the vary lives of the inmates because of its being a factor in the causation of violence within the prison system."

In Baker v. Hamilton, 345 Fed. Supp. 345, "The court further held that placement of juveniles in county jail consituted cruel and unusual punishment in violation of the Eighth Amendment, in view of cramped quarters, poor illumination, bad circulation of air, broken locks, no outdoor exercise or recreation, and no attempt at rehabilitation."

In Osborn v. Manson, 359 Fed. Supp. 1107 the Court held "that conditions of confinement of prisoners, held in administrative segregation in cells which had no running water and only covered buckets which were infrequently emptied by prisoners who had no opportunity for exercise other than to walk up and down two flights of stairs twice a day to wash and empty their buckets, were violative of basic concepts of decency and constituted cruel and unusual punishment."

In Johnson v. Lark, 359 Fed. Supp. 289 cited in the holding were "...three men in tiny two-man cells, absence of recreational facilities and outside exercise areas.... inadequate ventilation. . ." (from Pa. Commonwealth ex rel. Bryant v. Hendrick 444 Pa. 83, 280 A.2d 110). In Bryant, the Court held also that ". . .petitioners have been imprisoned in overcrowded, wet, badly ventilated and verminous cells. . ." and that this was evidence of violation of the Eighth Amendment respecting cruel and unusual punishment. (see also Hendrick v. Jackson 10 Pa. Commonwealth 392, 309 A.2d 187).

In Dillard v. Pitchess, 399 Fed. Supp. 1225 the Court said, "From the testimony at the trial, it is evident that the punishment imposed upon the pre-trial inmates confined in the jail is not due to the vindictiveness of those in charge of their custody, but stems instead from the antiquated nature of the facility itself."

Decisions should be available soon in two more cases concerning prisons, Campbell v. McGruder, et al. Civil Action #1462-71 U.S. Dist. Ct. D.C. and James v. Wallace in the Middle Alabama U.S. Dist. Ct., Northern Division.

MEANWHILE, THE SWEDES

While the U.S. Congress and our state legislatures seem to have been largely waiting for the Courts to tell them what to do to make our public interior environments habitable and useful, Sweden has made a significant step forward in one area at least - toward user participation in the design of some interior environments: "Sweden has just introduced a new law on democracy in the workplace that gives all workers the unquestionable right to equal say with the managers about their work, methods, equipment, environment and work policies...." Paul Harrison in Human Behavior, vol. 5, #8, August, 1976, p. 40.

"Since the beginning of 1974, new regulations have been produced concerning the Swedish building laws and worker protection laws which will have an important influence on both the methods for planning new working places and the workplaces themselves. To obtain building permission, which is necessary before any building can be started, all drawings and other relevant documents must be examined by the factory inspector.

In order for him to say whether the proposed conditions are satisfactory, he must contact the employees who will be affected by the building and find out whether they have had a say in, and suitable influence on, the planning of the new workplaces. When smaller changes are being made to workplaces, where no building permission is needed, the worker protection law says that the employees have the right to take part in the planning." T. Ivergard in Applied Ergonomics, vol. 6, #4, 1975, pp. 225-230.

Maybe we'll learn to beat the Courts to the punch one day.

PROGRESSIVE CANADIAN STANDARDS

Meanwhile, perhaps we might take a look at some Canadian standards that go far beyond the numbers game in most of the American court decisions; they show a genuine concern for people.

The design considerations that follow have been extracted from Part II, Section 10 of FACILITIES FOR MENTAL HEALTH SERVICES, Canadian Building Standards and Guide Material for Hospital and Mental Health Facilities. Department of National Health and Welfare, Canada, 1965.

Section 10 was prepared by Professor Kiyo Izumi, Architect-Planner.

"C. Design Considerations

C-1. There are not enough definitive studies of this nature to permit of rigid conclusions but based on the observations of psychologists, nurses, psychiatrists in existing mental hospitals and some architects, and research projects among mentally ill patients, assisted by experience simulated through drugs such as Lysergic Acid Diethylamide, the following is a suggested list of design considerations to be kept in mind: -

C-2. To avoid certain types of architectural design which lead to ambiguity, e.g., 2.1 The design of doorways where the size, proportion and treatment of the side-light is indistinguishable from the door itself.

2.2 Use of panelling in proportion and pattern in such a fashion to make doors, cupboards and other closing panels indistinguishable from the adjacent wall.

2.3 Use of trim, paint lines, hardware and other elements placed to simulate adjacent shelf or drawer when in fact these do not exist.

2.4 Built-in closets and other features, particularly in patients private rooms, which give the illusion of hidden spaces behind...."

C-3. To avoid qualities of finish that tend to heighten illusions...."

C-4. Proportion and scale of spaces and form should be commensurate with the human body. Monumental entrances, lobbies and other features should be avoided. The texture of materials, color and other architectural elements should be carefully considered so that they complement or are subordinate to the human element. Nothing is so disturbing as to be overwhelmed by the visual and physical environment...."

The list goes on, and the above is a small portion of it, but C-4 is sufficient as an example of concern for human beings who occupy and use hospital and mental health facilities in Canada.

RESIDENTIAL ENERGY CONSUMPTION: SOCIO-PHYSICAL DETERMINANTS OF ENERGY USE IN SINGLE FAMILY DWELLINGS

by

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The paper reports research designed to establish the factors that determine energy consumption, especially in single family detached dwelling units. The research asks the question is it the physical structural components of the housing or the life patterns carried on by the residents or both that make the difference in energy consumption? Using a human/environment ecosystem model, this question comes under scrutiny.

Key Words: Energy consumption; input/output models; lifestyle factors; physical environment; residential housing; socio-physical determinants; systems theory.

INTRODUCTION

The United States has a goal of energy independence by the year 1985. If this goal is to be reached given the finite supplies and "simultaneous failure" (1) of oil and gas supplies during the recent energy crisis (Winter 1973-74), a concerted effort must be launched to counterbalance fossil fuel based energy demand with energy conservation.

H. A. Bethe, 1967 Nobel Prize winner in physics, indicates that there are two major approaches to energy conservation (2):

1. Improved efficiency of methods whereby energy is consumed.
2. A change in living patterns.

Most energy conservation programs instigated since the energy crisis have been aimed at changes in technological standards of efficiency. For example, both the National Bureau of Standards and the American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE) have developed energy efficiency criteria for new buildings. Although a necessary condition toward energy conservation and thus energy self-sufficiency by 1985, these programs have at least three major obstacles (3):

1. The millions of older buildings where retro-fitting is both expensive and impossible in some cases.
2. The initial cost of making an energy efficient building is generally higher for both new and older buildings.
3. There is a great deal of uncertainty about what standards should be taken into consideration, including regional differences in climate, adequate and feasible systems that are also economically possible.
4. A fourth obstacle which needs to be added is that energy efficient programs and standards have been aimed at buildings in general. Common sense would indicate some differences in standards should be considered by building type--residential housing vs. other building types.

RESIDENTIAL HOUSING

The residential sector of the economy is directly accountable for 20 percent of the energy consumed in the United States. Given the recent period of energy uncertainty (the energy crisis of 1973-74) and the continued increase in energy cost, it becomes imperative to discover the factors that contribute to residential energy consumption in order to identify where energy efficient programs should be focused. That is, is it the design and the construction of the dwelling unit itself or the life patterns of the occupants or both that give rise to the energy consumed within the dwelling? The question in the long run boils down to: will energy efficient housing design (either through new construction or retro-fitting) be sufficient to bring about adequate energy savings or will basic changes in the lifestyle of the residential energy consumer be necessary?

In an attempt to answer these questions, a research problem was designed vis a vis a systems approach to discern the relative magnitude of relationships existent between direct residential energy consumption and (1) the physical-structural components of the dwelling units and (2) the human behavioral lifestyle patterns of the residential dwellers.

The research focused on the energy consumed in single family residential dwelling units for three critical reasons:

1. Single family dwellings are the most prevalent form of housing in the United States. Of the 67 million year-around housing units available in standard Metropolitan Statistical Areas, 69.4 per cent are single family units (1970 census).
2. Single family dwellings are the least energy efficient dwelling unit type (the Cost of Urban Sprawl, April 1974, p.60).
3. An accurate measurement of total direct energy consumption (in BTU's) by household energy mix was gained from utility companies and oil dealers.

To overcome deficiences in prior research on residential energy consumption, both physical-structural housing variables and socio-economic lifestyle variables were measured as exogenous to total direct residential energy consumption. Although most research done on residential energy consumption is relatively recent, having been generated during the period just prior to, during or since the energy crisis period (Winter 1973-74), not much attention has been given to researching the determinants of energy consumption in residences as the combined function of both physical-structural and behavioral components.

The emphases in household energy research has been on:

1. The dwelling unit as a physical primogenitor of energy consumption including such variables as: exterior climate, heating, and cooling systems (Size and efficiency), construction details, number of rooms, orientation on site to wind and solar exposure, type and location of windows and doors, appliance packages, etc. (Bullard, 1973; Hittman Assoc., 1973; Fox et al., 1973).
2. The reported behavior response by householders to the energy crisis period, particularly self-report studies of conservation behavior, energy knowledge, and energy policy acceptance (D. I. Warren, 1974 and 1975; Perlman and Warren, 1975; Murry et al., 1974; Gottleib

and Matre, 1975; Kilkeary and Thompson, 1975; and Zuiches, 1975).

3. The actual measure of behavior change (energy conservation behavior) by households to the energy problem (Heberlein, 1974 and 1975; Winett and Nietzel, 1975).
4. The inequities experienced during the energy crisis either as a function of socio-economic class or of sliding scale energy pricing mechanisms (Newman and Wachtel, 1974 a and b; Schwartz and Schwartz-Barcott, 1974).

None of the prior research done linked measured direct total energy count (BTU's) with physical housing factors, while assessing life style factors as possible determinants of energy consumption (B. Morrison, 1975).

THEORETICAL AND EMPIRICAL RESEARCH OBJECTIVES

The research had two basic objectives:

1. To test the viability of an hypothetical system input/output model of direct energy consumption in single family detached dwellings deduced from a human ecosystems conceptual model (see Figure 1).
2. To determine the relative importance of a selected set of socio-physical factors as determinants of the total amount of direct energy consumed (BTU's) in the single family detached dwelling units studied.

Two major hypotheses were generated which tested both the gross and net aspects of the dependent variable--total BTU's consumed directly in single family detached dwellings. These hypotheses indicated:

1. direction of relationship
2. rank ordered magnitudes of relationship
3. and that physical housing factor would contribute differently to energy consumption than household or family lifestyle factors.

RESEARCH METHOD

The research design for this study was a cross-sectional field survey conducted during May and June, 1974 (shortly after the peak energy crisis period and after the Arab oil embargo). The survey employed a multi-stage area probability sampling technique in which the randomly selected urban and rural areas of a mid-Michigan S.M.S.A. were successively subdivided into smaller sampling units, assuring a sample reflecting the urban and rural nature of the S.M.S.A. and a sample of intact households. Both self-administered questionnaires and personal interviews were used as survey techniques. Utility companies and fuel oil dealers provided the energy consumption data for the households surveyed.

The subsample used in this study is a portion of the original sample purposefully controlled on three variables to gain measurement precision and to exclude cases with missing data. The three variables controlled were:

1. Dwelling unit type--single family detached dwellings.
2. Complete energy consumption data for one year (June 1973 to May 1974). This included the appropriate energy mix for each household.
3. A measurement in square feet of the dwelling space.

MODE OF ANALYSIS

Based on both theoretical and methodological considerations stepwise regression and path analysis were used. From the first generalized human ecosystem model (Figure 1) broadly defined as the total system within which the problem of the research lies, a series of models were deduced via the Ashby "hypothetico-deductive" method, where the intent is to understand the wholistic system at the outset, but to reduce the system to a reasonable set of defined and measurable components (Ashby, 1962).

The first order hypothetical input/output model (Figure 2) is a model of the <u>idealized</u> set of variables to come under consideration <u>if</u> certain conditions held.

1. <u>If</u> all variables were available for measurement.
2. <u>If</u> all variables varied.

Since this was not the case in this study a second-order input/output model (Figure 3) was specified and tested.

THE FINDINGS AND DISCUSSION

<u>The Gross Analysis</u>

Two factors were used to indicate the gross measurement of factors contributing to energy consumption in single family dwellings. These were:

1. physical housing factors.
2. socio-economic lifestyle factors.

THE GROSS ANALYSIS

Total Direct Energy Consumption

Hypothesis I: Housing physical factors will explain more of the variance than family socio-economic factors for total direct energy consumption in single family detached dwelling units.

Physical housing factors will contribute more to the variance explained than the lifestyle factors as determinants of energy consumption in single family dwellings. Table 1 indicates the findings.

THE GROSS ANALYSIS

Energy Consumption

Table 1 -- Standardized Regression Coefficients, F-ratios, Probability of Sampling Error and Multiple Correlations of Two Independent Variables on Energy Consumption in Single Family Detached Dwelling Units.

	Energy Consumption		
Independent Variables	β	F	Probability of Sampling Error, One Tailed Test
Physical housing factors	.573	58.26	< .10
Family factors	.310	17.05	< .10
Overall F		44.28	< .0001
$R = .696$	df regression 2		
$R^2 = .485$	df residual 94		

The findings suggest that the hypothesis is supported, i.e., physical housing factors are more highly correlated with energy consumption than the lifestyle factors ($\beta = .573$ compared to $\beta = .310$); however, since the lifestyle factors contribute a respectable amount ($\beta = .310$) to the total variance explained ($R^2 = .485$) this set of factors must be considered important.

THE NET ANALYSIS

A detailed analysis of a number of selected factors hypothesized to contribute to energy consumption in single family dwellings is given for the purpose of understanding the particularistic function various factors played in the overall variance explained.

Table 2 indicates the outcome of the stepwise regression, where the independent variables appear in outcome rank order of magnitude.

The findings suggest that the directional relationships hypothesized hold with minor exceptions. However, the prior ranking of variables does shift substantially. Since the second order input/output model was considered a first rough approximation model based mainly on researcher speculation rather than an established theory of residential energy consumption or research replication, misjudges in rank ordering were considered possible.

NET ANALYSIS

Total Amount of Direct Energy Consumed in Single Family Detached Dwellings

Hypothesis II: Physical housing and family socio-economic factors relate to the total amount (in BTU's) of direct energy consumed in single family detached dwellings:

1) In the direction indicated by the signs below:

2) In the rank ordering magnitude of relationships stated below:

1. - Gross family income, 1973 (+).
2. - Total square feet in the dwelling (+).
3. - Presence of insulation in ceiling (-).
4. - Presence of insulation in walls (-).
5. - Presence of insulation in floors (-).
6. - Number of floor levels (+).
7. - Number of rooms in the dwelling (total) (+).
8. - Number of rooms heated (+).
9. - Number of rooms air conditioned (+).
10. - Number of major appliances in the dwelling (+).
11. - Type of construction materials (+).
12. - Number of windows (+).
13. - Number of doors to exterior (+).
14. - Location of dwelling (urban/rural) (+).
15. - Number of persons living in dwelling (+).
16. - Family life cycle (+).
17. - Belief in the reality of the energy problem (-).

NET ANALYSIS

Total Direct Energy Consumption

Table 2 -- Standardized Regression Coefficients, F-ratios, Probability of Sampling Error and Multiple Correlations of Seventeen Independent Variables on the Amount of Direct Total Energy Consumed in Single Family Detached Dwelling Units.

	Amount of Direct Total Energy Consumed		
Independent Variables	β	F	Probability of Sampling Error, One Tailed Test
Household size	.280	8.02	< .001
Major appliances	.211	3.19	< .01
Number of rooms	.173	1.30	≃ .25
Number of exterior doors	.168	2.38	< .05
Number of rooms heated	.165	1.71	< .25
Square feet	.081	.56	>> .25
Family gross income	.064	.35	>> .25
Number of floors	.055	.37	>> .25
Number of windows	.049	.24	>> .25
Insulation - floors	.027	.94	>> .25
Construction materials	.024	.73	>> .25
Family life cycle stage	.024	.58	>> .25
Number of rooms air cond.	-.007	.56	>> .25
Belief in energy problem	-.095	1.02	> .25
Insulation - walls	-.096	1.00	> .25
Location (rural/urban)	-.127	2.14	< .05
Insulation - ceiling	-.161	3.41	< .005
Overall F		4.38	< .0001

$R = .696$ df regression 17

$R^2 = .485$ df residual 79

The interesting outcome of the stepwise regression was the total amount of variance explained ($R^2 = .485$) and the outcome ordering.

SUMMARY

The conclusions, although somewhat tentative, reached from the analysis of this study are that although in the gross analysis the physical housing factors contribute most to energy consumption, certain lifestyle factors must be considered extremely important. In the net analysis the numbers of persons living within the dwelling unit were found to make the greatest difference in energy consumption. Number of major appliances along with certain physical housing construction factors also contributed to the overall variance explained, giving rise to a statement that is the persons within the dwelling unit and their aggregate demands on utilities and physical facilities (life style if you will) which add up to the energy consumed. Therefore, any programs designed to curb energy consumption in the residential sector, must be focused both on the residents and on the dwelling unit, if real energy efficiency is to be accomplished.

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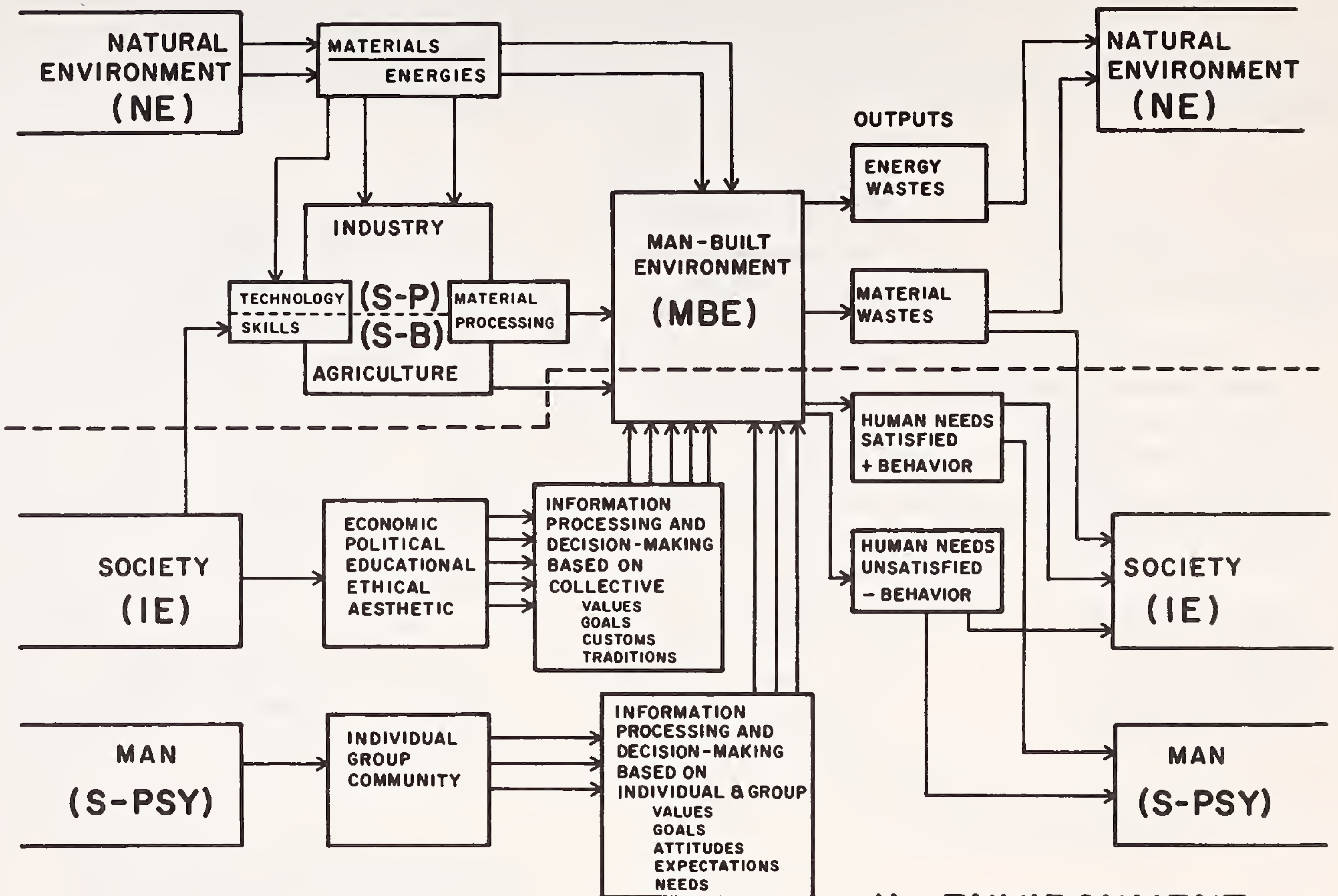

II. ENVIRONMENT

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Figure 1

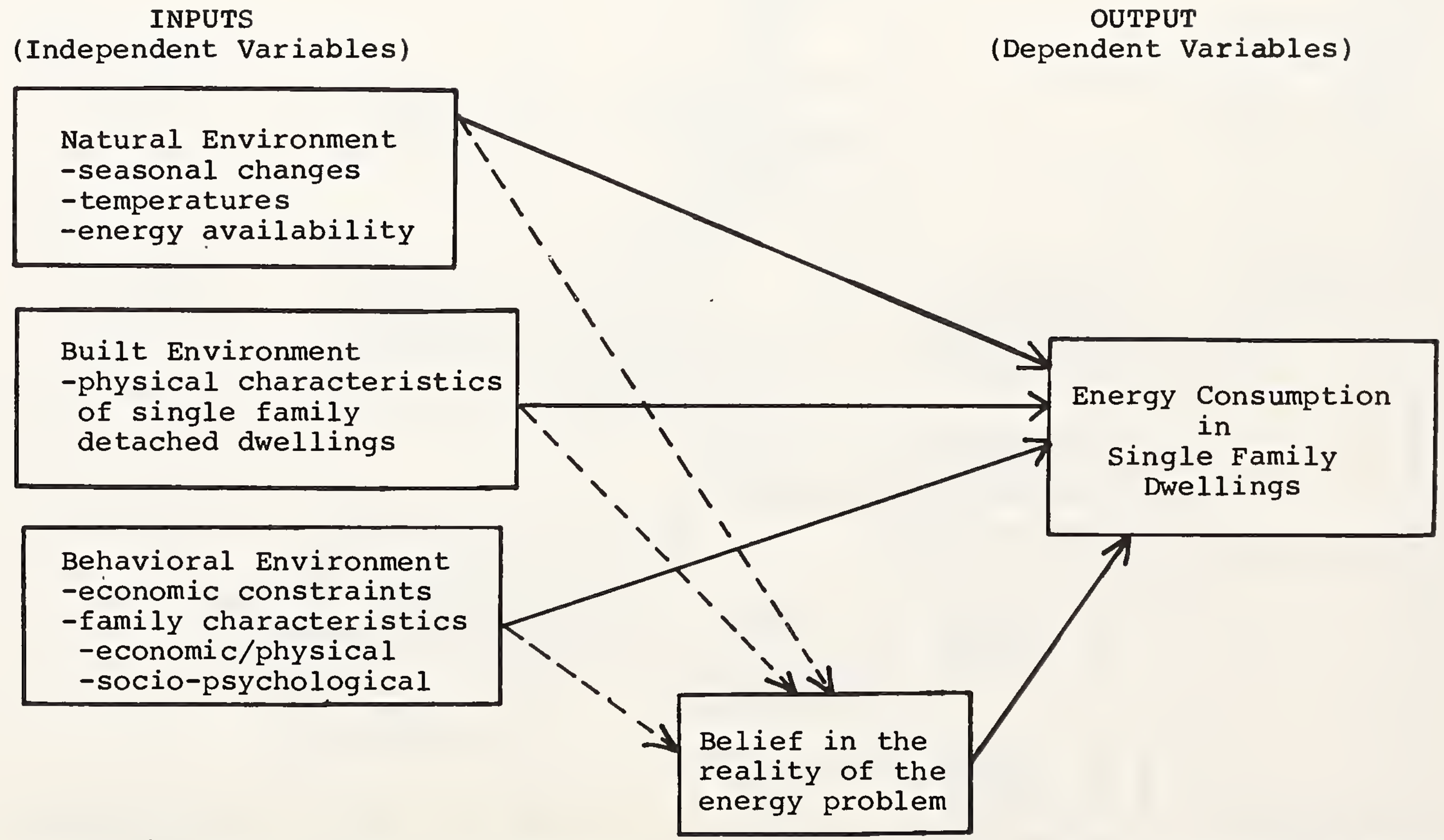

Figure 2.--First-Order Hypothetical Input/Output Model. Schema of Study Input/Output Variables and Their Hypothetical Relationships: Determinants of Energy Consumption in Single Family Detached Dwellings.

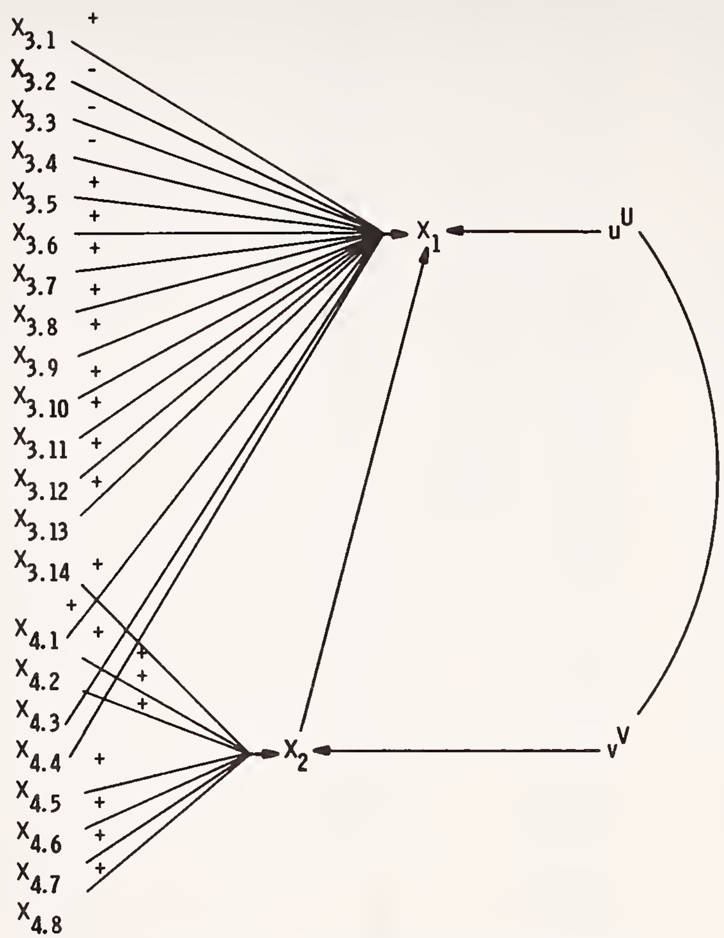

Figure 3-- Second-Order Hypothetical Input/Output Model. The Path-Analysis Model of the Hypothesized Relationships to be Tested: Determinants of Energy Consumption in Single Family Detached Dwellings.

where:

X_1 = Energy consumption
X_2 = Belief in energy problem
X_3 = Physical housing factors
- $X_{3.1}$ = total square feet
- $X_{3.2}$ = ceiling Insulation
- $X_{3.3}$ = wall insulation
- $X_{3.4}$ = floor insulation
- $X_{3.5}$ = number of floor levels
- $X_{3.6}$ = number of rooms
- $X_{3.7}$ = number of rooms heated
- $X_{3.8}$ = number of rooms air cond.
- $X_{3.9}$ = number of major appliances
- $X_{3.10}$ = construction materials
- $X_{3.11}$ = number of windows
- $X_{3.12}$ = number of doors
- $X_{3.13}$ = location (rural/urban)
- $X_{3.14}$ = housing tenure (owners/renters)

X_4 = Family factors
- $X_{4.1}$ = gross family income
- $X_{4.2}$ = mean education (husband and wife)
- $X_{4.3}$ = household size
- $X_{4.4}$ = family life cycle stage
- $X_{4.5}$ = reported energy costs
- $X_{4.6}$ = energy perception - electric
- $X_{4.7}$ = energy perception - fuel oil
- $X_{4.8}$ = energy perception - natural gas

u^U = Unexplained residual and/or measurement error in the energy consumption variable.
v^V = Unexplained residual and/or measurement error in the belief variable.

AVOID TUNNEL VISION IN IMPLEMENTATION OF
ENERGY CONSERVATION BUILDING STANDARDS

by

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Aside from recommendations to improve mechanical systems and components or to reduce lighting, most of the present thinking on energy conservation in buildings has the tunnel vision of looking almost exclusively toward lower "U" values. The FHA fell into the "U" value trap in revising their Minimum Property Standards. Even the more permissive and performance oriented ASHRAE Standard 90-75 has succumbed in part to the lower "U" value syndrome because, even though they permit alternative methods in achieving energy conservation, the criterion for allowable energy use by the alternative methods is based upon the estimated energy use of a similar hypothetical building using the appropriate ASHRAE average "U" values (U_o).

Lower "U" values are not the only way to achieve thermal energy efficiency, nor need they necessarily form the criterion for energy conservative building standards. There are many alternatives in energy conservation which are relatively independent of "U" values, several of which will be discussed in this paper.

Key Words: Alternatives; ASHRAE 90-75; building standards; buildings; energy conservation; Minimum Property Standards; multiple glazing; "U" values.

FENESTRATION

Fenestration, depending upon its design and orientation can produce beneficial or deleterious results which are not indicated by "U" values. Most energy conservation proposals are aimed at reducing heat loss through glass areas or delimiting the glass area for the heating season and towards reducing heat gain through the glass during the cooling season. These proposals, however logical appearing, pay practically no attention to the disparity of results which can result from differences in design and solar orientation.

"The Arkansas Story"[1] limits the total glass area to 8% of the total floor space and requires storm windows or double glazing. The FHA Minimum Property Standards, in essence, requires single, double or triple glazing depending upon the number of winter degree days. ASHRAE Standard 90-75 requires various average "U" values (U_o) for entire walls including glass areas as the basis of its energy use standards. To achieve the U_o might necessitate delimiting the amount of glass area or double or triple glazing. None of these proposals appear to consider possible benefits which can be achieved through good solar orientation, nor do they seem to consider that double and triple glazing can reduce the winter solar radiation heat gain from 15% to about 60% depending upon whether a window is double or triple glazed and the type of glass used. Acknowledging that ASHRAE 90-75 does allow for alternatives, this writer, nevertheless, believes that these statements are applicable to the Standard since, if good design and orientation were considered the resulting energy use criteria could possibly be lowered.

Table I demonstrates that South facing windows at North Latitude 40° (Chicago, Denver, New York, Etc.) on December 22nd are 1698% more efficient on a sunny day than North facing windows during the daylight hours, even though the "U" values are identical. The Table also shows an example in which all of the daylight hour heating requirements for an average winter day in Chicago can be provided by direct and diffuse solar radiation through a South facing window, with single glazing, in which the window area is 10% of the room floor area. Heavy drapes, drawn at night or on cloudy days, can substantially reduce heat losses during those periods. In the same example, the heat from diffuse radiation through a North facing window is only 6.9% of the heating requirement on an average winter day.. This indicates the tremendous disparity in energy use which is a result of design rather than "U" values.

In certain geographic locations where medium to high daily temperature differentials exist, glass can be used to help cool buildings. If the fenestration is designed to

[1]"The Arkansas Story" Report No. 1, Energy Conservation Ideas to Build On, Owens/Corning Fiberglas Co.

provide occupant privacy and is shielded from the sun during the day (or perhaps reflective glass is used) then uncovered single glass will radiate heat to the exterior night much more rapidly than the interior heat can transfer through the surrounding walls.

Since fenestration design and orientation can have such a significant impact on energy conservation, building standards which do not take into consideration both beneficial and deleterious potential of fenestration should be re-examined and changed if necessary to allow for designer alternatives and flexibility. This is particularly true for standards with respect to housing which mandate minimum natural light or multiple glazing irregardless of orientation.

RADIANT HEATING AND COOLING

Proposed energy conservative standards do not appear to consider the effectiveness of radiant heating or cooling, although a one degree change in the value of the MRT (mean radiant temperature of the surrounding surfaces) is assumed to have about 40% more effect than a one degree change in the air temperature.[2] While perhaps the exact magnitude can be debated, the effect of change in MRT can be readily demonstrated.

Assuming a comfort level in winter equivalent to a 70° ambient air temperature and similar MRT were desired and that an MRT of 78° could be achieved, then the air temperature could be reduced to approximately 59°. This could not, however, be used as the basis for design and sizing of equipment under the proposed Council of American Building Officials (CABO) energy conservative standard because the CABO standard states "Indoor design temperature <u>shall</u> <u>be</u> 70° F for heating and 78° for cooling."

During summer a room with an MRT of 70° and air temperature of 89° would be approximately equivalent in comfort to a room with air and MRT temperatures of about 78°.

Of course care must be used in the design of radiant systems so that the surfaces do not also radiate to the outside. Furthermore, compensation for rapid exterior temperature fluctuations can be difficult to achieve and periods of discomfort can result, in climatic areas subject to these fluctuations. Nevertheless, radiant heating and cooling used in suitable climatic regions can be energy conservative.

Some deleterious effects of radiant heating and cooling can result from injudicious design and use of large glass areas. The excessive body radiation to cold or undraped glass in winter or excessive solar radiation in summer causes discomfort and can be a

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[2] W. J. McGuinness and B. Stein, <u>Mechanical and Electrical Equipment for Buildings</u>, John Wiley and Sons, Inc. 5th Ed. p. 125.

"built in" design handicap which the mechanical system can not reasonably overcome (to say nothing of the energy wasted in trying to do so.)

MASSIVE CONSTRUCTION

The transient effects of thermal lag and energy storage capacity of massive construction have long been taken into consideration in the design of cooling systems but, due to inexpensive energy this phenomena has not been accounted for in the past with respect to its beneficial aspects during the heating season. Until recently heat loss calculations were typically based upon assumed steady state conditions using average low temperatures for an area and were solely a function of the "U" value of the construction, not of the transient effects of thermal lag or capacity storage of the building envelope materials. Most housing systems are still designed in this manner. But steady state conditions are mainly theoretical and mainly used to simplify the heat loss calculations, they seldom occur for long periods of time in actuality.

Massive construction (approximately 100 pound per cubic foot, or more) of masonry or concrete can have a thermal lag of up to 12 hours depending upon the wall thickness. Thermal lag is the time required to reach steady state conditions and during this period the walls are storing energy which will be released when temperature or radiation conditions change. The heat transfer through a massive wall, therefore, is out of phase with the diurnal cycles of solar radiation and air temperature and tends to reduce the peaks of heat transfer out of or into a building, which allows for sizing the heating (or cooling) equipment for more efficient operation. The NBS Building Science Series 45 states that the heat flows calculated by the steady state method were 29 to 69 percent <u>greater</u> than those measured under dynamic conditions for masonry walls. Computer programs have been developed which simulate the transient and dynamic effects and can be used for more efficient sizing of equipment but due to complexity and expense they are still not much used in housing design and, therefore, the advantage of massive contruction which is not indicated by its "U" value is still not being fully used.

The full advantage of the capacity storage of massive construction is still seldom used even in non residential construction. Massive construction combined with "smart" ventilation can form the basis for a passive solar heating system which produces results certainly not indicated by "U" values. So far passive solar heating systems have been mostly confined to a limited number of residential applications.

The Trombe, South facing wall is an excellent example of both a passive solar system and natural ventilation loop. See Figs. 1 and 2. The Trombe house built in the French Pyrenees uses a South facing concrete wall painted black to absorb and store solar energy. The exterior wall is one or more layers of glass and might not even meet FHA, MPS requirements nor ASHRAE recommended "U" values for a similar climatic region in the U.S. Yet according to the book "Other Homes and Garbage"[3] it is reported that although the house is poorly insulated, three quarters of the entire heating requirement on an average winter day is supplied by the system, even though the temperatures often fall below 0° F. During the summer, the high temperatures between the glass and concrete create a "chimney effect" thus inducing natural ventilation. The Trombe wall is, in this writer's opinion, but one example of the imaginative use of the energy storage capacity of massive construction. Such imagination should not be stifled by building standards which either will not admit to or discourage this type of innovation.

UNDERGROUND HOUSING

Papers and articles by this author[4] have indicated that, in the Chicago area, the energy use for heating and cooling underground housing is approximately one third of that of a similar sized above ground structure using the latest FHA, MPS maximum "U" values (i.e., a 67% savings). Energy savings for commercial, institutional and industrial structures could be even greater. Most of the phenomena which generate these savings are entirely independent of the "U" values of the construction.

Underground construction takes advantage of the relatively stable ground temperatures. Because of the relative warmth of the ground during the winter it could be said that one is taking advantage of a very low grade geothermal energy. In summer, the ground is cooler than the average outdoor temperature, thus helping to keep the structure cool.

There are other natural phenomena which add to the energy conservative aspects of underground housing. These factors include:

- Thermal lag in soil, which can be in the order of weeks, therefore, the most adverse ground and outdoor temperatures may not coincide.

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[3] J. Leckie, G. Masters, H. Whitehouse, L. Young; Other Homes and Garbage, Sierra Club Books, San Francisco, 1975.

[4] van der Meer, Wybe J., "Underground and Earth Covered Housing Deserve Consideration," a paper presented to The International Association of Housing Science, International Symposium on Housing Problems, May 25, 1976, Atlanta, Ga. Published in Symposium Proceedings.

Ibid. "Underground Housing, An Alternative Concept," New Mexico Building Magazine, September, 1976, pp 8-12.

Ibid. "Down to Earth Housing," Solar Age Magazine, September, 1976.

- Soils of low conductivity will build up a boundry layer of higher temperatures next to the building, thus slowing down or impeding heat transfer from the building.
- The conductivity of the soil may govern heat loss rather than the "U" factor of the walls, making the heat loss independent of the wall construction or insulation.
- The underground structure is not subject to the accelerated heat loss caused by winter winds, nor to the infiltration of cold air.

The energy benefits alone would appear to be sufficient justification for underground construction, but there also is the potential for other benefits as mentioned in the above cited references. However, most building codes will not permit underground housing because of mandatory natural light and ventilation requirements which appear arbitrary when viewed with respect to commercial or institutional building standards.

WATER PONDED ROOFS

The idea of water ponded roofs is not at all new. My father, the late W. J. van der Meer, Sr., Architect and Engineer, designed two hospitals in Illinois, in the early thirties to hold 6 inches of water on the roofs to help keep the building cool in the summer. I'm certain there are many more examples. But somehow or another, with the prevalence of air conditioning since the late forties less use or advantage seems to have been made of the energy conservative concept. The advantages of water ponded roofs stem from the reduction of heat by reflecting and refracting solar radiation and from the cooling effects of evaporation - not from the very slightly enhanced "U" value.

There is some design information available for water ponded roofs. The Trane Solar Tables[5], for example indicate that on July 23rd for North Latitude 40°, at the time of greatest heat transfer (2 PM Sun Time light construction; 4 to 6 PM, Heavy Construction) one inch of water will reduce the heat transfer in light construction by 58% and by 71% in heavy roof construction. Six inches of water will reduce the heat transfer in light and heavy roof construction by 89% and 82% respectively. The tables on which these figures were based are for dark colored roofs fully exposed to the sun. The savings would not be as great for light colored roofs or ones with reflective insulation. However, the dark roofs make some sense when considering the summer and winter cycles, since one can drastically reduce the heat gain in summer by water ponding while providing maximum solar radiation gain to help heat the roof and building during the winter when the water has been drained.

The Trane tables do not stipulate any specific relative humidities. Therefore, it is probably reasonable to assume that their tables are based mainly upon solar radiation and not the additional benefits of the cooling effects of evaporation from low relative

[5]Trane Solar Tables, Copyright 1966, The Trane Co., LaCrosse, Wisconsin.

humidities and summer breezes. In actuality, the performance of water ponded roofs could exceed that which is indicated by the tables. Experiments conducted by this writer in Albuquerque tend to confirm the possibility of better results.

The experiments conducted by this writer were on two successive, very similar clear days. Temperatures were recorded for 3 1/2 inches of ponded water, ambient air temperatures and under medium colored simulated roofing material without water ponding. The deviation of maximum daily air temperatures was only one degree F. The median relative humididity during the recorded hours was 24%. Table II shows graphic representation of the average of the recorded temperatures. (Note: The thermometer used under the simulated roofing recorded only up to 150°F. Temperatures exceeded 150°F. to the extent that it separated the mercury.) Since the summer design temperature for Albuquerque is 95°F., both days were quite representative- having an average maximum temperature of 96.5°F. Therefore, considering either maximum deviation from design temperature or from the maximum ambient temperature of the experiments produces little difference in results.

In reviewing the graphic results of the experiment, one can clearly see that the water heated slower and cooled faster than the ambient temperature, while the converse was true of the temperatures under the simulated roofing without water ponding. Considering maximum deviation from design temperature (because maximum water, roofing and air temperatures did not coincide), the temperature under the roofing exceeded the design temperature by an amount more than 9.67 times greater than the ponded water. In other words, the deviation of the ponded water temperature was less than 10.3% of the under roofing temperature. (Just exactly how much less was impossible to determine because of the lack of exact temperature readings due to exceeding the thermometer capabilities.) Yet these results for 3 1/2 inches of water are better than indicated for 6 inches of water in the Trane Solar Tables and thus tend to confirm that the effects of humidity are not included in those tables and that actual results could be even better than what would be estimated using those tables.

In one and two story buildings, with properly shaded fenestration, the major heat gain is through the roof. Thus water ponded roofs could be a significant contribution to energy conservation without requiring additional insulation. One side benefit is that thermal expansion and contraction of roofing would be greatly lessened, thereby giving a potential for less roofing and flashing problems.

WATER TRICKLING SYSTEMS AND ROOF SPRAYS

Two other systems which achieve their effects through natural phenomena rather than their insulation value, are water trickling systems and roof spray systems. Through the combined effects of the water temperature and evaporation it is possible to lower the roof temperatures (or wall temperatures if used on walls) below the ambient temperatures and thereby significantly reducing the heat gain during summer. However, if it is necessary to conserve water some mechanical energy would be necessary to recirculate the water.

In a water "trickling" system small quantities of water would be released continuously to uniformly cover and flow down a roof (or wall). This water would be collected and recycled, with water added to replace that lost through evaporation. However, since the water will collect heat as it passes over the roof, even if a fairly large reservoir is used, it would be desirable to have the water pass through a cooling tower before passing again over the roof. In this manner evaporation will help cool the roof and also the water to be passed over the roof. With this type of system on a 95° day, with 50% relative humidity, it would not be unreasonable to anticipate a 5° temperature drop, below ambient temperature, for the roof's surface. The lower the humidity the better the performance will be. This would actually represent a better performance than the 3 1/2 inches of ponded water roofs mentioned previously, but not without the cost of some additional energy for recirculation.

Roof spray systems can be run intermittently as long as the roof surface is kept moist. Since it is most effective on one or two story buildings no energy other than normal water pressure is needed. The Trane Solar Tables indicate that their performance is better than one inch of ponded water and only slightly less than six inches of ponded water.

REFLECTIVE INSULATION AND REFLECTIVITY

A sheet of reflective foil in direct contact on both of its sides with other materials has no significant value in heat flow retardation.[6] But since heat is transmitted across an air space by either a combination of radiation and convection or by radiation alone (depending upon the orientation and size of the air space and direction of temperature flow), reflective insulation is of importance when used in conjunction with an air space. Reflective lined air spaces are of value in both walls and roofs during summer or winter although the relative values change. In winter the heat transfer out through the walls or up through the roof is both by convection and radiation with a larger percentage by convection through the roof and, therefore, the reflective lined spaces in the roof (or ceiling) are somewhat less effective than those in the walls. During the summer the heat transfer downward through the roof (or ceiling) is entirely by radiation and reflective lined air spaces in the roofs perform better than in the walls where the heat transfer is by both radiation and convection.

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[6] W. J. McGuiness and B. Stein, Mechanical and Electrical Equipment for Buildings, 5th Ed., John Wiley and Sons. P. 142.

The reflectivity of wall and roof colors can also effect energy conservation - reflective or light colors can reduce summer heat gain whereas absorptive and dark colors can reduce winter heat loss on sunny days. Appropriate colors for major elements could be selected for the major energy use of a particular area (i.e., heating or cooling), or medium colors selected where the cooling and heating loads are relatively similar. Pink, for example, has almost identical absorption and reflection percentages.

Another energy conservative aspect of reflectivity is that solar gain through windows during the winter can be increased with properly designed reflectors. These reflectors can either be removable for summer or designed so that summer sun reflections will either miss the windows or be absorbed by exterior building elements. See Figs. 3-5.

In this section and that on water ponded roofs it has been shown that reflectivity can affect energy conservation, yet colors are seldom addressed in building standards and those proposed energy conservative standards which are primarily based on winter "U" values could discourage the use of reflective insulation and its superior summer performance especially in roofs (or ceilings).

NATURAL CONVECTION VENTILATION

Even in housing, little advantage is taken of natural ventilation to reduce or eliminate the energy used in mechanical ventilation. In most office buildings and other commercial and some institutional buildings, the windows are not even operable, thus requiring mechanical ventilation year around even in temperate weather. Yet natural ventilation can be provided by proper sitting and orientation with respect to prevailing winds and by the chimney effect of higher temperatures created by a variety of sources including solar radiation. The Trombe wall mentioned previously is one example of natural convection ventilation.

In a model test, Peter Stead, a graduate student in architecture at the University of New Mexico, used a chimney to induce ventilation. Approximately one air change every two minutes was achieved using 110 F. water and a chimney cross section of approximately 15% of the floor area. In climatic locations of medium to low relative humidity the achieved rate of air change is sufficient to provide evaporative cooling using continuously water soaked pads at the air inlets.

If a full range of energy conservation measures are to be considered, natural convection ventilation should be encouraged, however, this writer has seen little attention given to this facet of energy conservation.

INFILTRATION

Infiltration of cold or warm air can severely affect heat loss or heat gain as can the need for high ventilation rates required by certain types of occupancies. Actually, considerable attention is given to infiltration by most proposed energy conservation standards. It should also be realized that when high ventilation rates are required it does not necessarily imply high losses, if heat recovery systems are used.

Heat recovery systems can be quite simple. The simplest, perhaps, consisting of two rock storage tanks with fresh air pumped through one tank and exhaust air pumped through the other. The temperature rises in the exhaust tank until it reaches a particular design temperature, then the cycle is reversed and the air is preheated by rock storage and pumped through this tank until a design minimum temperature is reached, during this time the temperature in the other tank is rising from the exhaust air and becoming ready to start the reverse cycle. This type of system has been designed by Dr. Larry Bickle, M.E., for use in a year around swimming pool enclosure where a high ventilation rate was required to control the humidity.

MIGRATION OF MOISTURE

In addition to other possible untoward effects, the migration of moisture (in the form of vapor) through a wall can cause additional heat losses during the winter and heat gains in the summer. Yet, in the observations of this writer, these potential impacts on energy use are frequently not considered, possibly because the magnitudes are relatively small, but as more efficient walls are designed the percentage of heat loss (or heat gain) of moisture migration becomes more significant.

In winter, the loss of humidity from a room (or building) by migration of moisture through the wall not only results in an energy loss but can otherwise affect the comfort level, since the comfort level is a factor of both ambient temperature and relative humidity. In summer, the migration of moisture <u>into</u> a building (because vapor and heat travel in the same direction) will increase the cooling load and also affect the comfort level.

Moisture migration is related to the permeability of the wall materials, therefore, the nature of the wall materials, choice of interior and/or exterior paint and whether or not a vapor barrier is used, all affect the performance of the wall. Vapor barriers are frequently used in wood frame construction to preclude condensation in the walls and resulting possibilities of rotting wood or rendering some types of insulation ineffective. However, even some types of masonry construction may benefit from the use of a vapor barrier or impermeable paint finish. There are insulation batts manufactured with a vapor barrier on one side of the batt, but careless installation frequently makes it ineffective as far as overall wall performance is concerned.

Table III (based on calculations by Dr. Larry Bickle, M.E.) is a summary of calculated heat losses due to moisture migration for three different types of frame walls. These calculated losses are in addition to the heat transfer losses. Based on the assumed conditions, the additional losses for a wall with a vapor barrier are negligible, but for a wall of rather permeable materials the heat loss due to moisture migration can be approximately 17% of the heat transfer losses. It should be noted that the apparently better performance of the wall with a plaster interior finish and enamel paint is due mainly to the relative impermeability of the paint rather than the plaster.

Although the examples of Table III are for frame walls, designers might be well advised to check certain types of masonry walls to determine whether a vapor barrier or impermeable paint would be necessary or desirable to improve the performance of the wall. This writer has observed types of concrete masonry construction that would have benefited from some form of vapor barrier.

CONCLUSIONS

It has been the purpose of this paper to reiterate some of the alternatives in energy conservation - ones primarily independent of thermal resistances. It is hoped that this reiteration will stimulate building code officials to also think in terms of alternatives and adopt energy conservative building standards which encourage rather than stifle innovation. Such innovation has the potential to lead to better energy use standards and increased cost effectiveness of energy conservative measures than standards and measures based mainly on thermal resistance concepts.

It is the opinion of this writer that greater energy conservation could be achieved if maximum energy use criteria for heating and cooling (in BTU per degree day per square foot of building) were established for various categories of use such as residences, officies, stores, etc. and then allow the accomplishment of these goals by any methods which can be sustantiated. It is realized that considerable difficulties could be encountered both is the establishment of these goals and the implementation and regulation of a building standard of this nature, but it is hoped that the same type of creativity will be used by building code officials in implementing and regulating building standards as must be used by designers in their approach to energy conservation.

TABLE I

Solar gain - South vs North orientation

Direct solar radiation and diffuse solar radiation transmitted per square foot of window opening (85% glass).[1]

North: 59.8 BTU/s.f., total 8:00 AM to 5:00 PM

South: 1015.5 BTU/s.f., total 8:00 AM to 5:00 PM

$\frac{1015.5}{59.8} = 16.98 = 1698\%$

Example: A 12' x 20' x 8' high ground floor, middle room, of a 3 or more story building. Window on short side; other sides, floor and ceiling adjacent to occupied heated space. Window 10% of floor area. $U_w = 0.08$, $U_g = 1.13$, $T_i = 70$ (CABO recommendation) $T_o = 35.8$ (Average winter day, Chicago)

Heat loss

Window: 24 x 1.13 x 34.2 = 928 BTU/hr

Wall: (96-24) x 0.08 x 34.2 = 197 BTU/hr

Infiltration: 1920 x 0.018 x 34.2 = 1182 BTU/hr

Total 2307 BTU/hr

Total for 9 hours = 20763 BTU

Direct and Diffuse Solar Gain

North: 59.8 x 24 s.f. = 1435 BTU

$\frac{1435}{20763} \times 100 = 6.9\%$ of average day requirement

South: 1015.5 x 24 s.f. = 24372 BTU

24372 > 20763 BTU daytime requirement.

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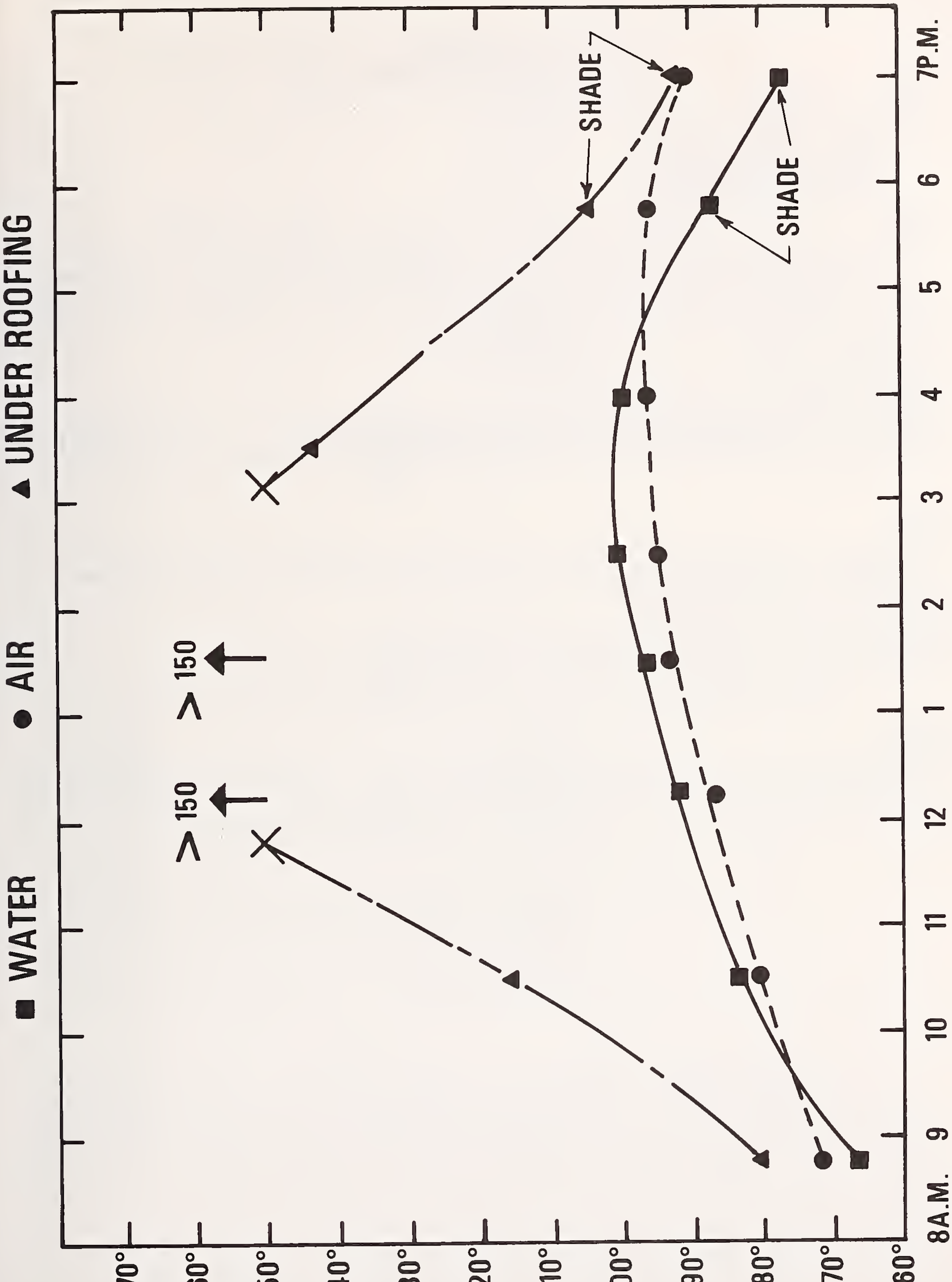
[1] Trane Solar Tables, (c) 1966, Trane Co., La Crosse, Wisconsin.

TABLE II



■ WATER
● AIR
▲ UNDER ROOFING
> 150
> 150
SHADE
SHADE
170°
160°
150°
140°
130°
120°
110°
100°
90°
80°
70°
60°
8A.M.
9
10
11
12
1
2
3
4
5
6
7P.M.

TABLE III

HEAT LOSS DUE TO MOISTURE MIGRATION

Assumed Conditions:

a) Outside: 30° F., 30% R.H.

b) Inside: 70° F., 50% R.H.

Wall A

Frame stud wall with 2 x 4's 16" O.C.; 3 1/2 loose fill insulation in stud space; exterior nominal one inch pine lap siding over 1/2" fiberboard sheathing; interior, 3/8" gypsum board with water emulsion paint.

R = 18.08, U = .055

Thermal Transfer = 40 x .055 = 2.2 BTU/hr/sf

Additional loss from Moisture Migration 0.38 BTU/hr/sf

Additional loss a percentage of thermal transfer: $\frac{0.38}{2.2} \times 100 = 17.2\%$

Wall B

Same as A except 3/4" plaster on metal lath with enamel paint in lieu of gypsum board and water emulsion paint.

Additional loss from Moisture Migration 0.041 BTU/hr/sf

Additional loss as percentage of thermal transfer $\frac{0.041}{2.2} \times 100 = 1.8\%$

Wall C

Same as A with 6 mil polyethylene film vapor barrier. Additional loss from Moisture Migration 0.0025 BTU/hr/sf i.e., negligible.

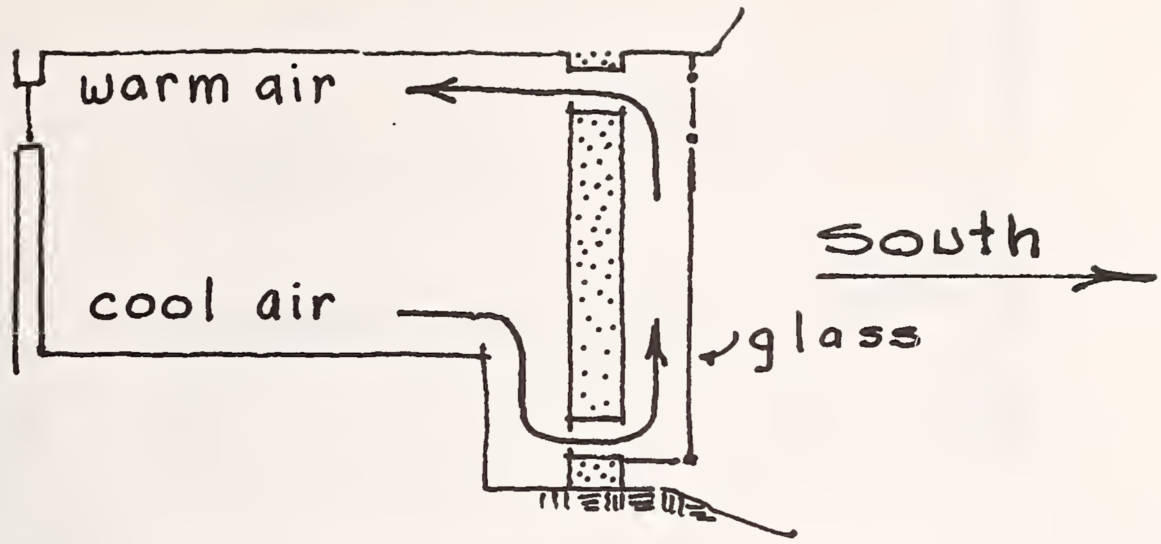


Fig. 1 • Trombe Wall - Winter

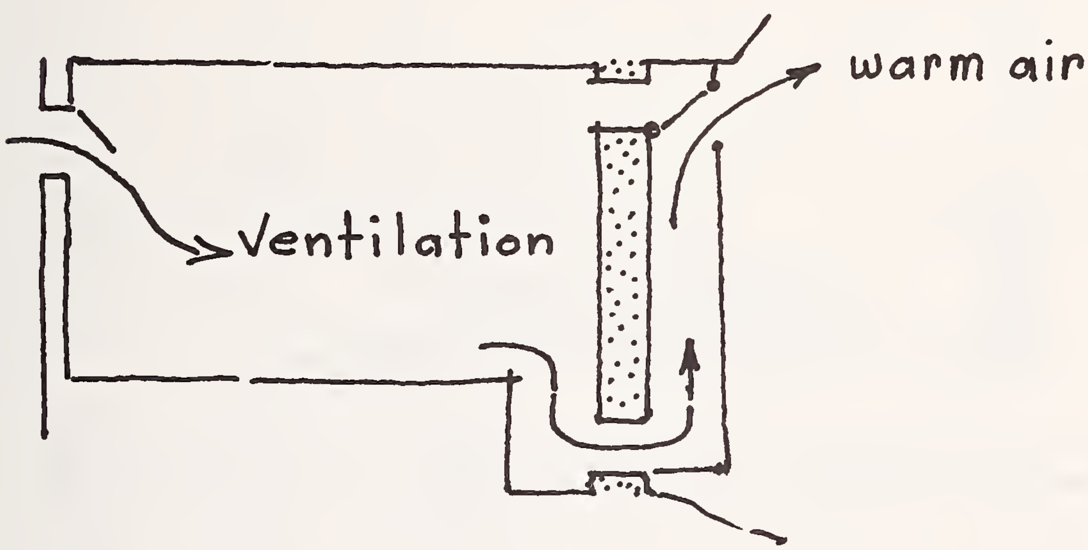
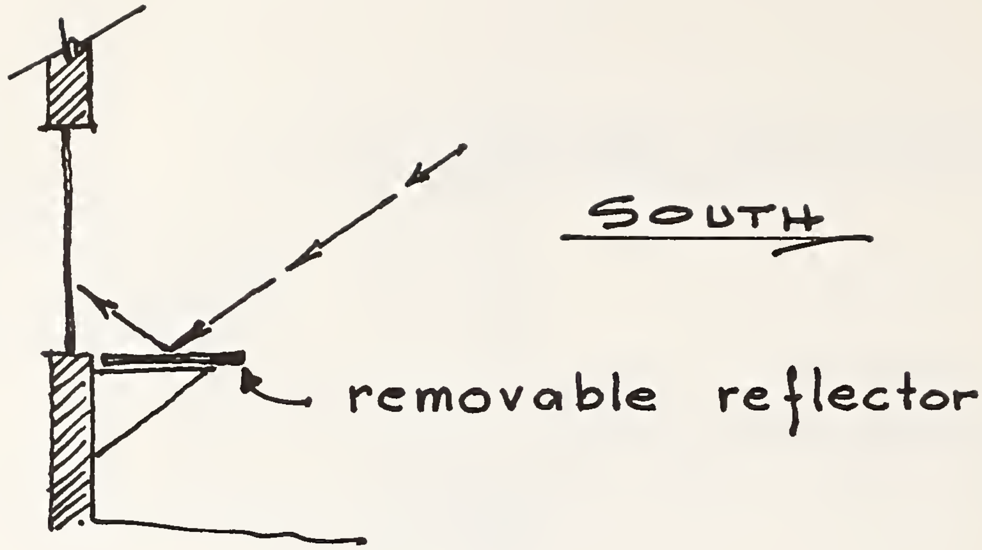
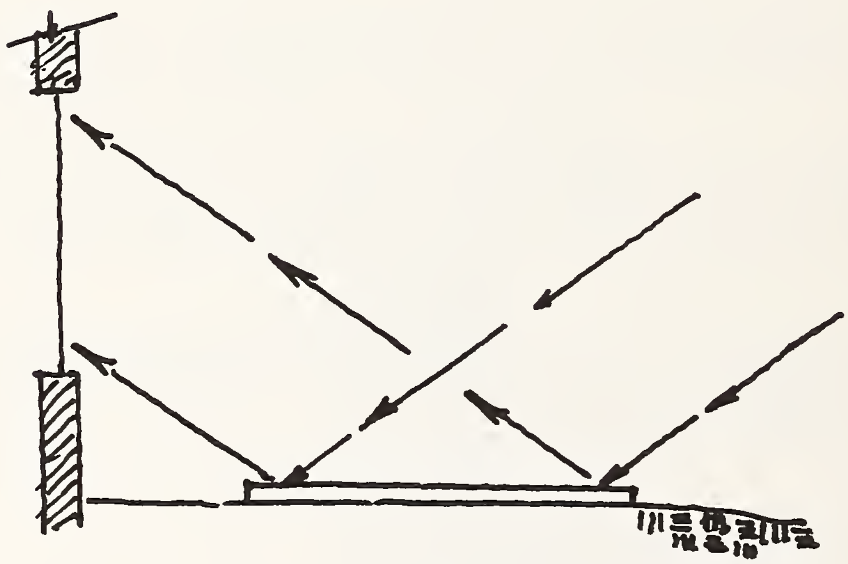


Fig. 2 • Trombe Wall - Summer



a) Removable Reflector on Building



b) Removable Reflector on ground

Fig. 3. Reflectors

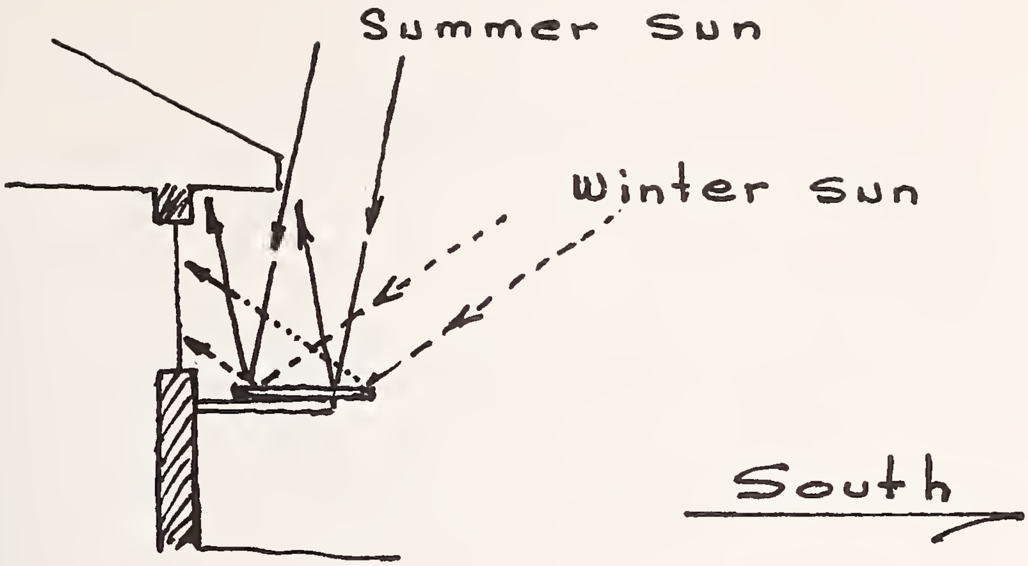


Fig. 4 Permanent Reflector
winter sun reflects into window
summer sun does not.

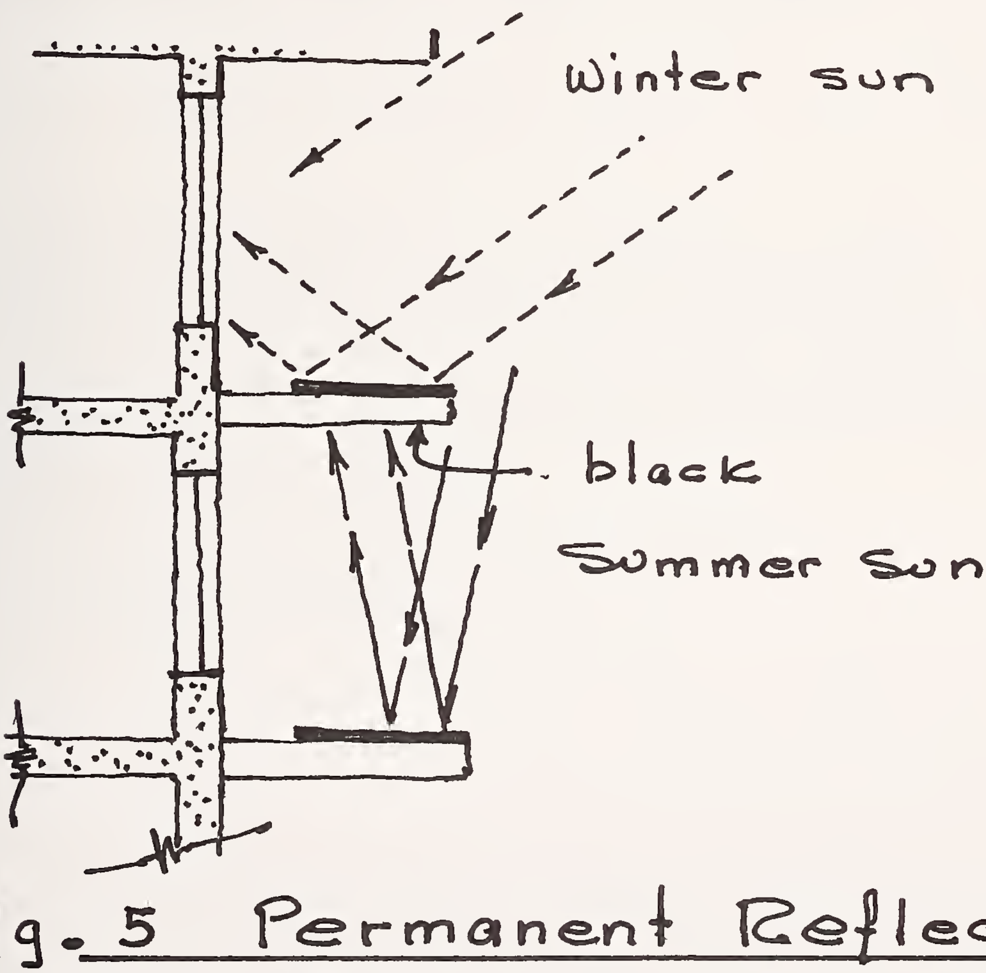


Fig. 5 Permanent Reflectors
Summer reflections absorbed by overhangs & kept away from windows above.

Standards for Solar Heating and Cooling Applications

by

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The "Solar Heating and Cooling Demonstration Act of 1974," along with the "National Program for Solar Heating and Cooling (Residential and Commercial Applications)," call for the development and implementation of performance criteria, consensus standards, certification procedures and design guidelines relating to solar heating and cooling systems and components. This paper describes activities being carried out by the National Bureau of Standards (NBS) in support of the previously cited Federal legislation and program plan.

In cooperation with ERDA and HUD, NBS is developing: (1) performance criteria for solar heating and cooling systems to be used in residential and commercial buildings; (2) standards for solar heating and domestic hot water systems that can be used in conjunction with HUD's Minimum Property Standards; (3) draft standards for materials to be used in solar systems; (4) plans for establishing a solar collector testing laboratory accreditation program; and (5) plans for identifying and developing other needed standards in cooperation with various organizations.

Key Words: Buildings; cooling; heating; performance criteria; solar collectors; solar energy; standards.

INTRODUCTION

Solar energy program activities being conducted within the Center for Building Technology, National Bureau of Standards (NBS), are primarily focused on projects pertaining to the development and implementation of performance criteria and standards for solar heating and cooling applications. These projects are being carried out in technical support of the Energy Research and Development Administration (ERDA) and Department of Housing and Urban Development (HUD) solar heating and cooling research and demonstration programs.

The Solar Heating and Cooling Demonstration Act (PL 93-409) was enacted in September 1974. It called for the demonstration of the practical use of solar heating in three years and combined solar heating and cooling in five years. Various sections of the Act assigned specific responsibilities to NBS. Some of these responsibilities include: (1) the development of interim performance criteria for solar heating systems and dwellings within 120 days; (2) the development of definitive performance criteria , as soon as feasible, using data obtained from the demonstration projects; (3) preparation of test procedures whereby manufacturers of solar systems and components can get their products certified as to compliance with the definitive performance criteria; and (4) monitoring and evaluating the performance and operation of various solar heating and cooling demonstration projects. The roles of Federal agencies in the overall solar heating and cooling research, development and demonstration program is shown in figure 1.

The current national program plan for solar heating and cooling, ERDA - 23A, was issued in October 1975 [1]*. The program goal, as stated in ERDA - 23A, is to stimulate industry to produce and distribute solar heating and cooling systems and thereby reduce the demand on present fossil fuel supplies. To achieve this goal, it will be necessary to: (1) develop economically viable and socially acceptable solar systems; (2) create needed information and data for various members of the building community; (3) eliminate various barriers which are identified; and (4) develop a market demand for solar equipment. The program plan also cites the following standard development and implementation objectives:

- Establish through cooperative action with appropriate technical organizations acceptable performance standards and certification procedures to be used to assess and implement possible incentives.

- Recommend, if warranted, model codes, regulations and ordinances as soon as possible and throughout the demonstration program.

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*See references at end of this paper.

- Develop and recommend 'consensus' standards for performance and testing of solar equipment.

- Insure the availability of accredited private-sector testing facilities as soon as possible.

- Develop and promulgate design guidelines for solar heating and cooling systems and components.

NBS PROGRAM ACTIVITIES

Interim Performance Criteria (Residential). As indicated previously, NBS's initial responsibility was to develop, within 120 days, interim performance criteria for solar heating/cooling systems and dwellings, which the Department of Housing and Urban Development (HUD) could utilize in the residential demonstration program. These criteria [2] were published in January 1975, and provide the basis for technical performance evaluation and procurement of solar systems and dwellings, and the basis for developing definitive performance criteria.

Interim Performance Criteria (Commercial). Another NBS task involves preparing interim performance criteria for solar heating/cooling systems and commercial (i.e., non-residential) buildings. Utilizing the interim performance criteria developed for the residential demonstration program, the National Aeronautics and Space Administration (NASA) has developed an interim performance criteria document for commercial solar systems and facilities [3]. During this past year, ERDA has assigned NBS the responsibility for continuing the development of these performance criteria. A revised document is scheduled to be published in November 1976.

Intermediate Solar Standards. In September 1975, HUD asked NBS to undertake the preparation of intermediate standards for solar heating and domestic hot water systems which would supplement the HUD Minimum Property Standards for single and multi-family dwellings and which can serve as a technical basis for the evaluation of solar systems financed under HUD mortgage insurance programs. These standards have been completed in draft form and are currently being disseminated by HUD for public and industry review and comments [4]. We anticipate that these intermediate solar standards will be finalized early in 1977. Different characteristics of these standards and the residential and commercial interim performance criteria documents are summarized in figure 2.

Technical Performance Data Plans. Another NBS project involves the preparation of plans to define technical performance data (i.e., instrumentation and non-instrumentation data) which should be collected and evaluated during the residential and commercial demonstration programs so as to provide an adequate data base for performance criteria and standards development and various other user needs. A report defining thermal data and performance evaluation factors has been recently published [5].

Standards Development Plan. The task of preparing a plan to guide the development and implementation of standards for solar heating and cooling applications is a key element in setting the needs and prioirities for research as well as standards development. An initial plan developed by NBS was published in August 1976 [6], and will be widely circulated for the purpose of obtaining review comments and suggestions. It will be revised on a periodic basis to keep it current with the status of solar standard development and implementation activities.

ANSI Steering Committee. As a result of discussions with other government agencies, standards-writing organizations and industry, NBS recommended to the American National Standards Institute (ANSI) that a Steering Committee on Solar Energy Standards Development be established. In January 1976, such a committee was established by the ANSI Executive Standards Council. The scope of this committee is as follows:

> "Without engaging in standards-writing activities, identify needs and formulate specific tasks leading to the development of national consensus standards for the utilization of solar energy for heating and cooling. Assign standards development projects to competent standards-writing organizations, and maintain a continuous overview of their activities in order to assure an orderly and effective process which will avoid duplication of effort and conflicting standards."

Organizations presently represented on the ANSI Solar Steering Committee include: Air Conditioning and Refrigeration Institute, American Gas Association, American Institute of Architects, Architectural Aluminum Manufacturers Association, American Society of Heating, Refrigerating and Air Conditioning Engineers, American Society for Testing and Materials, Consumers Action Now's Council on Environmental Alternatives, Department of Housing and Urban Development, Energy Research and Development Administration, Federal Energy Administration, General Services Administration, Institute of Electrical and Electronics Engineers, International Association of Plumbing and Mechanical Officials, Manufactured Housing Institute, National Aeronautics and Space Administration, National Association of Home Builders, National Bureau of Standards, National Conference of States on Building Codes and Standards and Solar Energy Industries Association.

NBS, in cooperation with the ANSI Solar Steering Committee, is identifying needs and priorities for developing standards, and with ERDA and HUD financial support, is establishing projects for generating draft standards. These draft standards can be utilized by appropriate standards-writing organizations as a starting point for the accelerated generation of national consensus standards (figure 3).

Thermal Performance Standards. To accelerate the development of national consensus standards for determining the thermal performance of solar collectors and thermal storage devices, NBS prepared draft standards [7, 8] which were transmitted to the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). ASHRAE has circulated proposed standards based on the NBS draft standards for public review and comments. It is anticipated that ASHRAE will approve the proposed standards (93P and 94P) for solar collectors and thermal storage devices during the early part of 1977.

Materials Standards. During 1976, NBS initiated five research projects to provide the technical basis for needed standards for materials used in solar heating and cooling systems. These projects will identify materials problems in existing and operational solar systems, and based on previously identified problems, will develop draft test standards for sealants, collector cover plates, collector insulation and collector absorptive coatings. The development and preparation of these draft standards will be carried out in close cooperation with ASTM Subcommittee E21.10 on Solar Heating and Cooling Applications.

Standards Implementation. The implementation of definitive performance criteria and standards for solar components and systems will require a comprehensive and cooperative program to accomplish nationwide deployment through the existing building regulatory system. This is especially critical since the existing system is already burdened with existing commitments. A discussion of various tasks such as laboratory accreditation, equipment certification, training and educational programs and manuals of accepted practice, to effectively implement the adoption of performance criteria and standards for solar heating and cooling applications is discussed in the previously referenced plan [6]. In the near future, NBS will begin work with ERDA, HUD and other interested organizations to develop criteria for evaluating the capabilities of testing laboratories which desire to determine the thermal performance of solar collectors in accordance with ASHRAE proposed standard 93P.

STATE ACTIVITIES

Considerable legislation relating to solar energy has been introduced and enacted by States during the past two years [9]. Of the 34 acts enacted relating to solar energy utilization during 1974 and 1975, ten acts provide for property tax incentives and several provide for income and sales tax incentives (Table 1). Several States (Florida, Connecticut and Minnesota) have adopted legislation calling for the adoption of standards for solar heating and cooling systems. If we are to aid in stimulating the development and marketing of solar heating and cooling equipment, it is essential that all governmental agencies and industry work together in the preparation and adoption of uniform and technically sound performance standards for such equipment.

CONCLUSIONS

As described, NBS solar energy program activities are primarily focused on the development and implementation of standards and performance criteria for solar heating and cooling applications. It is an important and challenging role which needs to be carried out in an expeditious and effective manner in cooperation with many organizations and individuals in the public and private sectors so as to help in stimulating the creation of a viable solar heating and cooling industry which can thereby aid in reducing the demand on present fossil fuel supplies.

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STATE ACTS RELATING TO SOLAR ENERGY 1974 - 76	TAX INCENTIVES			EASEMENTS & ZONING	STANDARDS &/OR CERTIFICATION	CODE PROVISIONS	PROVIDE STATE PROMOTION, INVESTIGATION OR R&D	STATE BUILDINGS TO USE SOLAR.
	REAL PROPERTY	INCOME	SALES					
Alabama								
Alaska								
Arizona	●	●					●	
Arkansas							●	
California		●					●	
Colorado	●			●			●	●
Connecticut	●				●			
Delaware								
Florida					●	●	●	
Georgia	●		●					
Hawaii	●	●					●	
Idaho		●						
Illinois	●							
Indiana	●							
Iowa							●	●
Kansas	●	●						
Kentucky								
Louisiana								
Maine							●	
Maryland	●						●	
Massachusetts	●							
Michigan	●		●				●	
Minnesota					●		●	
Mississippi								
Missouri								
Montana	●						●	
Nebraska							●	
Nevada								●
New Hampshire	●							
New Jersey								
New Mexico		●					●	●
New York							●	
North Carolina							●	
North Dakota	●							
Ohio							●	
Oklahoma								
Oregon	●			●				
Pennsylvania								
Rhode Island								
South Carolina								
South Dakota	●							
Tennessee								
Texas			●					
Utah								
Vermont	●						●	
Virginia							●	
Washington								
West Virginia								
Wisconsin								
Wyoming								

Source:
NBSIR 76-1082, "A Survey of State Legislation Relating to Solar Energy", April 1976, Robert M. Eisenhard, National Bureau of Standards. Publication sponsored by HUD and ERDA. (Updated to include 1976 data by the author).

Table 1 - State Acts Relating to Solar Energy

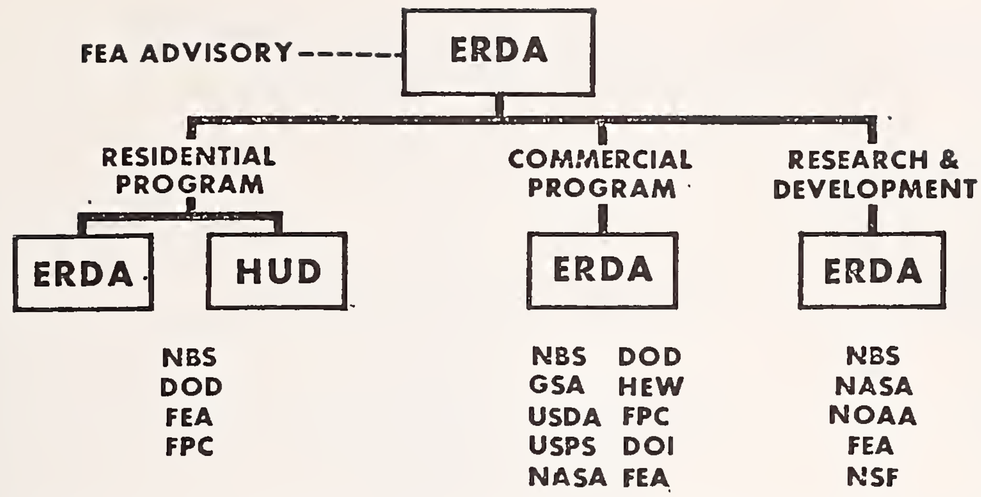

Figure 1 - Management Roles for Solar Heating and Cooling (ERDA-23A, October 1975)

	RESIDENTIAL & COMMERCIAL PERFORMANCE CRITERIA	INTERMEDIATE MPS
• Application	• Demonstration Programs	• Federal Housing Programs
• Scope	• Heating, Cooling, Hot Water	• Heating, Hot Water
• Basis	• Performance	• Performance/Prescriptive
• Format	• Performance Attributes	• MPS (Materials, Construction)
• Users	• ERDA, HUD, Contractors, A/E, Manufacturers	• HUD/FHA, VA, FmHA, Builders, A/E, Building Officials, Manufacturers

Figure 2 - Characteristics of Solar Criteria and Intermediate Standards

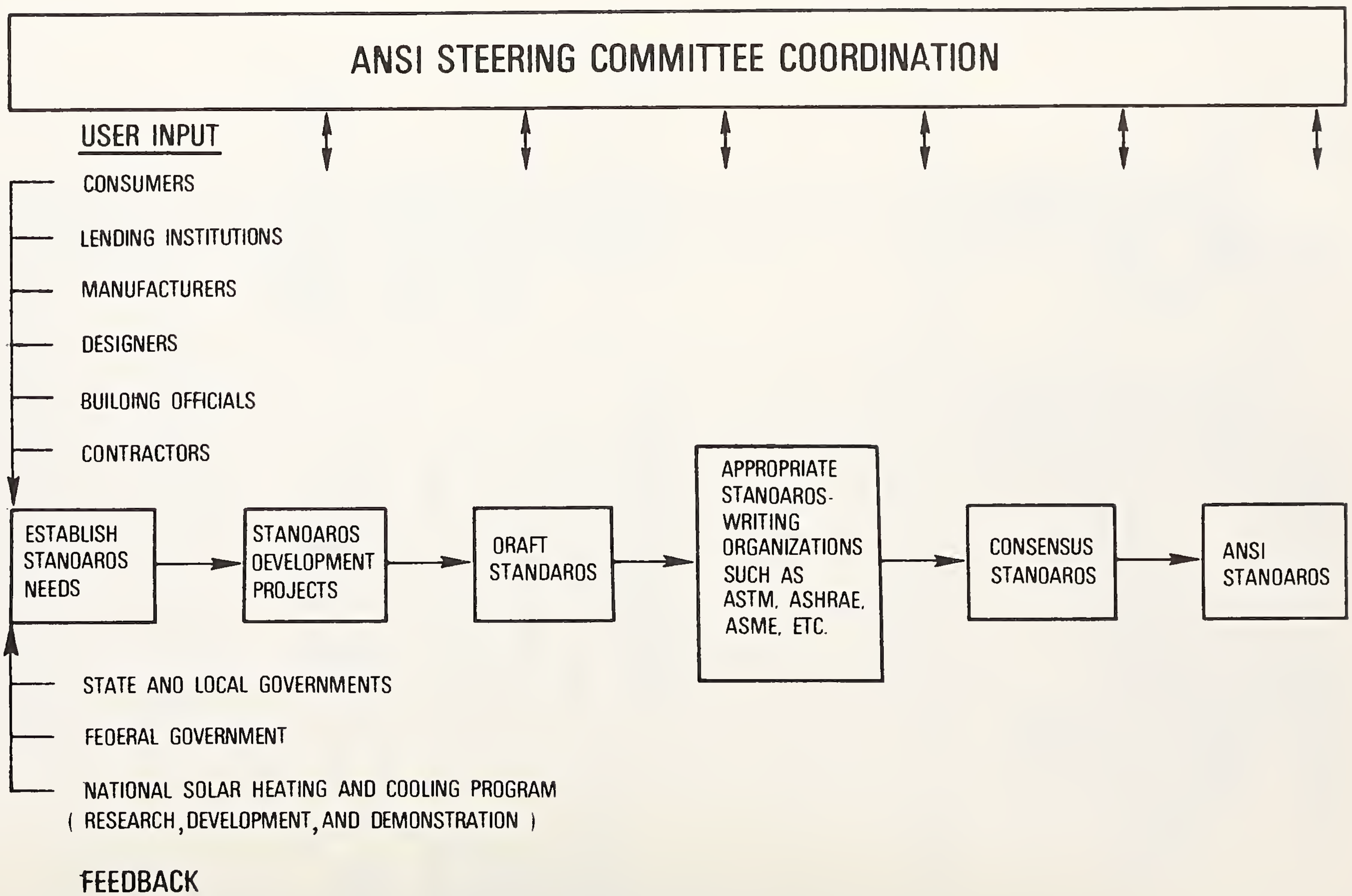

Figure 3 - Solar Standards Development

REGULATORY BARRIERS TO THE DIFFUSION OF INNOVATION: SOME EVIDENCE FROM BUILDING CODES

by

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Previous studies, including most prominently the reports of the Douglas and the Kaiser Commissions, have suggested that outmoded local regulation of residential construction has impeded technical progress in the industry. In this paper, we try to identify the determinants of differences across communities in building regulation. In particular, we use as our dependent variable the permissibility of four particular innovations in a cross section of political jurisdictions in 1970 and try to explain this permissibility using variables measuring attributes of building officials, local firms, labor unions, and housing demand. The data was taken from a special survey of local building departments conducted by Fields and Ventre in 1970. Our results indicate that the education of the chief building official and the level of unionization in the area are the two major factors explaining the probability that a jurisdiction will adopt a construction innovation in its code.

Key Words: Building official; building regulation; education; housing demand; innovation; regulatory barriers; residential construction; unionization.

PREFACE

We are indebted to Charles Field and Francis Ventre for making available to us the raw data from a survey they conducted in 1970 and for several useful conversations during the past year. Ventre's unpublished dissertation [22] was extremely helpful in explaining the technical characteristics of the building code provisions explored in this paper. We also acknowledge the helpful comments of colleagues at the Micro Economic Workshop at Yale University and the research assistance of Gail Trask and Robbe Burnstine. This research has been supported by a grant from the Sloan Foundation.

INTRODUCTION

It is widely alleged that housebuilding in the United States is a "backward industry" compared with either other sectors of the economy or with residential construction abroad. Precise measures of the "backwardness" of the residential construction industry are, however, ambiguous; little data are available which distinguish between housebuilding and other contract construction activities, such as road building.[1] Nevertheless, estimates made in the 1950's and 1960's suggest that by either measure of sectoral performance -- reduced input requirements for the same output (i.e., trends in real costs) or increased output for the same inputs (i.e., trends in input productivity) -- the construction industry has lagged behind other branches of the economy throughout this century.

Grebler, Blank, and Winnick [5], for example, concluded that productivity remained constant from about the turn of the century to the mid-fifties, while Denison found an absolute decline in input productivity from the depression onwards [2]. Similarly, Meyerson, Terrett and Wheaton [9] found that the average consumer was able to purchase more housing services in 1929 than in 1955 despite the real increase in general purchasing power during the period. Finally, crude evidence presented by Nelson, Peck and Kalacheck [12] suggests that the scale of Research and Development (R & D) in the contract construction industry is very small; the ratio of R & D expenditures to value added is three and a half times as large for the economy as a whole as for the construction industry [12, pp. 192-195].

The lagging productivity of the residential construction industry and its low level of R & D expenditures, coupled with the importance of housing in the consumer budget, have been cited as a rationale for public intervention to improve efficiency -- by the Brookings Institution study [12] in 1967 and by two federal commissions, the

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[1]See Sims [15] for a review of these issues.

Douglas Commission [11] in 1967 and the Kaiser Commission [14] in 1968. The much-publicized experimental program, "Operation Breakthrough," sponsored by HUD in the late 1960's was intended to facilitate rapid efficiency gains.

Although the precise "cause" of backwardness in the industry is difficult to identify, there are four peculiar characteristics of residential construction activity which may contribute to its relatively low rate of technical progress.

First, effective demand for housing is subject to wide fluctuations, produced in part by the vagaries of the credit market. These demand fluctuations may inhibit the adoption of cost-reducing innovations, especially those which would make the production process more capital-intensive and thus more vulnerable to instability in demand. Further, these cyclical fluctuations may bias the research and development process itself, to discourage the exploration of labor-saving innovations which have been the source of much of the observed productivity increases in other sectors of the economy.

Second, the small scale of firms in the construction industry may also reduce the incentives for private research and development. Small scale may be particularly problematic if many of the potential innovations in the industry are in organization, systems design, and in the integration of housing components. Here the minimum efficient scale for R & D activity is presumably rather large, and, more importantly, the returns to R & D not easily capturable by a single firm.

Third, the merits of a particular idea or potential innovation in housing may be especially hard to evaluate because the performance of any particular innovation in materials, design or construction method depends upon a complex interaction with other parts of the structure. Since the industry is highly fragmented, it may be especially hard for suppliers to judge the potential of an innovation. This too will inhibit the search for innovation.

Finally, the fragmentation of the market is reflected, not merely in a large number of small firms operating in local housing markets, but also in a cumbersome regulatory process which relies upon local political divisions to set standards and to enforce regulations in the materials, design performance and safety characteristics of residential structures. The bewildering variation in local regulations may very well mean that potentially profitable innovations are also illegal in many geographical areas. This reduces the scale at which an innovation can be marketed, its profitability, and may further discourage R & D investment. In particular, the variation in regulation may greatly inhibit research and development by suppliers of building materials and capital equipment (even if the supplying firms are themselves large) since the potential market of a successful innovation is restricted by local building codes.

This paper is concerned with the latter two characteristics -- in particular, with the operation of local building codes. If local variation in codes is indeed a serious obstacle to technical progress in residential construction, then it is of some interest to consider what factors are responsible for such diversity, as well as what other interests may be served by such local regulation. After a cursory review of the evidence on the relationship between efficiency and regulation in home building, we present empirical evidence suggesting some reasons for the observed variation in local building codes. In particular, we examine four specific cost-saving innovations in residential construction, and we investigate the factors associated with their permissibility in local jurisdictions.

THE COSTS OF LOCAL BUILDING CODES

The regulation of residential construction is typically delegated by states to local jurisdictions which, in turn, enforce standards and specifications governing the erection and construction of buildings. Clearly the enforcement of minimum standards restricts consumer sovereignty in the consumption of housing services. As with other forms of regulation (e.g., drugs and pharmaceuticals), these codes are rationalized as a means of protecting consumers from the consequences of their own ignorance. It seems reasonable to presume that few housing consumers (or drug consumers) are technically trained to evaluate fully the potential hazards of consuming such complex commodities. This is especially true since many critical components of the dwelling unit -- the character of the foundation, the wiring, heating and plumbing systems, etc. -- are difficult to evaluate in the final product.

In principle, of course, a perfectly informed market could obviate this need for regulation by providing optional insurance policies for purchase by the occupants of dwelling units. There is little reason to expect such a complex insurance market to develop, however, given ignorance on the part of consumers (and potential insurers) about the relative probabilities of infrequent, but nevertheless real, injury from structural hazard.

Despite this rationale for some form of regulation, there are indications that the fragmented regulatory process acts as a barrier to improved efficiency in housebuilding. The most direct complaint against the operation of building codes is that the system results in unneeded provisions and restrictions which add significantly to the cost of housing -- by delaying construction of dwelling units and by preventing the use of the most up-to-date and modern materials. Further, it has been alleged that the procedures for modernizing and amending such codes are slow and laborious, lacking in any objective standards, and are dominated by a very small group of local interests.[2]

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[2]These issues are discussed in some detail in the report of the Douglas Commission [11].

There is conflicting evidence on the magnitude of excess costs attributable to variations in building codes. Several studies have suggested that the direct effect of building codes upon construction costs is small. For example, Sherman Maisel's early study (1950) of the San Francisco housing market concluded that an increase of less than one percent in the costs of newly constructed housing was attributable to "known code inefficiencies." [8, pp. 249-250] Richard Muth's econometric analysis of single detached housing conducted in 1968 suggested that locally modified building codes increased average cost by about two percent (as reported in [16], p. 8).

Burns and Mittelbach [1], in their report to the Kaiser Commission, analyzed a survey conducted by House and Home (the leading trade journal) in 1958, and suggested that if the 10 most "wasteful practices" required by building codes were eliminated, the average cost saving for single family housing would be 5 to 7.5 percent. "By assuming the provisions [of building codes] are randomly distributed and by taking account of their varying role in communities, "the authors conclude that "...the estimates represent from 1.5 to 3 percent of the price of an average house." [1, p. 102]

Several other analysts have come to different conclusions, however. In expert testimony presented to the Kaiser Commission, Ralph J. Johnson [6] concludes that "...in large urban areas, it may be possible to achieve on the order of a 10 to 15 percent reduction in direct construction costs [or 5 to 8.25 percent of selling price by Johnson's calculations] ...if the constraints of codes and restrictive labor practices are removed and if the industry is allowed to produce as efficiently as it knows how" [6, p. 57]. Survey evidence gathered by the Douglas Commission indicated some real cost reductions achievable by mass production under more uniform building codes [11, p. 262]. The estimates indicated that if 21 "excessive requirements" were eliminated, $1838 would be cut from a typical $12,000 FHA insured house. Again, this 15.3% reduction in construction cost (or roughly 13% in sales price, if one-fifth of selling price is composed of the land component) represents the sum of 21 "excessive code requirements," not all of which are necessarily in effect in any particular jurisdiction. The commission report also notes the problems of one home manufacturer who estimated that, to produce a standard product acceptable to the jurisdictions within his six-state market area, would increase costs by $2492 or almost 21 percent.

More important than any increased costs directly attributable to the intrinsic aspects of building codes are the production inefficiencies attributable to their lack of uniformity. As noted by Stockfisch:

> The absence of such consistency [in building code provisions] has the effect of constituting subtle but real barriers to trade. As such they stifle specialization and the division

> of labor which is the principle [sic] source of efficiency and cost saving. The problem, as it afflicts the construction industry, may be viewed as either a housing problem (insofar as it impacts upon housing alternatives available to poor people), or as an "antitrust" problem which exerts a special incidence upon poor people insofar as it is responsible both for higher cost housing and reduced employment opportunities for low-skilled individuals who would find employment in an expanded manufacturing center.
>
> [16, p. xiii]

To the extent that greater uniformity in building codes would lower the costs of construction without compromising housing quality and safety, would facilitate the mass production of housing components, and would provide stronger incentives for research and development, it is of interest to consider why code revision to achievement across communities has not occurred more rapidly.

A SIMPLE MODEL OF THE REGULATORY PROCESS

Although local building regulation is the political responsibility of local government -- and regulations are thus formally enacted and enforced by elected representatives -- the technical complexity of such standards suggests that local building officials exercise considerable influence in proposing and evaluating alternative sets of standards. Thus, we are interested in identifying those factors which determine the willingness of local officials to permit the use of particular construction methods in their jurisdictions.

Ideally, construction standards would be a codification of performance specifications for newly constructed dwellings. In practice, however, standards are typically stated in terms of input requirements.[3] In order to judge the acceptability of an innovation, then, the local building official must first evaluate the results of performance tests conducted by a wide variety of other agencies (e.g., Underwriters Laboratory) on particular materials and designs. Based upon these evaluations, specific standards or input requirements are proposed and promulgated. Thus it appears that the progressiveness of local building codes should be directly related to the level of professionalism of the local officials: the amount and type of their professional contact, their backgrounds and their education.

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[3]Fields and Rivkin's 1975 review [3, p. 37] indicates: "In almost all codes, standards are expressed in specifications indicating how and/or what the content of an item should be."

The development of a new product or process in construction, even if it unambiguously reduces costs without affecting quality, will not invariably be welcomed by all interested parties. In particular, we might expect firms to be anxious to adopt the innovation to lower costs, especially since it appears that the demand for housing by consumers is price elastic (see Muth [10]). The response of organized labor, presumably interested in local jobs rather than profits, may be less than enthusiastic if the innovation reduces labor input requirements, reduces required skill levels, or if it replaces local labor with other labor (as with innovations in preassembled components). In principle, we should also expect housing consumers to respond favorably to innovations which would reduce final costs.

One can picture the local building official, then, as being buffeted about by three interest groups: firms, labor and consumers.

In common with other bureaucratic regulatory agencies charged with adopting standards in some poorly defined "public interest," it is natural to assume that local building departments have a self-interest in minimizing conflict (see, for example, Joskow [7]). Thus the responsiveness of the local official to proposals for change in building codes is likely to depend on the relative strength in his jurisdiction of construction firms, labor unions, and the conditions of housing demand.

This discussion suggests a simple model of the local regulatory process:

$$(1) \quad P = f(B;Pc) = g(B;\ I_F,\ I_L,\ I_H)$$

where P, the permissibility of some innovation in material, design or organization in the local building code, is a function of the professionalism of the local building department (B) and the perceived level of conflict (Pc) caused by permitting the proposed change. This conflict is, in turn, dependent upon the actual or potential interference by firms (I_F), organized labor (I_L), or housing consumers (I_H).

These interest groups will engage in informational or persuasion activities if the expected benefits of the activity exceed its costs. For firms, the benefits will be larger for innovations which have a larger impact on unit costs. Also, since the costs of lobbying activity are independent of output, we should expect larger firms, producing more units of output, to make greater efforts to secure the adoption of cost-reducing code changes. As the cost of lobbying activity increases, the profitability level required for intervention will increase.

For labor, the benefits of intervention to promote adoption of a code change should be greater for innovations which have a larger impact on unit costs (again, assuming price elastic demand for housing output). The benefits of intervention to oppose code changes will be greater for those innovations which are labor saving -- at least those which reduce the demand for local labor. Again, the strength of the incentive to undertake persuasional activity will vary directly with the size of the interest group -- the relative strength of organized labor.

Housing consumers, the least organized of the three interest groups, may be unlikely to undertake direct persuasion of local officials on matters of local building codes. However, we may expect that, in areas where housing demand is increasing rapidly, construction firms may push more vigorously for the adoption of innovations. Thus, even in the absence of organized consumer lobbies, increased housing demand should encourage the adoption of innovation.

This simple model suggests, then, that the permissibility of a particular innovation in material, design, or organization will increase with firm size, with the demand for housing, and with the magnitude of its reduction in unit cost, and will decrease with the unionization of the local labor market and the labor-savingness of the innovation. Holding these factors constant, localities with more professional building officials should be more likely to permit the innovation.

A CRUDE EMPIRICAL MODEL

This simple model of the regulatory process can be tested somewhat crudely by utilizing a special survey of local building departments conducted by Fields and Ventre [4] in 1970. Tabulations and analysis of these survey data appear in Fields and Rivkin [3] and Ventre [22]. This survey gathered information about the characteristics of building officials in a cross section of U.S. jurisdictions, as well as the specific provisions of the local building codes in force in those communities.

We have chosen four of these code provisions, which reflect the permissibility of particular materials and techniques and which are generally agreed to be "progressive," for analysis. A brief description of these "innovations" in residential construction is followed by a disscussion of measures of the independent variables and by the results of several empirical tests of the underlying model.

THE DEPENDENT VARIABLES

Each of these code provisions is somewhat technical and narrowly defined. Broadly speaking, the first two "innovations" represent the removal of redundancies in residential construction; these innovations arise from increased knowledge about material stress in construction materials. The third code provision represents the preassembly of housing components, an innovation in organization, and the fourth is the substitution of cheaper and more flexible construction material.

Specifically, the first innovation is the provision for using 2 x 3 inch studs instead of 2 x 4 inch studs in non-load-bearing interior partitions; the second is the provision for placing studs 24 inches apart instead of 16 inches apart in such partitions.

The use of 2 x 3 inch studs involves a reduction of 25 percent in the wood required in non-loading-bearing partitions. The wider placement of studs reduces the wood required in such partitions by 33 percent and simultaneously reduces the labor required for such partitions.

According to the report of the Douglas Commission, each of these relaxed standards is, in the light of current engineering knowledge, as effective as the more restrictive provision:

> Any objective standard or test indicates that the requirement for the use of 2 by 4's every 16 inches in non-loading-bearing partitions is an excessive one. They are not required to bear the stress and weight of the building or ceiling. Experts agree that 2 by 3's can be used just as effectively in interior partitions and in non-load-bearing walls, and that 2 by 4's spaced every 24 inches would be just as safe. There seems to be no expert or scientific data to refute these facts. The requirement for 2 by 4's every 16 inches in non-load-bearing walls clearly adds to both material costs and labor costs. [11, p. 258]

The third innovation is the permission to use preassembled drain, waste and ventilating systems instead of the assembly on-site of these components. This typically involves the substitution of a factory assembled plumbing wall (or "wet wall") with bathroom fixtures in-place instead of conventional on-site assembly of plumbing components.

This innovation has the effect of reducing the demand for local labor, since on-site assembly time is reduced substantially. Again, the evidence presented by the Douglas Commission suggests that this innovation is highly desirable:

> Among the more important methods of reducing building costs is the prefabrication or offsite assembly of plumbing or electrical units. This makes the use of mass production and assembly line techniques possible; work can be done more efficiently through specialization and the division of labor; and much of the work is freed from the added costs due to time lost because of inclement weather because it is done indoors. [11, p. 258]

The fourth innovation is the use of non-metallic (chiefly plastic) sheathed cable for electrical wiring systems instead of metal conduit. This makes wiring systems somewhat cheaper and easier to install and may reduce the skill requirement for electricians.

Estimates of the cost savings in construction attributable to any one of these code provisions is, as noted above, imprecise. Published estimates, as of 1968, suggest that for a $12,000 house the removal of redundant standards for studs would reduce costs by $100 (removal of other redundant standards for wood stress would reduce costs by $343). Removal of prohibitions on preassembled water fixtures would reduce costs by $135 to $250, and permission to use non-metallic cable by another $50 to $300 [11, pp. 263-266]. None of these potential cost savings is dramatic, but each is significant.

THE INDEPENDENT VARIABLES

As noted above, we expect that code provisions permitting each of these four innovations in residential construction depend upon the level of professionalism of the local building department. Since the evidence suggests that none of these innovations interferes with public health and safety, we expect that jurisdictions with better educated building officials with wider professional contacts will be more likely to permit them. Similarly, we should expect that jurisdictions where local labor unions are more powerful will be less likely to permit these innovations (with the possible exception of the provision for 2 x 3 inch studs). We also expect that jurisdictions where firms are relatively larger will be more likely to permit these innovations. Finally, those areas where housing demand is increasing are also more likely to permit these innovations.

In measuring these four influences, we use nine variables. Many of these variables are quite crudely estimated; the specific details of their computation appear in the appendix along with their means and standard deviations.

The professionalism of the local building officials is measured using four variables: the education of the chief building official (in years); the background of the chief building inspector, noted as a dummy variable with the value of 1 if his prior experience is in the union building trades and 0 otherwise; a measure of the amount of contact the chief building official reported with building professionals (material producers, other building officials, etc.); a measure of the proportion of the building official's professional contact which is with representatives of organized labor.

Pressure by firms for the adoption of these innovations is proxied by an estimate of the average size of construction firms in the SMSA. It is our hypothesis, as noted earlier, that larger firms have stronger incentives to lobby for code changes, and, secondly, that there may be some economies to scale in persuasion.

The proportion of building trade workers who are unionized is used as a measure of the importance of labor pressure against the adoption of innovations.

Finally, the change in housing demand is measured by the change in the vacancy rate in the SMSA between 1960 and 1970 and by the population growth in the jurisdiction during the same period.

In addition to these eight measures, we include one additional variable, to represent fiscal incentives for resistance to lower cost housing. Given the property tax financing of local public services, jurisdictions have an incentive to insure that the marginal house is more expensive than the average. We measure the relative exclusivity of jurisdictions, and their fiscal incentive to use building codes to ration entry, by the ratio of the median income in the jurisdiction to the median income in the SMSA.

Tables 1 and 2 list the independent variables and their expected signs. More detail on their computation appears in the appendix.

EMPIRICAL RESULTS

In this section, we present the results of three statistical analyses which explore the relationship between these nine independent variables and the permissibility of the four innovations.

Table 1 presents coefficient estimates relating the probability that these innovations in housebuilding are permitted in a sample of 608 local jurisdictions to the nine independent variables. Estimates of these four logistic models were computed by the method of maximum likelihood. A likelihood ratio test indicates that each equation is significant at better than the .01 level.

The four equations in Table 1 are interpreted in terms of the conditional probabilities that any of these innovations will be permitted, given the values of the independent variables.

Two of the variables are highly significant in all four equations: education of the chief building official, and unionization. In particular, increased formal education is strongly related to the probability that each innovation will be permitted,[4] while the

[4]The elasticities of probability of acceptance with respect to education computed at the point of means are .37, .18, .27, and .64 respectively.

unionization of construction workers significantly reduces the probability of adoption. Even for the utilization of 2 x 3 inch studs, which has little direct effect on the demand for labor, the results suggest that this innovation is less likely to be permitted in highly unionized housing markets.

The other variables have the anticipated signs, but the level of significance is much lower. For two of the four code provisions, it appears that the probability of adoption is inversely related to the proportion of the building official's professional contact with organized labor. There is also consistent evidence that these cost-saving innovations are less likely to be permitted in more affluent jurisdictions.

In only one case, however, do the results suggest a more liberal code provision in jurisdictions in housing markets characterized by larger firms.[5]

Table 2 presents the results from the more general estimation method suggested by Nerlove and Press [13]. The table presents joint estimates of the probability of adoption of each of these innovations, recognizing that the acceptance of these four innovations is jointly dependent upon the set of independent variables. Again, a likelihood ratio test indicates that the estimates as a group are highly significant.

The table indicates a strong positive association between the adoption of these innovations, even holding the other characteristics of the jurisdictions constant. As might be expected, the association is strongest between the innovations in the size and the placement of wood studs, but the other interactions are all highly significant. The results indicate that jurisdictions which permit one of these innovations are more likely to permit the others, even holding constant the effects of the other nine variables.

Although the statistical significance of the other coefficients is reduced somewhat by the inclusion of the jointly determined endogeneous variables, the results are generally consistent with the simple models. In particular, it appears that the unionization and education measures are important, and the other variables have the anticipated signs, if not significant t-ratios.

Tables 1 and 2 have indicated the relationship between the probability that each of these four innovations was permitted in 1970 and the set of nine independent variables. Among those communities which permitted each innovation, there are substantial differences in the timing of adoption -- with some communities adopting an innovation rapidly and others only after a considerable time lag. We can utilize an additional piece of

[5] In part, this may result from the extremely crude measure of this variable. See the appendix.

information gathered in the Fields-Ventre survey, namely the year in which each community first adopted each innovation, to investigate, over time, the diffusion of these cost-saving techniques across communities, again in a somewhat crude manner.

Table 3 describes the timing of the adoption of these more permissive building regulations in the sample of communities. As the table indicates, the logistic curve denoting a sigmoidal diffusion pattern with an inflection point at fifty percent, fits the diffusion pattern over time of each of these innovations quite well. The estimates indicate that the interval between the time when ten percent of the communities have adopted the building code revision and the time when ninety percent have accepted the more progressive standard is 42-47 years for the innovations in material and is somewhat longer for the labor savings innovations.

Table 4 investigates the timing of the adoption of these building code changes in local communities, using the 1970 values of the independent variables. Again, we hypothesize that those jurisdictions with more professional building officials, and those housing markets with larger firms on average, and less unionization will be the early adopters of the code changes which permit cost savings.[6]

Table 4 reports the coefficients relating the lag associated with the adoption of each of the four innovations to the nine independent variables. The estimates were obtained by maximum likelihood using the estimation method for limited dependent variables suggested by Tobin [17]. The dependent variable is the year in which each innovation was adopted by the jurisdiction. (Those jurisdictions which had not adopted the innovation by 1970 are the limiting cases). Thus a negative sign for any coefficient indicates that it is associated with early adoption in the local building code.

As in the previous analysis, the two variables which are highly significant across all four equations are the education of the chief building official and the extent of unionization in the local area. An additional year of education is associated with the adoption of an innovation 1-2 years earlier. Higher levels of unionization are associated with longer lags in the adoption of these innovations in construction. Holding other factors constant, a jurisdiction in a completely unionized local construction market permits these four innovations between 4 and 20 years after a jurisdiction in a market with no unionization. The relative income measure is also highly significant in three of the four equations, suggesting that relatively wealthy communities are slow to permit

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[6]We require an assumption of continuity to test this hypothesis, e.g., we must assume that those jurisdictions characterized by better-educated building officials in 1970 were generally characterized by better-educated building officials during the period of diffusion of these innovations.

these cost reducing construction methods. Again, it is worth noting that there is only a weak relationship between the timing of the adoption of an innovation and the average size of housebuilding firms, at least as measured in this study.[7]

CONCLUSIONS

This paper set out to identify the determinants of local variation in building codes. By concentrating on four innovations in housebuilding which are generally agreed to be progressive, we investigated the relationship between the provisions of local codes and several characteristics of the chief building official and the local community. Although our results are hardly definitive, they suggest that the educational level of the chief building official and the extent of unionization in the local construction industry exert a strong influence on the acceptance and the timing of acceptance of these innovations. Thus the analysis provides some support for the conclusion that less professional local officials and highly organized labor markets in construction inhibit the diffusion of technical progress in housebuilding.

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[7] In addition to the results reported in the text, we estimated several of the models using alternative measures of firm size (e.g., the number of housebuilding firms in the SMSA with more than 500 employees) as independent variables. The results were no different from those reported in the text.

APPENDIX

This appendix indicates the sources of data and the assumptions used to define the variables discussed in the text.

The variables measuring professionalism of the local building officials, as well as the dependent variables in the analysis were taken from the original survey of jurisdictions, as reported in [4].

Years of education of the chief building inspector was estimated from responses coded in four categories.[8]

The dummy variable reflecting a background in union building trades was taken directly from the survey instrument.

The variable measuring the amount of professional contact of the chief building inspector was computed from responses to two questions asking how frequently the chief building inspector had official business and personal contact with each of five classes of professionals. Responses were obtained in four classes (e.g., "often, occasionally, rarely, never"). Responses to these questions were assigned values from 1 to 4 and aggregated, resulting in a somewhat crude measure of the amount and intensity of contact with other professionals with a range between 0 and 40.

The variable measuring the proportion of contact with union personnel is the ratio of the computed measure for union contact to the measure for total contact with professionals.

The dependent variables were taken directly from the questionnaire.

The variables measuring demand pressure were taken from the U.S. Census of Population and housing [18] for 1960 and 1970. The change in the vacancy rate is measured as the proportionate change in the available vacant dwelling units to total dwelling units between 1960 and 1970 for the SMSA as a whole.[9]

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[8] "1-8 grades" (assigned a value of 8); "9-12 grades" (12); "some college" (14); "college graduate" (16).

[9] i.e., $(VR_{1970} - VR_{1960})/VR_{1960}$ where VR is the ratio of available vacant to total dwelling units in the SMSA.

The local growth rate is measured by the proportionate change in population in the sampled jurisdiction in the same time period.[10]

Relative income is the ratio of median income for households in the sampled jurisdiction to the median income for households in the metropolitan area.

The average firm size was estimated from data reported in the 1970 City and County Data Book [19] for each SMSA. Size data are reported in 6 categories of employment and were aggregated by using the mid-points.

The proportion of unionized workers in the building trades was estimated by combining data from two sources. Estimates of the proportion of unionized workers in 19 building trades were available for a selection of SMSA's from the Bureau of Labor Statistics' Industry Wage Survey [21, pp. 27-92]. For other SMSA's we were forced to rely upon state data indicating the proportion of unionized workers in non-farm occupations [20, p. 367]. For 147 out of the 608 jurisdictions analyzed in Tables 1, 2, and 4 we were forced to rely upon this more crude estimate of unionization; even for the remaining 461 jurisdictions the unionization measure is subject to error, since the sample sizes are sometimes rather small.

The sample size for the logistic analyses reported in Tables 1 and 2 is 608 of the total of 1028 jurisdictions sampled, representing all communities in Standard Metropolitan Statistical Areas for which complete data were available. The sample size for the analysis of the timing of code revisions (Table 4) was reduced to 488 because data on the year of building code revision was not available for a number of communities.

Appendix Table 1 presents a summary of the raw data analyzed in the text.

[10] i.e., $(P_{1970} - P_{1960})/P_{1960}$ where P is the population of the jurisdiction.

TABLE 1

LOGISTIC ESTIMATES OF MARGINAL PROBABILITY OF ACCEPTANCE OF FOUR INNOVATIONS IN A CROSS SECTION OF JURISDICTIONS

		Innovation			
	Expected Sign	Plastic Cable	Pre-assembled Plumbing	2 x 3 Inch Studs	24 Inch Placement of Studs
Independent Variables:					
I. Professionalism					
Education	+	0.086 (3.15)	0.126 (4.61)	0.067 (2.52)	0.098 (3.75)
Union Background	-	-0.057 (0.55)	-0.342 (3.34)	-0.133 (1.27)	-0.021 (0.22)
Amount of Contact	+	-0.008 (1.06)	0.009 (1.33)	0.003 (0.39)	0.006 (0.81)
Union Contact	-	-1.392 (2.09)	0.057 (0.09)	-1.435 (2.19)	-0.452 (0.73)
II. Demand Pressure					
Δ Vacancy Rate	-	-0.164 (1.04)	-0.759 (4.83)	-0.195 (1.30)	-0.002 (0.02)
Local Population Growth	+	0.020 (0.27)	0.315 (3.28)	0.034 (0.48)	-0.012 (0.18)
Relative Income	-	-0.203 (1.074)	-0.394 (2.02)	-0.339 (1.83)	-0.307 (1.66)
III. Pressure Groups					
Average Firm Size	+	0.010 (0.63)	0.002 (0.12)	0.001 (0.64)	0.047 (3.30)
Proportion Unionized	-	-1.043 (6.60)	-0.293 (1.95)	-3.326 (2.43)	-0.624 (4.22)
Intercept		-0.736 (1.47)	-1.151 (2.31)	-0.071 (0.15)	-1.289 (2.65)
$-2 \log L/L_0$		67.08	78.92	22.98	53.76

asymptotic t-ratios in parentheses

χ^2 (.01, 9df) = 21.67

608 jurisdictions

TABLE 2
ESTIMATES OF THE JOINT PROBABILITY OF ACCEPTANCE OF FOUR INNOVATIONS INCLUDING BIVARIATE INTERACTION EFFECTS

Independent Variables:	Expected Sign	Innovation			
		Plastic Cable	Pre-assembled Plumbing	2 x 3 Inch Studs	24 Inch Placement of Studs
I. Professionalism					
Education	+	0.046 (1.31)	0.095 (2.62)	0.009 (0.26)	0.062 (1.74)
Union Background	-	0.028 (0.21)	-0.353 (2.56)	-0.064 (0.47)	0.087 (0.65)
Amount of Contact	+	-0.012 (1.32)	0.011 (1.18)	0.000 (0.05)	0.005 (0.58)
Union Contact	-	-1.272 (1.54)	0.724 (0.86)	-1.380 (1.61)	-0.071 (0.09)
II. Demand Pressure					
Δ Vacancy Rate	-	-0.002 (0.00)	-0.810 (4.13)	-0.042 (0.21)	-0.230 (1.23)
Local Population Growth	+	-0.034 (0.38)	0.346 (3.29)	-0.186 (0.21)	-0.067 (0.84)
Relative Income	-	-0.055 (0.23)	-0.276 (1.07)	-0.189 (0.76)	-0.165 (0.66)
III. Pressure Groups					
Average Firm Size	+	0.008 (0.44)	-0.001 (0.04)	0.057 (3.16)	0.065 (3.71)
Proportion Unionized	-	-1.025 (4.92)	-0.030 (0.14)	-0.550 (2.60)	-0.581 (2.82)
IV. Bivariate Interaction					
Cable	+	-	0.226 (3.76)	0.156 (2.64)	0.152 (2.66)
DWV	+	0.226 (3.76)	-	0.250 (4.15)	0.212 (3.91)
Two by three	+	0.156 (2.64)	0.250 (4.15)	-	0.337 (5.37)
24 Inch	+	0.152 (2.66)	0.212 (3.91)	0.337 (5.37)	-
Intercept		-0.386 (0.60)	-0.952 (1.41)	0.673 (1.03)	-1.221 (1.87)

$-2 \log L/L_O = 93.07$

$\chi^2(.01, 48df) \cong 76.15$

asymptotic t-ratios in parentheses

608 observations

TABLE 3

LOGISTIC CURVES INDICATING THE

DIFFUSION OF INNOVATION OVER TIME

$$\log \left[\frac{p}{1-p}\right] = a + bt$$

Innovation	a	b	R^2	Interval between 10 and 90 percent adoption
two by three inch studs	-183.2	.0930 (.0017)	.979	47 years
24 inch placement of studs	-165.4	.0836 (.0022)	.956	53 years
preassembled plumbing	-174.7	.0884 (.0023)	.962	50 years
plastic cable	-205.3	.1047 (.0019)	.981	42 years

t-ratios in parentheses

p is the proportion of jurisdictions permitting an innovation at year t.

TABLE 4
TOBIT ESTIMATES OF THE YEAR OF BUILDING CODE LIBERALIZATION

Independent Variables:	Expected Sign	Innovation: Plastic Cable	Innovation: Pre-assembled Plumbing	Innovation: 2 x 3 Inch Studs	Innovation: 24 Inch Placement of Studs
I. Professionalism					
Education	-	-2.227 (3.91)	-2.163 (3.87)	-1.170 (2.40)	-2.002 (3.636)
Union Background	+	1.347 (0.63)	5.581 (2.81)	2.257 (1.21)	1.985 (0.59)
Amount of Contact	-	0.007 (0.04)	-0.232 (1.63)	-0.104 (0.80)	-0.138 (0.96)
Union Contact	+	26.744 (2.08)	1.188 (0.10)	10.741 (0.96)	2.871 (0.22)
II. Demand Pressure					
Δ Vacancy Rate	+	3.591 (1.19)	16.093 (5.20)	3.382 (1.28)	-0.276 (0.09)
Local Population Growth	-	0.632 (0.49)	-2.995 (2.65)	0.250 (0.22)	0.552 (0.46)
Relative Income	+	4.326 (1.19)	7.533 (2.00)	6.532 (1.92)	8.761 (2.17)
III. Pressure Groups					
Average Firm Size	-	-0.010 (0.04)	-0.113 (0.43)	0.486 (1.99)	-0.702 (2.68)
Proportion Unionized	+	19.700 (6.00)	7.260 (2.411)	3.700 (1.35)	9.350 (3.04)
Intercept		1989.936 (21.227)	1942.534 (18.390)	1972.177 (21.52)	1993.702 (18.71)
$-2 \log L/L_O$		86.90	110.02	75.53	81.15

$\chi^2(.01, 9df) = 21.67$

asymptotic t-ratios in parentheses

488 observations

APPENDIX TABLE 1

MEANS AND STANDARD DEVIATIONS OF VARIABLES USED IN ANALYSIS (608 JURISDICTIONS)

	Mean	Variance	Minimum	Maximum
I. Professionalism				
Education (years)	13.914	3.203	8.000	16.000
Union Background dummy	0.322	-	0.000	1.000
Amount of Contact	23.743	41.444	0.000	38.000
Union Contact	0.251	0.005	0.000	0.583
II. Demand Pressure				
Δ Vacancy Rate	-0.086	0.090	-0.631	1.379
Local Population Growth	0.399	0.470	-0.937	7.478
Relative Income	1.071	0.059	0.705	2.926
III. Pressure Groups				
Average Firm Size	13.575	10.775	5.250	27.780
Proportion Unionized	0.482	8.762	0.078	0.983
IV. Dependent Variables				
Cable	0.692			
DWV	0.546			
Two-by-Three Inch Studs	0.706			
24 Inch Placement	0.533			

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EFFECTIVENESS OF U.S. MUNICIPAL DESIGN REVIEW PROGRAMS -- PRELIMINARY FINDINGS

by

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Design review and architectural controls as regulatory devices for improving building and site design began in the United States in 1930. By 1949, there were some 30 municipalities in the United States using such controls. The desire for more flexible regulatory instruments which could deal with unique contextual situations and designs as well as provide the means for designers to exercise their ingenuity in solving complex problems has resulted in this quasi-judicial regulatory technique becoming increasingly popular throughout the United States. In spite of this growing popularity there has been neither a systematic inventory or evaluation of this particular technique. This study has attempted a comprehensive analysis of design review and architectural control boards in municipalities in the United States with a population of greater than 25,000. In general, it tries to identify the goals, functions, structures, and techniques used by such boards and attempts to relate these to the effectiveness of such boards in achieving these goals.

Key Words: Architectural controls; buildings; design review; land use; municipalities; regulation; site design.

INTRODUCTION

The use of design review as an urban land-use guidance tool appears to have been increasing significantly in the United States. This quasi-judicial approach to regulation has become quite attractive to local officials in that it provides greater administrative flexibility than do conventional zoning and building regulations (Kaiser, Elfers, Cohn, Hufschmidt, Reichert and Stanland, 1973). This flexibility enables building and planning officials to work together with designers and developers to achieve mutually satisfactory solutions to problems within the broader context of local planning goals and policies. By eliminating the pragmatic constraints necessary in the development and enforcement of traditional regulations, design review is presumed to provide a methodological framework which enhances creative design and optimize the possibility of achieving public as well as private sector goals.

Considerable research has been done on specific land-use planning tools, e.g., bulk and density controls, transfer of development rights, bonus systems, etc.. However, little has been published in the last 20 years systematically reporting on the structure, procedures and effectiveness of the design review programs in American cities. Nevertheless, their increased popularity and the total number existing in the U.S. indicate a heavy reliance on this method for guiding urban land-use. Further, as indicated by Fagin (1964), as well as through the review of state enabling legislation and local ordinances, considerable variety exists in these programs. With such importance ascribed to design review programs and their increasing popularity, an analysis of the differential approaches and their relative effectiveness is desirable. In so doing, the effectiveness of design review in improving the quality of American cities may be enhanced.

METHODOLOGY

A questionnaire was mailed to all 924 municipalities in the United States which had 1970 populations of 25,000 or more. The questionnaire was designed to ascertain whether the community used design review or architectural controls as part of its urban guidance system, as well as to obtain information concerning the structure, procedures and effectiveness of the design review process. If the municipality did not use design review or architectural controls, the questionnaire attempted to determine if it desired to do so, the problems it was facing, etc.

In order to assess effectiveness, the respondents were asked to rank the effectiveness of their own program on a scale of 1 to 10 with 1 signifying "ineffective" and 10 signifying "extremely effective." In addition, to self-anchor these ratings, the respondents were asked if they knew of design review programs in other communities and to identify and rank the least and most effective of these on the above type scale. Unfortunately, the responses, to the self-anchoring question were few and most failed to rank the communities they mentioned. (This was surprising since a majority of the respondents indicated that ordinances from other communities were a major source of relevant information in the creation of their own programs.) This was extremely unfortunate in that an important refinement was lost in developing the measure of effectiveness. Thus, effectiveness in this question was defined as self-perceived "effectiveness."

The questions asked were designed to elicit information on the programs in relation to effectiveness and were derived from organizational and design theory developed earlier (Cohn, 1968, 1969, 1972; and Kaiser, et al., 1973). Some of these are believed to have major significance with respect to effective performance while others were designed to aid in further refining and validating the data. All respondents were asked if the municipality used design review. The "yes" respondents were asked fourty-two questions: 2 measured effectiveness (1 was unusable); 4 ascertained demographic data; 3 probed for information regarding future plans; and 33 were designed to elicit information on structure, process, techniques, etc. related to effective performance (1 of these was unusable). Of the latter 33 questions, 9 had multiple components. This yielded a total of 79 usable variables.

Those communities who indicated that design review and/or architectural control programs did not exist were asked four questions. These were designed to determine if the municipality desired to do so, if it had attempted to establish a program, why it had not been established and the names of other communities with such programs.

Almost half (458 or 49.6%) of the questionnaires were completed. Of these, 187 (40.8%) municipalities responded that they used design controls and 271 (59.2%) indicated that they did not. The responses came from 49 of the 50 states with Delaware being the only exception (Delaware has only one municipality with this large a population). The average response by state was 54.9% of the possible municipalities indicating that the respondents in the survey had come, for the most part, from the smaller states on a percentage basis. In Idaho, for example, 3 of 4 cities responded (a rate of 75%) and Vermont 1 out of 1 for 100%. In New Jersey, on the other hand, only 20 of 62 responded (32.2%) and in Illinois 27 of 59 completed the questionnaire (45.8%).

The data were nominally coded and frequency distributions arrayed for each variable. The data on effectiveness, scored by the respondents on a scale of 1 (ineffective) to 10 (highly effective) was collapsed into three categories in order to increase the number of cases in each category and enhance the clarity of the findings (see Table 1).

EFFECTIVENESS

Collapsed Category	Response on Questionnaire Scale (1-10)	# Respondents	% of Total
Low	1 thru 4	26	14.6
Medium	5 thru 7	85	47.8
High	8 thru 10	67	37.6
Total		178	100.0

Table 1

Transformation of the Effectiveness Ranking

Finally, the variables associated with effectiveness of performance of the design review programs were correlated with the effectiveness measures and analyzed using the chi-square test. Significant levels of less than or equal to .05 were viewed as statistically significant while those greater than .05 but less than or equal to .10 were viewed as trends. In all, 14 independent measures were found to be significantly correlated with the effectiveness of performance and 7 had trends in this direction.

RESULTS

Because of time and space constraints, no attempt has been made to analyze all of the variables in depth or to investigate relationships between them. In addition, variables which did not have statistically significant results are not reported unless they are of major interest.

ANALYSIS: THE NO RESPONDENTS

This section of the analysis concerns the respondents who reported that they did not have design review programs. On the basis of the questionnaire this group can be categorized as follows:

Desire Design Review	Implementation Attempted: Yes	Implementation Attempted: No	
Yes	Type 1 14.5%	Type II 33.7%	48.2%
No	Type III 2.0%	Type IV 49.8%	51.8%
	16.5%	83.5%	100%

Table 2

Categorization of "No" Responses

TYPE I This group comprised 41 of the "no" respondents or 14.5%. Fourteen (14) municipalities indicated that they are currently in the process of either discussing or creating a design review ordinance.

TYPE II This group comprised 95 of these respondents or 33.7%. There were at least three municipalities in this group in which no agreement could be reached between the various governmental bodies. For example, one suggested that the planning board favored appearance controls and the city council did not, while another indicated that both the city council and the planning board favored controls but that the building inspection department did not.

The respondents in TYPES I and II offered a variety of reasons for their inability to establish the design review programs in their communities. These include: (1) Lack of support and strong developer opposition; (2) No legal basis for the ordinance; (3) Not enough staff and/or funds for this task; (4) City council refused to take action (on the basis of pressure); and (5) No "theme" on which to establish the controls.

TYPE III This group comprised only 5 of the respondents or less than 2%. This is perhaps the most interesting of the groups in that it includes municipalities where there was a lack of political support as well as opposition to design regulations. Sample responses include:

> Strong opposition (to design review) for fear it would restrict people from doing work on their own property. A building code was a basic step in design we had hoped to establish. The downtown merchants are attempting to refurbish buildings in the downtown area and are attempting to control architecutral controls (sic) on a voluntary basis.
>
> Opposition from builders, architects, etc.; difficult to administer; time demand on review authority too great to devote adequate time to application; inconsistency due to changes in membership and attendance.
>
> The idea was considered by the (city) council but was discarded as being inoperable.
>
> Architectural control was included as a part of a proposed Historical District Ordinance. Said ordinance was not adopted because of the strong powers to be given to the Historical District Commission which would not be under the control of the City Council.

TYPE IV Half of the respondents fell into this group. None of the respondents in this category offered explanations for either attempting or desiring design review.

	# responses as reported	adjusted	% total reported	% total adjusted	% increase (adjusted)
Pre 1950	9	9	5.4	4.3	-
1950-1954	9	9	5.4	4.3	0
1955-1959	16	16	9.6	7.6	88.9
1960-1964	31	31	18.8	14.8	97.0
1965-1969	57	57	34.3	27.1	88.0
1970 only	44		26.5		
1970-1974 (projected)		88		41.9	77.0
	166	210	100.0	100.0	

TABLE 3

Frequency of Design Review Programs in the United States by Initiation Date

ANALYSIS: THE YES RESPONDENTS

General Characteristics. This section concerns the analysis of those municipalities exercising design review. The growth of this form of urban guidance technique is clearly established on the basis of the data received. The data, however, are somewhat misleading. The data was gathered in the late summer and early fall of 1973. Thus, the actual number of programs initiated after 1969 (44 cases) reflect a 2 1/2 year growth period and can be assumed to be approximately half of the cases for a projected five year period 1970-1974. For this period there would be approximately 88 cases (see Table 3 and Figure 1). This is not an unreasonable projection, particularly in light of the 41 "no" respondents who indicated that they were discussing or creating design review ordinances. With more than a 75% growth for each period, the continued growth as indicated in Figure 1 is impressive.

Effectiveness was correlated with the number of years the programs have been in existence and no significance was found. Further, the respondents were asked how many projects or applications they reviewed annually and these data were correlated with the measure of effectiveness (Table 4). The resultant chi-square was equal to 23.967 with 14 degrees of freedom, a level of significance of 0.04. Although the number of cases in the higher frequencies is small, it is clear that effectiveness increases with increase in the number of projects reviewed (see Figure 2). For example, in those municipalities reviewing 0-50 projects annually, 20.2% view themselves as low in effectiveness and 29.2% as high in effectiveness. In contrast, in the 200-500 projects per annum category, only 7.7% judge themselves as low in effectiveness and 69.2% as high in that attribute. An interesting aspect of this is with respect to the group which processes the greatest number of applications, i.e., the 501 and over. None of the respondents ranked themselves as low in effectiveness, 45.5% were moderately effective and 54.5% as highly effective. It may well be that the benefits of size are eroded at some point over 500 projects per year under current systems of administration.

Projects Reviewed Annually — COUNT / ROW PCT / COL PCT / TOT PCT	Effectiveness: Low	Med.	High	ROW TOTAL
0-50	18 20.2 81.8 10.9	45 50.6 56.3 27.3	26 29.2 41.3 15.8	89 53.9
51-100	1 3.4 4.5 0.6	18 62.1 22.5 10.9	10 34.5 15.9 6.1	29 17.6
101-200	2 8.7 9.1 1.2	9 39.1 11.3 5.5	12 52.2 19.0 7.3	23 13.9
201-500	1 7.7 4.5 0.6	3 23.1 3.8 1.8	9 69.2 14.3 5.4	13 7.9
501 and over	0 0.0 0.0 0.0	5 45.5 6.3 1.2	6 54.5 9.5 1.8	11 6.6
COLUMN TOTAL	22 13.3	80 48.5	63 38.2	165 100.0

TABLE 4

Number of Projects Annually Reviewed
Related to Effectiveness

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
Changes: Yes	5 6.3 20.0 2.8	39 48.8 46.4 22.2	36 45.0 53.7 20.5	80 45.5
No	20 20.8 80.0 11.4	45 46.9 53.6 25.6	31 32.3 46.3 17.6	96 54.5
COLUMN TOTAL	25 14.2	84 47.7	67 38.1	176 100.0

TABLE 5

Significant Programmatic Change

Related to Effectiveness

One of the questions dealt with the occurence, if any, of significant changes in the structure or operation of the design review process since its inception. Underlying this question is the notion that evaluation, feedback, and change is conducive to effective performance. The data indicate that 45.4% of the municipalities have implemented such changes and 54.6% have not (see Table 5). Analysis of the correlation between this variable and effectiveness yielded a chi-square of 8.417 with 2 degrees of freedom. This is significant at the 0.01 level. A review of the data clearly indicates that a considerably higher percentage who changed their programs are in the high level of effectiveness (see Figure 3). This suggests that program change is associated with increased effectiveness. The respondents were also asked to specify the nature of these changes. The 85 responses may be categorized as follows in Table 6.

	# Responses	%
Integration with other agencies	3	3.5
Increased professional staff	5	5.9
Changes in the process (e.g., established priorities or objectives more systematic review, etc.).	7	8.3
Organizational changes (shift of authority, established professional staff, increased number of designers).	13	15.3
Stricter controls	20	23.5
Expanded the scope of control (increased area of city or number of land-uses)	32	37.7
Other	5	5.8
Total	85	100.0

TABLE 6

Types of Changes in Design Review Organizations

This suggests that when the municipality exercises stricter and expanded controls, (61.2% of the cases) organizational power over the environment is augmented and effectiveness is enhanced.

Program Goals Respondents were asked to identify the basic goals of their program. These goals are listed in Table 7.

GOAL	# Responses	% Responses
Beauty for Beauty's Sake	69	42.4
Improved Economy	41	23.7
Health and Well-being	82	49.1
Historic-Cultural	55	34.1

TABLE 7

Basic Goals or Purposes of the Programs

(Since more than one goal was specified by some respondents, the total % responses is greater than 100%.)

Only the analysis of the historic-cultural goal yielded statistically significant results with respect to effectiveness (see Table 8). The chi-square was equal to 4.657 with 2 degrees of freedom which is significant at the 0.09 level. Of those who identified historic-cultural preservation as a primary goal, 49.1% viewed themselves as highly effective while only 9.1% judged themselves low in effectiveness. In contrast, of those who did not specify this goal, 33% and 17.4% perceived themself as being of high and low effectiveness, respectively (see Figure 4). Though on the surface somewhat odd, there may be an explanation. While economic grounds are a more legitimate basis for using the police power, this orientation does not necessarily help to significantly affect esthetic ends. Health and well-being is also a legitimate use of the police power, but knowledge of the socio-epidemiological implications of the environment is in the embryonic stage and the immediate relationship is probably weak in any case. While in some instances there is little difference between beauty and historic-cultural goals, the latter is usually on sounder legal footing as well as with respect to political support (Kaiser, et al., 1973). This historic-cultural perspective, although limited, permits not only stricter legal controls but provides more support from the municipal legislative body than does a purely esthetic basis. This, of course, does not speak to the extent of coverage of the municipality but simply indicates a greater source of power in affecting historic district regulation. The definition and scope of historic preservation, however, has expanded significantly of late encompassing larger segments of the urban environment (Kaiser, et al., 1973) and has made this a more powerful device.

COUNT ROW PCT COL PCT TOT PCT		Effectiveness		ROW TOTAL
	Low	Med.	High	
Goals: No	19 17.4 79.2 11.6	54 49.5 70.1 32.9	36 33.0 57.1 22.0	109 66.5
Goals: Yes	5 9.1 20.8 3.0	23 41.8 29.9 14.0	27 49.1 42.9 16.5	55 33.5
COLUMN TOTAL	24 14.6	77 47.0	63 38.4	164 100.0

TABLE 8

Effectiveness and Historical-Cultural Goals

The municipalities were also asked to describe the standard of quality of the esthetic environment that they hoped to achieve through their design review programs by identifying which of the following best described the potential effectiveness of the program: 1) it can achieve a beautiful city; 2) it can generally improve the appearance of the city but will not result in a beautiful city; 3) it can only result in eliminating the worst or ugliest buildings and other related elements; 4) and others. These responses were correlated with effectiveness (see Table 9). The analysis yielded a chi-square value of 25.304 with 6 degrees of freedom and a significance level of 0.0003. The data indicated that as the goal becomes less esthetically demanding, i.e. from achieving a beautiful city to merely eliminating ugliness, the percentage of respondents who view themselves as low in effectiveness increased substantially (see Figure 5). Conversely, the opposite is the case with respect to high effectiveness. This is interpreted to mean that those municipalities with higher esthetic goals are more apt to judge themselves as more effective. This could suggest that municipalities with higher standards invest more in their programs. Further analysis of the data should help to clarify this.

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
Beautify	2 9.1 8.7 1.2	9 40.9 11.5 5.6	11 50.0 18.0 6.8	22 13.6
Generally Improve	8 7.8 34.8 4.9	50 48.5 64.1 30.9	45 43.7 73.8 27.8	103 63.6
Eliminate The Ugly	8 44.4 34.8 4.9	8 44.4 10.3 4.9	2 11.1 3.3 1.2	18 11.1
Affect Selected Areas	5 26.3 21.7 3.1	11 57.9 14.1 6.8	3 15.8 4.9 1.9	19 11.7
COLUMN TOTAL	23 14.2	78 48.1	61 37.7	162 100.1

Esthetic Goal

TABLE 9

Effectiveness as Related to Esthetic Goals

Organizational Power As indicated elsewhere (Cohn, 1968, 1972, 1975), the proper use of power is essential to an effective design review program. Because of the limits of legal power available, the extensive use of informal types of power is necessary as is the judicial selection of the proper type of power most effective with each applicant. Several questions were asked to probe this attribute of the program. The analysis suggests that there is no relationship between effectiveness and: 1) the particular municipal body which sets objectives and policies; 2) the ultimate decision-maker or appeal source; 3) the use of informal or formal power; 4) or whether the review body differentiates between architects and developers, realtors, etc. (In the latter case 93.2% indicated that they do not treat architects differently.) As suggested above, some of these results are extremely surprising but, if the theory is sound, may simply indicate that considerable room exists for improvement in most municipal design review program. The data and experience suggest that the respondents may not be fully aware of their behaviors and further investigation may provide additional insight into this matter.

The respondents were also asked what percentage of the total number of projects reviewed annually were rejected. The responses were cross-tabulated with effectiveness and are shown in Table 10. The chi-square was equal to 16.096 with 10 degrees of freedom and a significance level of 0.09, signifying a trend. This is generally interpreted, with caution, to indicate that the propensity to reject applications is related to effectiveness. More specifically, the data suggest the following effectiveness ranking (see Figure 6). Those who reject more than 41% of the applications are most effective (18.2% low and 54.5% high); those rejecting 1 to 10% (8.6% low and 40.0% high) and 11 to 20% (5.3% low and 31.6% high) rank second in effectiveness; those rejecting 21 to 40% rank third in effectiveness (20.0% low and 20% high), and those who do not reject any applications are least effective (31.3% low, 25.0% high). The future analysis of these data as related to the number of projects reviewed may cast more light on this relationship.

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
0%	10 31.3 45.5 6.8	14 43.8 18.9 9.5	8 25.0 15.7 5.4	32 21.8
1-10%	6 8.6 27.3 4.1	36 51.4 48.6 24.5	28 40.0 54.9 19.0	70 47.6
11-20%	1 5.3 4.5 0.7	12 63.2 16.2 8.2	6 31.6 11.8 4.1	19 12.9
21-40%	3 20.0 13.6 2.1	9 60.0 12.2 6.1	3 20.0 5.9 2.0	15 10.4
41-100%	2 18.2 9.1 1.4	3 27.3 4.1 2.0	6 54.5 11.8 4.1	11 7.5
COLUMN TOTAL	22 15.0	74 50.3	51 34.7	147 100.0

% Projects Rejected Annually

TABLE 10

Effectiveness as Related to the Percentage
of Projects Rejected Annually

Many municipalities believe that the offering to design suggestions to the building applicant, such as providing sketches, will increase their effectiveness. Essentially, this is a remunerative form of power, but it also serves to directly improve the quality of the solution when the suggestion is accepted. Several questions were asked regarding this practice (see Table 11).

When proposed buildings are "acceptable" within your qualitative standards, do you nevertheless make suggestions as to improvements which you think are desirable?

YES	NO
92.9%	7.1%

Do you provide sketch solutions to the applicants?

Frequently	17.2%
Often	26.1%
Seldom	41.1%
Never	15.6%

In cases where sketches are provided to the applicant, what is the purpose?

Clarify the applicant's ideas	6.7%
Offer alternate solution	69.3%
Both of the above	24.0%

TABLE 11

Design Services Offered to Applicants

Chi-square analysis yielded no significant relationships in any of these cases. As can be seen, making suggestions is almost a universal practice and 43.3% provide sketches often or frequently. It is my judgment from discussions with planners that if the practice was not so expensive or time-consuming, it would be more pervasive. If this analysis is correct, it makes little difference whether this practice is followed.

Systematic Design Approaches A set of questions were asked to ascertain the degree to which the agencies systematically approached the development and implementation of their programs. As has been noted elsewhere (Cohn, 1968, 1975; Kaiser et al., 1973) this is believed to be highly related to the effectiveness of such programs. Several subjects of interest were found in this area.

The municipalities were asked to mention the most relevant sources of information used to initially design the review program. Five sources were specified. The following percentages of respondents obtained relevant information from them: (1) state and federal guidelines, 14%; (2) model processes, 11%; (3) ASPO, 16%; (4) other communities, 66%; and (5) in-house staff, 34%. Two sources were found to have significant correlations with effectiveness: a) federal and state guidelines and b) ordinances from other communities (see Table 12 and 13, respectively). In the first case, that is, state and federal guidelines, the chi-square was equal to 6.23 with 2 degrees of freedom and a significance level of 0.044. Only 26.15% of those agencies rated themselves as highly effective while 30.4% rated themselves as having low effectiveness (see Figure 7). Of those who did not use these 38.7% and 11.3% ranked themselves as high and low effectiveness respectively. This suggests that state and federal guidelines, normally found in enabling legislation, contributes to <u>ineffectiveness</u>. It is reasonable to conclude that the sole reliance on such guidelines is to be avoided.

The analysis of those municipalities which received information used for creating their programs from the ordinances of other communities yield a chi-square value of 4.717 with 2 degrees of freedom and a significance level of 0.09. Of these, 11.0% rated themselves as having low effectiveness, 54.1% as moderately effective and 34.9% rated themselves as highly effective (see Figure 8). Of those that did not, 19.6%, 37.5% and 42.9% rated themselves as low, moderate and high effectiveness respectively. This is interpreted as a trend indicating that the use of ordinances from other communities the creation of new design review processes contributes to effectiveness

The fact that such a high percentage of the municipalities sought information from other communities (66%) and in-house staff (34%) and so few found relevant guidelines from the other sources should come as no surprise. Little contemporary information has been available in the last 15 to 20 years from these other sources and state enabling legislation for the most part provides only the basic structure. The findings in Table 13 when compared with data concerning the respondents knowledge of the programs other communities are puzzling. As indicated above, very few of the respondents mentioned names of other communities exercising design review. Most of those who did failed to rank them in terms of effectiveness. Thus, it is surprising that 66% of the communities used ordinances of other municipalities as the basis for creating their own design review program, and yet did not identify them or specify their effectiveness. This can possibly be explained, by the fact that although ordinances from other communities were obtained, the respondents had little or no knowledge as to the operation or effectiveness of these particular programs.

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
State or Federal Guidelines: No	16 11.3 69.6 9.8	69 48.9 87.3 42.1	56 39.7 90.3 34.1	141 86.0
Yes	7 30.4 30.4 4.3	10 43.5 12.7 6.1	6 26.1 9.7 3.7	23 14.0
COLUMN	23	79	62	164

TABLE 12

Effectiveness of Programs Using State or Federal Guidelines in Creating Program

COUNT / ROW PCT / COL PCT / TOT PCT	Effectiveness: Low	Med.	High	ROW TOTAL
Other Communities: No	11 19.6 47.8 6.7	21 37.5 26.3 12.7	24 42.9 38.7 14.5	56 33.9
Yes	12 11.0 52.2 7.3	59 54.1 73.8 35.8	38 34.9 61.3 23.0	109 66.1
COLUMN TOTAL	23 13.9	80 48.5	62 37.6	165 100.0

TABLE 13
Effectiveness of Communities
Using Review Ordinances from Other Communities
in Creating Program

The respondents were asked whether in conjunction with the development of their program a systematic inventory and analysis was made of the visual character and attributes of the community (see Table 14). The analysis of this data yielded a chi-square value of 13.91 with 2 degrees of freedom and a significance level of 0.001. The table indicates that of those who undertook a systematic inventory, 55.9% rated themselves as highly effective, while only 6.8% rated themselves as low in effectiveness. On the other hand, of those who did not perform a systematic inventory, only 28.2% rated themselves as highly while 18.8% save themselves as low in effectiveness (see Figure 9). This suggests, as anticipated, that such procedures do lead to greater programmatic effectiveness.

	COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
Systematic Inventory	Yes	4 6.8 15.4 2.3	22 37.3 26.2 12.5	33 55.9 50.0 18.8	59 33.5
	No	22 18.8 84.6 12.5	62 53.0 73.8 35.2	33 28.2 50.0 18.8	117 66.5
	COLUMN TOTAL	25 14.8	84 47.7	66 37.5	176 100.0

TABLE 14
Effectiveness of the Use of
Systematic Inventories and Analysis

A subset of questions were directed at determining the role of policy-making in the use of design review. The respondents were asked whether they established policies or objectives related to their goals, and if these were specially stated. Of the toatl 49.1% indicated that they had indeed established policies and objectives, and 64.3% of those (or 31.6% of the total response) indicated that the goals and objectives were explicitly stated (see Table 15). Chi-square analysis of this data equals 12.033 with 4 degrees of freedom and a significance level of 0.01. Only 28% of those communities who do not have policies and objectives felt that their programs were highly effective while 23% judged the performance as low. However, of those who had developed policies and objectives which were explicitly stated, 44.4% judged their programs to be highly effective which only 9.3% judged themselves ineffective. Of those municipalities who developed policies and objectives but who had not explicitly specified them, 53.3% felt their programs to be highly effective (see Figure 10). This data suggests that the development of policies and objectives as related to goals is significantly correlated with effectiveness. Further, it can be seen that effectiveness is not improved with the explicit statement of policies and objectives.

The general finding that the development of policies and objectives is related to effectiveness is not surprising. This notion is the very cornerstone of planning and administrative methodology and was applied to the process of design review previously (Cohn, 1968; Kaiser, et al., 1973). However, it is perplexing to note that those municipalities which do not explicitly articulate their objectives, view themselves as more effective than other groups. A possible explanation is that identification (but lack of specification) of the policies and objectives aids in providing additional <u>flexibility</u> in the review process. Flexibility, one of the main objectives of this urban guidance tool, seems to be facilitated by this degree of apparent ambiguity. An important condition, however, is that the objectives and policies be clear in the minds of the reviewing body. This procedure may create other undesirable consequences, however, and the matter deserves further investigation.

<u>Scope of Application of the Regulation</u> The questionnaire probed the extent to which the review organization actually had control over the environment. One question asked whether or not the entire city was regulated. Additional questions, asked whether or not specific areas within the city (e.g., the CBD, entrances, business areas, historic areas, etc.) or specific land uses within these geographic areas were controlled. Chi-square analysis indicated no significance between these data and effectiveness. No more than one-third of the respondents regulated any of these areas. This appears somewhat surprising for two reasons: first, planners are often heard to complain about the geographic limitations of their programs; and second, the data presented here indicated that increases in geographic areas and land-uses was <u>positively</u> associated with increasing effectiveness. Further investigation of the interaction of the variables may clarify this surprising finding.

Significant relationships were found with respect to the regulation of specific building characteristics and effectiveness. The respondents were asked whether they had control over the following elements: general building form, style, color, location, materials, windows and doors, roof form, color, and materials, fences, architectural detail, exterior mechanical equipment, landscaping, and maintenance. In each case they were asked whether they exercised legal control, informal control, or both legal and informal control. Significant results were found for general building form, style, location, materials, windows and doors, and roof materials. In the correlation of general building form with effectiveness, the chi-square was equal to 11.11 with 8 degrees of freedom and a significance level of 0.02 (Table 16A). Only 15.8% of those exercising no controls ranked themselves as highly effective. In contrast, 21.6% of those exercising informal controls, 48.8% of those having formal controls, and 66.7% of those exercising both informal and formal, controls ranked themselves highly effective. Of those who had no controls, it is interesting to note that 26.3% ranked themselves as low in effectiveness, while only 15.7% who had informal controls, 12.8% who had formal controls and none of those who had both formal and informal controls ranked themselves low in effectiveness (see Figure 11A). Thus, it can be seen that effectiveness is positively related to the increase in control of general building form. These relationships can be ordered as follows: informal control is more effective than no control, legal control is more effective than informal, and the combination of both legal and informal control is the most effective. As mentioned earlier these may be some ambiguity with respect to distinguishing informal from formal controls and their ranking in this case may be faulty. On the other hand, the data may simply indicate a lack of awareness of the techniques for exercising informal power and its full potential for fulfilling the objectives of these programs. This matter needs further investigation.

Policies or Objectives	COUNT ROW PCT COL PCT TOT PCT	Effectiveness: Low	Med.	High	ROW TOTAL
	Yes (Explicit)	5 9.3 19.2 2.9	25 46.3 31.3 14.6	24 44.4 31.3 14.0	54 31.6
	Yes (Not Explicit)	1 3.3 3.8 0.6	13 43.3 16.3 7.6	16 53.3 24.6 9.4	30 17.5
	No	20 23.0 76.9 11.7	42 48.3 52.5 24.6	24 28.7 38.5 14.6	87 50.9
	COLUMN TOTAL	26 15.2	80 46.8	65 38.0	171 100.0

TABLE 15

Effectiveness and Program Policies and Objectives

Type of Control: COUNT / ROW PCT / COL PCT / TOT PCT	Effectiveness: Low	Effectiveness: Med.	Effectiveness: High	ROW TOTAL
No Response	1	5	5	11
	9.1	45.5	45.5	6.4
	4.0	6.0	7.7	
	0.6	2.9	2.9	
Legal Control	11	33	42	86
	12.8	38.4	48.8	49.7
	44.0	39.8	64.6	
	6.4	19.1	24.3	
Informal Control	8	32	11	51
	15.7	62.7	21.6	29.5
	32.0	38.6	16.9	
	4.6	18.5	6.4	
Both 2 & 3	0	2	4	6
	0.0	33.3	66.7	3.5
	0.0	2.4	6.2	
	0.0	1.2	2.3	
No Control	5	11	3	19
	26.3	57.9	15.8	11.0
	20.0	13.3	4.6	
	2.9	6.4	1.7	
COLUMN TOTAL		83	65	173
	14.5	48.0	37.6	100.0

TABLE 16A

Effectiveness and the Control

(By Type) of General Building Form

The correlation of the control of general building style to effectiveness yielded a chi-square of 19.45 with 8 degrees of freedom, a significance level of 0.01 (see Table 16B and Figure 11B). General building location equals 17.676 with 8 degrees of freedom and a significance level of 0.02 (Table 16C) and that of general building materials a chi-square of 23.47 with 8 degrees of freedom and a level of significance of 0.002 (Table 16D). The chi-square analysis of the control of windows and of doors yielded values of 21.69 with 8 degrees of freedom and a significance level of 0.005 and 22.805 with 8 degrees of freedom and a significance level of 0.003, respectively (Table 16E and 16F). The control of roof materials is the final building element indicating a significant relationship with effectiveness (Table 16G). Analysis indicated a chi-square of 22.77 with 8 degrees of freedom and a significance level of 0.003. In all of the above cases, the interpretation of the data is similar to that described for general building form with the exception that the exact role of the combined legal and informal control is not as obvious. Generally, it appears that effectiveness is enhanced by the control of these elements.

Graphic Requirements for Application Several questions were asked to ascertain the extent and quality of graphic information required of the applicant. The first question examined whether site plans, elevations, building perspectives, site perspectives, material specifications, building models, photos of the site and landscape plans were required, as well as whether they were necessary for a preliminary review, final application, or both of these. A second question asked if site plans of the adjacent area, elevations of adjacent buildings, or photos of the adjacent buildings were mandatory. No significant statistical relationships were found between these requirements and effectiveness with the exception of the requirements for building elevations and site perspectives. Analysis of building elevations yielded a chi-square equal to 13.099 with 8 degrees of freedom and a significance level of 0.10 (see Table 17 and figure 12). Interpretation of the direction to this correlation suggests that effectiveness is greatest when building elevations are required for both final and preliminary approval. It was also found that effectiveness was greater when elevations were required for preliminary approval than when required for final approval. Where one might expect that effectiveness would be greater when elevations are mandatory for final approval, submission of the design at a preliminary stage enhances the opportunity for negotiation and improvement and leads to greater effectiveness (Cohn, 1968).

Analysis of the relationship between the requirements for the submission of site perspectives and effectiveness gave a chi-square equal to 18.704 with 8 degrees of freedom and a level of significance of 0.016 (see Table 18). The interpretation of the direction of this relationship is similar to that of the control of the building elevations variable, i.e., the requirements enhances effectiveness with the following qualifications (see Figure 13). The data clearly suggest that requiring site elevations at both preliminary and final review is most effective (5.0% low and 60.0% high effectiveness). Both

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
No Response	0 0.0 0.0 0.0	8 72.7 9.6 4.6	3 27.3 4.6 1.7	11 6.4
Legal Control	10 14.3 40.0 5.8	24 34.3 28.9 13.9	36 51.4 55.4 20.8	70 40.5
Informal Control	6 9.8 24.0 3.5	36 59.0 43.4 20.8	19 31.1 29.2 11.0	61 35.3
Both 2 & 3	1 33.3 4.0 0.6	1 33.3 1.2 0.6	1 33.3 1.5 0.6	3 1.7
No Control	8 28.6 32.0 4.6	14 50.0 16.9 8.1	6 21.4 9.2 3.5	28 16.2
COLUMN TOTAL	25 14.5	83 48.0	65 37.6	173 100.0

TABLE 16B

Effectiveness and the Control

(By Type) of General Building Style

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
No Response	0 0.0 0.0 0.0	7 53.8 8.4 4.0	6 46.2 9.2 3.5	13 7.5
Legal Control	17 15.2 68.0 9.8	51 45.5 61.4 29.5	44 39.3 67.7 25.4	112 64.7
Informal Control	3 9.4 12.0 1.7	17 53.1 20.5 9.8	12 37.5 18.5 6.9	32 18.5
Both 2 & 3	1 10.0 4.0 0.6	6 60.0 7.2 3.5	3 30.0 4.6 1.7	10 5.8
No Control	4 66.7 16.0 2.3	2 33.3 2.4 1.2	0 0.0 0.0 0.0	6 3.5
COLUMN TOTAL	25 14.5	83 48.0	65 37.6	173 100.0

Type of Control

TABLE 16C

Effectiveness and the Control

(By Type) of the General Building Location

Type of Control — COUNT / ROW PCT / COL PCT / TOT PCT	Effectiveness: Low	Med.	High	ROW TOTAL
No Response	1 9.1 4.0 0.6	6 54.5 7.2 3.5	4 36.4 6.2 2.3	11 6.4
Legal Control	11 13.3 44.0 6.4	33 39.8 39.8 19.1	39 47.0 60.0 22.5	83 48.0
Informal Control	4 7.4 16.0 2.3	32 59.3 38.6 18.5	18 33.3 27.7 10.4	54 31.2
Both 2 & 3	1 12.5 4.0 0.6	5 62.5 6.0 2.9	2 25.0 3.1 1.2	8 4.6
No Control	8 47.1 32.0 4.6	7 41.2 8.4 4.0	2 11.8 3.1 1.2	17 9.8
COLUMN TOTAL	25 14.5	83 48.0	65 37.6	173 100.0

TABLE 16D

Effectiveness and the Control

(By Type) of General Building Materials

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
No Response	3 12.0 12.0 1.7	13 52.0 15.7 7.5	9 36.0 13.8 5.2	25 14.5
Legal Control	6 10.9 24.0 3.5	23 41.8 27.7 13.3	26 47.3 40.0 15.0	55 31.8
Informal Control	5 8.8 20.0 2.9	29 50.9 34.9 16.8	23 40.4 35.4 13.3	57 32.9
Both 2 & 3	0 0.0 0.0 0.0	6 75.0 7.2 3.5	2 25.0 3.1 1.2	8 4.6
No Control	11 39.3 44.0 6.4	12 42.9 14.5 6.9	5 17.9 7.7 2.9	28 16.2
COLUMN TOTAL	25 14.5	83 48.0	65 37.6	173 100.0

Type of Control

TABLE 16E

Effectiveness and the Control

(By Type) of Building Fenestration

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
No Response	3 12.0 12.0 1.7	12 48.0 14.5 6.9	10 40.0 15.4 5.8	25 14.5
Legal Control	6 10.7 24.0 3.5	24 42.9 28.9 13.9	26 46.4 40.0 15.0	56 32.4
Informal Control	5 8.5 20.0 2.9	33 55.9 39.8 19.1	21 35.6 32.3 12.1	59 34.1
Both 2 & 3	0 0.0 0.0 0.0	5 71.4 6.0 2.9	2 28.6 3.1 1.2	7 4.0
No Control	11 42.3 44.0 6.4	9 34.6 10.8 5.2	6 23.1 9.2 3.5	26 15.0
COLUMN TOTAL	25 14.5	83 48.0	65 37.6	173 100.0

Doors

TABLE 16F
Effectiveness and the Control
(By Types) of Doors

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
No Response	2 10.0 8.0 1.2	12 60.0 14.5 6.9	6 30.0 9.2 3.5	20 11.6
Legal Control	9 12.0 36.0 5.2	30 40.0 36.1 17.3	36 48.0 55.4 20.8	75 43.4
Informal Control	5 10.2 20.0 2.9	25 51.0 30.1 14.5	19 38.8 29.2 11.0	49 28.3
Both 2 & 3	0 0.0 0.0 0.0	5 71.4 6.0 2.9	2 28.6 3.1 1.2	7 4.0
No Control	9 40.9 36.0 5.2	11 50.0 13.3 6.4	2 9.1 3.1 1.2	22 12.7
COLUMN TOTAL	25 14.5	83 48.0	65 37.6	173 100.0

Type of Controls

TABLE 16G

Effectiveness and the Control

(By Type) of Roof Materials

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
Building Elevations: No Response	1 25.0 3.8 0.6	3 75.0 3.6 1.7	0 0.0 0.0 0.0	4 2.3
Req'd by Prelim. Applica.	3 8.3 11.5 1.7	19 52.8 22.6 10.8	14 38.9 21.2 8.0	36 20.5
Req'd w/ Final Applica.	12 19.4 46.2 6.8	32 51.6 38.1 18.2	18 29.0 27.3 10.2	62 35.2
Req'd w/ both 2 & 3	9 13.0 34.6 5.1	26 37.7 31.0 14.8	34 49.3 51.5 19.3	69 39.2
Not req'd	1 20.0 3.8 0.6	4 80.0 4.8 2.3	0 0.0 0.0 0.0	5 2.8
COLUMN TOTAL	26 14.8	84 47.7	66 37.5	176 100.0

TABLE 17

Effectiveness of Requiring Building Elevations with Application

COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
No Response	3 12.5 11.5 1.7	14 58.3 16.7 8.0	7 29.2 10.6 4.0	24 13.6
Req'd by Prelim. Applica.	2 10.5 7.7 1.1	16 84.2 19.0 9.1	1 5.3 1.5 0.6	19 10.8
Req'd w/ Final Applica.	5 20.8 19.2 2.8	10 41.7 11.9 5.7	9 37.5 13.6 5.1	24 13.6
Req'd w/ both 2 & 3	1 5.0 3.8 0.6	7 35.0 8.3 4.0	12 60.0 18.2 6.8	20 11.4
Not req'd	15 16.9 57.7 8.5	37 41.6 44.0 21.0	37 41.6 56.1 21.0	89 50.6
COLUMN TOTAL	26 14.8	84 47.7	66 37.5	176 100.0

Site Perspectives

TABLE 18

Effectiveness of Requiring Site
Perspectives with Building Applications

not requiring and requiring site perspectives only at final review (16.9% low, 41.6% high and 20.8% low and 37.5% high) appear to be moderately effective. Requiring this information only for preliminary review appears to be least effective. The role of preliminary review is somewhat puzzling and may be clarified following additional analysis.

The questionnaire asked whether the review process required a specific level of quality or professionalism in the drawings required with the application. The data indicated that 66.9% of the municipalities do specify a standard and 33.1% do not (see Table 19). Relating these data to effectiveness, the resultant chi-square was equal to 4.735 with 2 degrees of freedom, a significance level of 0.09. Of those specifying standards, 42.7% saw themselves as highly effective, while 13.7% saw themselves as low in effectiveness. Of those not specifying such a standard, 25.9% viewed themselves as highly effective and 17.2% saw themselves as low in effectiveness. This suggests that the specifying of standards for the quality of drawings accompanying applications increases effective performance (see Figure 14).

Drawing Quality	COUNT ROW PCT COL PCT TOT PCT	Effectiveness Low	 Med.	 High	ROW TOTAL
	Specified	16 13.7 61.5 9.1	51 43.6 60.7 29.1	50 42.7 76.9 28.6	117 66.9
	Not Specified	10 17.2 38.5 5.7	33 56.9 39.3 18.9	15 25.9 23.1 8.6	58 33.1
	COLUMN TOTAL	26 14.9	84 48.0	65 37.1	175 100.0

TABLE 19
Effectiveness of Specifying Quality
of Application Drawings

Drawing Standard	# responses	%
"Stamped" by licensed professional	26	48.15
Professional quality	7	12.96
Adequate to ascertain performance	13	24.08
"Good", readable drawings	8	14.81
Total	54	100.00

TABLE 20

Distribution of responses with respect to drawing quality or standards

The nature of these standards is shown in Table 21. While there is no data to indicate that quality of design is related to quality of drawings, there is reason to believe that drawing quality is related to effective performance through the simple mechanism of improving the flow of information and the capacity of the review body to accurately interpret the proposed building and thereby make sounder decisions (Cohn, 1968, 1975).

SUMMARY AND CONCLUSIONS

Data was obtained through a nation-wide survey of 924 American cities with populations greater than 25,000. It was designed to obtain knowledge with regard to the structure, procedures and effectiveness of design review programs.

The data was coded and frequency distributions analyzed. The data indicated that there has been a growth of greater than 75% each five years since 1960 in the use of this urban land use guidance method. Fourty-one percent of these cities were currently exercising design review and approximately 50% of the respondents not using the method were interested in developing programs. Design review has indeed become an important device in guiding urban land use and will become more so.

A measure of perceived effectiveness obtained in the survey was correlated with the related variables using chi-square analysis. In all, 14 variables were found to be statistically correlated with the effectiveness of the performance of the municipal programs and 7 were found to have trends in the direction of statistical significance.

A significant correlation was found between the number of project reviewed annually by the organization, that is, effectiveness was found to increase with the increase in the number of projects reviewed annually. The analysis also clearly indicated that a positive relationship existed between changes in the design review program and their effectiveness. Organization which had implemented significant changes were higher in effectiveness. The data further suggested that these changes were in the nature of stricter and expanded program regulation rather than changes in procedures or organization.

Data was obtained with respect to organization goals and these data were correlated with perceived effectiveness. The data indicated that programs with primary historic-cultural goals perceived themselves to be highly effective. No statistical correlation with program effectiveness was found with programs whose primary goals were esthetic, economic or health and well-being. The data suggested, however, that for organizations with primarily esthetic goals, effectiveness increased with the stringency of the program's expectations. Municipalities believing that their programs would achieve a beautiful city were more effective than those who believed it would improve community appearance or eliminate urban ugliness. Similarly, those who believed it would improve the urban esthetic were more effective than those who believed it would eliminate ugliness.

A statistical correlation was found between effective performance and the percentage of projects rejected annually by the municipality. In general the greater the percentage of applications rejected annually, the more effective the municipalities judged their performance.

A set of variables related to the degree of systematic data gathering, analysis, goal setting, etc. was correlated with the measure of effective performance. The analysis indicated a significant negative correlation between organizations which used federal and state guidelines (presumably state enabling legislation) as a primary basis for designing their programs and organizational effectiveness. A statistically significant positive correlation, however, existed between those organization which used ordinances from other communities for this purpose and their effectiveness. The use of systemmatic surveys and data analysis was also positively associated with high effectiveness. The respondents were questioned as to whether or not program policies and objectives were established and if these were specifically stated. A positive correlation was found, i.e., those municipalities which did not establish policies and objectives judged themselves to be least effective, those who established and specifically stated objectives and policies were more effective, and those who established them but did not - specifically state they were most effective.

Finally, the relationship between the program's effectiveness and the extent to which the program regulated all land-uses in the city was analyzed. The respondents identified those portions of the city as well as the specific land-uses which were subject to review. These data were correlated with effectiveness of performance but not significant statistical correlation was found. This was particularly puzzling since other data suggested that a positive relationship should exist and many planners appear to believe in the concept.

Data on 15 architectural attributes controlled by informal and formal power were correlated with the measure of effectiveness. Effectiveness was found to be positively correlated with the control of building form, location, and materials windows, doors and roof materials. Informal control was found to be more effective than no control, formal control was more effective than informal control, and the combination of both was the most effective form of regulation. No significance was found between effectiveness and the control of building color, roof form or color, fences, architectural detail, exterior mechanical equipment, landscaping or maintenance.

No statistical correlations were found to exist with respect to several other major variables. These include: (1) the longevity of the program; (2) the organizational and decision-making model; (3) the amount of design services offered to the building applicants; and (4) the amount of the city under the control of the program.

Several words of caution are necessary with respect to these findings. It must be remembered that the self-anchor measures of effectiveness were unusable. We are dealing not only with <u>perceived</u> effectiveness but individual differences in the scale. Second, it is also possible, as indicated by the analysis of the effectiveness ranking of communities by number of projects reviewed, that there may be some systematic bias in the ratings. However, there is no evidence or logic to support the notion that systematic biases do exist either by size or from other sources.

Third, several of the questions required judgmental responses. Though these questions were formulated in such a manner as to call for responses from persons with primary responsibility in the program, it is possible that this may not have always been the case.

Fourth, the findings were based on survey data. Had the data been gathered using objective or behavioral measures of effectiveness, it would be possible to have greater confidence in the generalibility of the findings. Finally, only preliminary findings are being reported. Further clarification and relationships between variables will emerge as the data area explored and analyzed in depth. Nevertheless, this survey provides usable and relevant information on design review programs which is not otherwise available. With some reasonable caution, the data can provide a guide to creating and/or improving municipal design review programs.

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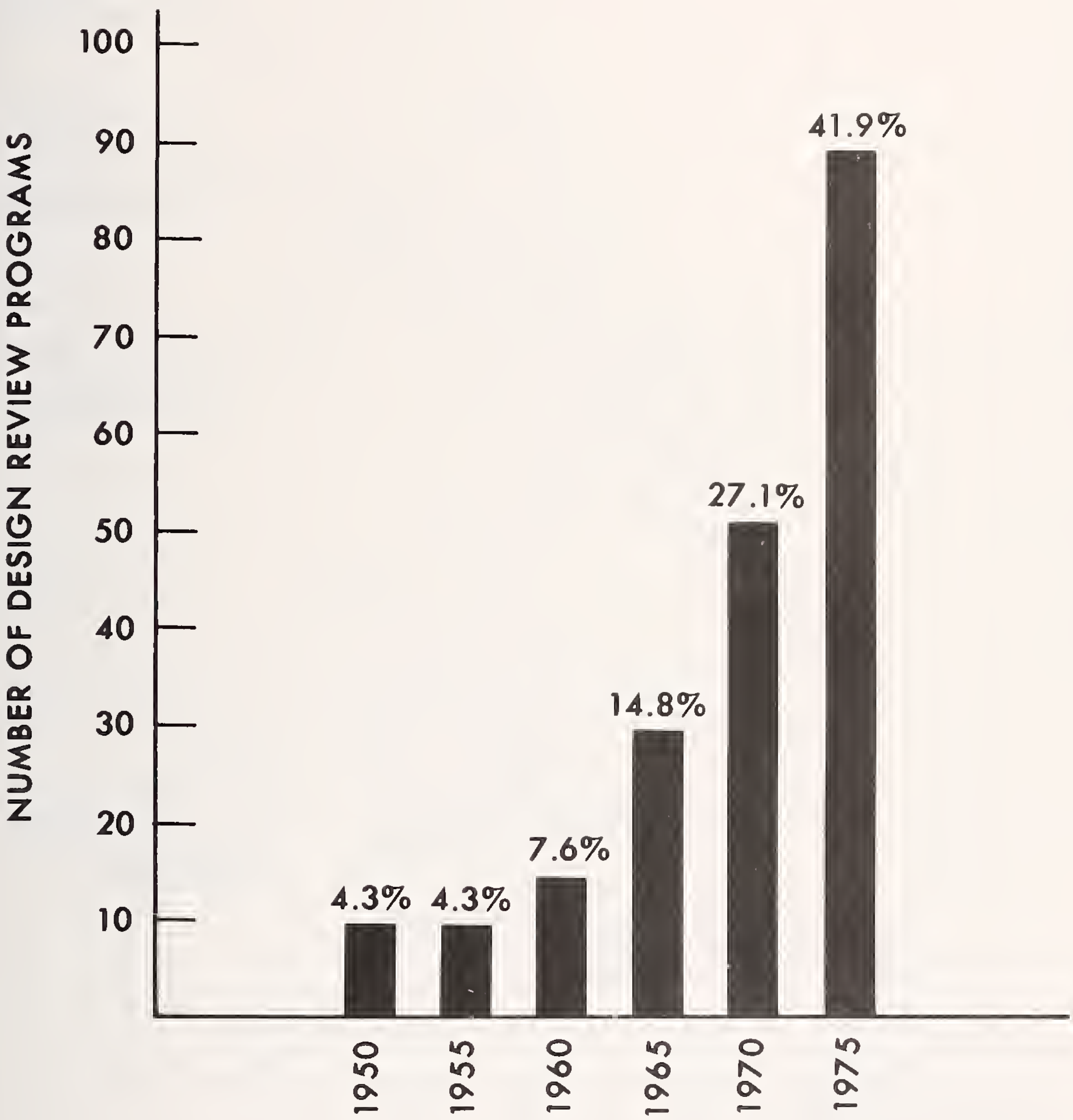

FIGURE 1
Growth of Design Review Programs
in U.S. Municipalities
(adjusted figures)

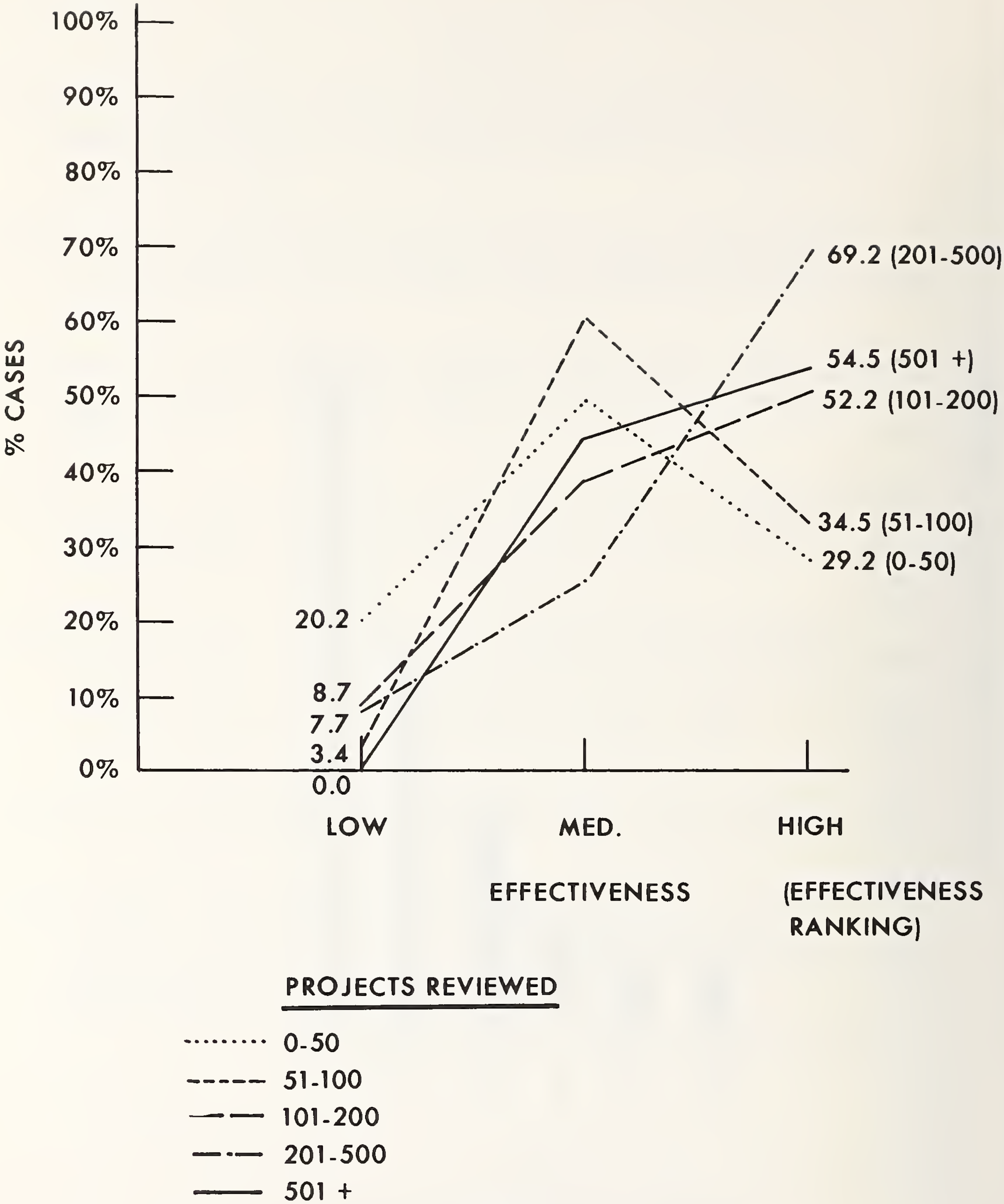

FIGURE 2

Project Annually Reviewed Related to Effectiveness

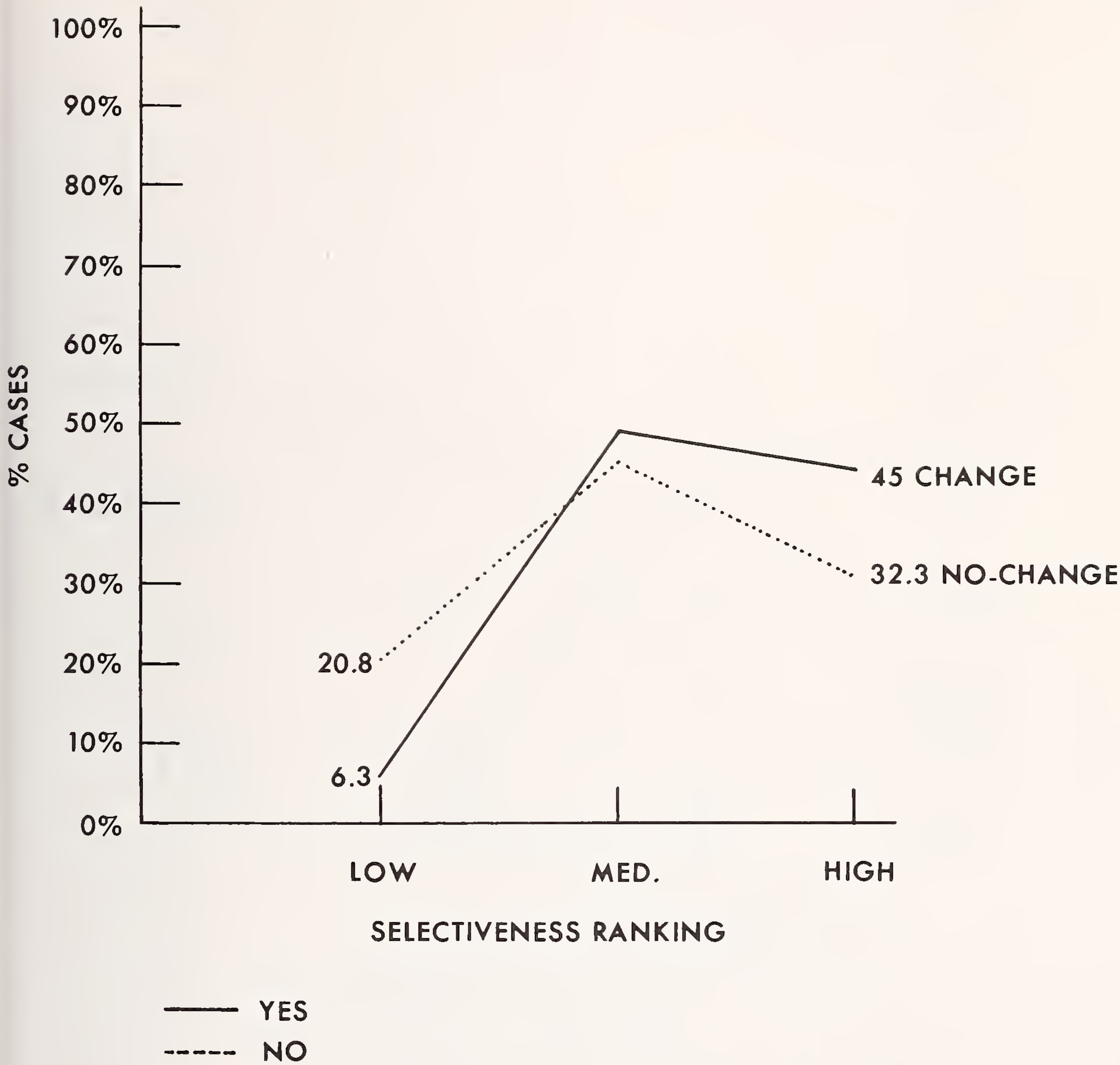

FIGURE 3

Significant Programmatic Change Related to Effectiveness

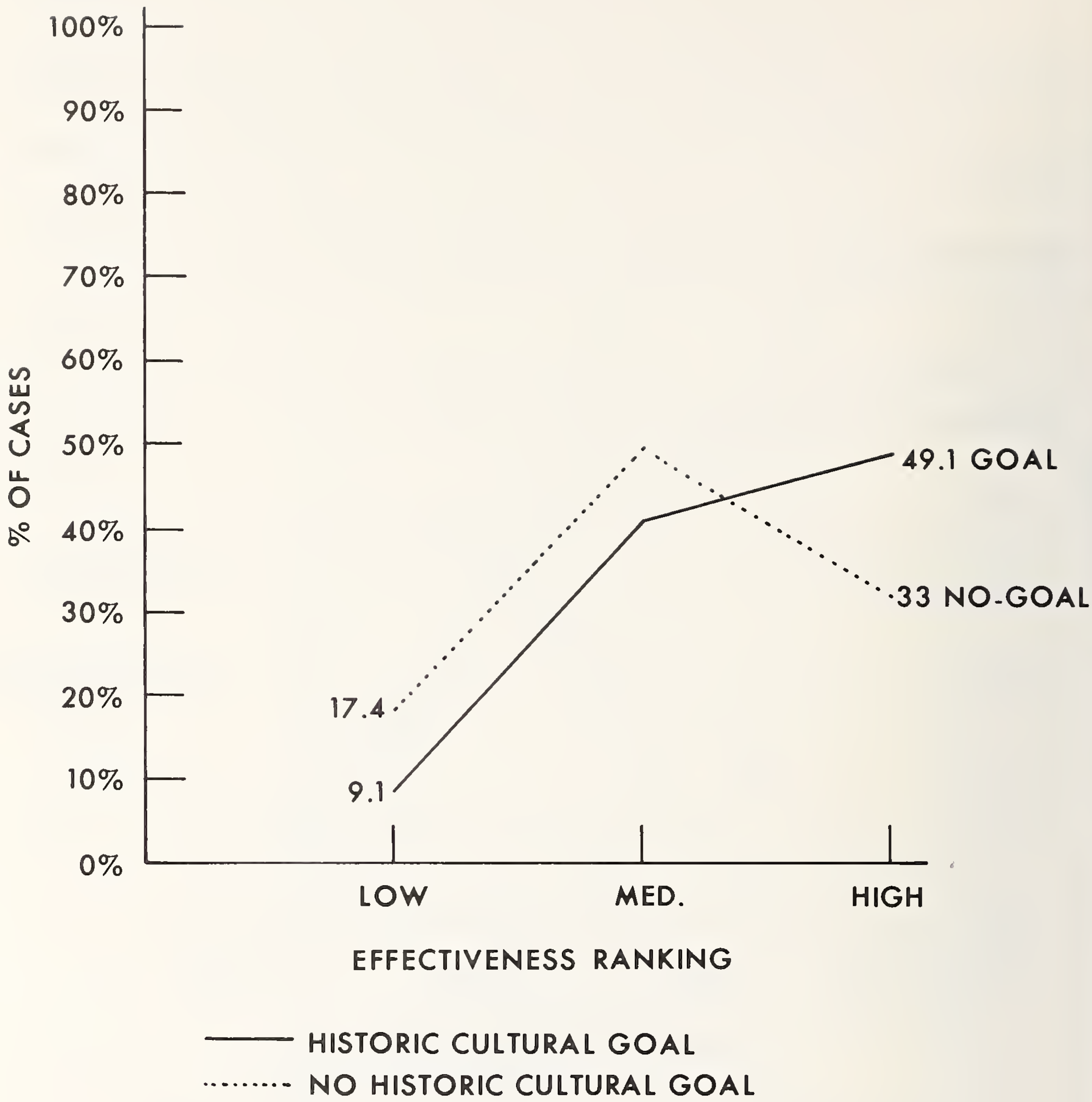

FIGURE 4
Effectiveness and Historic-Cultural Goals

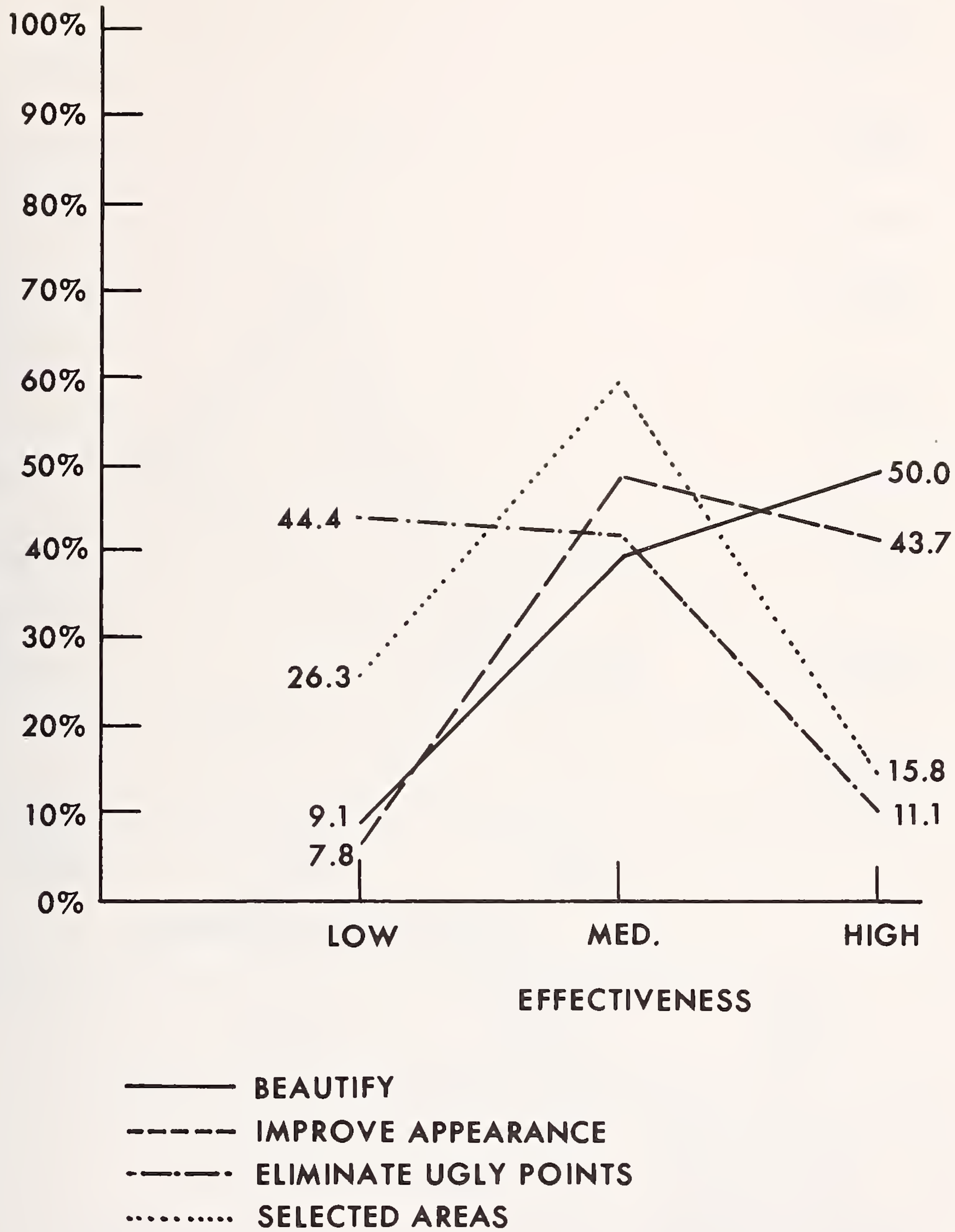

FIGURE 5

Effectiveness as Related to Esthetic Goals

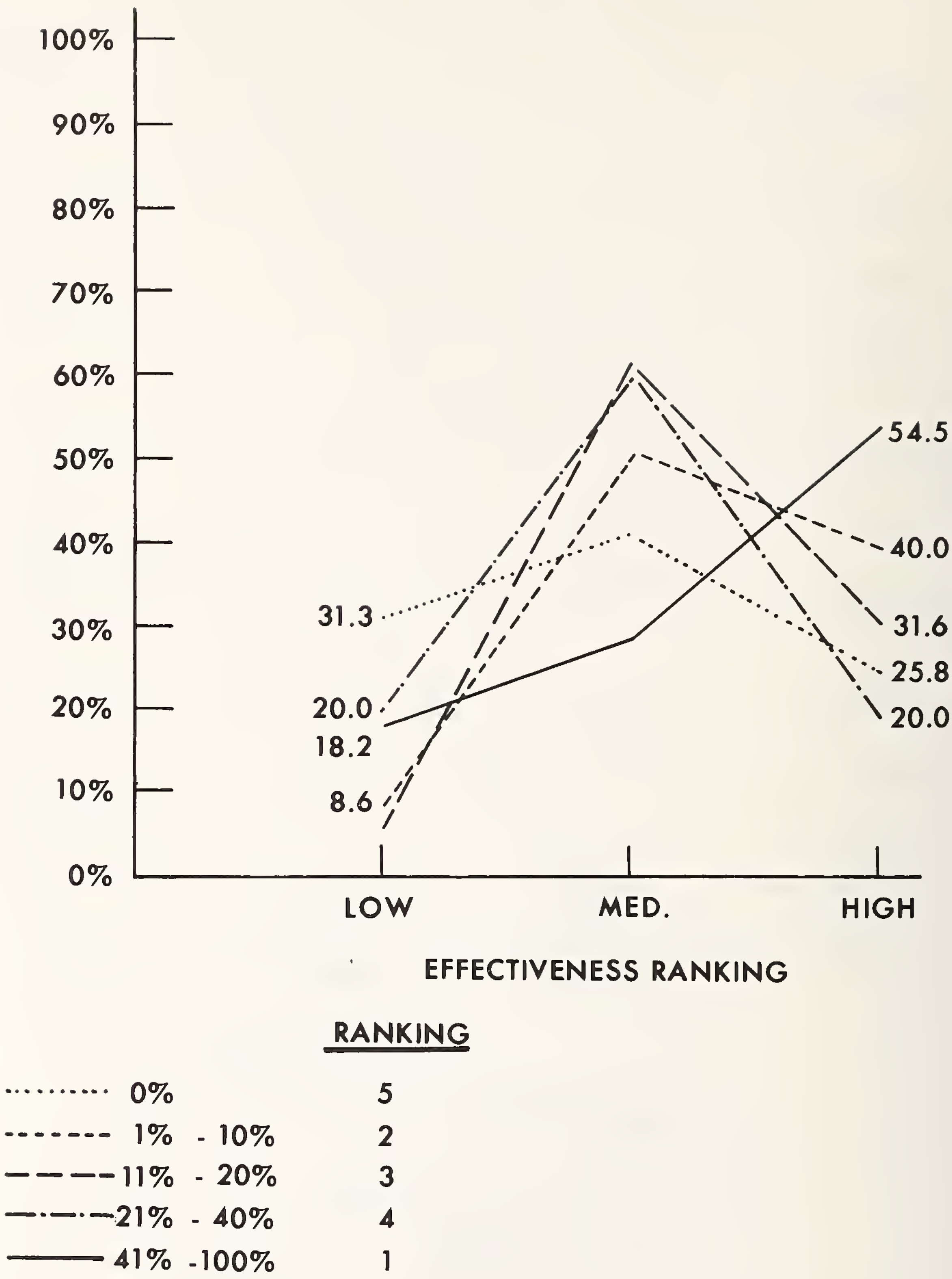

FIGURE 6

Effectiveness as Related to the % of Projects Rejected Annually

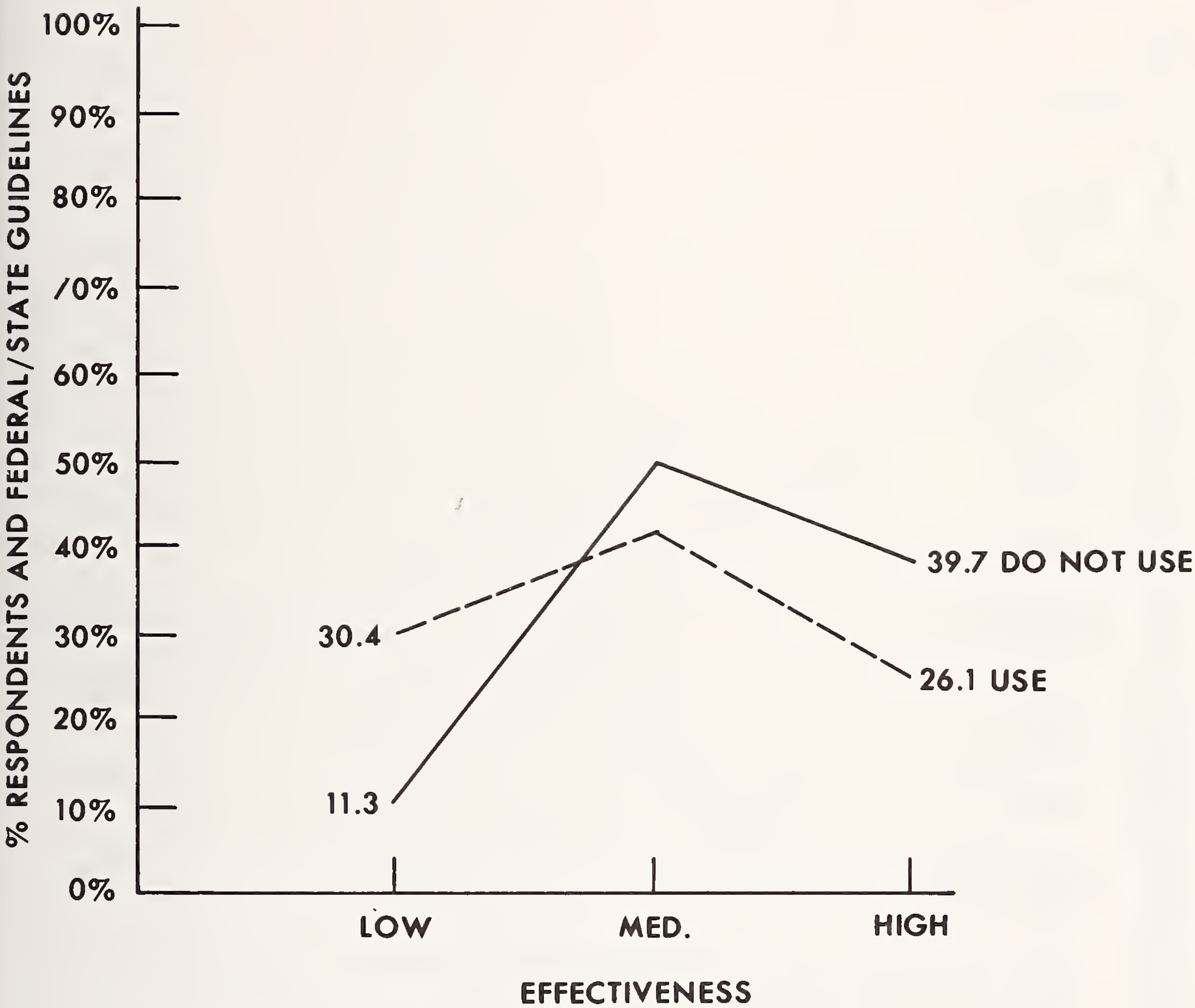

FIGURE 7
Effectiveness of Programs Using State or Federal Guidelines in Creating Program

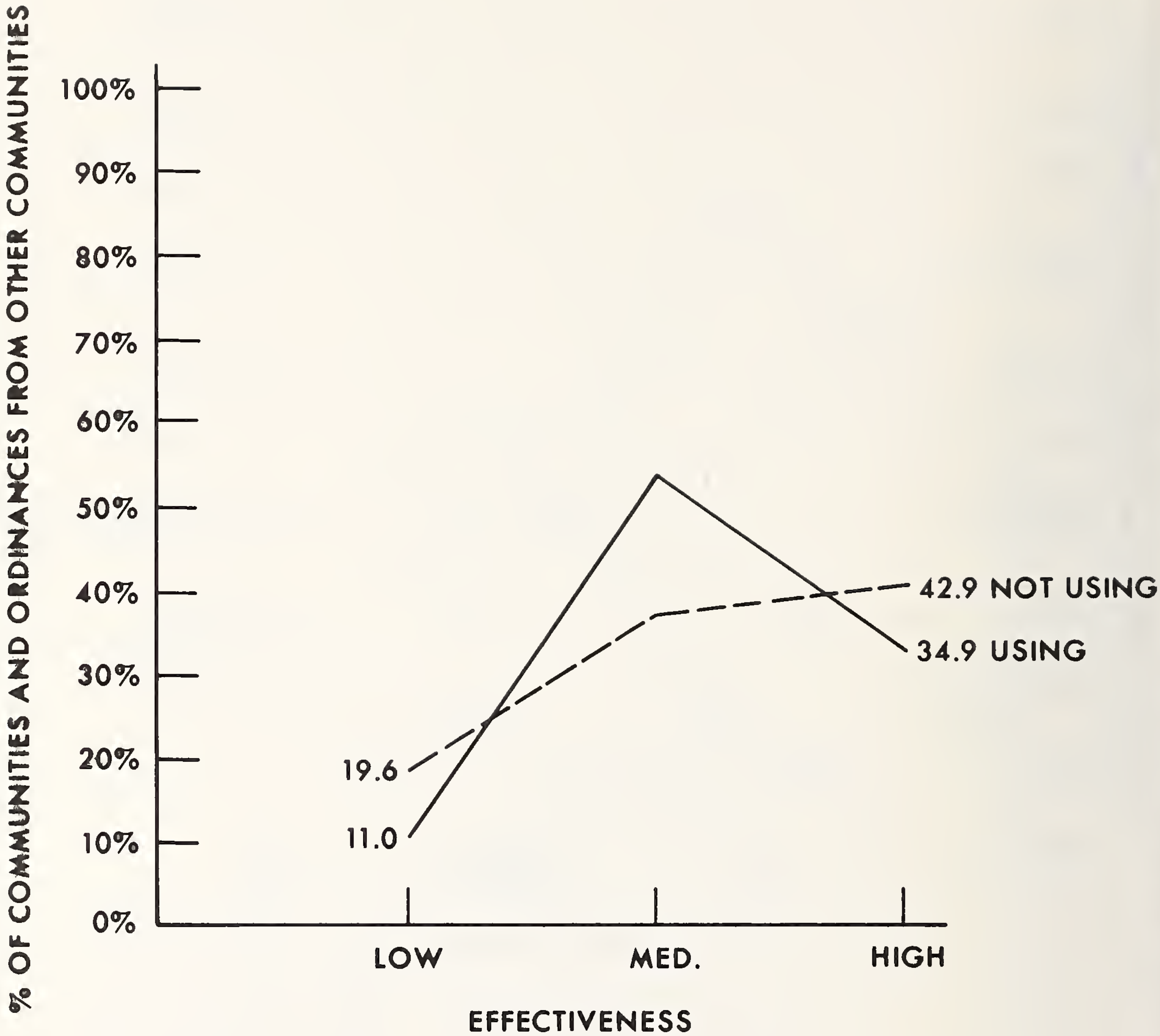

FIGURE 8

Effectiveness of Communities Using Review Ordinances from Other Communities in Creating Programs

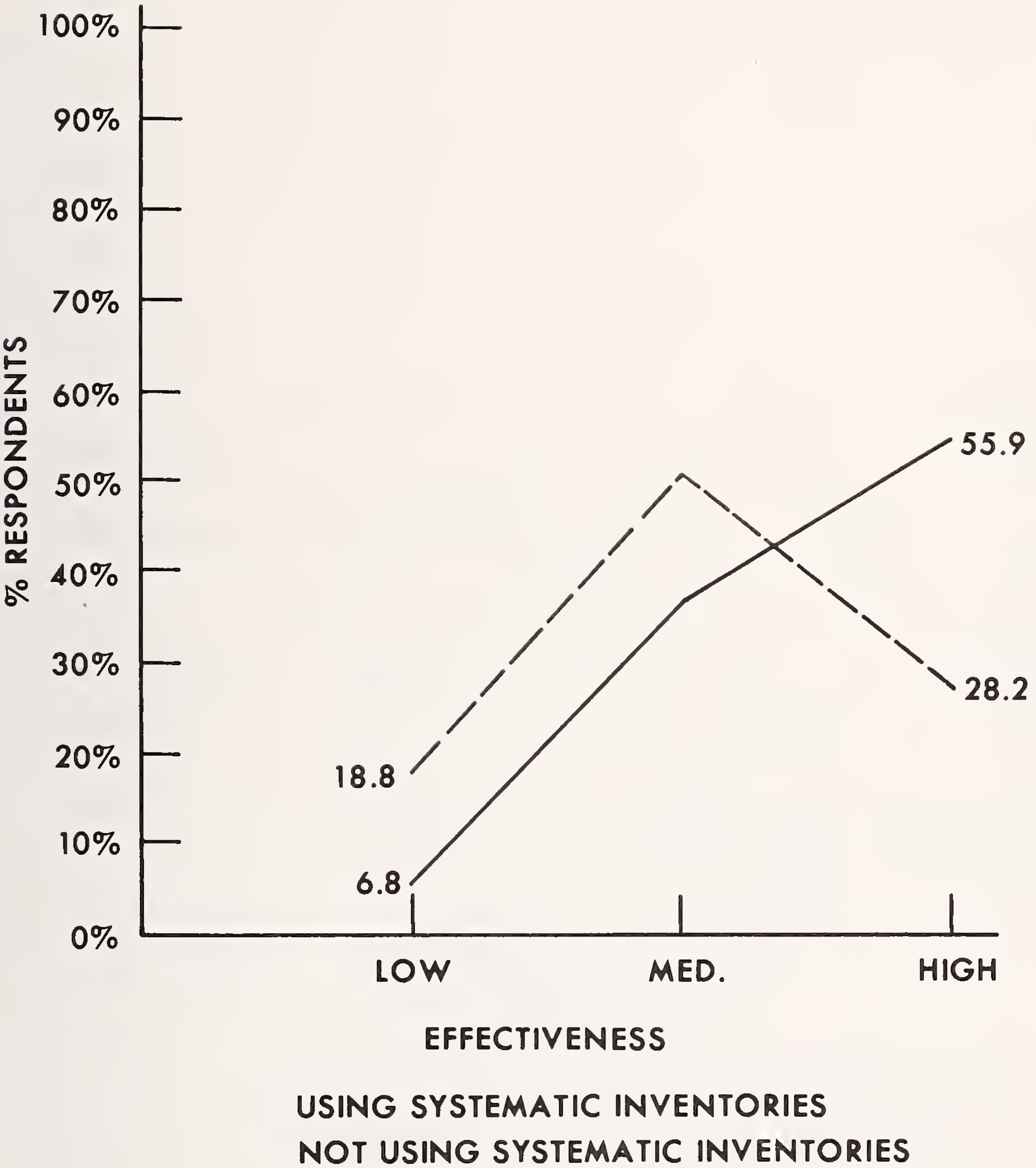

FIGURE 9
Effectiveness and the Use of Systematic Inventories and Analysis

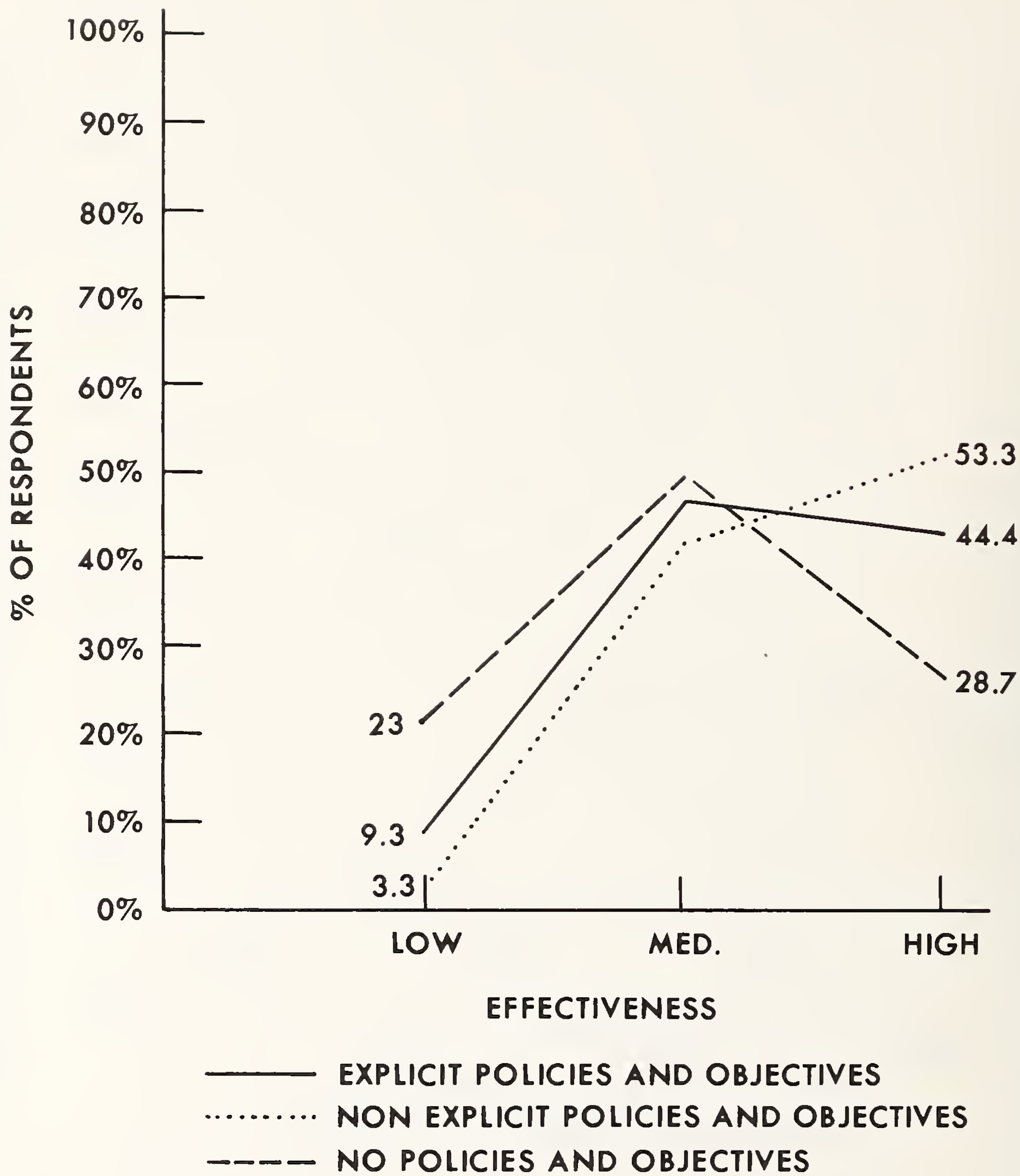

FIGURE 10

Effectiveness and Program Policies and Objectives

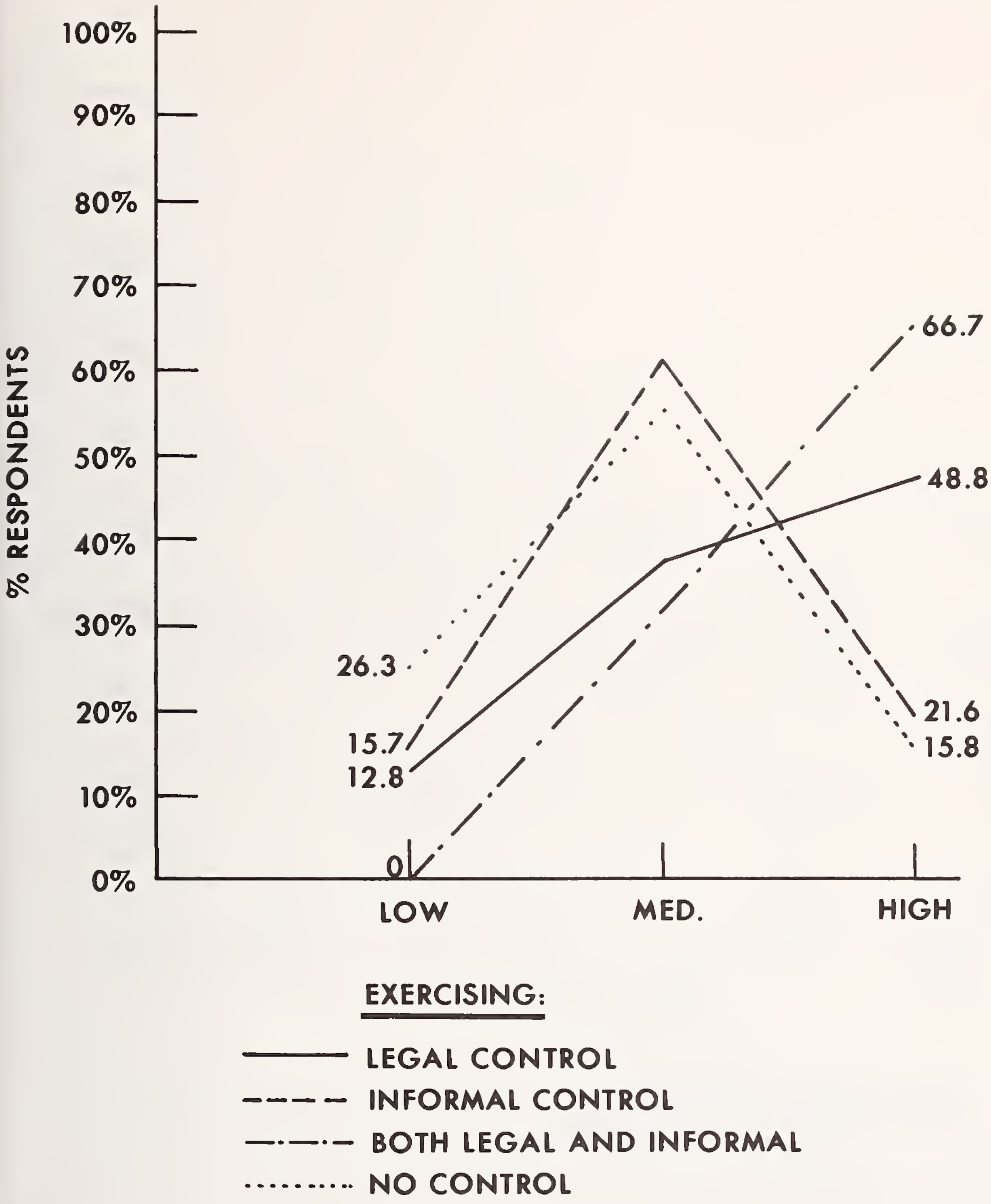

FIGURE 11A

Effectiveness and the Control (By Type)
of General Building Form

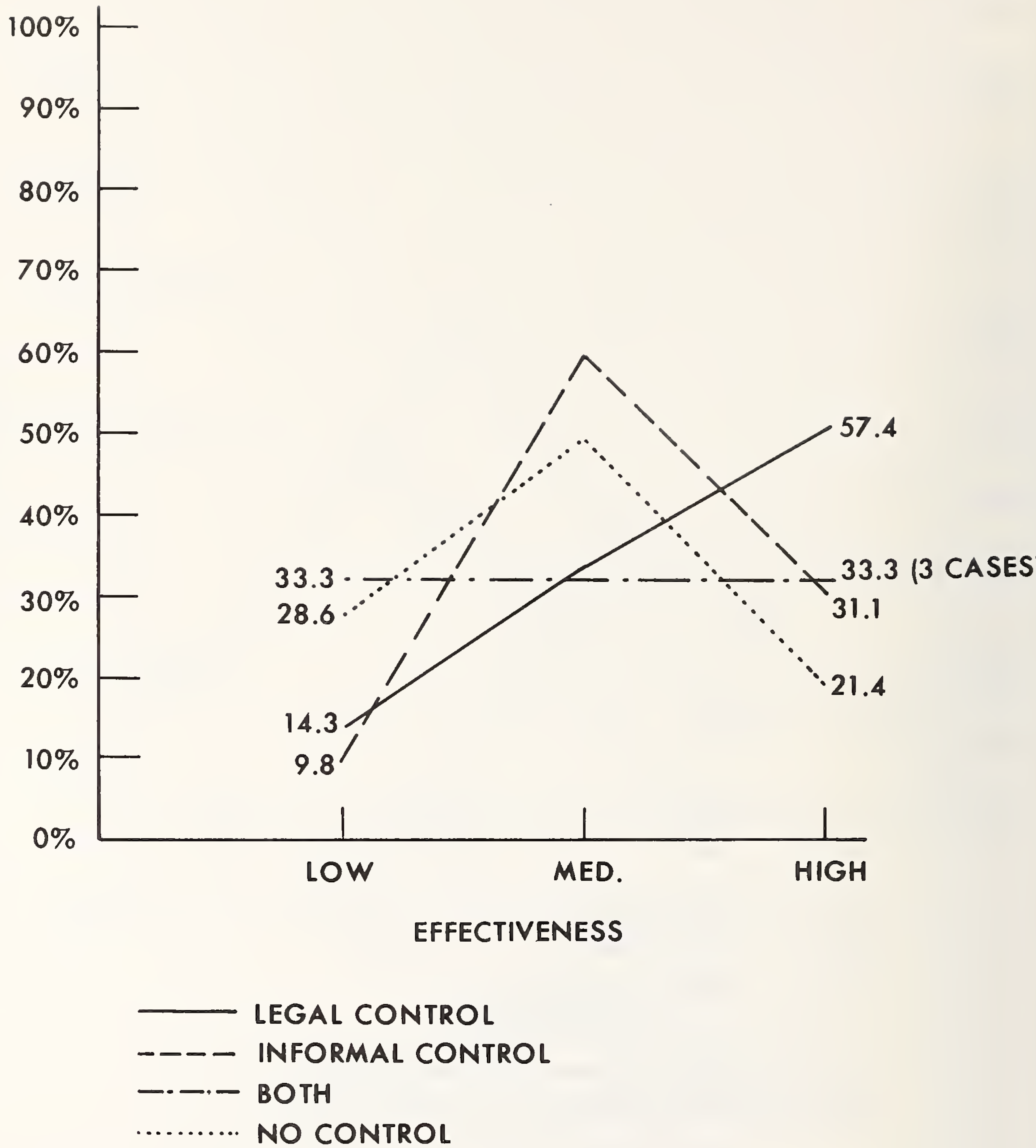

FIGURE 11B

Effectiveness and the Control

(By Type) of General Building Style

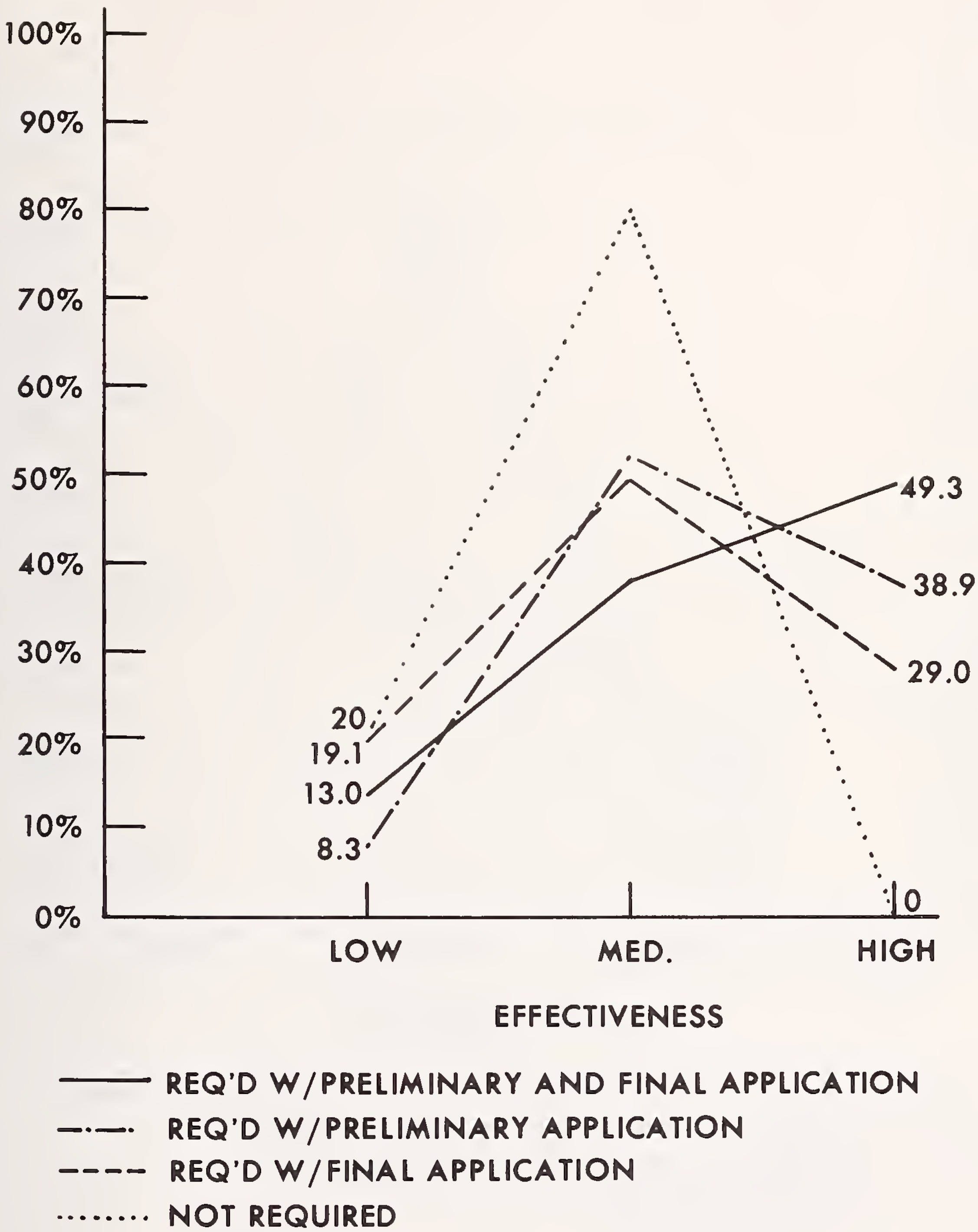

FIGURE 12

Effectiveness of Requiring Building Elevations with Applications

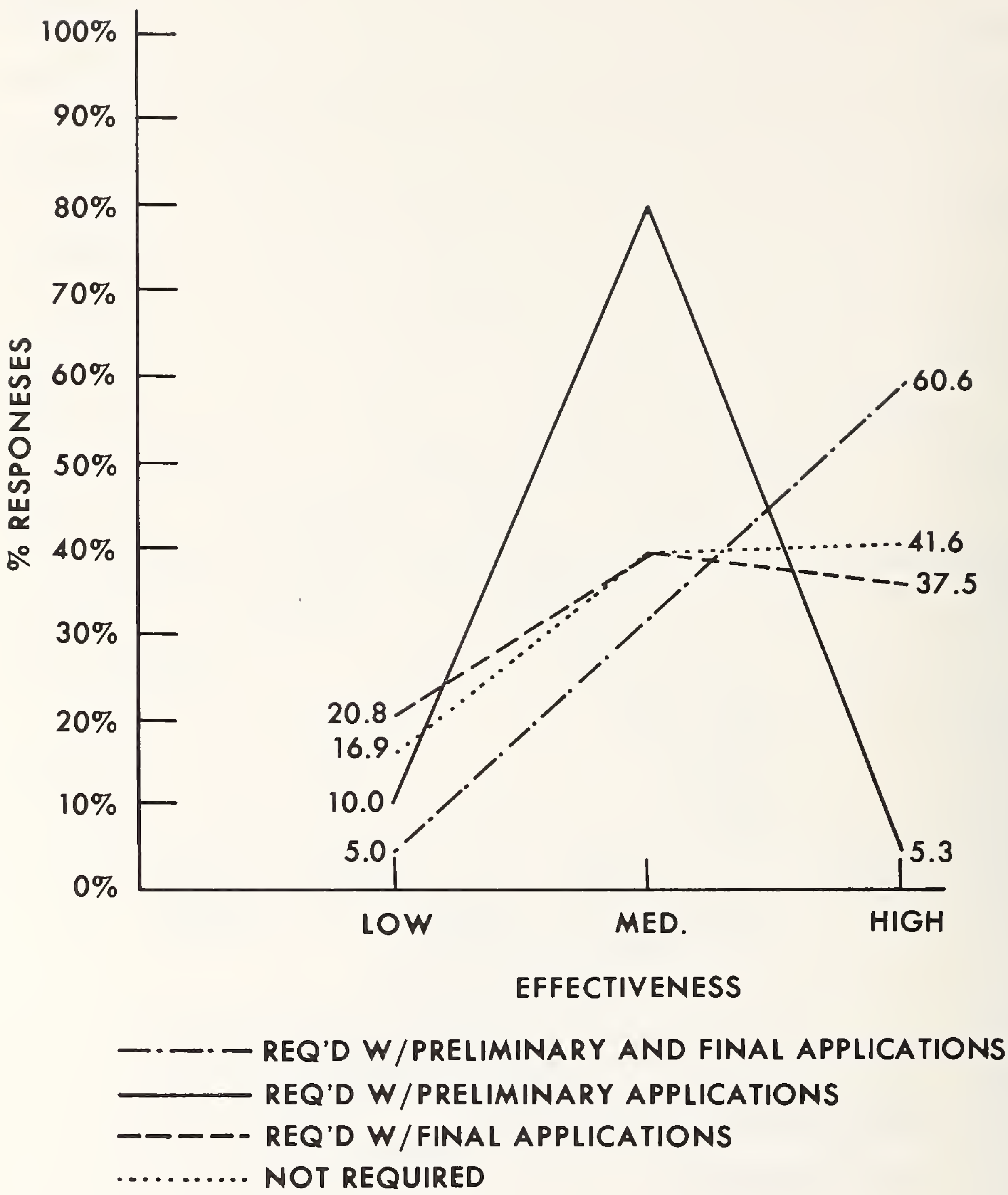

FIGURE 13

Effectiveness of Requiring Site Perspectives with Building Applications

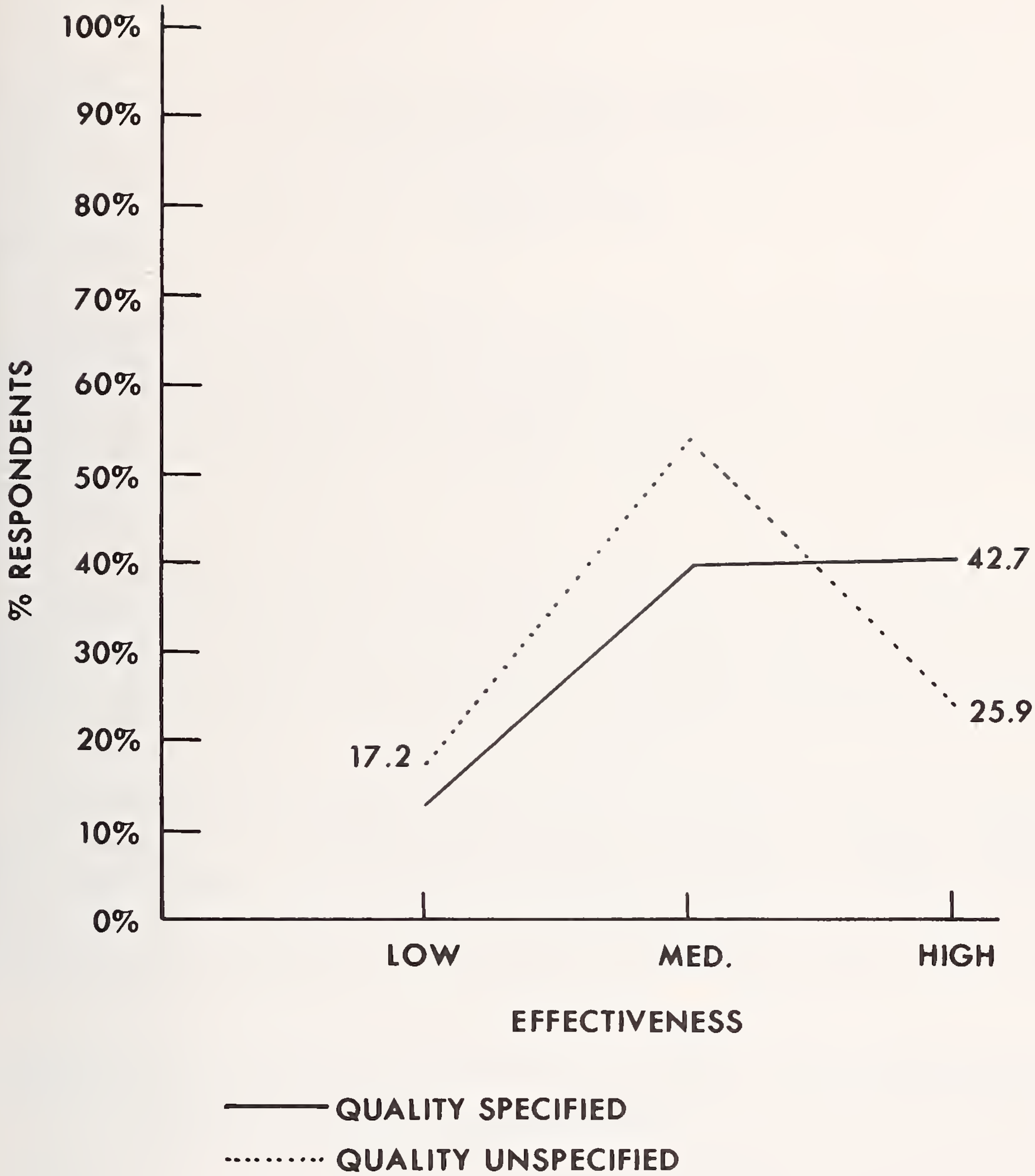

FIGURE 14

Effectiveness of Specifying the Quality of Application Drawings

NATURAL ENVIRONMENTAL CARRYING CAPACITY
AND BUILDING REGULATION

by

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This paper is an attempt to examine the concept of "natural environmental carrying capacity" in relationship to building regulation. Principally it is an examination of the representational problem involved in achieving conformance between building regulatory mechanisms and understanding of the fundamental characteristics and processes of the natural system.

The first part of the paper presents the concept of "natural environmental carrying capacity" and the problem of translating this into performance standards. Within this framework some of the difficulties of incorporating these concepts in present building regulation formats are described. An attempt is also made to distinguish those environmental issues that seem to be most appropriately regulated at the building code level.

The second part of the paper briefly describes a systematic approach whereby building performance standards can be developed that reflect the ability of different geographic areas within a region to absorb building developments without upsetting the balance of the natural system. This approach takes into consideration the interaction between various building and land-use types with a broad range of natural environmental characteristics.

Key Words: Building codes; carrying capacity; environment; land use; natural system; performance standards; regulatory process

INTRODUCTION

The principal purpose of this paper is to propose and elaborate upon a theoretical framework whereby the natural environmental bases of building codes and other related regulatory processes may be more closely examined. The proposed framework consists of three elements: an abstract notion of natural environmental carrying capacity and its relationship to building; the establishment of performance standards; and the incorporation of these standards into codes and other regulatory mechanisms. The basic intent of the paper is to explore the process whereby notions of carrying capacity become translated into threshold values or performance standards and finally into building regulations. In short it is an examination of the representational problem involved in achieving conformance between the regulation of building practice and a more fundamental understanding of natural system integrity. In the discussion of this representational problem, comments will be made regarding the degree to which existing performance standard mechanisms and codes appear to correspond to the notion of carrying capacity.

The final section of the paper is a brief description of a particular approach taken by the authors to attack this representational problem, particularly in the development of initial performance standard concepts. This approach has been applied to an underdeveloped area and will serve to further illustrate many of the points made in the earlier section of the paper.

Throughout the paper a particular attitude is taken concerning what appears to be an appropriate relationship between building regulation and the concept of carrying capacity. It is an attitude that reflects a desire for the least amount of regulation necessary to ensure the integrity of natural systems and for regulation in a manner that very closely reflects the characteristics and processes of these systems.

THE CONCEPT OF NATURAL ENVIRONMENTAL CARRYING CAPACITY

The notion of natural environmental carrying capacity is by no means new. At least as far back as 1864, George Perkins Marsh[1] saw nature as a complex network of processes with a finite capacity to absorb outside intervention, and stressed man's dutiful role in helping to preserve this network. More contemporary studies in the planning arena by Ian HcHarg, Phil Lewis[2] and others have been empirical attempts to understand, identify and respect natural carrying capacity in relationship to building development. Basically, natural environmental carrying capacity is the ability of the natural system to incorporate

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[1]Marsh, George, P., 1864, Man and Nature, or Physical Geography as Modified by Human Action, Scribner and Company, New York. (New edition: Scribner, N.Y., 1964).

[2]McHarg, Ian L., 1969, Design with Nature, Natural History Press, New York, and Lewis, Phillip H., 1964, Quality Corridors for Wisconsin, Landscape Architecture Quarterly, January.

changes without altering its overall structure.

The natural system, or environment, may be described as a network of interacting factors. The artifacts of these interactions appear as patterns of distributions and occurrences of living and non-living things. Biologists have long recognized that all living things survive within a relatively narrow range of physical conditions. If this range is exceeded, then the organism cannot survive. Similarly, non-living materials constituting the building blocks for the continued development of life, such as soils, water and other familiar features, are also defined by the physical situation in which they exist.

Another important concept involved in the notion of environment and carrying capacity is the sequence of the interactions that occur between individual entities. For example, vegetation requires nourishment derived from various non-living source materials. These source materials are then entrained in the plant and removed from continued availability for other plant species. Upon biological degradation of the plant the non-living source material is again made available for further plant development thus describing a mineral cycle

Examination of the physical conditions existing throughout the earth's surface demonstrates that each physical parameter, (for example, temperature), has a finite global range defined by maximum and minimum values. Values grade between these extremes and thus the distribution of the range becomes another important descriptive feature of environments. All living and non-living materials recognized on the surface of the earth occur over limited portions of these ranges. The extreme tolerance values for individual organisms and non-living materials within these ranges are the limiting factors determining their occurrence. This fact partially accounts for the development of latitudinal differences in the distribution of environmental features, thus introducing a spatial element.

There is a time dimension to this concept as well. The nature of the fossil record indicates that living and non-living materials gradually change to adapt to gradual changes in the environmental setting. The geologic record contains many excellent examples of the results of too rapid a change on the materials affected. The result of such rapid changes is usually a radical restructuring of the complex of living and non-living systems accompanied by the elimination or extinction of many life forms. Recovery of the previous balance is almost never witnessed, but instead, slow replacement of extinct organisms with newer forms is shown. This brief example demonstrates the importance of rates of change as well as the kinds of change impacting the environment.

Man's ability to effect rapid changes on the natural system in which he lives has resulted in major alterations to the structure of the natural system. Some actions are directly absorbed by the system, inducing no apparent structural change; some actions induce changes that are reversible once the action ceases; other actions cause changes that are irreversible. Rivers, for example, can revert to their natural conditions if pollution sources cease to dump effluent into them. Pollutants can be simply assimilated in the bottom sediments or removed by flow into marine waters. On the other hand, land cleared of climax forest communities for farming purposes may not revert to the original forest community when abandoned, because farming processes can alter the composition of the soil by removing critical nutrients and adding others in the form of artificial fertilizers.

The environmental system can be conveniently visualized as a rubber ball. If the ball is struck very lightly, it merely absorbs the blow without any change. If the blow is delivered over an extended period of time, no change will affect it. However, if the ball is struck so that the blow is instantaneous, it will deform. After a short time, the ball will assume its original shape in response to the elastic properties of the material. If the ball is struck extremely hard so that the force of the blow exceeds its elastic limit, it will remain permanently deformed. The natural environment is analagous to such a ball. If the action results in changes of small magnitude occurring over a long period of time, the system may absorb the change without any alteration. However, if an action produces a massive impact, the environment will be irrecoverably altered. The notion of carrying capacity can be best understood using the analogy of the rubber ball as the elastic limit of the system. In other words, it is the magnitude of impact irreversibly altering the system. This irreversible alteration of the system, and hence extension beyond the limits of natural carrying capacity, can take the form of disruption of any of the four previously mentioned processes bounding this concept, namely: interaction, sequence of interaction, tolerance ranges, and rate of change.

In more practical terms this concept embraces the points at which the amount and extent of liquid effluent discharges, atmospheric emmissions, land-base modifications and so on, approach a limit that irreversibly changes the natural system. In effect these are attributes of our built environments that we often seek to control through subsequent performance standards and regulations in order to help maintain concepts of environmental quality.

With the incorporation of what might be termed the reciprocal relationship between the built environment and the natural environment, the carrying capacity concept can be broadened still further to include the capacity to support human habitation. This may at first appear to be somewhat contradictory. However, in many instances when natural environmental carrying capacity is exceeded either in part or as a whole by man's activity, the resulting environment is often rendered unsuitable for either the same or other forms of human use. Excessive ground-water withdrawal in some parts of the U.S. results in irreversible land surface subsidence. If this subsidence occurs in areas of low elevation adjacent to permanent water bodies the subsequent flooding poses a severe encumbrance on land use activity. This inclusion also allows the fundamental basis for many forms of building regulation, namely, the protection of public health, safety and welfare, to be addressed. There are many instances in which degradation resulting from activities that exceed the natural environmental carrying capacity are potentially injurious to the public health safety and welfare. The instance just cited of excessive ground water withdrawal increasing the flood hazard, is one such example. Severe impairment of water quality precluding vital recreational activities and destroying productive aquatic resources is yet another example.

Of course there are instances where the intrinsic characteristics of the natural environment, often unrelated to human activity, render sites unsuitable for development. The presence of active faults, the presence of areas with high natural flood potentials are fairly clear examples. The concept, therefore, of natural environment carrying capacity presented here, primarily focuses on the distortion of the natural system to a point of permanent change, but also includes the ramifications of such a resultant environment or its intrinsic characteristics for human use and particularly in this paper, for building development.

ENVIRONMENTAL PERFORMANCE STANDARDS

The concept of carrying capacity described here includes definition of all limiting values of environmental gradients or processes regulating the composition of ecosystems. Theoretically, performance standards consist of each of these limiting values, and their sum is equivalent to the regional carrying capacity. Therefore under ideal circumstances, performance standards may be directly defined using the carrying capacity concept by determining the limiting values on each environmental gradient. Because they vary continuously in space and time, the environmental gradients for any region can be quantified only by obtaining long temporal and spatial records of measured variation. Many physical parameters are difficult to measure, and some are not directly measurable by any means. Therefore, direct information pertaining to the variation of these parameters is unobtainable and performance standards based on limiting values of such unmeasurable parameters cannot be ascertained. Therefore, the carrying capacity concept as discussed here is often not directly applicable to the development of performance standards. Yet necessity for the development of performance standards to regulate the severity of environmental impacts is clear.

The underlying processes of the natural environment may be indirectly estimated by assuming that all environmental features (plants, soils, etc.), occur within limiting values on environmental gradients. Where these values exceed the limits, the feature cannot exist. Therefore, the occurrence and distribution patterns of many individual environmental features can be indicative of the physical structure in which they exist and can be analyzed to reveal estimates of carrying capacity values.

Many approaches have been developed on this basis for the purpose of defining building performance standards. McHarg's overlay technique is an attempt to define carrying capacity and suitability for development based on a knowledge of how certain landscape features behave in combination with various types of building development. Other approaches have been developed for defining performance standards for specific aspects of land-use natural environmental interaction. For instance, Thurow, Toner and Erley[3] summarize a series of such standards including consideration of such things as erosion, storm water runoff and devegetation. Another approach, to be described later in this paper, attempts to develop a holistic view of carrying capacity in relationship to building performance.

However, a central problem in the development of meaningful performance standards is the technological feasibility of setting precise numerical measurements on the behavior of natural processes in relationship to building activity. There are still a great number of unknowns and constant debate surrounding the present state of our knowledge about environmental systems. Even if precise numerical measurements can be made regarding the impact of building on the natural system, the setting of performance standards generally involves some adjudication about acceptable magnitudes of impact. Theoretically, of course, these performance standards should correspond to what might be termed the elastic limits of the system, to use the rubber ball analogy. However, because our knowledge of these elastic limits is often conjectural or imprecise at best, the selection of performance standards crosses into the arena of value judgment and the "objective" notion of carrying capacity becomes inbued with more "subjective" concerns for environmental quality. The emphasis shifts from a position where the functioning of the natural system is the subject towards one where the felt effects of the system function are at issue. As can be seen from the arguments over such things as E.P.A. ambient air standards, the lack of a "direct" link between threshold and carrying capacity makes the performance standards very difficult to enforce in a regulatory process that assumes such a linkage.

There is another related problem that needs to be overcome in order for appropriate building performance standards to be established that are reflective of our more fundamental understanding of carrying capacity. While a considerable amount of research has been devoted by the scientific and technical community to increasing understanding of how natural processes work, extension of these efforts into the realm of planning and building regulation have just begun. The result is an apparent lag between estimates of various facets of carrying capacity expressed as tolerance limits and incorporation of this

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[3] Thurow, C., Toner, W. and Erley, D., 1975, Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators, American Society of Planning Officials, Report Nos. 307, 308.

information into the more specific realm of building performance standards and regulatory processes. Because current representations of the complete concept of carrying capacity are imperfect either by a lack of definitive knowledge or by omission, the reluctance of those involved in the building regulation process to fully embrace this body of knowledge is perhaps wise and understandable. However, there does appear the need for a more concerted effort in bridging the gap between the research specialists and those involved in building regulation.

At this point it is perhaps important to summarize the perceived difference between the concept of natural carrying capacity and performance standards. Current performance standards are seen to be first approximations of various aspects of carrying capacity and represent, for further implementation purposes, an operational definition of carrying capacity. They are seen to usually take the form of a technical description of environmental tolerance limits largely in terms of units of measurement that are consistent with the material and energy flow transactions that occur between land use activities and the natural environment. They are not per se standards that can necessarily be used directly as building regulations, but represent more the performance levels regulation seek to achieve.

BUILDING CODES AND REGULATIONS

In terms of this theoretical construct, building codes, and other related regulations, are considered as a further representation of performance standards for the purpose of exercising control. The translation of environmentally-based building performance standards into a codified regulatory process must take place against the backdrop of several often conflicting considerations.

First, it must be recognized that current building regulation involves a many-tiered system of checks and balances. This, of course, raises the issue of which mechanism is most appropriate to regulate various environmental considerations. Consider an example from a state that has enabled counties and municipalities to enact zoning ordinances and that also has a state program for controlling areas of critical environmental concern. Four regulatory tiers are present. First, the state delineates areas of critical environmental concern. Second, either the county or the city erects a zoning map. Third, the subdivision platting process that is applicable under either city or county ordinances and fourth, is the building code applicable on a lot-by-lot or building by building basis. A critical aspect of a well-developed regulatory scheme is to select the correct level of resolution for attacking various problems.

Second, any of the above-mentioned regulations must be based within the ambit of the police power. The police power[4] is the continuing right of the community to restrict an

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[4] Sax, J., 1964, Takings and the police power, Yale Law Journal, Vol. 74, pg. 36.

individual's rights in the name of public health, safety or welfare. Depending upon judicial interpretation of the extent of the police power[5] this concept may limit the translation of certain environmental issues derived from the concept of carrying capacity to the building regulation process. For example, the Wisconsin Supreme Court[6] upheld the action of Marinette County in denying a permit seeking to fill marshlands against the landowner's claim that the action was taking of land without due process. In this case, the Wisconsin Supreme Court recognized, among other things, the contribution of marshlands to the production of fish in lakes and thereby held a larger or overriding public welfare interest in the preservation of marshland. However, it is not clear where the limits of this expanded definition of public welfare lie.

A general tendency in the courts is to uphold restrictions based upon finite limits of some resource deemed necessary for public health, safety or welfare. For example, restrictions upon residential densities based upon a finite fresh water supply for a community would most likely be upheld. Similarly, building density limits derived from well-documented scientific determination of the maximum assimilative capacity of a lake or receiving stream would most likely be upheld. More problematical, however, are instances involving rare or endangered plants and animals. In such a case, it may be argued that an amenity issue, rather than a public welfare issue, is involved. Will the courts uphold restrictions based upon such an expanded definition of public welfare? Undoubtedly, courts have upheld restrictions on the use of land which are based on amenity considerations,[7] but these have not been restrictions disallowing all uses of the land. In other words, the courts may allow amenity considerations to be upheld if they do not prevent development, but instead shape the development. The preservation of unique vegetation, for example, may be best accomplished through a parks requirement that could be imposed at the subdivision platting level; the building code, in this instance, could be a secondary enforcement device. The major portion of the unique vegetation could be included in the park that was platted at the subdivision level, and control of building placement upon the subdivided lots could be used to protect ancillary patches or extensions of the vegetation type from clearing activities accompanying construction of the building *per se*. As such, the two levels of regulation begin to function to achieve an end that neither could accomplish totally alone.

Keeping in mind that the building code is the lowest level of regulatory resolution and that such a code is generally an enforcement mechanism for larger, community-based

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[5]Bosselman, F., Callies, D. and Banta, J., 1973, The Taking Issue: An Analysis of the Constitutional Limits of Land Use Control, U.S. Government Printing Office for the Council on Environmental Quality, Washington, D.C.

[6]Just v. Marinette County, 201 N.W. 2d 761 (Wis., 1972).

[7]Matter of McCormack v. Lawrence, 8ERC 1461 (N.Y.S.Ct., 1975).

policies, what environmentally-oriented considerations are amenable for regulation at this level? First, floor elevation considerations and structural characteristics of buildings are clearly within the province of the building code. In fact, the building code is the primary means of exhibiting compliance with the Flood Disaster Protection Act.[8] Similarly, hurricane wind protection and other severe climatic events may be integrated into building code structural requirements. Second, water use and waste water production may be enforced by the building code, although the analysis leading to such limits will necessarily have a much larger spatial focus. For example, if non-point source water pollution is a problem, then the building code could be used to enforce the amount of soil coverage and the exposure of cleared land during construction. Third, if particulate air pollution is problematical, the building code could certainly limit the contribution of the individual dwelling unit to the problem. However, the issue of the contribution of automobiles to the pollution problem is more appropriately addressed at a larger level, perhaps by emission density zoning. If a valid reason existed for limiting the devegetation of a lot, the building code and permit system have the resolution to enforce predetermined limits upon clearing. And, of course, energy conservation in homes and buildings is amenable to inclusion in the building permit process because this falls within the more materials-oriented scope of traditional building codes.

However, there are several technical difficulties that are raised by the concepts of natural environmental carrying capacity and performance standards, particularly when strong representational correspondence is sought between regulation and environmental problem. The first of these technical difficulties has to do with the spatial variation of the natural setting and therefore the spatial variation in its ability to withstand impact or be an acceptable site for building development. Ideally, building regulations should take into account varying regional conditions and responsively reflect these variations down to the individual site level. Under this kind of scrutiny, the formulation of the environmental aspects of a code might well take the form of an elaborate series of "if-then" propositions. This may be contrasted with the invariant and all-inclusive character of many present formats. For example, the Southern Building Code,[9] adopted in its entirety by most cities in the south, is composed of numerous absolute statements concerning materials specifications for buildings. While such a listing of specifications is not necessarily arbitrary when applied to such uniform characteristics as conductivity, resistivity, fireproofing and other traditional subjects with which such codes are concerned, it is impossible to write specifications based on a carrying-capacity analysis that are universally applicable and thereby free from the charge of arbitrariness. In fact, spatial variation occurs across municipalities, not to mention counties and states. Therefore, an analysis of

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[8] Disaster Relief Act of 1970, P.L. 91-606 as amended Flood Disaster Protection Act of 1973, P.L. 93-234 (Dec. 31, 1973).

[9] Southern Building Code Congress, 1973 ed. with 1974 amendments, Southern Standard Building Code, Birmingham, Alabama.

the spatial variation in the carrying capacity of the land would need to be undertaken by those municipalities or counties desiring to implement such a system and become reflected in that system.

A practical consideration of some magnitude can be immediately raised concerning the level of sensitivity with which this spatial variation can be realistically expressed by the code. A clear response to this concern is not immediately apparent. The need for administrative simplicity, often reflected in uniformity, seems to run counter to such an expression of variation. Also, even though the carrying-capacity analysis may identify certain variables of importance, these variables may not be subject to inclusion at the building code level, due to our imperfect understanding of the manner in which the natural environment works or due to the level of resolution which is obtainable from such an analysis. For example, assume that a certain geographical area contains a unique type of vegetation and an endangered mammal species. An initial tendency might be to attempt to preserve the mammal by preserving the vegetation type. However, in this situation, our understanding of the environment may not be sophisticated enough to be able to directly support such a restriction. Additionally, it is not clear that a problem of this type is amenable to solution at the building code level. A second example may be found in non-point source air pollution controls. It may be very difficult to translate a problem that is important at a community-wide level down to the individual contribution of the lot, thereby rendering this a problem amenable to solution by the building code.

A second technical difficulty involves temporal variations in both the natural and man-made environments. The carrying capacity concept includes not only single instances of environmental impact but the cumulative effects of many instances of such impact in a given locale. Here performance standards are really tantamount to allowable budgets, rather than the threshold for a single impact taken in isolation. This concept has already been taken into account in EPA's air and water programs but can also have application at the level of smaller geographical areas and within the building code process.

The amount of coverage that is allowable on a site in relationship to storm water runoff can be subject to regulation at the building code level. Given that coverage standards and regulations for specific lot types have been originally derived from consideration of the runoff characteristics of an area, enforcement of controls should not just terminate with the isolated application of these regulations. Given that the original regulation was formulated on the basis of some aggregate allowable amount of coverage in relationship to acceptable levels of natural disturbance and led to different requirements for different development types, regulatory control of development types independently from one another may lead to cumulative impacts that are in excess of acceptable standards if over-development occurs of a type that has less stringent minimum coverage requirements. In other words, the temporal, combinatorial occurrence of impacts must be monitored. This is obviously difficult to accomplish within the framework of a fixed set of regulations that are applied independently and equally in all instances. A method of getting around this difficulty by making the amount of allowable minimum coverage of each lot type truly reflective of all possible combinations of development types in an area, may prove to be overly punitive in a situation that realized less than its full development potential.

Consideration of temporal variation of a different sort can also be raised. Building practice itself is a constantly changing process. Regulations that are appropriate at one point in time may be quite inappropriate at some future time. Anticipation and encouragement of innovations in building practice should be incorporated into the design of the regulatory process. This is particularly important when considering environmental bases of building regulations where development and acceptance of new building responses is still in a somewhat embryonic form. The volume of runoff from a site, for instance, is increased with increases in the amount of impervious surface. This increased volume of runoff is quite often not a problem until it increases the flooding potential, generally at a community-wide scale. There are a variety of methods for mitigating this flood potential; some involve traditional engineering concepts and others involve the use of landscape features to retard overland flow or more closely mimic the behavior of the natural system. There would seem to be no reason why a development could not grossly exceed the performance standard expressed in terms of maximum allowable area of impervious surface if the development also included landscape features which brought the increased flooding potential within acceptable limits and thus did not impose an externality on neighboring developments. In cases such as this, the tendency to develop overly restrictive codified solutions may work against the performance standard concept.

Another problem posed by temporal variations may be demonstrated by regional rainfall patterns. Assuming that non-point source pollution, particularly that contributed by erosion, has been found to be problematical and that a building code requires that mulching be used during construction, an exception to the imposition of such a requirement may be seen in the annual rainfall pattern. If such a pattern shows that three consecutive months have very low rainfall totals, then an exception to such a code could be made for construction commencing during the first two weeks of the three-month period. In this manner, temporal variations in the natural environmental system become mimicked in the building code regulations, thereby preventing the imposition of unnecessary controls.

AN APPROACH FOR DEVELOPING BUILDING PERFORMANCE STANDARDS

Following the basic environmental principles outlined earlier, development of reasonable and effective performance standards for any region ideally involves a one by one evaluation of the effects of building development on the tolerance limits of each natural feature of that region. From a practical point of view, however, this is an almost limitless task. Furthermore, little may be known about the behavior of a particular feature, and therefore such detailed assessment of its reaction to change is not predictable.

A more practical approach to performance standard development must be derived. The remaining sections of this paper are devoted to describing an attempt to develop such a methodology and to incorporate its results in the form of building performance guidelines.[10] The study area for the exercise was Chambers County, Texas, until recently, a sparsely populated, predominantly rural county on the urban fringe of Houston.

The procedure involved description of the natural environment of Chambers County in terms of the occurrence and distribution of easily observable landscape features such as plants, animals, hydrologic elements, and soils. This raw information was found to be relatively readily available in the form of maps summarizing the spatial variability of a particular feature from specified points of observation. These maps represented continuous surfaces of variation and for analysis purposes had to be reduced to some kind of discrete form. To accomplish this a spatial referencing system of rectilinear grid cells, keyed to latitude-longitude co-ordinates, was selected. Data was encoded by measuring the value for each feature in each cell of the grid.

The basic concept underlying this approach to performance standards was to attempt to isolate those cells, or geographic areas, that has essentially similar landscape features and to be able to isolate those features within these areas that were most sensitive to building development. The principle here was that areas having very similar natural environmental characteristics would perform very similarly in response to built development. It was an attempt to deal systematically with the problem of responding to spatial variation in the environmental context and of attaching some meaning to this variation from the point of view of desirable building performance.

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[10] This methodology is more fully described in, Rowe, P.G. (editor), 1974, An Approach to Natural Environmental Analysis, Rice Center for Community Design and Research, Houston, Texas, and Rowe, P.G. (editor), 1976, An Approach for Describing Natural Systems and for Assessing Natural Environmental Impacts, Rice Center for Community Design and Research, Houston, Texas.

To isolate these similar areas, called "environmental units," the grid cells were compared to one another on the basis of their landscape features and a hierarchy of cells erected. It was found that many multi-variate classification techniques existed that could be appropriate for this purpose. However, many of these required extensive a priori assumptions regarding the types of frequency distribution present in the data. On close analysis it was found that these sorts of assumptions could not be made. Finally, an unweighted pair group method of cluster analysis[11] was selected using Sorensen's coefficient[12] as the measure of similarity (disimilarity). This technique also had the advantage of providing a hierarchical classification of cells at different levels of similarity in the form of a treelike diagram (dendrogram) that displayed all existing relationships within the data. This was important as it allowed more subtle environmental relationships to be recognized and also allowed discrimination of small homogeneous regions within larger regions. Further analysis of the hierarchical structure of the fundamental land units permitted critical features at each level to be isolated. These features are those most responsible for the cell-grouping seen at this level and interpretively are those potentially most critical to building performance within the local region. Features critical to larger more general groups tend to be more sensitive to development within the larger region. Thus, as one moves through the classification, groups merge and become more general, accepting wider and wider variability in their features and broader application of their resultant critical features.

Development of a set of performance standards from the ordered list of critical features pertinent to each hierarchical level required numerous assumptions concerning the way in which building development affects each feature on the list. In many cases, this information was available in already established engineering and scientific principles. For instance the relationship between local identifiable natural features such as soils, vegetative cover and climate and the increases in impermeability occasioned by building development, allowed flood hazard potentials to be estimated.

The resulting description of building performance standards took the form of a map displaying of "environmental units" at various hierarchical levels, a brief description of the critical variables associated with each unit and a statement of recommended building performance and building practice with respect to these features. No attempt has

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[11]See Sokal, R.R. and Sneath, P.H.A., 1973, Principles of Numerical Taxonomy, W.H. Freeman, San Francisco, California and Gevirtz, J.L., Park, R.A. and Friedman, G.M., 1971, Paraecology of benthonic foraminifera and associated micro-organisms of the continental shelf off Long Island, New York, Journal of Paleontology, v.45, p. 153.

[12]Gevirtz, J.L., 1971, op cit.

yet been made to codify these recommendations into a more conventional regulatory control instrument. However, these recommendations have been used to advise those developing within the area, in addition to existing subdivision ordinances and the like. An advantage of the procedure is that it may be readily altered to conform to new data and refinements in the engineering and scientific principles used to develop it. It does address the issue of spatial variation in the potential land use-natural environment response mechanism and it does facilitate a clear and systematic transition to be made from notions of natural environmental carrying capacity to building performance requirements that are directly reflective of this concept.

CONCLUSIONS

In conclusion, the process of moving from a general concept of carrying capacity that includes notions about the relationship between built and natural environments, to the establishment of technically realizable thresholds consistent with these concepts, and finally to a practical regulatory mechanism, is athwart with problems. Information becomes lost and each successive representation of the carrying capacity concept becomes only an approximation. But this is by no means unique to the incorporation of environmental bases within the regulatory process. Other bases also can become similarly obscured. However, perhaps what is unique about the problem of incorporating environmental bases is the extent to which there is a lack of clearly definable link between the fundamental background objectives of the regulation and the form of the regulation itself.

Also, unlike many other bases of building regulation where the operating environment or sphere of influence can be assumed to be roughly uniform, environmental bases must reflect considerable spatial and, to a lesser extent, temporal variation. As discussed, recognition and incorporation of this variation poses potential representational difficulties for the present format of building codes and other similar regulatory mechanisms.

A practical approach has been briefly described that attempts to overcome some of the difficulties in representing notions of carrying capacity in building performance guidelines, most notably the need to reflect spatial variation. However, this concept is still very much in an experimental stage and has not been exposed to the rigours of sustained practical application.

DECISION-AIDING COMMUNICATIONS IN THE REGULATORY AGENCY:
THE PARTISAN USES OF TECHNICAL INFORMATION

by

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This paper, based on a nationally representative survey of 1,200 municipal building departments, describes the partisan uses of information in a regulatory setting. Each of the agencies was facing a specific decision to alter its regulations to accommodate innovative building techniques. The agencies identified the various members of the building community--builders, designers, vendors, users, regulators--who came forward to initiate the change, to discuss its advantages or disadvantages, and then to assert a position either supporting or resisting the agency decision to modify the regulation. The local building industry, accused by many of being the greatest source of resistance to technical innovation, was found to be the strongest force for change, equaling sometimes surpassing the positive influence of the model code groups.

Key words: Regulation; building codes; decision making; public policy.

INTRODUCTION

Responsible regulation of building technology requires that codes be technically current and socially responsive. That is to say that regulations themselves must reflect a dynamic equilibrium between emerging social needs and new technological opportunities. Maintaining the building code in this condition is a responsibility of the regulatory agency. In discharging this duty, building officials must determine the adequacy and appropriateness of innovative building techniques with respect to public safety, health, and welfare before permitting their use in the jurisdiction for which they are responsible. This paper describes how those determinations are made and identifies those elements of the building community that participate in those decisions. This information is based on a nationally representative survey of about one thousand local building departments.[1] The survey results interpreted in this paper show that some widely held beliefs about who influences the code change process are, quite simply, wrong.

AN OUTLINE OF THE CODE CHANGE PROCESS

A sponsor seeking regulatory approval for a new technique presents to the building department data (often in the form of engineering standards and test methods) showing the candidate technique's compliance with or equivalence to applicable code requirements. The regulatory agency might require evidence of further testing to specified engineering standards by qualified laboratories. The sponsor provides this information, usually at considerable additional expense. The effort is worth the cost, though, because once a regulatory agency approves the material, method, assembly, or engineering standard under review, a new market area is opened to the innovator.

This is the bare-bones outlines of the procedure by which state and local codes undergo piecemeal or incremental modernization. The process is repeated thousands of times--recall there are over 5,000 local and a score of state building codes in force in the U.S. Moreover, the process might involve a slightly different cast of participants and there are variations in the substantive documentation required in each jurisdiction.

DECISION-AIDING COMMUNICATION IN BUILDING REGULATORY AGENCIES

When faced with potentially difficult technical decisions, the scant agency resources for independent determination of technological questions are routinely augmented by the agency's constituency and other sources of information. In other words, the agency consults with its clientele and reference groups before acting. The clientele are those individuals and organizations whose lives and livelihoods are immediately affected by the agency actions; the reference entities are the several score of professional associations and technical societies who can legitimize or otherwise authenticate the action of the public officials.

The decision-aiding communications to the local building departments take several forms. There are personal interactions with the technical representatives acting for vendors of building products, with local contractors and builders, and with architects and engineers who appear frequently at the agency's door in the course of routine business. There is association with other local building officials either in periodic formal meetings (typical for jurisdictions subscribing to one of the model codes) or on an occasional basis. There is, too, the sporadic involvement with citizens, singly or in groups, seeking relief of one sort or another. The relative frequency of those personal encounters is shown in Figure 1. Finally, there are the impersonal sources of technical information: principally, engineering reports, sales literature, test results, trade periodicals, and government publications.

These personal and impersonal information channels each have distinctive, though not always obvious, biases or predispositions: some are clearly promotional; others, scrupulously impartial. Agencies use these channels in a continuing surveillance of their political and technological environment.[2] From this environment and these sources come signals for agency action or inaction. These messages course through personal and impersonal channels to the key officials in the building department. And, in this transmission, the weight lent to the messages is affected by the qualities of both the sources and the channels. All the foregoing are commonplaces of communications theory[3] and all are manifested in the communications preceding the technical decisions of building departments.

How important are these message flows to the agency?

A 1970 International City Management Association (ICMA) survey of local building departments found that although the department staff members occasionally initiate suggestions for improving the local code, the preponderance of the more innovative practices are brought in from outside the agency, chiefly by the agency's clientele. Discussions of imminent changes are carried on widely. But support for and resistance to code changes under review call forth intensive participation by only a few members of the agency's professional reference groups and from its clientele, which is itself a mere subset of the total building community.

In brief, the staff-short agency faced with a decision on innovative technology resorts to a form of collective decision-making. Others from beyond the agency may contribute to this decision by providing information on either the technique itself or the ramifications--both social and technical--of code-approval of the technique. But since most of the sources of this information have a partisan interest in the decision, the agency interposes between itself and this information-bearing clientele a filter of skepticism. This filtration function must be incorporated into any model of information flow in regulatory policy making.

The model of the agency decision process proposed in this paper is framed in a way both to reconstruct the tacit logic of the decision and to isolate precisely those functions of the agency clientele about which the least is known and the most is speculated. Both normative and behavioral theories of decision making plus the author's own experience in local, State, and Federal regulatory policymaking recommend that the agency decision to accommodate the regulations to an innovative technique may be usefully analyzed as a multi-stage process with members of clientele and reference groups each playing a greater or lesser role at each of the stages.[4]

The agency engages the participation of its clientele and reference groups in different modes as it progresses, stage by stage, to a decision. Accordingly, the five modes of participation open to the clientele and reference groups are as: 1) originators of proposed code changes, forwarding them for the agency's consideration; 2) discussants of those changes with agency officials while the changes are under review; 3) service as trustworthy sources of information pertaining to the innovation and its implications for the building community; 4) supporters of the proposed change; and 5) resistors of the proposed change.

The members of the clientele--those whose welfare and livelihoods are directly affected by agency decisions--are: architects and engineers, building material producers or suppliers, and their national and local representatives; local or out of town builders and, a special case of the latter, manufacturers of prefabricated buildings; and representatives of international unions and their local business agents; and, the ultimate clients, representatives of the general public, usually spokesmen for civic and voter groups. The reference entities--individuals or groups with whom building officials "identify" (in the psychological sense) and to whom the officials look for legitimation and approval--include: first and foremost, building officials from near and far and particularly those organized into professional groups like the model code associations and, much less prominent, the trade and professional media that inform and, to a degree, muster the strikingly diverse building community.

The clientele and reference groups include both the industry-based agents of technological change, who typically advocate use of new materials, products, or methods, and the spokesmen for enhanced building performance, who typically advocate safer and more economical buildings. Both groups try to achieve their goals by influencing regulatory policy in their favor but the greater or lesser influence of one group in comparison to the other (and, in fact, the actual make-up of those groups) can be known only after agency decisions have been documented and analyzed. By tracing actual agency decisions through each of the five stages mentioned earlier, the differential influence of the several actors at each stage can be identified. A thousand building departments reported to the ICMA how this five-part process variously involved twenty members of the building community as the agency reached a decision on modifying the building regulations to accommodate innovative techniques. This provides the data base for the following description of the partisan uses of technical information.

Table 1 lists the 14 techniques the agencies were considering when they reported to the ICMA. The 14 techniques, collectively, may be considered an index of technological currency. That is, codes that permit more of the 14 techniques may be considered more progressive and up to date.

CLIENTELE AND REFERENCE GROUP INFLUENCES ON REGULATORY DECISIONS

The ICMA survey indicates that the building department's clientele and, to a much lesser extent, its reference groups utterly dominate the flow of communications affecting code changes under consideration. They eclipse in importance even the building department staff itself. This is true at every stage of the process: introducing the innovation, discussing it, providing trustworth information on the change, and arguing for or against the change. The survey also indicates, however, that the clientele, strong as it is, represents so many diverse interests that its collective characteristic is one of ambivalence in the face of technological change. With the possible exception of the building trade unions, there were no members of the agency clientele in persistent and pervasive opposition to the modernization of building regulations. This finding undercuts two widely held but thinly-substantiated beliefs. The first is that local building interests categorically attempt to suppress regulatory acceptance of technological innovation. The second is that the responsible officials succumb to this pressure. Contrary to these beliefs, which we may call the "obstructionist doctrine," the ICMA data reveal that local building interests were, in fact, the leading advocates of the 14 code changes.

The close-up view of the agency clientele in action reveals who specifically among them are the most active advocates of regulations that are technologically responsive: suppliers of building products and the builders who use them are the prominent sources of new ideas. Somewhat surprisingly, architects and engineers, whose professional ethoses (and popular stereotypes) would place them in a technological _avant-garde_ are not prominent innovators--at least not on code changes considered by building officials to be the "most difficult" among the 14 on the index of technological currency. When the building officials reported to ICMA on the "least difficult" changes, the design profession figured much more prominently as initiators. Local building officials reported the same tendencies for themselves: low participation on difficult (and, likely, controversial) decisions; high participation on less difficult decisions. This suggests that the design professionals that serve the building industry are much less venturesome and innovative than are the construction professionals, the builders. In other words, in matters of changing regulations to accommodate technical change, the design professionals actually behave in much the same way as do regulatory bureaucrats they frequently malign. The building product suppliers and the builders themselves are the prominent advocates of technological currency in the building codes, as the following diagrams illustrate.

Figures 2a through 2e illustrate the ICMA survey findings on the greater or lesser participation of the clientele and reference groups at each of the five stages of the agency decision to adopt a recent code change. The figures are a composite of agency-identified participants in decisions concerning all of the fourteen techniques comprising the index of technological curreny. The agency clientele and reference groups are listed at the left margin. They are arranged in descending order of their "trustworthiness" as sources of information on the code change under review. (The responding agencies provided this ranking, as will be explained shortly.) The horizontal bars represent the relative extent of clientele and reference group participation in the various decision phases. Let us analyze each of the Figures visually at first and then search for significant intercorrelations among the actors and the roles they play in the change process.

Figure 2a illustrates the first appearance of "technology-push" on the regulatory system, and the push comes from the industrial agents of technological change: building product suppliers and the local builders. It is these suppliers and builders, and not the putative avant-garde of designers, who bring to the building department the initial suggestion to revise the code to accommodate the techniques comprising the index of technological currency. The first awareness of a technical possibility comes by way of personal, rather than documentary, sources. Sales representatives and builders are more prominent sources of new ideas than are periodicals, brochures, or government reports. This deserves a comment.

Local building officials are exceptional in their primary reliance on personal experience and interaction rather than documentary sources of novel technology. Exceptional because studies of technological communication--whether in the realms of medicine or agriculture and involving either physicians or farmers--report that impersonal media and documentary sources usually bring the first awareness of an innovative practice. Generally, according to communications researchers, this initial awareness through an impersonal source is followed by personal contact and face-to-face relations between the change-agent and the user. These personal contacts and relations legitimize the information (often by adding detail) previously transmitted through the impersonal medium. This "two-step flow of communication"[5]--from impersonal media through the opinion leader to the final receivers--so prominent in studies of both mass communications and innovation does not apply to the local building official. Rather, he relies on more basic, interpersonal means of monitoring his technological environment. In the view of some media specialists, this reliance on personal communications instead of more efficient mass communications is a defining characteristic of primitive societies in less-developed economies.[6] Since much of its innovation proceeds without benefit of modern diffusion techniques, there may be a justification for calling this aspect of the building industry "primitive."

A final observation also touches on the anomalous behavior in the building department when a technological change is initiated. In most studies of innovation--and especially those involving collective decisions (as when an agency and its clientele participate)--initiators of those decisions are likely to be cosmopolites and persons without routine and everyday contact with the social system that is the locus of the change.[7] Not so in the building regulatory agency. Here, even the "idea men"--mostly from among the clientele--tend to the local building material supplier, the local builder, the local staff.

An explanation for this may be that the "local" initiators of change--the building products suppliers and builders--are in many cases merely local agents for firms that produce and market construction goods nationally. The case of the builders is similar. They, typically, are members of local builders' associations whose national federation, the National Association of Homebuilders (NAHB), provides the local associations with technical assistance. Thus, even residential construction, that most local of industries, has numerous connections with national organizations.

The second of the five stages of agency decision making is the widespread discussion given to newly proposed code changes. Of the five decision-aiding activities analyzed here, "discussion" enjoys the widest participation. Just how widely discussion is spread is illustrated in Figure 2b. Discussion of prospective code changes serves several important purposes both for the agency and for the agency's clientele. It gives to both an opportunity to identify and corroborate the probable impact the prospective code change might have and it is the place where the agency and clientele both put a technological toe in the political water without an irrevocable commitment to support or resist the adoption of the proposed change. Clearly, "discussion" is an activity with high payoffs in several categories. It is virtually costless to both agency and clientele since most of the discussants are already regularly encountered during the routine office day.[8]

What, precisely, are the benefits of discussion? For the clientele, the discussion step serves as a distant early warning of potential policy changes that might induce a disruption of stable marketing arrangements among competing building product manufacturers. If the discussion period is long enough--and it may be months--the local clientele had an opportunity to consult with their national and regional affiliates for advice on tactics either to advance, retard, or be neutral to the prospective change.

The agency, for its part, "discusses" the prospective change with its reference groups, notably, the model code associations or building officials nearby or in distant cities. Another benefit the agency derives from the "discussion" stage is the momentary visibility it enjoys among the clientele, showing that the code the agency enforces is an "open code, openly arrive at." An important secondary agency use of the discussion stage is to identify possible effects of the code change that might redound harshly upon the agency itself. Such circumspection would save the agency later embarrassment at the hands of parties aggrieved by an adverse code decision and its consequences. It must be borne in mind that the avoidance of embarrassment is a prominent consideration in any organizational decision--whether with the Joint Chiefs of Staff or in the building department--and especially so when a "wrong decision" might effect the economic welfare of local industry groups or the life safety of a community's inhabitants. Either eventuality could result in the chief executive's disciplining the erring department. Since only one local building official in eight has a specified term of office, and since for half that one in eight the term is one year,[9] discipline could take catastrophic form: dismissal if punishment for error exceeds reward for non-error, this biases the decision making quite strongly--it favors status quo, for example.

A final utility of the discussion phase may be psychological. The job-insecure and poorly-paid local officials have an opportunity to associate with their certainly more affluent and often higher status clients. It is a truism of social psychology that lower status members of social hierarchies with little or no possibility of social mobility direct their communications upward "as a form of substitute upward locomotion."[10]

We suggested at the outset of this study that the development of regulatory policy, indeed, the very evolution of the regulatory function, is a dialectical process that seeks a dynamic equilibrium between the forces representing the diverse interests of specific sectors of the building community. The building regulatory system must respond to shifting societal values and to emerging technological possibilities. We may call one a "society-pull" and the other a "technology-push," both impinging on the building regulatory system. In contemporary America, "technology-push" is dominated by industrial agents of technical change while "society-pull" is largely in the hands of public agencies and "public interest" groups. This ever-present but usually subdued dialectical process rises to maximum visibility during the agency decision to accommodate innovative technology. At that time, the constituents of the building community come forward to support or resist the building department's contemplated change in the regulation. Figures 2d and 2e identify the participants in this process and the horizontal bars denote relative degrees of partisan ship among the agency's clientele and reference groups. The ardor of their partisan ship may be gauged by the relative lengths of the bars: strongest supporters of the code changes included in the index of technological currency are, in decreasing order, local builders, local building product suppliers, out of town building product suppliers, manufacturers of prefabricated buildings and the design professions (the latter two tied); strongest resistors of code changes in the index are: local union representatives, local building product suppliers, and international union representatives. These results invite interpretation.

On visual inspection alone, Figure 2d shows that, generally speaking, those who initiate the changes, usually the industrial agents of "technology-push," are those who come out and fight the hardest for them. This is to be expected and the statistics bear out the expectation: the rank orders of the rosters of "originating" actors (illustrated in Figure 2a) and "supporting" actors (illustrated in Figure 2d) are highly correlated. (Table 2 lists the extent of agreement among the rank ordering of actors at each of the decision stages.) Also to be expected: the rosters of actors "supporting" and "resisting" the code modification are in relative disarrary with respect to one another. However, one is not the inverse of the other.[11] In other words, constituent groups among the clientele that may strongly support a code change also contain elements that might resist the change. For instance, a code change to allow the substitution of one building material for another (as in the case of PLADRN or MTLCHM; see Table 1 for explanation of abbreviations) might provoke a conflict among building product manufacturers. Similarly, a definitional change that might enable the substitution of one trade for another (as happened when the BOCA Basic Building Code redefined terms describing installation of underground utilities) might provoke a reaction and conflict among the building trades unions. The warning should be obvious: generalizations addressing the entire agency clientele are instantly suspect. Unfortunately, the popular but mistaken "obstructionist doctrine" relies on and propagates such erroneous generalizations.

In identifying the patterns of communication and of potential influence, Figure 2c, that indicating trust, is the most telling diagram of all. It reveals that local building departments are leery of and deliberately weigh the flood of signals, messages and blandishments that bombard them from the individuals and organizations identified in Figures 2a, b, d, and e. Some signals are severely discounted: these are represented in the diagram by the lower ranked actors; others are respected: these are the actors at the head of the roster in Figure 2c. Why should this be so?

Building officials know that they, responsible for regulations that can dispense or withhold economic privaleges, are pursued ardently by their clientele. This suit (a "technology-push" on the building regulatory system) must be weighed against considerations of the public welfare with which the agency is entrusted (when the agency acts as a "society-pull" on the building regulatory system). This push and pull must also be weighed against the well-being of other segments of the clientele (who exert society-pull and technology-push from other directions). Moreover, there is a management clientele within the agency and motivations among individual officials themselves that affect the degree of skepticism or deference given the incoming messages. In the parlance of communications science, the regulatory officials must discriminate between "signal" and "noise" as they gather information on which to base a rational decision.

Credibility, as it is selectively extended to the several participants, is measured to a relative scale in Figure 2c and can be used to calibrate the volume and nature of client-agency communication.[12] Social psychologists report that, other things being equal, the higher the trustworthiness of an information source, the higher likelihood of its credibility and influence with the decision-maker seeking information. In a structure of formal authority, of course, the hierarchial place of the information source would likely to dictate its credibility and the deference paid to it, especially by those in subordinate positions.[13] But the present study deals with an informal system outside the formal structure of governmental authority. That informal system, however, is no less influential for its informality. The system is influential because it links the building department and its personnel with the local and national building community.

THE EFFECTS OF THE MODEL CODES ON THE AGENCY DECISION PROCESS

Building regulations are based on one of three sources: they may be adapted from any of the four advisory model codes; they may be based upon the regulations of a superior government, usually a State, but occasionally a county; or they may be drafted by the enforcing agency itself. Roughly three-fourths of all codes in use at the time of the ICMA survey were based on one of the model codes. Those jurisdictions basing their codes on the model codes were, in fact, enforcing regulations that were more technically current. Specifically, localities enforcing codes based on models prohibited fewer of the techniques comprising the index of technological currency described earlier; in contrast, jurisdictions enforcing locally-drafted regulations prohibited significantly more techniques.[14]

What is it about an association with a model code group that results in a more technically current code? How does affiliation with a model code association affect the code change decision process in the building agency? The ICMA survey revealed that the code modification process in agencies enforcing model code differs only slightly from the process used in agencies enforcing agency-based codes. This finding is clearly illustrated in Figure 3a through 3e whose horizontal bars depicting the extent of clientele and reference group participation in the code change decisions are similar to those found in Figure 2a through 2e with but one change: each bar in Figure 3a through 3e distinquishes among the bases of the regulations being acted upon: model code based regulations, state/county code-based regulations, or agency drafted regulations. From this analysis, there is hardly any difference in clientele participation, role by role, in agency code modernization decisions. Why, then, do agencies basing their codes upon the national models have more technically current codes?

To a certain extent, model code cities act with greater autonomy and more freedom from the partisans in their local clientele. This is demonstrated in Figure 3a, where building departments without recourse to the technical services of the model code organizations are shown to be much more reliant on local sources for new ideas. Local building material producers or supplier representatives, both with wholly respectable and legitimate but nevertheless highly partisan interests in one or another technique, completely dominate the origin of new ideas among departments enforcing a locally-written code. But the same figure shows that model code agencies are not immune from local influences either, and although they are less reliant than local code agencies on the necessarily partisan recommendations of the local suppliers, agencies enforcing model-based codes are twice as likely to pick up new ideas from their local sources as they are from the meeting of their own model code associations. But the departments affiliated with model code organizations have an important advantage over the locally-oriented agencies: they have access to a source of technical judgement that is relatively free of partisan leanings toward one or another technique. This is the critical difference.

This difference between the code change decision processes in the three types of jurisdictions is mapped in Figure 3a through 3e. The exception that matters is in the centrally important "trust" role: it is clear that in the absence of an alternative, the model code movement has drawn itself the role of impartial legitimizer of technological innovations. This essential role of autonomous authenticator of technical options has emerged under different auspices in different countries;[15] in the United States, this role has been assumed by the model code associations. Let us consider how this situation came about.

Both in Figure 3c and in Table 3 (the later is merely the rank order of the trustworthy sources by code type),[16] we see the difficulty under which most building departments--whether or not they subscribe to a model code--are forced to operate. Too small to specialize internally, attached to governments too small to develop the necessary independent evaluation of building products, the departments enforcing agency-written codes are forced to place greatest significance on the testimony of salesmen and vendors who are perceived as partisan advocates of one or another techniques. To offset this, the agencies seek autonomous, independent expertise. For the present, the expertise is the "stock in trade" of the model code groups, one of the "correlative services offered with the code," in the words of a respected model code official.[17] The phrase "for the present" is used advisedly, however, for the newly founded National Institute of Building Sciences (NIBS) has been authorized by Congress to pursue "correlative services" of its own.[18]

CONCLUSION

The findings in this study confirm some but undercut more of the widely held views about the nature of technological change in building construction and the social controls on that process operating through the building regulatory system. Regulations are continually altered to accommodate innovative technology and this work appears to be a cooperative effort of the regulators and the regulated. Affected groups in the building community--but rarely from the building-using public--come forward to supplement the meager technical resources of the agency at every step in the updating process: to nominate a candidate technique, to discuss its virtues and shortcomings, to support or resist its adoption into the regulations governing the building enterprise. This is a form and a forum of regulatory politics, but not the only one, for other arenas beckon for study: the decision process within the model code groups, for one. For the moment, though, recall that the obstructionist doctrine alleges that a conspiracy of entrenched, usually local building interests dominate the code modification process and that this is to blame for technologically somnolent industry. But, surely, this is a page from a sophist's textbook: invidious results deriving from insidious causes. For when the dynamics of this process are analyzed, conspiracies of local actors are found not in control of these deliberations. In the first place, agency officials are in control and are usually skeptical of zealous partisan advocacy in behalf of a favored building technique. To counter this stridency, officials discount a great deal of what they hear from partisans of one or another candidate techniques. These officials consult with each other, mainly with their professional peers through the programs of the model code associations. And they invest their greatest trust in those sources of technical information whom they consider to be impartial. In the second place, even when one or two actors are extraordinarily assertive, their views frequently do not prevail. Let me cite a specific case. Of the 14 items comprising the index of technological currency, the innovation that diffused with greatest speed during the 1960's was plastic pipe for use in drain, waste and vent systems. Plastic pipe gained in less than ten years a level of regulatory acceptance that took copper pipe over 40 years to achieve. Similarly, plastic pipe, while commercially available only a little over 10 years, had by 1970 achieved 80 percent of the regulatory acceptance won by non-metallic sheathed electrical cable, a material on the market since World War II. These data from the ICMA survey are illustrated in Figure 4. Plastic pipe achieved this rapid acceptance by regulatory agencies in the face of the most intense mobilization of resistance by industry and labor groups in the memory of most building officials at work today. Yet to many if not most observers of the building industry of the last ten years, the battle for acceptance of plastic pipe is usually cited as an example of the failure of regulations to remain current because of local industry pressure.[19]

The building regulatory system--through its networks of codes, standards and associated administrative apparatus--casts a pervasive and prevailing influence over the form and content of the built environment. Through this system, governments assert a form of social control over the rate and direction of change in building technology. Social choices among technical possibilities are made whenever regulations are amended to permit the use of innovative building techniques. These regulatory choices have economic and social ramifications for the building industry and for building owners and users. Consequently, these code decisions are contentious, closely attended, and likely influenced in some way by the parties benefitted or deprived thereby. One form this influence takes is the timely provision of technical information for the decision-makers' use. This paper has tried to shed some light on that process.

FOOTNOTES

1. The International City Management Association administered this survey in 1970 to the building departments of all U.S. municipalities over 10,000 population and a small sample of smaller cities and towns. About half of all departments questioned responded (in two related analyses, η = 930 and 1,241) and returns from each city size class above 10,000 were large enough to be representative. In sum, the generalizations in this paper are valid for cities over 10,000 but should be extended to places under 10,000 with caution.

2. A thorough discussion of clientism among agencies is found in Grant McConnel, Private Power and American Democracy (New York: Vintage, 1966) and in Ira Sharkansky, Public Administration: Policy Making in Government Agencies (Chicago, Markham, 1970). The importance of environmental monitoring and its particular relation innovation is analyzed in Paul R. Lawrence and Jay W. Lorsch, Organization and Environment: Managing Differentiation and Integration (Boston, Division of Research, Harvard Graduate School of Business Administration, 1967).

3. See, for instance, Colin Cherry, On Human Communication (Cambridge: MIT Press, 1957) and Ronald G. Havelock, et. al. Planning for Innovation (Ann Arbor: University of Michigan, Institute for Social Research, July 1969), especially Chapters 5 and 6.

4. This model is based on the literatures on the diffusion of technological innovation and on administrative decision making. Since documentation on the administration of the building regulatory function is confined to manuals of recommended practice, it was necessary to interview directly many building officials on these matters.

5. Elihu Katz, "The Two-Step Flow of Communication: An Up to Date Report on an "hypothesis, "Public Opinion Quarterly," Vol. 21, (Summer 1957), pp. 61-78. This landmark article established the importance of the "impersonal medium - personal contact" chain. This concept displaced the then-extant notion of media influencing mass behavior directly.

6. E. Rogers and F. Shoemaker, Communication of Innovation, (New York, Free Press, 1971), p. 256. Richard L. Meier and Karl Deutsch have also written on communication as an indicator of development.

7. Ibid., p. 277.

8. See Figure 1.

9. Charles G. Field and Francis T. Ventre, "Local Regulation of Building: Agencies, Codes, Politics," 1971 Municipal Year Book (Washington, ICMA, 1971), pp. 139-165.

10. Thomas J. Allen and Stephen I. Cohen, "Information Flow in Research and Development Laboratories," Administrative Science Quarterly, Vol., 14, No. 1, (March, 1969), p. 16. Allen and Cohen cite several authorities for this, notably, H. H. Kelley.

11. If they were, their Spearman Rank Order Correlation coefficients would approach R = -1.0. As it is, the coefficient of rank-order correlation between the "support" and "resist" rosters in R = -0.26 and is statistically unsignificant.

12. An adjustment for each actor on any innovation might be stated symbolically as:

$$PI_{ij} = fT_{ij}(O_{ij} + D_{ij})(S_{ij} - R_{ij}), \text{ where}$$

PI = potential influence;

T = poust index;

O = index of original sponsorhip of innovation;

D = index of discussion activity;

S = index of supporting activity;

R = index of resisting activity;

i = actor;

j = specific innovation.

O and D are comulative properties but S and R are complementary; the cumulation of the latter yeilds are an algebraic sign that is associative and is distributed across all terms in the expression making a vector of a scalar.

13. A book-length treatment of this subject is: Harold L. Wilensky, Organizational Intelligence: Knowledge and Policy in Government and Industry (New York, Basic Books, 1967).

14. Field and Ventre, op. cit.

15. Methods and institutions for the evaluation cf building technqiues by national organizations in South Africa, the United Kingdom, France, the Netherlands, Austria, Belgium, Spain, Italy, Portugal, Japan, and Denmark are described in a set of papers in Performance Concept in Buildings, proceedings of a joint RILEM-ASTM-CIB Symposium, Vol. 1, invited papers. Issued as National Bureau of Standards Special Publication 361, Volume 1. The papers are found at pp. 491-534.

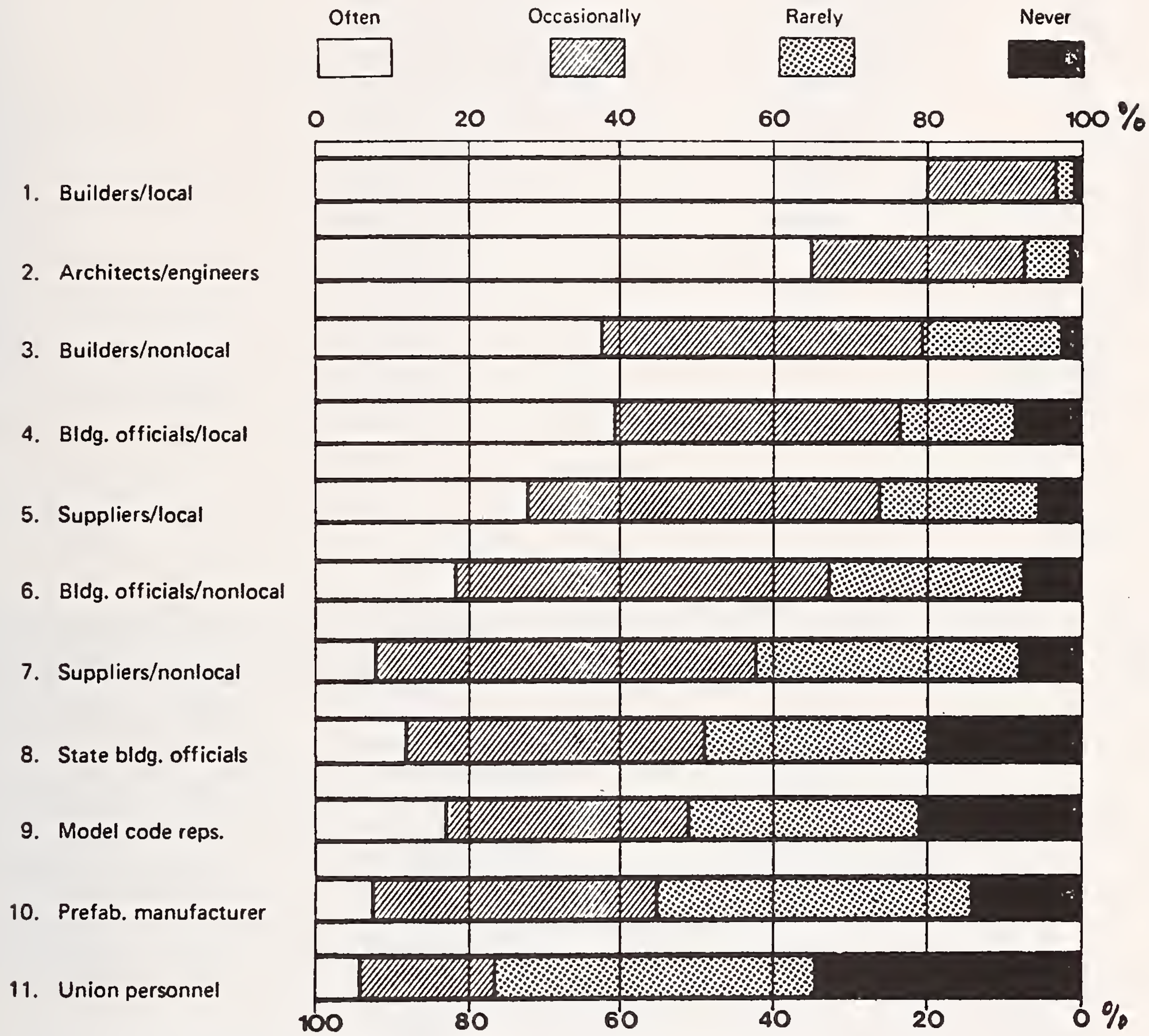
16. The rosters of actors participating in code modification decisions in model and in non-model code agencies are highly rank-order correlated, role by role. The largest discrepancy occurs on the "trust" question. The Spearman R's: Originate, 0.93; Discuss, 0.92; Trust, 0.85; Support, 0.91; Resist, 0.88.

17. Paul E. Baseler, "Revision and Administration of the Building Code," Management Information Service, Report No. 208 (May, 1061), ICMA, p. 44. Italics in the Original.

18. The Institute was established by Title VIII of the Housing and Community Development Act of 1974, Public Law 93-383.

19. The "Battle of Plastic Pipe" is documented in Francis T. Ventre Social Control of Technological Innovation: The Regulation of Building Construction, unpublished doctoral dissertation, Massachusetts Institute of Technology, June, 1973, Chapter 6.

Figure 1: FREQUENCY OF BUSINESS CONTRACT WITH LOCAL BUILDING DEPARTMENT

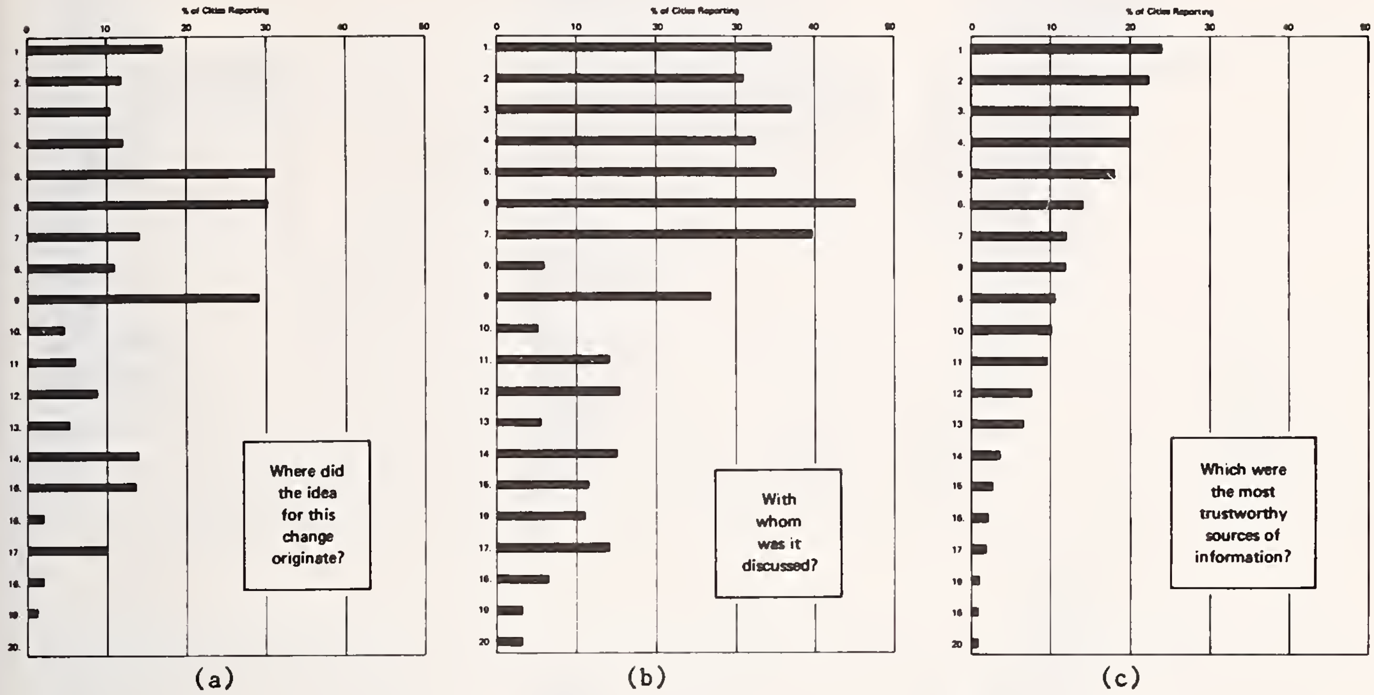


1. Builder personnel: local. 2. Architects or engineers. 3. Builder personnel: out-of-town. 4. Building officials from cities: within your county. 5. Building material producers and suppliers personnel: local. 6. Building officials from cities: outside your county. 7. Building material producers and suppliers personnel: out-of-town. 8. Building official from state building agency. 9. Representative of a model code group. 10. Prefabricated home manufacturer or his representative. 11. Building trade union personnel.

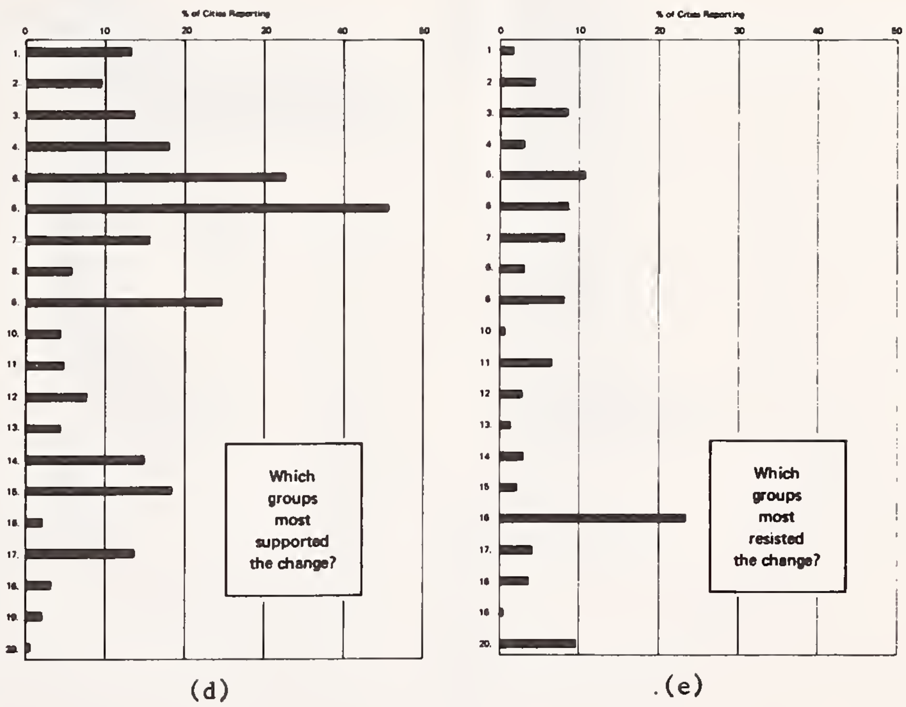
TABLE 1 CLASSIFICATION OF ELEMENTS OF THE INDEX OF TECHNOLOGICAL CURRENCY

Identi-fication Number	CODE CHANGES	SYMBOL	TYPE OF CHANGE: MATERIAL SUBSTITUTION	MATERIAL ELIMINATION	METHOD	DESIGN
1.	Nonmetallic Sheathed electrical cable	NMTCBL	X			
2.	Prefabricated metal chimneys	MTLCHM	X		X	
3.	Off-site preassembled combination drain, waste, and vent plumbing system for bathroom installation	PLMTRE			X	
4.	Off-site preassembled electrical wiring harness for installation at electrical entrance to dwelling	WRHRNS			X	
5.	Wood roof trusses, placed 24" on center	WDTRUS			X	X
6.	Cooper pipe in drain, waste. and vent plumbing systems	COPDRN	X			
7.	ABS (acrylonitrile-butadiene-styrene) or PVC (polyvinyl-chloride) plastic pipe in drain, waste, and vent plumbing systems	PLADRN	X			
8.	Bathrooms or toilet facilities equipped with ducts for natural or mechanical ventilation, in lieu of operable windows (or skylights)	BTHDCT	X			X
9.	Party walls without continuous air space	PRTYWL				X
10.	Use of single top and bottom plates in non-loading vearing interior partitions	SNGLPL		X		X
11.	Use of 2" x 3" studs in non-loading bearing interior partitions	2X3STD		X		X
12.	Placement of 2" x 4" studs 24" on center in non-load-bearing interior partitions	2X4STD		X		X
13.	In wood frame construction, sheathing at least ½ inch thick, in lieu of corner bracing	WDSHTH		X		X
14.	Wood frame exterior walls in multi-family structures of three stories or less	WDFRMF	X			X

Figure 2: PARTICIPATION IN COLLECTIVE DECISION MAKING IN THE LOCAL BUILDING DEPARTMENT, BY ACTOR AND BY ROLE.



1. Meetings of professional associations. 2. Building officials from cities outside county. 3. Building officials from cities within county. 4. Architects or engineers. 5. Building material producers or supplier representatives: local. 6. Builder representatives: local. 7. Building department staff. 8. Trade or professional magazines. 9. Building material producers or supplier representatives: out-of-town. 10. Government publications. 11. Other sources. 12. Meetings or conventions of materials producers. 13. Building product catalogs. 14. Yourself. 15. Prefabricated home manufacturer representatives. 16. Union representatives: local. 17. Builder representatives: out-of-town. 18. Civic or voter groups. 19. Mass media (TV, magazines, newspapers). 20. Union representatives: out-of-town.



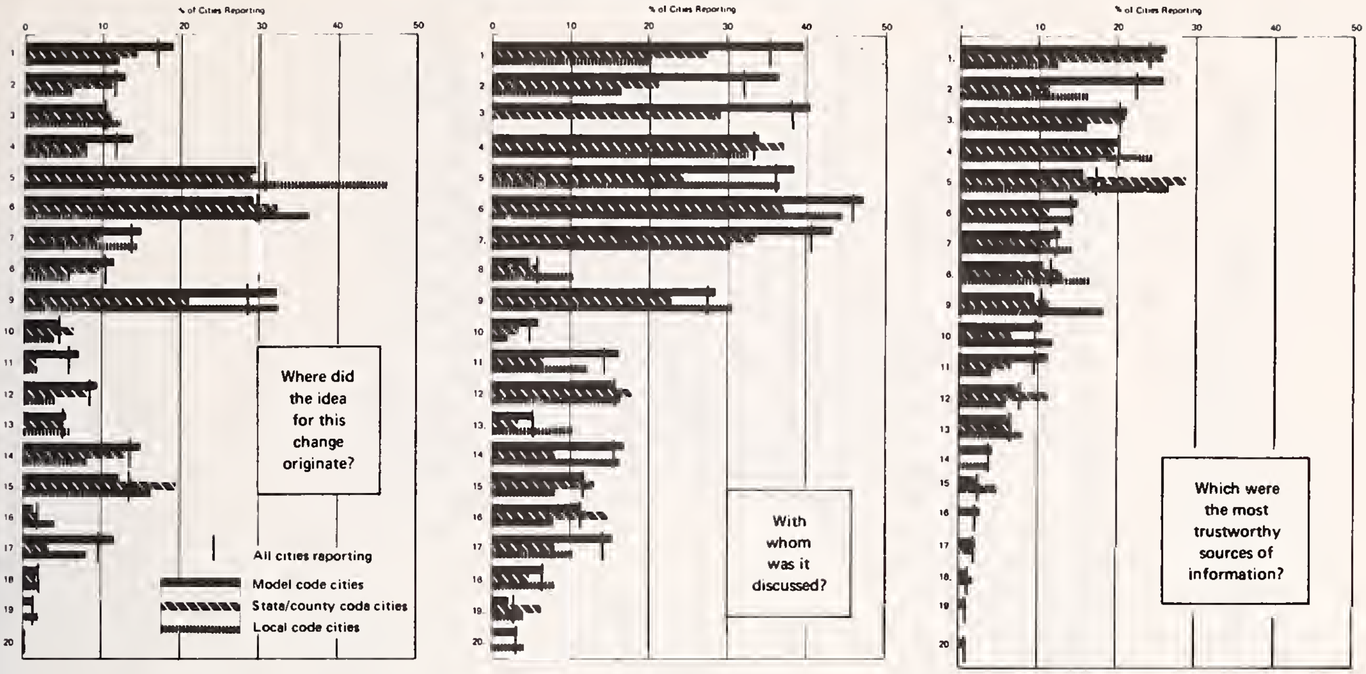
For the most difficult code item adoption: (a) where did the idea for this change originate? (b) with whom was it discussed? (c) which were the most trustworthy sources of information? (d) which groups most supported the change? (e) which groups most resisted the change?

Table 2

Concordance Between Rank-Ordered Rosters of Actors Prominent in Local Building Department Decisions on Innovative Technology

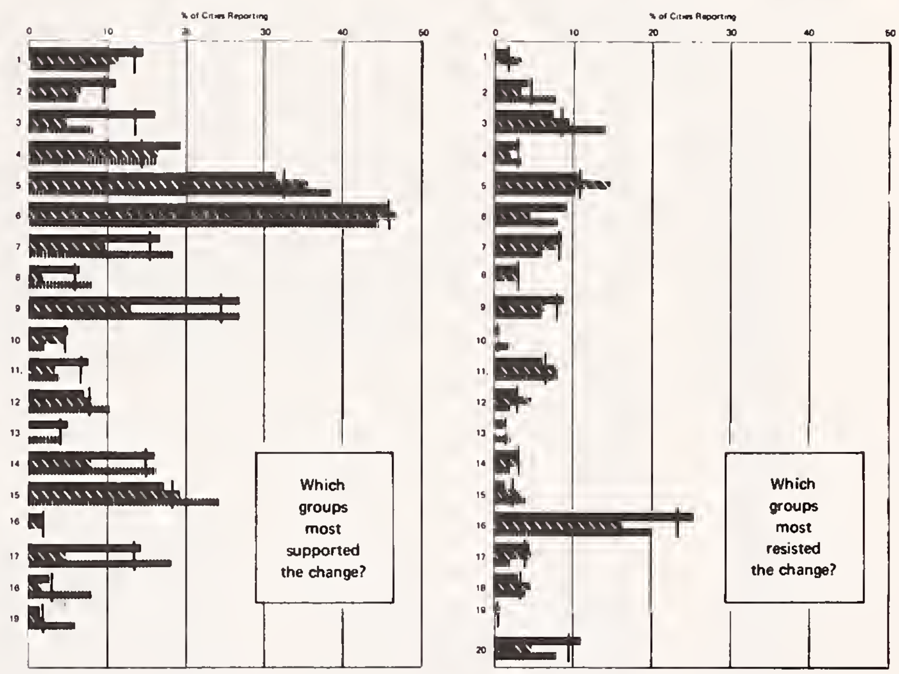
	Rosters Compared	Spearman's R	Student's t	Statistical Significance p
1)	Trust vs. Originate	0.68	3.93	0.005%
2)	Trust vs. Discuss	0.79	5.46	0.005%
3)	Trust vs. Support	0.53	2.65	0.01 p 0.005%
4)	Trust vs. Resist	0.12	0.51	25 p 40%
5)	Support vs. Resist	0.26	1.15	10 p 25%
6)	Originate vs. Support	0.93	4.19	0.0005%
7)	Originate vs. Resist	0.28	1.17	10 p 25%
8)	Support (with union representatives suppressed) vs. Resist (with union representatives suppressed)	0.74	3.64	0.005 p 0.0005%

Figure 3: PARTICIPATION IN COLLECTIVE DECISION MAKING IN THE LOCAL BUILDING DEPARTMENT, BY ACTOR AND BY ROLE, CONTROLLING FOR TYPE OF LOCAL CODE IN FORCE



(a) (b) (c)

1. Meetings of professional associations.
2. Building officials from cities outside county.
3. Building officials from cities within county.
4. Architects or engineers. 5. Building material producers or supplier representatives: local.
6. Builder representatives: local. 7. Building department staff. 8. Trade or professional magazines. 9. Building material producers or supplier representatives: out-of-town. 10. Government publications. 11. Other sources. 12. Meetings or conventions of materials producers.
13. Building product catalogs. 14. Yourself.
15. Prefabricated home manufacturer representatives. 16. Union representatives: local.
17. Builder representatives: out-of-town.
18. Civic or voter groups. 19. Mass media (TV, magazines, newspapers). 20. Union representatives: out-of-town.



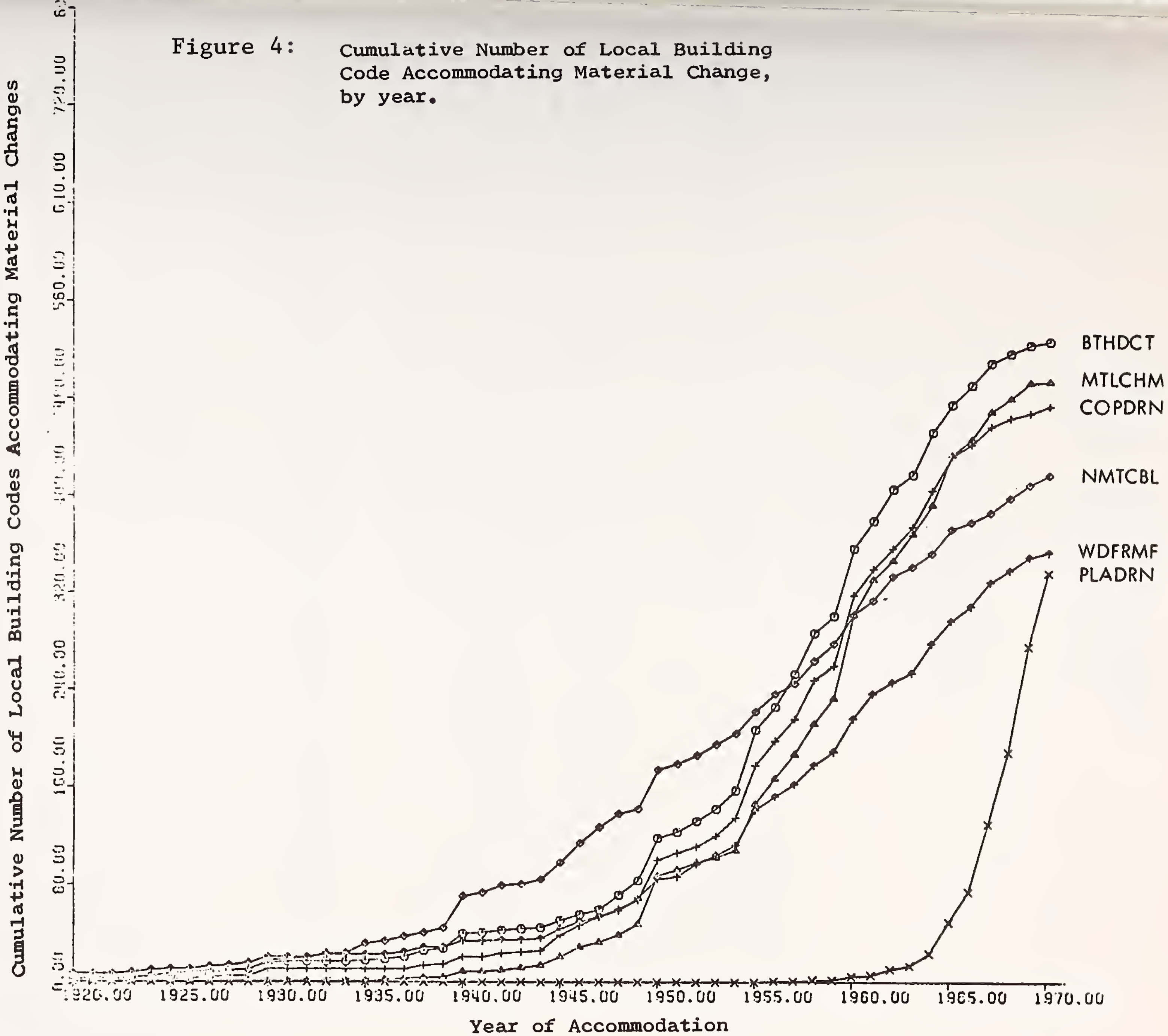
(d) (e).

For the most difficult code item adoption with responses disaggregated by code type: (a) where did the idea for this change originate? (b) with whom was it discussed? (c) which were the most trustworthy sources of information? (d) which groups most supported the change? (e) which groups most resisted the change?

TABLE 3: LOCAL BUILDING OFFICIALS' RANKING OF MOST TRUSTED SORUCE OF INFORMATION ON MOST DIFFICULT CODE ITEM ADOPTION DECISION, BY TYPE OF CODE

Model code	State/county	Local code
1 Meetings of professional associations	1 Local building material producer or supplier representative	1 Local building material producer or supplier representative
2 Building officials from distant cities	2 Meetings of professional associations	2 Architects or engineers
3 Building officials from nearby cities	3 Building officials from nearby cities	3 Out-of-town building material producer or supplier representative
4 Architects or engineers	4 Architects or engineers	4 Trade or professional magazines or journals
5 Local building material producer or supplier representative	5 Trade of professional magazines or journals	4 Building officials from nearby cities
6 Local builder representative	6 Building department staff	4 Building officials from distant cities
7 Building department staff	6 Meetings or conventions of building materials producers	7 Building department staff
8 Other unspecified sources	6 Building officials from distant cities	7 Local builder representative
9 Government publications	6 Local builder representatives	9 Meetings of professional associations
9 Trade or professional magazines or journals	6 Out-of-town building material producer or supplier representative	9 Government publications
11 Out-of-town building material producer or supplier representative	11 Government publications	11 Building product catalogs or brochures
12 Meetings or conventions of building materials producers	11 Building product catalogs or brochures	12 Meetings or conventions of building materials producers
13 Building product catalogs or brochures	11 Other unspecified sources	13 Yourself
14 Yourself	14 Prefabricated home manufacturer representatives	13 Unspecified other sources
15 Local building trades union representative	15 Out-of-town builder representatives	15 Local building trades union representative
16 Prefabricated home manufacturer representative	15 Civic or voter groups	15 Out-of-town building trades union representative
16 Out-of-town builder representative	17 Yourself	15 Prefabricated home manufacturer representative
18 Mass media	17 Local building trades union representative	15 Out-of-town builder representative
18 Civic or voter groups	17 Out-of-town building trades union representative	20 Mass media
18 Out-of-town building trades union representative	20 Mass media	

Figure 4: Cumulative Number of Local Building Code Accommodating Material Change, by year.



OREGON'S EXPERIENCE IN STATEWIDE
CODE UNIFORMITY--THIRD YEAR

by

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This paper has its genesis in an article written in mid-1974 and appearing in the Building Standards magazine of November-December, 1975. The information has been up-dated with the latest Oregon experiences. Prior to 1971, Oregon had four independent agencies enforcing building regulations, with all of the related problems of code conflicts, duplication and nonuniformity of interpretation. In 1971, all of these functions were transferred to the Department of Commerce. New responsibilities were added in 1973, including a law setting statewide code uniformity, state-local government relations, personnel training and certification, adoption of model codes, appeals, statistical reporting, and energy conservation. Model codes have been adopted for all specialty codes. Some of the model codes are almost "pure"; others have significant amendments. A struggle is now under way between advocates of pure model codes and those who have amended it, over the number and quality of amendments.

Key Words: Building regulation; code administration; enforcement; funding; local government; model codes; state-local relations; statewide codes; uniformity.

INTRODUCTION

This paper has its genesis in an article written in mid-1974 and appearing in the Building Standards magazine of November-December, 1975. This work was published under former Oregon Building Codes Administrator, Harry L. Baker's name. Mr. Baker is now deceased. The information has been up-dated with the latest Oregon experiences by Walter M. Friday, P.E., Chief Structural Codes Engineer, who did much of the research and preparation on the original Building Standards article.

Oregon has been recognized for its leadership and performance in a number of areas, including: environmental protection, the Bottle Bill, fire reporting system, interstate highway system, land use planning, and (most recently) energy policy. While these issues were in the spotlight, a quieter revolution was underway in building regulation.

HISTORY

Prior to 1971 the State of Oregon had electrical, boiler, elevator and mobile home codes, with inspection and permit systems. There was also a state plumbing code with a small staff which assisted local government, but with no permit or inspection service. The State Fire Marshal had adopted portions of the Uniform Building Code as the Fire and Life Safety Code and was reviewing plans under these regulations.

Most large cities had codes for construction, and a few had adopted mechanical codes. At the state level, several of the system codes, which we now call specialty codes, were enforced by different arms of state government: plumbing by the Health Department; electrical, boiler and elevator by the Bureau of Labor; fire and exiting requirements by the State Fire Marshal. Some local governments regulated the structural and mechanical systems. Through this piecemeal approach, some duplication occurred; goals were different, and there was no continuity of policy. The state codes were minimum, and local government was allowed to increase standards at will. Since there were no state structural or mechanical codes, cities and counties usually adopted the Uniform Building Code, but amended it either up or down at their discretion. Except for the largest cities, there was little regulation of mechanical systems. Fifty-three different variations of the Uniform Building Code were alleged in the Portland metropolitan area, and sixteen counties and many small cities had no codes.

Legislation was introduced in 1971 proposing a unified code program. The bill was not adopted, but existing state code-enforcing bodies were brought together in the Department of Commerce in two divisions, the Fire Marshal's office and the Safety Division. The Safety Division included the electrical, plumbing, boiler and elevator functions.

In the 1973 legislature the effort for a statewide building code was renewed and subsequently passed by a vote of 84 to 6. Key concepts (see Figure 1) included in this legislation are a statewide uniformity; adoption of model codes; state building code composed of specialty codes, i.e., structural, mechanical, electrical, plumbing, boiler, elevator; local enforcement, entire state covered by a crazy-quilt fabric of enforcement; certification of building inspectors and officials by July 1, 1977; a training program financed by a 1 percent surcharge on all building permits; structural and mechanical codes enabled, including an ambitious time schedule to implement them; a study program for identifying and resolving conflicts with existing statutes and administrative rules and statistical records systems. Another bill provided for a plumbing permit fee and inspection system. Comparisons of organization charts of 1971, 1972, 1973, 1976 and 1977 (possible) are shown in Figures 2A, 2B, 2C, 2D, and 2E. Figure 3 shows manpower changes.

The 1975 legislature tinkered with the structural/mechanical program by:

--exempting agricultural buildings on farms (previously done by administrative rule),

--exempting moved dwellings from complying with new construction requirements,

--reducing penalties from a class "B" misdemeanor to a violation to permit enforcement through municipal courts,

--set fees for mechanical permits, and

--2% surcharge on permits to support statutory functions at state level.

With this background, we will now explore:

1. The concept of code uniformity.
2. Local administration.
3. Certification and training.
4. Program financing.

CODE UNIFORMITY

The Oregon State building code is composed of the combined specialty codes as shown in Figure 4. The segments labeled Mobile Home Parks and Mobile Home Set-ups are outside the circle because they are not defined as parts of the state building code, though enforced by the Building Codes Division.

Figure 5 shows the status of adoption of model codes. Note all codes are based on the nationally recognized model codes. The looseleaf edition of the Uniform Building Code is used, and the Uniform Mechanical Code and Uniform Plumbing Codes are made looseleaf by shearing the back binding and punching holes for use in ring binders.

Amended pages to the UBC, UPC, and UMC are printed on yellow paper and cut and punched to fit the looseleaf model codes. Yellow pages are to alert users that "some" deviation from the model exists on that page. The goal is to eliminate yellow pages over the comming years by submitting the code amendments to ICBO and IAPMO, or by reevaluation.

Amendments to the Uniform Building Code deal with statutes, administration, definitions, deletions of chapters on grading and excavation, elevator and boiler regulation covered by existing law, inclusion of fire and life safety provisions, addition of a chapter on energy conservation, and expansion of the chapter on prefabricated construction. Another 13 pages are snowload graphs for each Oregon county. The result is 100 yellow pages of changes in the 700 pages in the Uniform Building Code. Many of these pages are pure UBC with the exception of one or two sentences.

The Oregon State building code has been referred to as a "minimum-maximum" code. In other words, not only does the code establish minimum standards for local government, it also sets the maximum limits they may impose. This concept has been tested in court and is now pending on appeal. This case revolves around the adoption by the City of Troutdale (pop. 2400) of a double wall construction ordinance. Builders' testimony at this trial indicated that there were significant savings due to code uniformity. There is a provision that a city or county with a unique condition may request State sanction of a local amendment. Several of these amendments have been proposed to the structural code, and the ten-man policy board which reviews them has sent most of these requests back to the communities for justification. The statute also allows such amendments to be effective statewide.

Proposals pending include a chapter on security to make new structures less vulnerable to burglary and a refined insulation and energy requirement related to ASHRAE 90-75.

LOCAL ADMINISTRATION

All of the State is under the state building code; however, the code may be administered by city, county or state. Under this system a city may administer the state building code; if it elects not to do so, and a surrounding county has elected to enforce the code, the county enforces within the nonparticipating cities. If both the city and county elect not to enforce the code, the State assumes the obligation.

By May 1 of each year, each city and county must report its option on enforcing the state codes to become effective the next July 1. Theoretically, under this system the responsibility could shift each year, but practically it has stabilized with only small changes each year.

Twenty-four counties (67 percent) of 36 in the State administer the Structural and Mechanical Specialty Codes. Two counties are having the state do the larger structures, and they are inspecting one- and two-family dwellings; and 10 counties (28 percent) are leaving enforcement to the state. Of 240 incorporated cities in the State, 121 (50.4 percent) have their own programs; 79 (39.9 percent) are administered by another city or county. The remaining 40 cities (16.7 percent) are enforced by the state without a contract. Figure 9 shows distribution of enforcement option by city size and how they have changed in the last two years. The small cities are discontinuing enforcement and leaving it to the surrounding county or are contracting with adjacent cities. This number will likely surge higher when certification is required. Figures 6 and 7 show Oregon county names and geographic distribution of who is enforcing the specialty codes in each county.

The bar graphs in Figure 7 show that most of the state's population is regulated under the structural/mechanical code by local government, while a significant portion of the area of the state is controlled by the State Building Codes Division. The maps show the changes which have occurred in structural/mechanical enforcement responsibility in three years.

Figure 8 shows the counties ranked by total population and population per square mile in descending order. Counties administered by the state are indicated by an asterisk. Those counties with shared local and state responsibility are shown with a plus (+) sign. Note that counties served by the state are those with small total population and persons per square mile. Sparsely populated areas have chosen state regulation rather than establishing their own programs. Due to the small population and large travel distances, code administration in the Eastern Oregon counties is much more expensive than more populated western counties. This situation will test the mettle of state staff to provide effective inspection service at a reasonable cost.

CERTIFICATION AND TRAINING

The statute requires certification of all Building Officials by July 1, 1977. A method of certification has now been determined. This issue was one of the most difficult to resolve. Interest groups include code enforcement personnel, builders, local governments, engineers and architects. A lawsuit may yet be filed by engineers to require structural plans review by registered engineers. The three ICBO chapters in the State of Oregon have recommended the adoption of ICBO certification examinations, but the statute dictates a local examination.

Many Oregon inspectors are participating in the ICBO certification examination, anyway. Figures show Oregon inspectors have a 58.5 percent passing rate, compared to 43.8 percent for the rest of the participants, excluding the Oregonians. We suspect this 15 percent higher passing rate shows intense motivation due to pending Oregon certification.

Related to certification is a 1 percent surcharge on all structural, mechanical, electrical and plumbing permits issued in the State of Oregon. In other words, a $10 permit would actually cost $10.10. The additional 1 percent fee is remitted to the state by local governments and placed in a fund to support development of training programs. Classes have been arranged through the state's community colleges to train building inspectors and building officials. Due to certification, we believe many small communities will discontinue their single-man or part-time building inspector and contract with or turn inspections over to the larger agencies.

In the short time the state building code has been in effect, there has been an increase in the salaries paid to building inspectors. It is not clear whether this is a supply-and-demand phenomenon caused by counties and the state bidding for employees, or is recognition by local governments of the value of their trained employees.

PROGRAM FINANCING

The state program is funded from revenue only. No general fund monies support is provided. Sources of funds are:

Specialty code permits: Structural, Plumbing, Electrical, Mechanical*,
Boiler, Mobile Home Parks

Plans Review: Fire and Life Safety only
Full review

Licensing: Plumbers, Electricians, Mobile Home Parks, Elevators,
Boilers, publications

Surcharges on all permits issued in state:

A.	Administrative*	2%
B.	Education	1%
	Total	3%

Fees marked by the asterisk (*) were imposed by 1975 legislature to increase revenue. Some propose higher surcharges to offset red ink in the structural, mechanical, and plumbing programs caused by increased costs assigned for transportation and office space related to high fuel cost and inflation.

FUTURE

Due to program cost and certification standards, we foresee that the number of jurisdictions administering building codes will decrease in Oregon. The remaining entities will be financially stronger. There will be fewer building department personnel, but better qualified, full-time employees in western Oregon. Most cities over 5000 population will continue code programs. The county becomes key code agency for small cities in the western third of the State. The State of Oregon will be the prime administrator of codes in the sparsely populated eastern two-thirds of the State.

KEY CONCEPTS OF OREGON BUILDING REGULATION SYSTEM

Concept	Remarks
Unity of Supervision	All codes related to building construction under one agency Establish basic goals Unit policy Remove conflicts
Uniform Model Codes statewide Minimum-Maximum	 Local government may not raise or lower standards without cause
Entire state covered by regulation Local Administration City First option County Second option State regulates what is left, i.e., unregulated counties and unregulated cities within those counties	 Retained Including unregulated cities within its boundaries
Education Program 1 percent surcharge on permits	 For training, development and coordination. Goal is uniformity of interpretation and the protection of the public
Certification	Building officials, inspectors, and plans examiners by July 1, 1977
Appeals process to the state level	
Statistical Reporting System	To collect building information
Energy Conservation	Thermal insulation now only for residential occupancies

FIGURE 1

ABRIDGED ORGANIZATION CHARTS SHOWING
UNIFICATION OF BUILDING REGULATION IN THE STATE OF OREGON

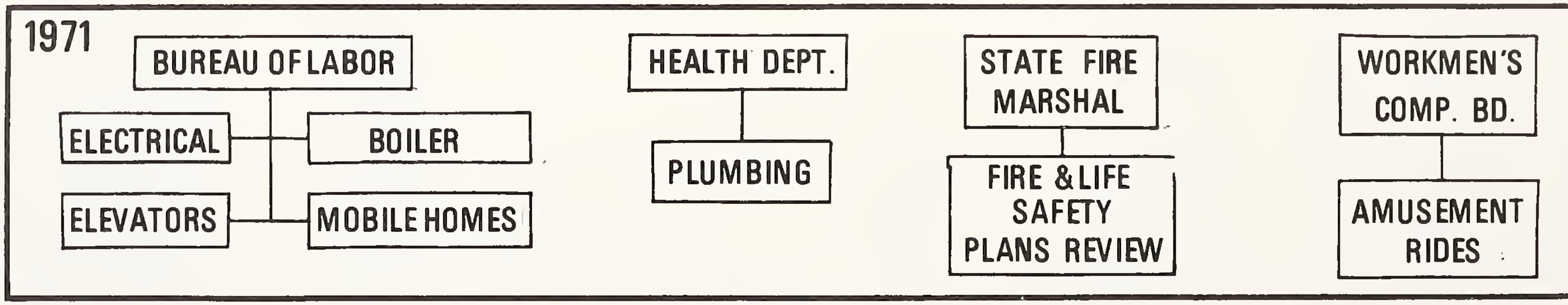


FIGURE 2A

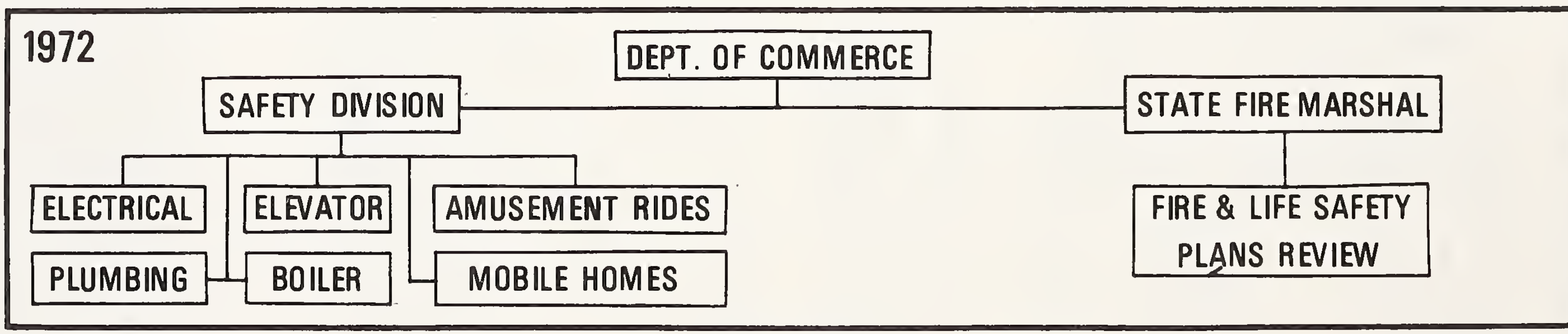


FIGURE 2B

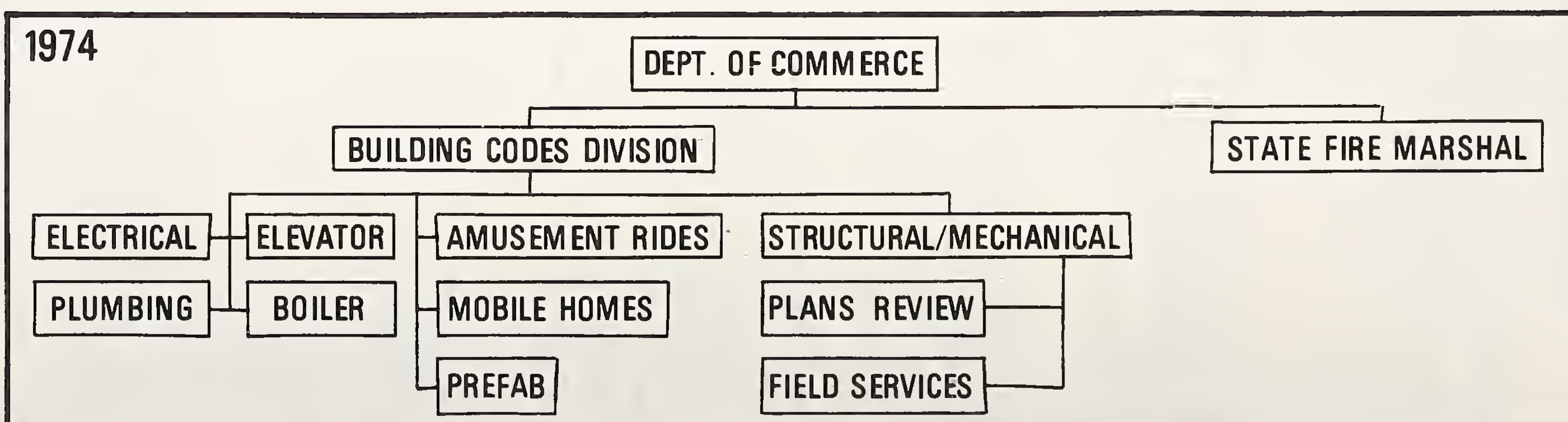


FIGURE 2C

ABRIDGED ORGANIZATION CHARTS SHOWING
UNIFICATION OF BUILDING REGULATION IN THE STATE OF OREGON CONT...

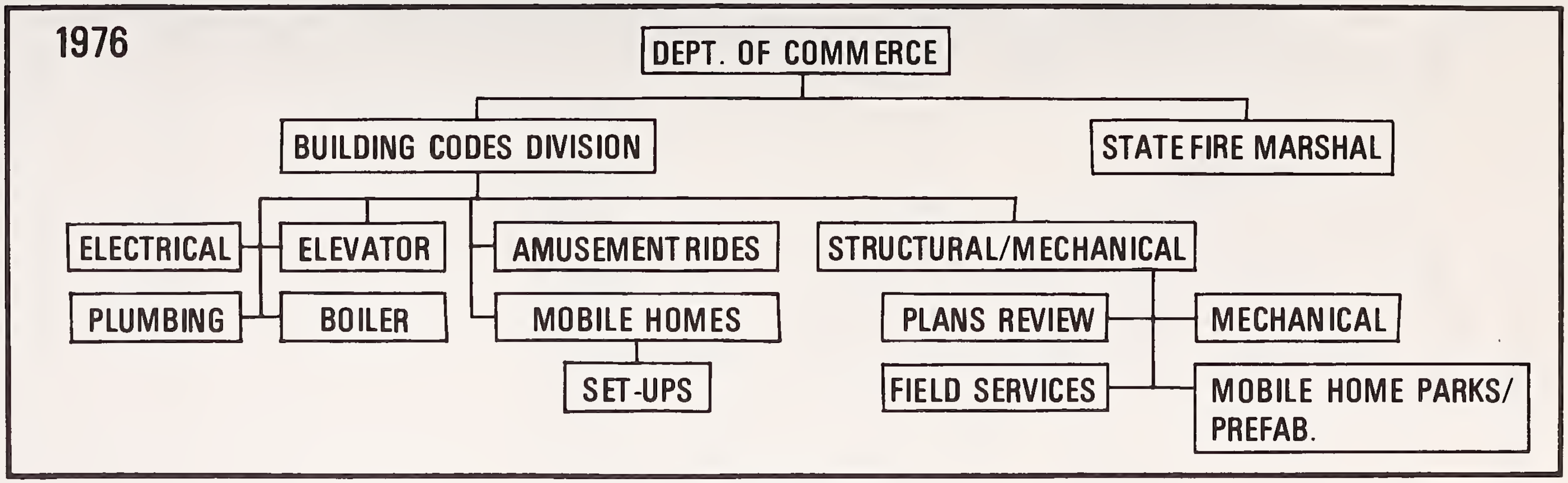


FIGURE 2D

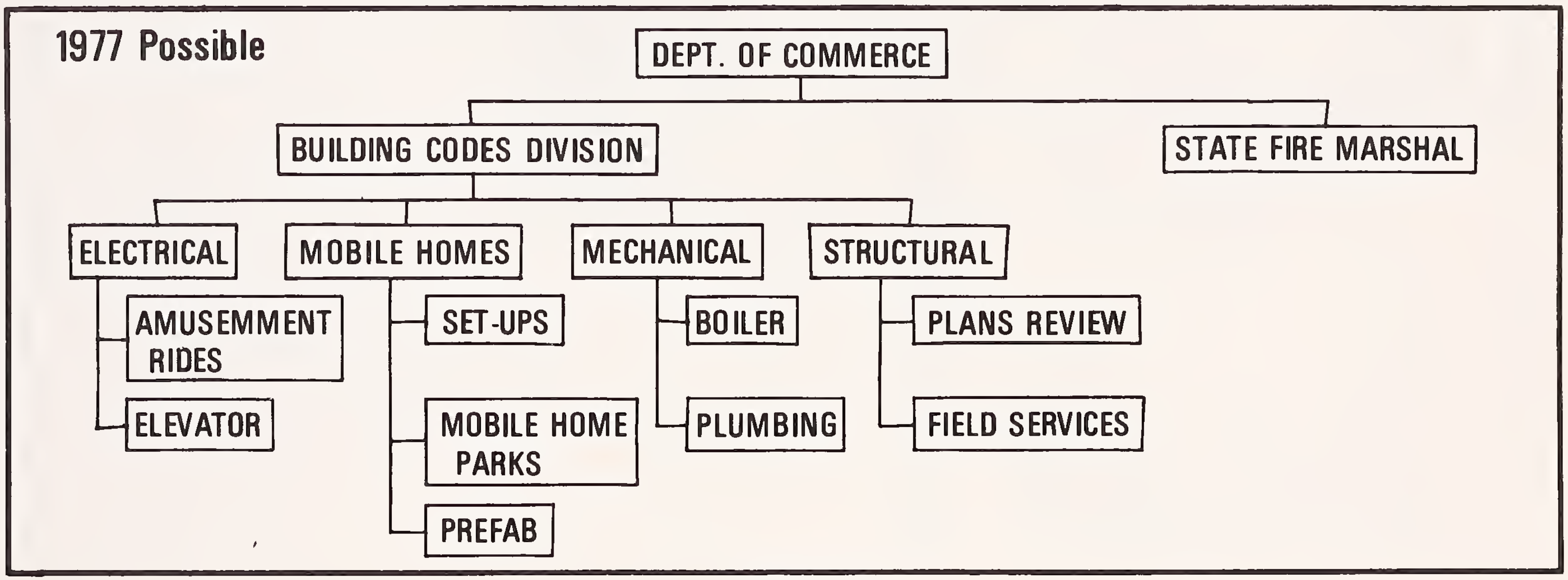


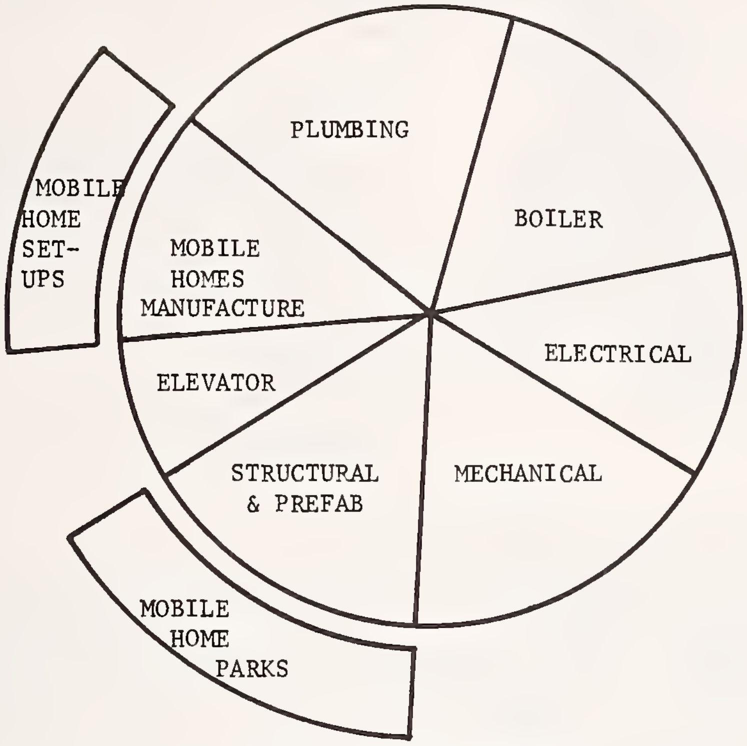
FIGURE 2E

AUTHORIZED STAFFING LEVELS

Section	1974 Auth	1974 Empl'd	1975 Auth	1975 Empl'd	1976 Auth	1976 Empl'd
Administrative	4	4	15	12	15	15
Electrical	37	33	39	33	39	34
Plumbing	23	14	21	14	21	14
Struc/Mech	65	23	39	27	39	30
Mobile Homes	13	13	17	13	16	15
Boiler	17	15	20	18	20	19
Elevator	6	6	7	7	7	7
Amusement Rides	*	*	*	*	*	*
Certification	—	—	2	1.5	2	2
Totals	165	108	160	125.5	159	136

*Electrical staff administers this program.

FIGURE 3



TOTAL BUILDING CODE
MADE UP OF SPECIALTY CODES

FIGURE 4

The Oregon Building Code is composed of components called specialty codes. The segments outside the circle show codes enforced by the Division, but not part of the "building code".

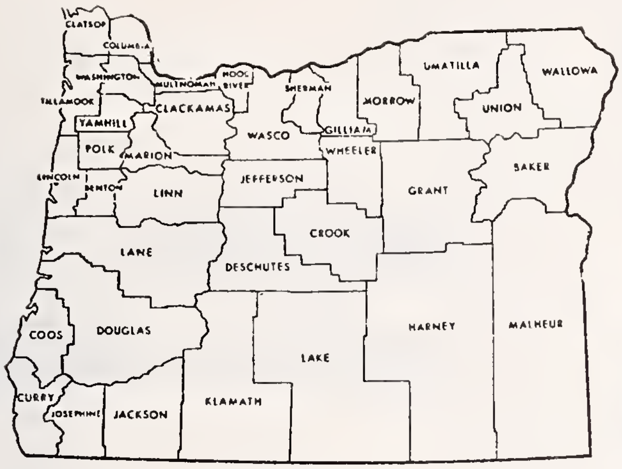
MODEL CODES ADOPTED
WITH AMENDMENTS

Specialty Code	Model Code
Boiler	ASME & Pressure Vessel Code 1974
Electrical	NEC 1975
Elevator	ANSI A 17-1 1971
Mechanical	UMC 1973**
Plumbing	UPC 1973**
Structural & Fire & Life Safety*	UBC 1973**
Mobile Homes	HUD Standards

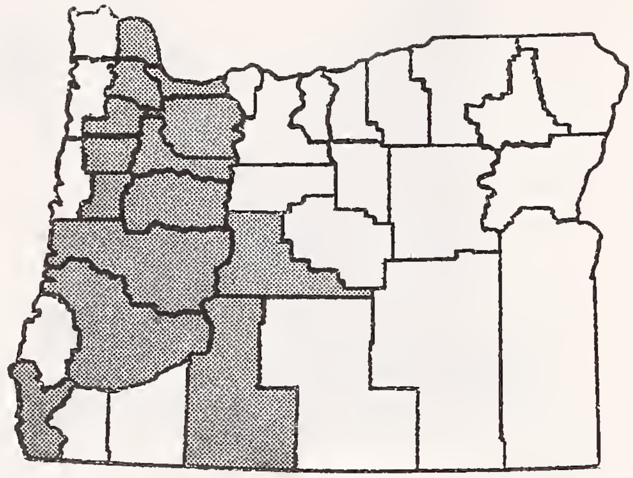
*State Fire Marshal simultaneously adopts portions.

**1976 edition in process of adoption.

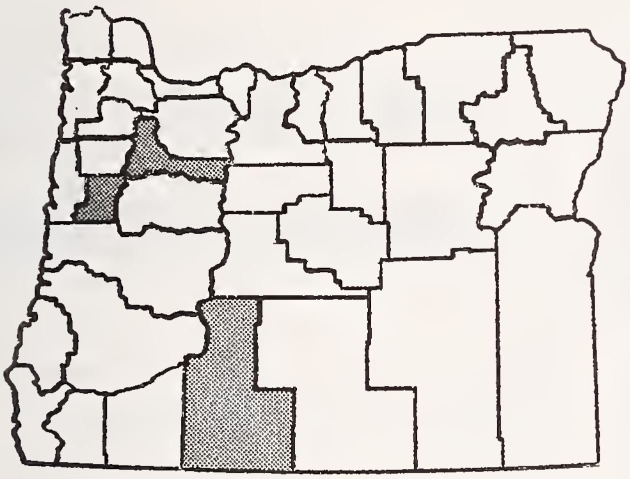
FIGURE 5



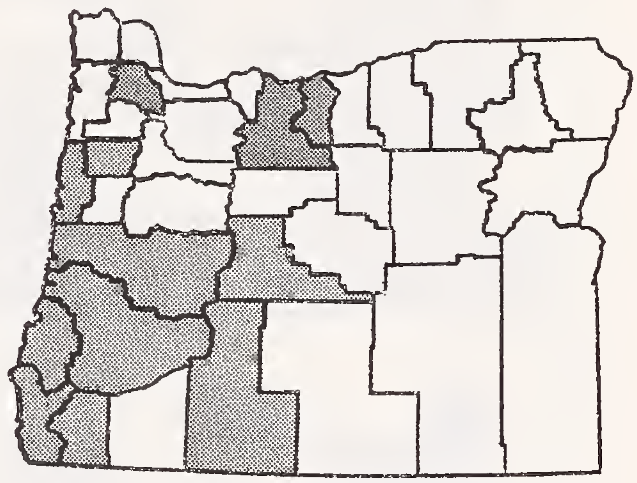
County Names



Plumbing Code



Electrical Code



Mobile Home Parks

Boiler Code, Elevator Code, and Amusement Rides are statewide, state-administered programs.

Legend:
Local Administration
State Administration

FIGURE 6

STRUCTURAL/MECHANICAL CODE ENFORCEMENT

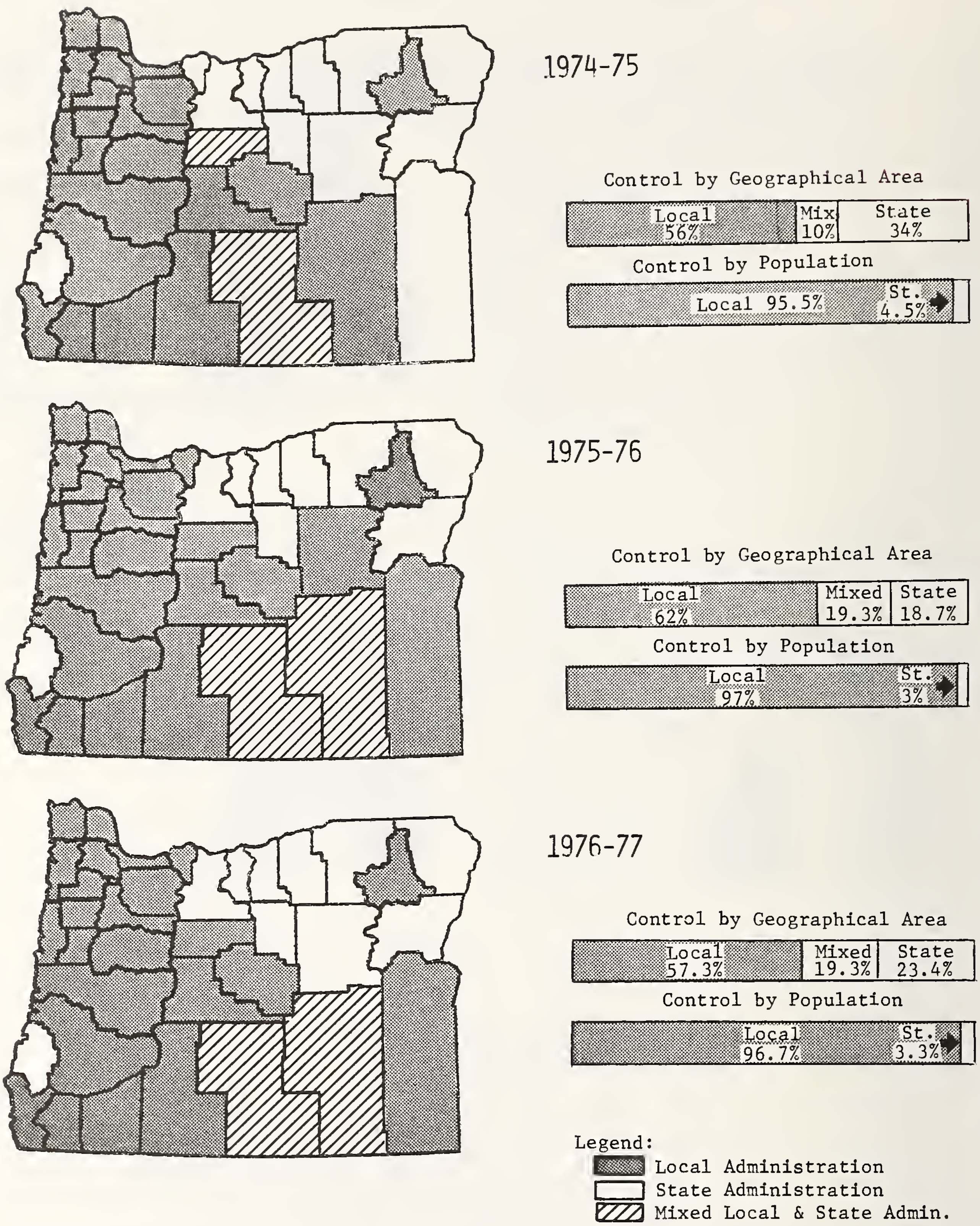


FIGURE 7

OREGON COUNTIES RANKED BY
POPULATION AND
PERSONS PER SQUARE MILE

Based on 1974 Oregon Blue Book statistics

Rank	County	Population	Rank	County	Pop/Sq. Mile
1.	Multnomah	544,900	1.	Multnomah	1192.34
2.	Lane	237,000	2.	Washington	259.45
3.	Clackamas	196,900	3.	Marion	140.34
4.	Washington	189,400	4.	Clackamas	104.01
5.	Marion	164,900	5.	Benton	95.06
6.	Jackson	108,100	6.	Yamhill	61.62
7.	Linn	79,900	7.	Polk	59.12
8.	Douglas	78,500	8.	Lane	51.41
9.	Benton	63,500	9.	Columbia	46.09
*10.	Coos	59,070	10.	Jackson	38.32
11.	Klamath	53,400	*11.	Coos	36.31
12.	Umatilla	47,250	12.	Linn	34.78
13.	Josephine	45,100	13.	Clatsop	31.55
14.	Yamhill	44,000	14.	Josephine	27.75
15.	Polk	40,050	15.	Lincoln	27.35
16.	Deschutes	39,890	16.	Hood River	25.75
17.	Columbia	31,160	17.	Tillamook	16.20
18.	Clatsop	29,060	18.	Douglas	15.43
19.	Lincoln	27,300	*19.	Umatilla	14.58
20.	Malheur	24,100	20.	Deschutes	13.04
21.	Union	21,800	21.	Union	10.72
*22.	Wasco	20,050	22.	Klamath	8.68
23.	Tillamook	18,450	*23.	Wasco	8.38
*24.	Baker	15,280	24.	Curry	8.38
25.	Hood River	13,800	25.	Jefferson	5.29
26.	Curry	13,650	*26.	Baker	4.95
27.	Crook	11,460	27.	Crook	3.84
28.	Jefferson	9,490	*28.	Sherman	2.55
*29.	Grant	7,450	29.	Malheur	2.43
+30.	Harney	7,240	*30.	Morrow	2.30
*31.	Wallowa	6,630	*31.	Wallowa	2.08
+32.	Lake	6,450	*32.	Grant	1.64
*33.	Morrow	4,750	*33.	Gilliam	1.61
*34.	Sherman	2,130	*34.	Wheeler	1.13
*35.	Gilliam	1,955	+35.	Lake	0.77
*36.	Wheeler	1,935	+36.	Harney	0.71

*Structural and Mechanical Specialty Codes administered by State of Oregon.
+State has responsibility for large buildings.

FIGURE 8

DISTRIBUTION OF OREGON CITIES
BY POPULATION & WHAT LEVEL OF GOVERNMENT
PROVIDES BUILDING & MECHANICAL INSPECTION SERVICE

*Includes all cities which indicated they have a building official.
No credit is given state for partial responsibility in cities.

Population Range (modified log scale)	1974-75 No. of Cities Served By Jurisdiction Class			1975-76 No. of Cities Served By Jurisdiction Class			1976-77 No. of Cities Served By Jurisdiction Class		
	City*	County or Contr. City	State	City*	County or Contr. City	State	City*	County or Contr. City	State
0-4.9	1	-	-	1	-	-	1	-	-
5-9.9	-	-	1	-	1	-	-	-	1
10-49.9	-	-	1	-	-	1	-	-	1
50-99.9	-	1	3	-	2	2	-	2	2
100-499.9	12	24	25	13	28	21	12	24	23
500-999.9	19	17	9	20	19	8	18	22	10
1,000-4,999.9	53	20	5	53	24	3	49	30	3
5,000-9,999.9	16	1	1	17	1	-	15	1	-
10,000-49,999.9	19	-	-	19	-	-	23	-	-
50,000-99,999.9	2	-	-	2	-	-	2	-	-
100,000-499,999.9	1	-	-	1	-	-	1	-	-
	123	63	45	126	75	35	121	79	40
	53%	27%	20%	53.4%	31.8%	14.8%	50.4%	32.9%	16.7%
Total	231			236			240		
	1973-74 Oregon Blue Book Population Estimates			1973-74 Oregon Blue Book Population Estimates			1975-76 Oregon Blue Book Population Estimates		

FIGURE 9

This figure shows changes in past three years of city responsibility. There has been a reduction in the number of cities regulated by cities and the state, and an increase in the number regulated by the counties.

REGULATION AND COMMUNICATION IN THE IMPLEMENTATION OF A BUILDING CODE FOR ACCESSIBILITY TO THE PHYSICALLY HANDICAPPED

by

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The State of North Carolina pioneered enabling legislation and development of building code requirements for accessibility to the physically handicapped. The "Handicapped Section" of the North Carolina State Building Code encompasses almost every occupancy classification in publicly- and privately-owned buildings. Requirements extend from small equipment items, such as water fountains, to spatial arrangements including site development, seating and laboratory space. Consequences of implementing these laws, effective in 1973, were profound for code administrators, the building community and the public.

The approach to implementation is an "extension" approach to code administration, which is exemplary of regulatory reform for the public benefit. Access to public buildings is mandated by law (Public Law 90-480); annually more states and model codes are adopting standards for accessibility. As a possible model for others, this paper seeks to explain how the "Handicapped Section" of the Code was developed and enacted, how it is being publicized and enforced and how it is being maintained.

Key Words: Accessibility standards; building code; code administration; communication; enabling legislation; physically handicapped; regulation.

BACKGROUND

The activity initiating the establishment of a "Handicapped Section" of the State Building Code began in 1967 with a legislative effort to introduce into the North Carolina General Statutes the accessibility standard approved by the American National Standards Institute (ANSI). Though the bill passed in the State House of Representatives, it was defeated by a single vote in the State Senate Committee. This Senate Committee recognized the capabilities of the State Building Code Council[1] both to promulgate new standards and to revise old ones without legislative action. Thus, the responsibility of studying and adopting the proposed standard was vested with the Code Council. With coaxing from the original sponsoring legislator, the first "Handicapped Section" of the State Building Code was enacted as a supplement to Chapter XI, "Means of Egress Requirements"; it was and still is entitled "Section IIX: Making Buildings and Facilities Accessible to and Usable by the Physically Handicapped." In its 1967 edition, Section IIX of the Code was composed primarily of "should's", largely duplicating the ANSI Standard, instead of "shall's"; hence, it was viewed as recommending compliance. The limitations were quickly realized.

In 1969, a "wheelchair demonstration" was organized to bring the attention to inaccessibility of State buildings. The Governor, State Attorney General, several State legislators, local officials and others, confined to wheelchairs or restricted by other simulated physical handicaps, attempted to go to offices and usual meeting places. Obvious architectural barriers impeded their efforts. By late 1970, the Governor was sufficiently impressed to appoint a Study Committee on Architectural Barriers, chaired by the same legislator. This Committee produced an interim report in 1971; was continued by the next Governor; and produced its final report in 1972. The recommendations of this Committee included proposed revisions for Section IIX.

With the deliberation characteristic of North Carolina's approach to innovation, the Building Code Council organized an ad hoc committee of three of its members to revise

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[1]The State Building Code Council is composed of nine members appointed by the Governor consisting of one registered architect, one licensed general contractor, one registered engineer practicing structural engineering, one registered engineer practicing mechanical engineering, one registered engineer practicing electrical engineering, one licensed plumbing and heating contractor, one municipal building inspector, a representative of the public who is not a member of the building construction industry, and a representative of the engineering staff of a State agency charged with approval of plans of State-owned buildings.

(North Carolina General Statute 143-139 (b)[3]). Another section of the same General Statute (North Carolina General Statute 143-136 (a)) created the State Building Code Council. (The Engineering Division serves as staff of the Council.) The Council and the Engineering Division must maintain maximum communication with local building code officials in order to insure enforcement of the Code. The network of communication is key to implementation of all sections. This cannot be overemphasized in viewing the "Handicapped Section" which was entirely new when it became effective and brought into the process of the code enforcement more scrutiny of such new aspects as site plans, circulation paths and hardware.

IMPLEMENTATION

Thus, in 1973, North Carolina had the first section of the building code designed to facilitate accessibility of buildings and sites to the physically handicapped. It was soon apparent that the written form was not sufficiently clear to designers or code officials, who were forced to concentrate new effort on many traditional building elements. Ronald Mace, a paraplegic architect confined to a wheelchair, was commissioned by the Governor's Study Committee and later by the Department of Insurance to clarify this section of the Building Code. He designed an Illustrated Handbook of the Handicapped Section of the North Carolina State Building Code which was first printed in 1974 and has been used throughout the nation and numerous foreign countries both as a text and as a basis for similar codes. The Handbook contains the Code verbatim with schematic illustrations of minimum and preferred solutions (figure 1). This was a first step toward making this novel section of the Code comprehensible. Building officials, government agencies, design professionals and others were furnished first copies of the Handbook without charge. A need still existed for more immediate sensitizing and educating of those involved in code administration and design practice. Ronald Mace, as Special Consultant to the Commissioner of Insurance, devised a slide presentation which, on one screen, provided illustrations from the Handbook and, on an adjacent screen, the problems of handicapped citizens if architectural barriers exist and the abilities of independent mobility if these barriers do not exist. This slide presentation has been used for seminars for code officials, design professionals, students and civic groups.

The "Bill of Rights for Handicapped People" (North Carolina General Statute Chapter 168) also became effective in 1973. This law, reminiscent of the Civil Rights Act of 1964, provides: (1) the right of access to and use of publicly - and privately-owned spaces, public conveyances and accommodations, etc.; (2) that the visually handicapped may be accompanied by a guide dog and are entitled to keep a guide dog in leased premises

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[3]Referenced sections of the North Carolina General Statutes are reproduced in as part of the General Construction, Volume 1, North Carolina State Building Code.

Section IIX. This committee was charged with recommending changes to the section "which would not cause a real hardship on the owners, designers and constructors of buildings within the State and which would also provide for accessibility for the physically handicapped" (Foreword to Section IIX). The ad hoc committee held several meetings to (1) enlist expertise and gain input from the building community and other concerned groups and individuals and (2) provide those dedicated to establishing this standard and opportunity to convey to others the necessity of implementation.[2]

The bargaining involved in structuring this section of the Code cannot be understated. Cooperative bargaining is exemplified in acceptance by the Home Builders' Association of a percentage of units in multi-family dwellings designed to accommodate handicapped people. To support this, a tax credit against income taxes was enacted to offset the additional cost of construction of these units (North Carolina General Statute 105-130.22 and 105-151.1). After almost a year of negotiation and compromise between the agents of various groups, the ad hoc committee of the Code Council produced the final version of the Code which became effective 1 September 1973.

It is pertinent to briefly retrace these events to emphasize that legislation was not enacted overnight in North Carolina and implementation of these measures through the State Building Code was not instantaneous. The process of development, implementation, education and now amendment has been underway for about ten years. (Prior even to this, there were noteworthy events which are more difficult to identify and relate to the Building Code per se).

Certain structural aspects of the administration of the State Building Code must be reviewed before completing this history. In North Carolina, the Legislature has charged the Commissioner of Insurance with general supervision, through the Engineering and Building Codes Division, of the administration and enforcement of all sections of the Code (except elevators). This must be accomplished with cooperation of local inspectors who are appointed by the governing body of municipalities and counties

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[2]Representatives participated from the Governor's Study Committee on Architectural Barriers; N.C. Chapter of American Institute of Architects; Professional Engineers of North Carolina; Council of Code Officials; N.C. Home Builders Association; N.C. General Contractors of America; N.C. Association of Plumbing, Heating and Cooling Contractors; N.C. Electrical Contractors Association and State Government agencies including the Property Control Division, Department of Administration; Medical Care Commission, Department of Human Resources and Division of School Planning, Department of Public Instruction.

without extra charge; (3) that drivers shall take necessary precautions when the visually handicapped approach using a designated cane; and (4) the right to employment, habilitation, rehabilitation services and housing (The Housing Section was added in 1975). The inclusive language of this Act provides motivation for the newest area of involvement in providing accessibility to the physically handicapped in North Carolina: the modification of existing buildings. The necessity of making modifications to existing buildings is encouraged by the provision of a tax deduction for the removal of architectural barriers (North Carolina General Statute 105-130.5 (a)(8), (b)(10) and (c)(24)). This tax deduction is allowed for the entire cost of renovation and is taken fully in the year the renovation is completed.

Accessibility Modifications: Guidelines for Modifications to Existing Buildings for Accessibility is also an illustrated book. It has been designed in a format to help designers, owners, handicapped citizens, code administrators and others study an existing building, determine its problems and make recommendations for budget review and architectural implementation. As illustrated in figure 2, a survey of the existing building is keyed to an explanation and illustration of some architectural alternatives. The book recognizes that while most situations can be analyzed and solved, some solutions are costly. Therefore, it seeks to give a sense of priorities and alternatives for modifying a building. To complement this book, another slide presentation is being developed which will be similar to that used for elaboration of An Illustrated Handbook.

DEVELOPMENT

During the past year, communication of the "Handicapped Section" of the Building Code has been furthered by another event, the establishment of the Special Office for the Handicapped within the Engineering and Building Codes Division. The Office is directed by an architect to provide interpretations, technical advice and information on compliance with code and legislative requirements for the handicapped. The Special Office provides additional information on design solutions responsive to the problems of handicapped people, encourages increased consideration for the needs of the handicapped beyond the minimal requirements mandated by the Building Code and encourages and assists with modifications to existing buildings.

Public awareness of the laws, the Building Code and the Special Office are requisite to effective implementation. "Are You Aware. . ." is a single-page, folded brochure (figure 3) which summarizes pertinent information on each of these topics. More than 18,000 brochures have been distributed through extension, rehabilitation, health and social services and organizations of municipal governments, design professionals, code administrators, churches and handicapped citizens. The brochure is being used to generate interest, increase awareness and further knowledge and expectation of the public in the ability of the building code as an affirmative and beneficial regulatory tool.

The "Handicapped Section" of the Code has a published supplement to update 1974 printings of the Handbook. The "Supplement" contains (1) illustrations of some interpretations such as toilet stalls for children and a minimum accessible toilet room for use in very small buildings, (2) additions to pertinent laws and (3) preferred changes and additions to this section of the Code. The preferred changes and additions are currently being considered for amendment by the Building Code Council. These amendments were proposed by Ronald Mace on the basis of experience in using the current Code. Other comments and amendments have been submitted by manufacturers, design professionals and handicapped citizens. The process of amendment involves a hearing by an ad hoc committee of three Code Council members which recommends action on each item to the Council. The Code Council considers the items at its regular public hearing; then, after possible further alteration, adopts or rejects the items for inclusion within the Code. This process provides the Council, the Division, the Special Office and concerned organizations and individuals a viable mechanism for developing and improving the content of the Code.

CONCLUSION

The process of establishing and maintaining this "Section" of the Code has obviously required the dedication of many individuals and organizations. A great responsibility is now vested with local building code officials as handicapped citizens, design professionals and many others anticipate the accessibility of newly constructed facilities and the results of modifications of old ones. This presents a new challenge in the area of code enforcement: Accessibility for the physically handicapped is an everyday issue; it does not become important at the moment a catastrophe such as a fire or an earthquake occurs. There is vigilance on the part of many individuals, who are increasingly aware of the building code, its force of law and its powerful, real and potential benefit. And there is optimism for continued success based on North Carolina's established system of administration of the State Building Code and a strong tradition of local enforcement and public cooperation.

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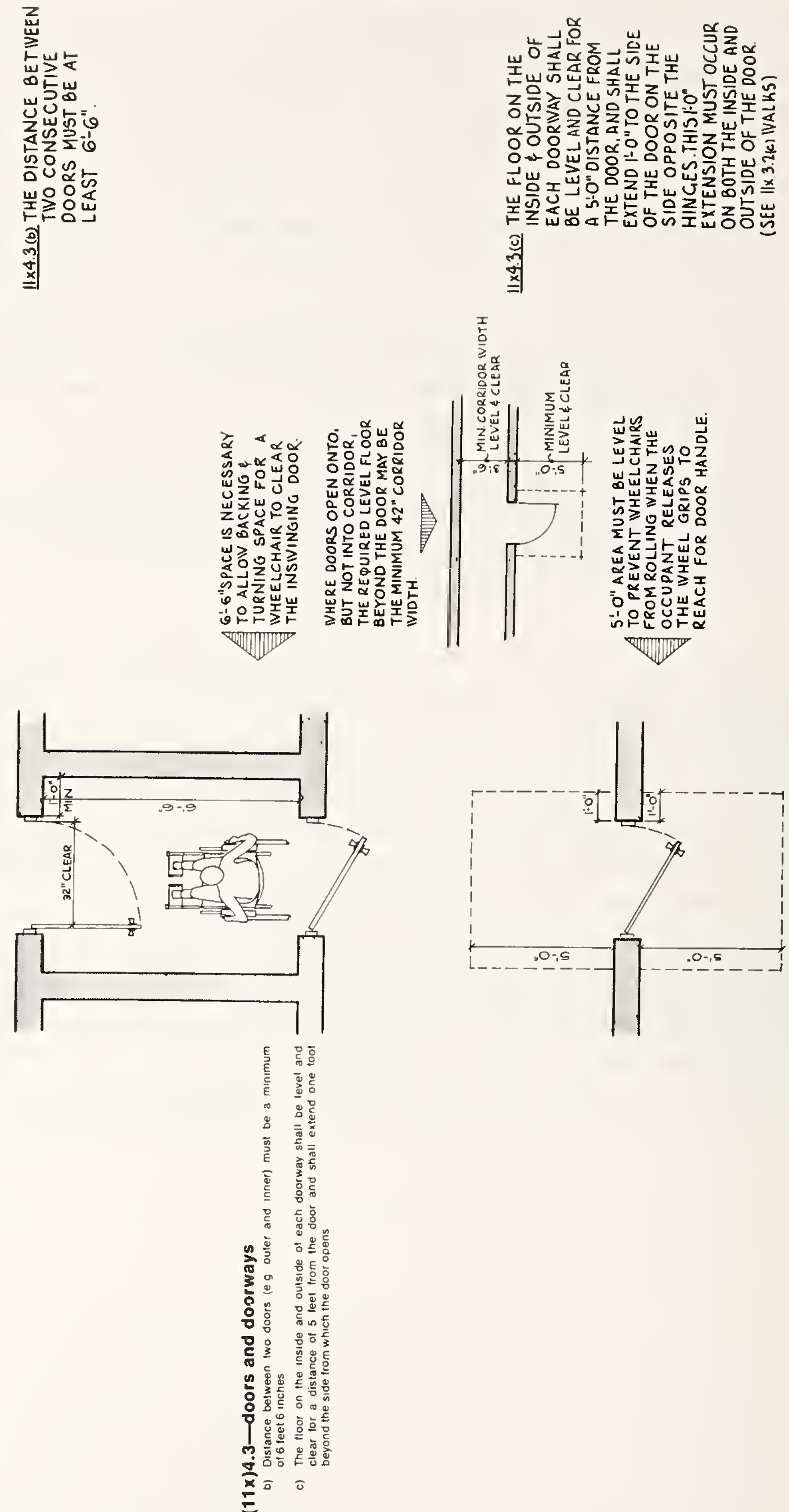


FIGURE 1 Example from "An Illustrated Handbook of the Handicapped Section of the North Carolina State Building Code."

ENTRANCE APPROACH, pp. 6-17

1. Is there any entrance to the building that is at grade level? If so, does the approach meet the requirements in Site Considerations? If so, is the rest of the building accessible from the grade level entrance? For example, if this entrance is at the basement level, is there an elevator to the floors above?
If a grade level entrance is at a level that does not allow access to the rest of the building, then the problem of interior changes in level must be considered (see pp. 28-35), or an entrance at another level must be found.

2. If no entrance is at grade level, then which entrance to the building is closest to grade level either up or down? See pp. 6-7.
Is there enough room to build a ramp to this entrance? See pp. 6-13.

3. If there is no existing entrance which can be successfully ramped, is there a location where the ground level is closer to the floor level where a ramp might be installed? See p. 16
If so, is there a window at that location which could be made into a door?
If not, can a door be cut into the wall at that location? See p. 16

4. Is it possible to install a lift to the entrance? See p. 14

5. Is it possible to use earthworks to raise or lower the ground to the level of the entrance? See p. 10.

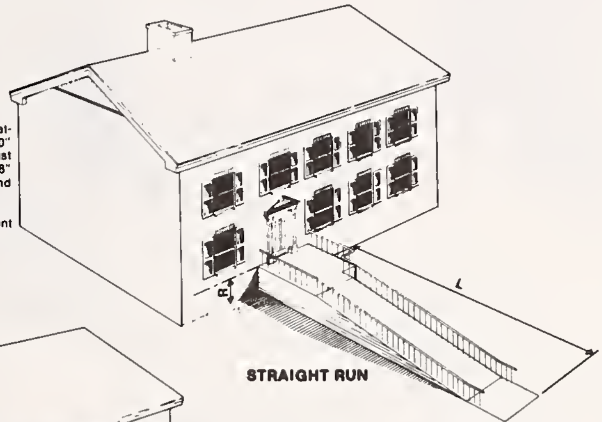
6. Is it possible to bridge to the building from another accessible building? See p. 15.

If there is no way to modify an entrance so that it does not have steps, then the building will not be accessible to an unaccompanied person in a wheelchair. However, other people may be able to enter, as can a person in a wheelchair with help, so consideration must still be given to making interior spaces accessible. Special consideration should be given to the toilet rooms and to those facilities which are the primary function of the building for both customers and employees.

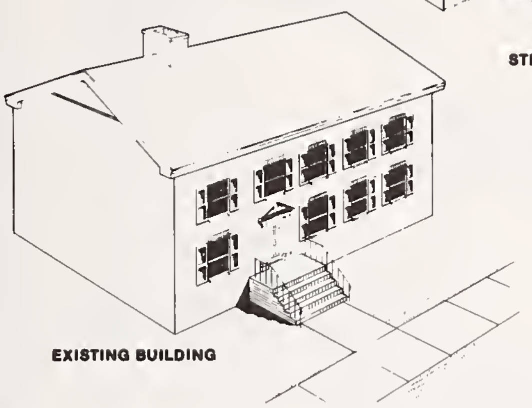
entrance approach ramps

Ramps must have 5'-0" x 5'-0" level platforms at top and bottom, must be at least 4'-0" wide, must not exceed 1 in 12 slope, must have handrails on both sides that are 2'-8" high and extend 1'-6" [*] beyond top and bottom of ramp.

Surfaces of ramps must be slip-resistant materials.



STRAIGHT RUN

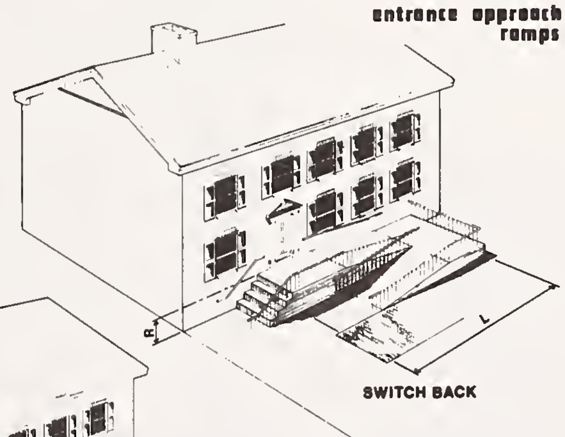


EXISTING BUILDING

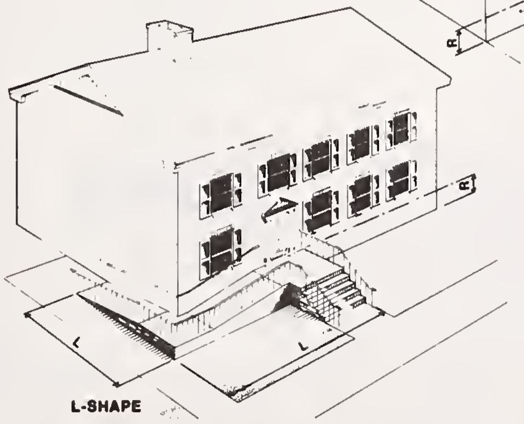
See tables on page 13 for space requirements for ramps of known floor elevation (R) above ground. For additional information on ramps, see pp. 32-33.

entrance approach ramps

Ramps can run parallel to exterior walls and turn corners if necessary.



SWITCH BACK



L-SHAPE

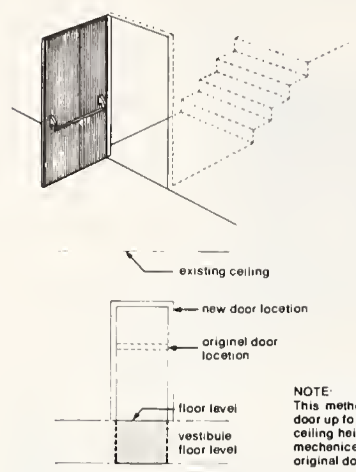
For exterior railing requirements and details, see N. C. State Building Code, Section 1108.8, Exterior Balconies.

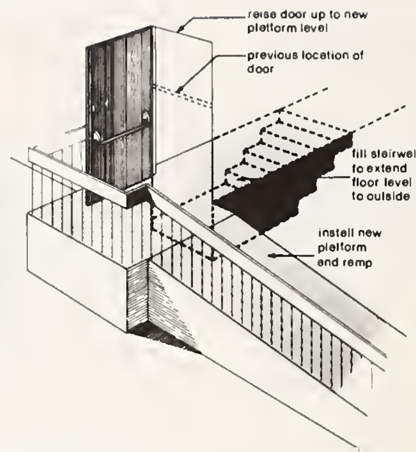
FIGURE 2, PART 1 Example from "Accessibility Modifications: Guidelines For Modifications to Existing Buildings for Accessibility."

entrance approach
split level vestibule

Entrances which have an interior vestibule floor with steps up to entry floor level can be difficult to modify for accessibility due to lack of space inside for ramp to be installed

Such entrances could be made accessible by filling the stairwell to extend floor level to exterior where a new level platform and ramp could be installed. Platforms must be at least 5'-0" x 5'-0", with 1'-6" [*] clear to pull side of door

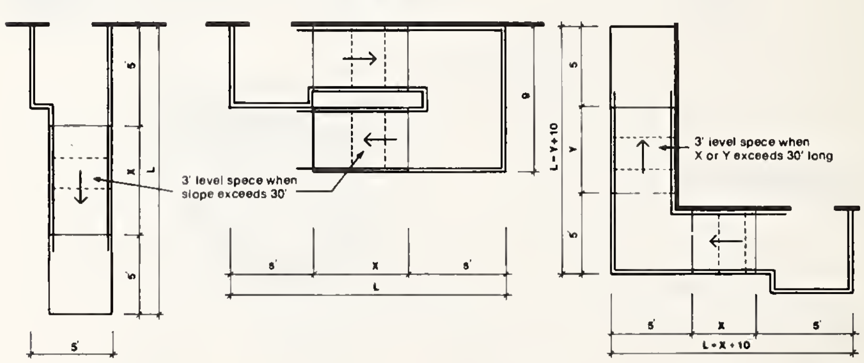




NOTE:
This method is dependent upon raising the door up to floor level. There must be sufficient ceiling height and any structural members or mechanical equipment in the well over the original door may have to be moved.

entrance approach
space requirements for ramps

STRAIGHT RUN | **SWITCH BACK RAMP EQUAL RUN** | **L-SHAPE**



STRAIGHT RUN

R	1'	2'	3'	4'	5'	6'
X	12'	24'	39'	51'	63'	75'
L	22'	34'	49'	61'	73'	85'

Note: Tables assume flat sites and 1 in 12 slopes.
Sites which slope may require longer or shorter ramps depending on direction of ramp and slope of site. Ramps should be oriented to minimize their length.

SWITCH BACK RAMP EQUAL RUN

R	1'	2'	3'	4'	5'	6'
X	6'	12'	18'	24'	30'	39'
L	16'	22'	28'	34'	40'	49'

Wherever possible the length of the slope of ramps should be evenly divided.

L = total length of ramp
R = rise
X and Y = length of the slope

L-SHAPE

R	1'	2'	3'	4'	5'	6'
X + Y	12'	24'	36'	48'	60'	75'
			39'	51'	63'	78'

Whenever either X or Y exceeds 30' add 3' for rest area.

FIGURE 2, PART 2 Example from "Accessibility Modifications: Guidelines For Modifications to Existing Buildings for Accessibility."

...of north carolina laws for the handicapped ?

Recent laws passed in North Carolina provide:

equal rights   N.C. Statutes 168 and 128-15.3

Handicapped persons—those with physical, visual, or mental disabilities—have a right to education, a job, a place to live, and a chance to enjoy themselves.

North Carolina laws ensure that the handicapped have a right to rehabilitation services and to equal opportunity for employment. State Government policies prohibit discrimination on the basis of any physical handicap and emphasize a positive attitude toward recruiting and hiring.

The handicapped have a right to access and use of transportation, streets, walks, buildings, and all facilities used by the public.

The blind have the right to keep and be accompanied by a guide dog. Drivers should watch out for the blind using a designated cane or with a guide dog.

parking privileges   N.C. Statute 20-37.6

Disabled people displaying a special license plate from the Department of Motor Vehicles may park for an unlimited time where parking is normally permitted.

curb ramps   N.C. Statute 136-44.14

Whenever new curbs are built, or old ones are reconstructed, each block must have at least two curb ramps connecting the sidewalk and the street.

tax credits   N.C. Sta. 105-130.5, 105-151.1, 105-130.22

To encourage building owners to remove barriers, tax credits are available for the cost of renovating an existing building to make it accessible to the handicapped. The renovation work must include grade level or ramped entrances, space to move around the public areas, and accessible toilet rooms.

Also, tax credits are available to owners of multi-family rental units for building units which conform to the handicapped section of the building code.

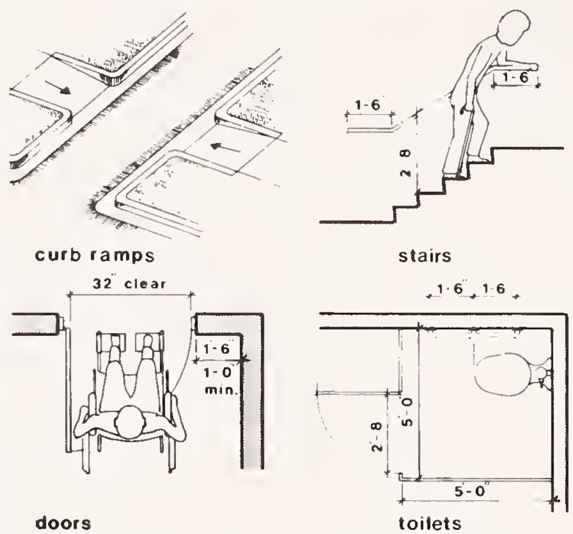
housing   N.C. Statute 168

Handicapped people have the same rights to rental or leased housing as others and cannot be denied access to housing or charged extra for a guide dog.

...of the handicapped section of the north carolina building code ?

North Carolina has a uniform building code which regulates building construction to protect the health, safety, and welfare of the public. Recent modifications to the building code have established minimum requirements which affect the design of almost all new and remodeled buildings in the State to make them accessible to and usable by the physically handicapped.

These requirements have been fully illustrated in *An Illustrated Handbook of the Handicapped Section of the North Carolina State Building Code.*



The code also contains requirements affecting assembly seating, kitchens, bathrooms, elevators, telephones, and other equipment and facilities.

Your local building inspector and the North Carolina Department of Insurance are responsible for seeing that new and remodeled buildings comply with these code requirements and for enforcing penalties. The name and address of your building inspector may be obtained by writing the Department of Insurance.

...of the special office for the handicapped ?

The Special Office for the Handicapped has been established within the Engineering and Codes Division of the North Carolina Department of Insurance for the purpose of general administration of the building code requirements for the handicapped.

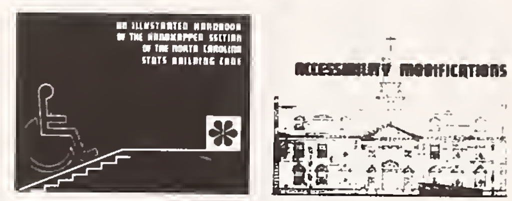
The Office is staffed full time by an architect in order to provide interpretations, technical advice, and information on compliance with North Carolina code and legislative requirements for the handicapped.

The Special Office also provides additional information on design solutions to the problems of handicapped people, encourages increased consideration for the needs of the handicapped beyond the minimal requirements mandated by the Building Code, and encourages and assists with modifications to existing buildings.

publications

In addition to *An Illustrated Handbook*, the Special Office has produced *Accessibility Modifications: Guidelines for Modifications to Existing Buildings for Accessibility*. This new book is an illustrated working guide showing how to study a building, determine its problems, and make design recommendations for budget review and architectural implementation.

Both publications are available at a minimal cost from the North Carolina Department of Insurance, Engineering Division, P.O. Box 26387, Raleigh, North Carolina 27611.



additional information

For more information write or call:
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North Carolina Department of Insurance
P.O. Box 26387   Raleigh, NC 27611
Telephone   (919) 829-2203

FIGURE 3 "Are Your Aware" Brochure

THE FUTURE OF BUILDING REGULATORY RESEARCH
(A Summary of Session Three Deliberations)

In a departure from the format of the other technical sessions of the conference, session three was reserved for an evening panel discussion. Dr. Francis T. Ventre of NBS organized this panel and served as moderator for the session. The theme of the session, "The Future of Building Regulatory Research," provided a subject for discussion by the panel members all of whom have been directly involved in one or more aspects of the nation's building regulatory system. The subject also provided a variety of different researchers and regulators an opportunity for interaction on those regulatory issues that might be addressed by future building regulatory research.

Panelists were selected to provide the Conference with diverse perspectives on building regulatory research. Those serving as panelists (in the order in which they presented their opening statements) were:

Name	Institutional Affiliation
Mr. James C. Spence	Manager of Engineering and Research Services, American Iron and Steel Institute
Mr. C. Morgan Edwards	Chief, Division of Industrialized and Manufactured Housing, Pennsylvania Department of Community Affairs
Mr. Ted H. Carter	Executive Director, International Conference of Building Officials
Mr. Glen R. Swenson	Director, Utah State Building Board; President, National Conference of States on Building Codes and Standards, Inc.; and Member of the Board of Directors, National Institute of Building Sciences
Mr. Robert J. Kapsch	Assistant Chief, Office of Building Standards and Codes Services, National Bureau of Standards
Dr. Francis T. Ventre	Scientific Assistant to the Director, Institute for Applied Technology, National Bureau of Standards

After opening remarks by Dr. Ventre, each panelist gave a brief informal description of their individual institutional orientation toward issues that deal with building regulatory research. This portion of the Proceedings is a summary report of the panel's remarks and the ensuing discussion.

In his opening remarks, Dr. Ventre likened the existing building regulatory system to a dark continent; "a lot of people have an idea about parts of the building regulatory system but not many have a sense of the system in its entirety." Research on the building regulatory system generally occurs in isolated instances under the auspices of various institutions - academic, industry, government, and others. Moreover, the research is often directed towards achieving limited, often technology specific needs. While this is successful in itself--regulations affecting specific product classes are generally soundly based--the problems of an overall regulatory system, the areas at the junction of one or more technologies, go largely unexamined. This Conference itself, said Dr. Ventre, was originally planned as an attempt to bring these researchers together along with other people who have strong convictions or questions that such researchers can help to answer.

Mr. Spence outlined the position of industry with respect to research and the application of research findings. He indicated that industry exerts tremendous influence on building regulations through its research efforts. Industry generally applies its research efforts to problems that have to do with the application of their products (e.g., concrete, steel, wood, etc.) and the development of those products so as to improve their marketability in the construction marketplace. He identified industry's interest in improved design procedures for basic construction materials (e.g., specification for the design of cold formed steel structural members, ultimate strength design procedure for concrete) and the consensus process as necessary so as to transfer research findings into recommended design criteria. These recommended design criteria are then normally adopted by reference into the nationally recognized model building codes and the codes of various governmental jurisdictions.

Morgan Edwards addressed the specific needs of building officials and code enforcement personnel that could be facilitated by appropriate research efforts. He felt that the greatest problem faced by State and local building officials is in the implementation and enforcement of building regulations. After development of a new standard, there is a need for educational programs and other enforcement mechanisms for preparing code enforcement personnel to implement that standard in the field. He recommended that researchers give appropriate consideration to the enforcement function as a vital part of the entire regulatory process because without enforcement the rest becomes strictly academic.
Mr. Edwards also indicated that building officials are unique in that they wear three hats - that of an enforcer, an administrator, and a technician. In these roles, and particularly as an enforcer, the building official does not have the sophisticated equipment, administrative procedures, or back-up systems that have been developed and are

available to their counterparts in the police department. He expressed concern that equal attention in the form of time and resources be given to the administration and enforcement aspects of regulation as is given to technical research when developing new codes and standards - particularly in the development and promulgation of performance based standards.

Mr. Carter described the strong interests of the model code organizations with respect to their needs for the existence of competent basic research. The following reasons for supporting research were cited, even though they are areas that most people would not necessarily identify with regulatory research.

1. Traditional building code requirements need sound technical data as basis of justification.

2. The public and the professions will better accept code requirements that are based on research and sound criteria.

3. Research-based code provisions facilitate code uniformity and minimizes code interpretation problems.

4. Minimum code provisions can be extended by extrapolation to cover conditions not otherwise anticipated if the data base from which the provision was developed is sound and can be retreived.

Mr. Carter indicated that, based on volume, the content of building codes is made of approximately 10 percent administrative provisions, 70 percent design criteria (which seldom change), and the remaining 20 percent general code requirements. It is this latter category--general code requirements--where most of the present code problems exist with respect to impact on construction costs and nonuniformity among code jurisdictions. Some examples of research needs dealing with general code provisions were given as:

1. Allowable areas and allowable heights established for buildings based on type of construction and occupancy. Research is needed to determine if present requirements are reasonable since the source of these figures cannot be verified today.

2. Fire resistance ratings of buildings and structural elements of buildings. Formulas are needed, based on research findings, that would provide fire resistance ratings without the need for expensive testing procedures.

3. Smoke toxicity - the present regulations on smoke toxicity are not responsive to the problem in that the approach in determining smoke toxicity values is not scientific.

4. Elevators cannot be recognized as a legal means of egress for handicapped yet how can elderly persons be easily evacuated from high rise buildings?

Mr. Glen Swenson provided a different perspective on research needs - primarily a philosophical one. He related how in the past governments tended to make decisions and then carried them out. Now a different approach has evolved--people have developed a desire to participate. No longer will people accept decisions without question - people are requiring the right of self-determination. This situation could be a significant problem when the desireability of self-determination is weighed against the need to regulate. Somewhere the question of self-determination vs. regulation will have to be reconciled, particularly in our area of concern which deals with consumer protection through building regulations. Mr. Swenson also introduced another trend related to self-determination, "public accountability." Public officials will have to justify what they do. It is in this area that research can respond to the anticipated demand for accountability. Research can provide the justification and in a sense could be the vehicle to preserve the code regulatory approach in the building regulatory process of the future. The public will have to be convinced and made to realize that building codes are in their best interest. In this vain, thorough and competent research should not only be looked upon as a tool for developing new technology for regulations but also as a vehicle for informing the public.

Mr. Robert Kapsch of NBS outlined the areas of opportunity for funding and institutional support for researchers who want to contribute to this field of research which will provide a firmer technical basis for our regulatory system. He indicated that such support has increased in the last few years and gave a brief summary of building regulatory research opportunities at the Federal level. These were as follows:

1. Research grants such as those available through the National Science Foundation's (NSF) Research Applied to National Needs (RANN) program.

2. Smaller research contracts in support of specific programmatic objectives of Federal agencies, such as those provided by the Department of Housing and Urban Development (HUD) or the Energy Research and Development Administration (ERDA).

3. Opportunities under the Intergovernmental Personnel Act (IPA) which permits employees of State and local government and universities to work at a Federal agency for a specific time period (from two weeks up to two years).

He also spoke of the various Federal agencies that have a direct or indirect impact on building regulation. Among those covered were:

1. National Bureau of Standards in its Center for Building Technology (CBT), Center for Fire Research (CFR) and Experimental Technology Incentives Program (ETIP), where there is interest in studying regulations as a possible constraint to the introduction of innovation.

2. The National Fire Prevention and Control Administration of the Department of Commerce in its legislative responsibility to study regulations.

3. The recent Energy legislation in Title 3 of P.L. 94-385 (The Energy Conservation and Production Act of 1976) brings the various Federal agencies into a partnership with the States for the purposes of regulating energy conservation in buildings.

4. In the Solar Heating and Cooling Demonstration Act of 1974 (P.L. 93-409) Congress mandated a requirement that regulations be studied with respect to the introduction of solar heating and cooling systems.

5. Both the Department of Housing and Urban Development (HUD) and the Law Enforcement Assistance Administration (LEAA) are interested in studying the regulatory aspects of physical security in buildings.

6. There are a number of other Federal agencies with varying degrees of interest in regulatory research related to buildings and construction. These include:
   - OSHA (Occupational Safety and Health Administration)
   - EPA (Environmental Health Administration)
   - CPSC (Consumer Product Safety Commission)
   - GSA (General Services Administration)
   - VA (Veterans Administration)
   - DOD (Department of Defense)

7. There are also several Federal grant or loan programs with specific "conditions of participation" which contain criteria that, to some extent, overlap the traditional regulatory system. Examples of these programs are the Department of Health, Education and Welfare's (HEW) Hill-Burton Criteria, and Medicare/Medicaid Programs as well as HUD/FEA's Minimum Property Standards.

The presentations by the panelists were concluded with some pertinent observations by Dr. Ventre. He described a recent program undertaken by the National Science Foundation (NSF) in its Division of Advanced Productivity Research and Technology which examines the issue of productivity in the U.S. economy. The program is specifically pursuing studies of regulations and their effect on productivity, since in our economic system productivity in both the public and private sectors is closely related to the quality of regulation. One project has been funded for study in California to examine the relationship of building industry productivity and building industry regulation. The NSF program director has offered to make available to attendees of this conference descriptions of the NSF program in this area of research. Those seeking further information may write to the Director, Division of Advanced Productivity Research and Technology, National Science Foundation, Washington, D.C., 20550.

Dr. Ventre also mentioned the NBS effort in compiling a directory of researchers involved in building regulatory research as a means for facilitating the spread of new knowledge and understanding in the building and research communities. The directory will provide the names and addresses of researchers and brief descriptions of current research projects.

CATALOGUE OF BUILDING SAFETY INSTRUMENTS

by

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A building regulation is an instrument to achieve a goal - building safety. At any time and place the building ordinance, bylaw, or act is seen as "the" instrument and little thought is given to other instruments (existing or possible), attention is usually focused inwardly on the bylaw or code. The focus of this paper encompasses many instruments all of which have been or are being used. These instruments ranging from custom to research include law, authority, training, education, standards, guidelines, and administrative techniques. The characteristics of each instrument are discussed. This is an aid to their selective use. Building safety can be likened to a garden which flourishes with the use of many tools, or instruments, from hoes, picks, and rakes to watering cans and fertilizers but only when the right tool is chosen for a specific task at the right time and place. The paper is written in definitive form as a contribution for discussion and subsequent inclusion in a proposed manual of building safety knowledge.

Key Words: Building codes; building safety; control; instruments; knowledge; legislation; life safety; regulation; standards.

THE ESTABLISHED SYSTEM

Safety is, or should be, one of the criteria to be satisfied in building design. It is a goal and building codes are the most common means of achieving this goal. It may be observed, however, that building codes are, more often than not, regarded as the end rather than the means.

Building codes have become a statement of what safety is. They specify what must be done and do not indicate what is the expected end result of taking the actions prescribed. There are good reasons why they do not indicate what is expected, and we will come to these; but the omission of these expectations creates the situation just described which is a misconception of what safety is about. In reality, safety involves much more than building codes, but as long as codes are seen as the end rather than the means then there is no incentive to look at other means or in other directions since the end (the code) is so easily available. Thus building codes do not so much encourage the pursuit or life safety as define what life safety is to be.

The idea of a law as the definition of building safety is unrealistic in today's world. This is because law is a poor instrument for defining something as complex as safety. If codes can be seen as one of several means of achieving safety the way is open to consider other means as well.

The purpose of this paper is to discuss the various means that are available and indicate their characteristics. With this knowledge those responsible for safety will be able to choose a suitable instrument or a suitable combination when a particular problem is faced. Like the gardener, these people will have not just one but a whole shed of tools from which they can choose one or more depending on the particular problem at hand. The emphasis will then be much less on improving codes as such and more on achieving safety through control (which might include the code).

Take a hard look at today's codes. What does it mean if a code needs continual improvement? How can safety be achieved if the tools we use to get it are constantly in for repairs? In what other business would this be tolerated? When a code is in for repair it is because of being used for purposes for which it was never intended. If it was used only where law is appropriate it might hardly have to be revised at all. The key question is, therefore, not building codes per se but the broad process of building control including law and any other instruments which will further safety in the most reliable and efficient way.

SYSTEMS OF CONTROL - THE SIGNIFICANCE OF AUTHORITY

Control is basically a way of exercising power in the service of a particular goal. Building safety control is more narrowly defined because it is limited to building and because building safety is a socially acceptable goal at the community level. Not all goals of individuals and groups are acceptable in this way.

The idea of acceptable or legitimate goals is important to the concept of systems of control. Building safety control is the exercise of power in the service of legitimate goals. This type of power is usually called authority. (1)

Authority is usually associated with government but this view is incorrect. Goals are legitimized by the community and the goals of the community's government are usually legitimate, but, since it is the community and not its government that is able to legitimize, the community can and does make authoritative certain goals and efforts of many voluntary groups and individuals outside the government and may not accept certain efforts of the government (as with prohibition for instance).

In the building safety area these voluntary groups include associations of building officials and professional and technical associations such as ACI, NFPA, ASHRAE, etc. Within the normal frames of reference most adult individuals are authorities regarding their own acts. In law the owner is responsible for building safety and there is nothing to prevent him from pursuing this goal independently if in the process he does not contravene any law. (But he is not likely to since as we have said, what he is apt to know about safety is wholly contained in the code anyway.)

The "Compact Dictionary of Canadian English" defines "authority" as: 1) the right to act, 2) one whose knowledge or judgement on a subject is entitled to acceptance, 3) a book, quotation, and 4) authorities, people in power, as government officials.

While authority is important, it is really more important to acknowledge that original authority, the authority to authorize, one might say, rests with the community and not with the state. Over eons of time, increasing knowledge and increasing specialization has led the community to recognize or accede to the authority of special groups and individuals and to create special authorities such as the state, but it is with the community that it all began.

Thus in discussing instruments of building safety control we will be discussing those instruments that are used with authority, the authority which rests with or is delegated by the community as a whole. In certain matters the community has delegated authority specifically to the state which uses law as its principle instrument; and in others reliance is placed upon voluntary groups which have acquired special knowledge (either directly, or through delegation by the state). These specialties serve as valuable instruments in the service of safety control.

In the catalogue that follows law comes first, then knowledge - observed and theoretical, then custom and finally there is a brief statement on several other instruments including money, licensing, symbolism, function and the natural world.

CATALOGUE OF BUILDING SAFETY INSTRUMENTS

It is not the intention, in the remarks that follow, to offer a full description of instruments of control but rather to highlight the attributes or characteristics that are of particular relevance to the field of building safety. The focus is on the mechanics - how does each instrument work in practice. Despite the very best intent, diligence and expert use, instruments of control often fail to do their job. The causes of failure are obscure. The control should work but it does not. Why it does not may not even be known to those involved. Building by-laws or enacted building regulations are a good example.

LEGISLATION

Legislation is the principal instrument that the government is authorized to use to maintain control. Building regulation has been achieved mainly through municipal bylaws authorized by the state or province (in North America) but there is a tendency toward greater state or provincial control.

The purpose of building law is control. It is to change or up-grade building to a norm. While the purpose is to create change, to force better construction, building ordinances or bylaws are effective only if they do not change. The more they change the less they are a norm. It is fundamental to law that all cases within any class are treated the same. The more the law changes the less this is possible.

It is noteworthy, in this connection, that many phenomena that threaten safety and which require control do not change. Climate is a good example. The changes in the last hundred years have not been sufficient to warrant changes in the safety norm. The same could be said of the physics and chemistry of fire or the mechanics of building materials. These are the principles or laws of nature and they do not change. Even the human condition is stable or reasonably so and the tolerable level of risk is similarly stable or slow to change (although the identification of the source and responsibility for the risk may have changed).

Superficially therefore, law would appear to be a good instrument of control for building safety. Yet apparently this is not so because building by-laws and ordinances have been subject to almost continual modification. In fact, specialist agencies have been formed to attempt to speed up the rate of change. Since the more the law changes the less is its effect these efforts are toward the loosening rather than the tightening of control, or at least the replacement of law as the means of control.

What then is the cause of this failure? It is not in the intent of law but in the mechanics, or grammatical constructions, that are used to express the intent. The customary form is the imperative and the imperative is, in effect, a verbal order frozen in the written word. The law is said to be "always speaking," (2) Now, if law is or must be an order, to what can orders be applied? Obviously they must be applied to persons and not to things and an order to a person must, almost necessarily, refer to some physical act, "build this," "repair that," "construct so and so." The law cannot require action about the principles or laws of nature which as we have said, do not change, so it is forced to use, as its substance, human actions involving building. Since these are almost infinitely variable and almost constantly changing it is these that force the law to change.

We might add further, that even if the grammatical contruction caused no difficulties it would be inappropriate for a state agency to make imperative the laws of nature. The state has been granted authority over the members of the community. It has no authority over nature.

The state has the authority to set arbitrary limits <u>based</u> on the laws of nature, declaring what we know of these rules. This could be achieved if the declaratory or indicative grammatical construction is acceptable. For example, "The maximum allowable working stress of so and so in bending <u>is</u> such and such." This would be legal and workable but cumbersome and there are other and better ways to achieve this end.

In fact, much of what purports to be imperative in building codes is really arbitrary limits or definitions like that already mentioned masquerading as orders. Wherever the grammatical form "shall be" is used the declaratory "is" is really meant. How does one order a person to be something? Much absurdity could be removed from modern building codes merely by using the indicative instead of the imperative form of the verb "to be."

Many users of codes say that everyone knows what they mean, so why worry? Another comment is that these are <u>merely</u> semantic problems and that the real safety problems are more important. Yet the words really are important because permission to build is entirely a paper issue, worked out in symbolic or linguistic terms. No work can commence until the plans and specifications have been checked against the words in the law. It is important therefore that the words say what they are meant to say. Otherwise there is no law. It becomes approval by the official rather than the code.

The literal meaning of the words is important in another and more fundamental way. The law must be the written words. There are only two places where the law can be, in the words, or in somebody's mind, but who's mind? Legislation was a major achievement of Magna Carta. (3) The law was the words written down and neither the king nor anyone else could change it or interpret it to personal advantage.

Even before Magna Carta the first building assize was proclaimed in 1189. This building assize, the original building ordinance in the English speaking world, was a writ or ordinance, an agreement written down. (4)

It was a device developed in the cities which were communities of free individuals. The written word was the only possible way to record agreements among them. The alternative was the system on the feudal manors where the Lord of the manor had authority and everyone on the manor was subservient to him. (5)

Thus legislation, where meaning rests with the words as written down, is a functional and necessary part of the representative system of government. The strength of the system is in its ability to control. It is unthinkable that a casual attitude should be taken to the meaning of words and so weaken the system upon which safety control and indeed any truly representative or democratic system depends. (6)

When a person says that the words are not important he is, perhaps unknowingly, attributing to law characteristics that belong to another instrument which is the application of special knowledge. So, where the written words are ignored, or where the law is frequently changed, or where there is need of much interpretation, the interests of safety are perhaps being served but not through law. These are all indications that law is not an appropriate tool in the circumstances.

The written word, as the essential characteristic of legislation, raises further difficulties with a technical document like a building code. Early legislation, including the early building assizes had long preambles which gave the intent. Over the centuries preambles have been gradually eliminated because they eroded the authority of law. When the intent of a clause is given builders could always find a way of meeting it that was different from what the law prescribed. The question is not the degree to which alternatives are valid technically. The instrument is law. It must be effective as law and anything that erodes its authority is eliminated. (7)

The mechanics of legislation are such that control is possible even though the code writers, or legislative group, or anyone else have little knowledge of the problem. Law does not depend on adequate knowledge to be effective. Cases can be cited where a building code required the builder to do a specific thing and was then revised to require him to do exactly the opposite. The law was no less effective in one case than in the other. The force of law is through authority which is assigned to it by the community. The basis of building law is hopefully adequate knowledge; but it can be a mechanically well drafted and forceful law regardless of whether or not it is technically sound.

A historical account of the instruments of building safety control has been omitted because of its length from this paper. Were it included that account would show that control for at least 40,000 years has been with the instruments that were available. It was originally myth, then custom. Then legislation became possible with the written word and necessary with the city. Scientific knowledge has weakened all these instruments and is becoming the major force in control today, but we must remember that in earlier times the law was effective with different kinds of knowledge and partly because there was relatively little technical knowledge to use.

Law can be effective without adequate or suitable knowledge because its force can be applied without a test of its technical validity. A law requiring fire-resistive walls can be proclaimed and it could be fifty to one hundred years before a fire occurred to test it. When a fire does occur, the lack of preamble, the lack of explanation results in no one remembering the reason for the law so there is no way of knowing what law or what clause is being tested.

There have been standards (such as the stair riser/tread ratio) which have been followed for centuries, even though during this period the standardized inch has become smaller, people have become larger and recently, editorial errors, the substitution of one number for another, have been found the original standard. (8)

It is a general rule that committees are not obliged to give reasons for their decisions so with law you do not ask why, you take what it says on faith. It is important to believe but not to understand.

KNOWLEDGE

Knowledge is essentially the ability to distinguish. (9) First off, therefore, there is no such thing as knowledge of one thing. Tradition is the process of passing on the same thing from generation to generation so knowledge is the opposite of tradition.

Another characteristic of knowledge is its detachment. The knowledge of a thing is apart from the thing. By way of contrast tradition is not detached. This is why tradition passes on the same thing. It passes on itself. For knowledge there must be at least two things. Knowledge cannot be part of either one so through knowledge we have choice and since choices must be different knowledge leads to variety and change. The complexity of society is directly related to the state of knowledge. The relative simplicity of early society reflects a lesser sum of knowledge. These remarks have identified knowledge by distinguishing it from tradition. (10)

We can learn more about knowledge if we distinguish it from law and learn a little more about law at the same time. The purpose of using knowledge with law is to distinguish, steel from concrete, vent stack from stack vent or assembly from institutional. The reason is that one legal rule cannot apply to all these things, so we distinguish them and write a rule for each.

In building codes some of these categories of knowledge are more sure than others. Occupancy is an example of the latter. In this case, where there is doubt, a specific duty is imposed on the building official to classify the building according to occupancy. This is a well-known strategy. Where there is a possibility, or likelihood of doubt a responsibility for deciding is assigned. There is no such requirement in the structural or plumbing sections. In those sections everyone knows and can distinguish but occupancy is an example of deciding what things are by by-law as a substitute for adequate knowledge.

Here we see the function of law as an instrument for achieving decisions and avoiding a stalemate. Knowledge plays a part and eventually when knowledge is adequate law is unnecessary and may become disused.

There is another common example in building standards, this time relating to the substantive action. In other words, it relates to what must be done rather than what things are. We refer to the requirements for bending moment and shear in structural standards. Among the many load stress relationships to be resolved in design it is the practice to check a beam or other flexural member for both shear and bending because a short deep beam will fail in shear before bending and a long slender one in bending before shear. Hence it is a vital matter of safety to check both and use the most critical factor. This is a question of process. It is the kind of control easily accomplished with the normal grammatical construction, the imperative command used in law. Yet this requirement is omitted altogether in codes and standards.

Here again control is achieved through knowledge and since knowledge is found elsewhere, it is unnecessary to resort to law. It is a professional system of control. These necessary safety measures which are an integral part of design have become established by professions through observation, physical testing, professional debate, practice, and a willingness by the group to agree on appropriate limits. Members of the group must qualify for entrance by meeting or exceeding certain educational norms and must show both practical aptitude and ethical responsibility to be certified as qualified to practice. In practice these professionals never work singly. As a member of one or several licensing and professional societies they are continually receiving new information and enriching their store of knowledge on their specialist subject.

The general public may not know it but the bending-shear question just discussed is such common knowledge to all the members of the profession that it is not worth putting into standards. The professionals write down and set limits for those matters that could be debatable. Thus professional standards are never a complete standard of safety. They are complete when supplemented by the education and certification qualifications of the professional. (11)

Now let us ask, why is the checking of bending and shear not in the law? The reason is not because it is seen to be obvious and everybody knows it. The word "code" means the entire set of rules on any matter. A building code is intended to be a complete compendium of building safety. It is not a policy of building codes to leave certain matters out because they are obvious. For example, building codes require that a dwelling have at least one exit.

No, the reason is that the professionals have not raised the issue. The code makers accept what the professionals give them. They have no other choice since the professionals are the authority whether acknowledged or not, and their authority is the authority of special knowledge which they generate and maintain.

Here we wish to raise a question. When technical standards are made a part of the law either by enactment or reference does this foster or hinder safety? To the authors there appear to be two points at issue. The first involves authority; does a transfer of authority, in fact, take place? The second involves mechanics, does the translation of knowledge into legal form clarify or obscure the objective? These are loaded questions. The authors take the view that such a transfer hinders safety. They do not suggest by this that codes be abandoned. Instead they propose that the present system be objectively and realistically appraised and action be taken depending on the result.

The special professional groups have the authority of knowledge. (12) The state cannot have this; they may only borrow it or buy it. Therefore with enactment or adoption of technical standards knowledge-authority becomes translated into sovereign authority. The instrument for sovereign control is legislation. Meaning lies with the written words. The principle change in the translation is to replace a fluid, evolving and adapting control by an exact statement which is generally in the form of a directive.

One loss is the loss of flexibility to control the variety of situations found in practice. This is not simply a question of economics. Control is usually a unique combination of factors for each hazard situation. The values may have to be drawn from several sources and compromises made. Where the flexibility to treat each situation as unique is lost it is a loss in safety as well as economy, convenience and efficiency.

Another loss is a loss in clarity and coherence. The standard must be translated from technical to legal language. This is not being done by lawyers since they are not proficient in the technical speciality. It is usually done by the professionals in the speciality concerned. (13)

Professional specialist standards began to be written in late 19th century with personal or individual standards for what was then proprietary design. These were not accredited by the community and were alternatives to design regulated by the state. It was made clear to the professionals at that time that until each speciality got together and prepared a peer group standard their knowledge and methods would not be acceptable. Thus individually patented, or proprietary systems became subject to a special standard which was written in legal form by non-legally trained people, so it could be accepted by the legal administrators who did not understand it because it dealt with special knowledge that they could have no access to. It has been this way ever since. In effect, straight forward knowledge is encoded by amateurs and then decoded by other amateurs trying to second-guess what the original coders were up to. This is done because safety is codified legally and regarded as being the prerogative of the state. This whole process is tremendously expensive and wasteful of time.

THE PROBLEM OF PROFESSIONAL INERTIA

The only gains that the authors can see are short-term selfish ones. To maintain the status-quo is easier and creates no immediate expense. There is no doubt that detailed arragements would have to be made if the professional specialist groups were to be recognized as the authorities for certain specialist kinds of knowledge and for the design procedures to go with them. For some groups changes and developments in education and the qualifying and accreditation of the members would be necessary as well as involvement in research and testing and other means of gaining and updating the knowledge in their field. Policing would have to be by the professional groups.

In effect the technical groups would accept a direct responsibility for safety. Technical disputes would be settled through courts of peers, not in the law. When it was agreed technically that a design was safe the matter would be turned over to the state which would deal with the legal matters involved, relating to property and rights. Something resembling this system has been in effect in the Bahamas since 1971 when the Commonwealth of the Bahama Islands was created, although in this case the technical policing for safety remains with the State. (14) It took some effort to achieve this and to go further and involve voluntary groups directly would add a burden which some professional groups would resist unless or until they were forced into it for whatever reasons.

TWO KINDS OF KNOWLEDGE

Philosophers through the ages have recognized that there are two kinds of knowledge and each of these thinkers had his own name for, and way of defining them. Four our purposes they can be regarded as "observed" knowledge and theoretical knowledge. (15)

Observed knowledge results from the direct interplay of the senses, (sight, sound, smell and touch), with the real world. The accumulated knowledge of what happens in the world is experience. Older people are usually more experienced than young people. They have been observing for a longer time and have experienced the longer natural rhythms and some of the more rare exceptions. (16)

We have already said that knowledge is a process of distinguishing. It may be added now that anything observed is not knowledge until it has been communicated. For this it requires a name. Anything that is observed once is not likely to register. What registers gets named. It has been observed frequently. Thus names are given to similar things, classes of things. We have discussed classed of occupancy.

UNIQUENESS OF THINGS

Everything that is named, while it belongs to a class, is really unique. It is said that no two fingerprints, or no two grains of sand on a beach are exactly the same. The reason is that everything in the world (or universe, if you like) is the result of a complex set of unique forces. These forces create, prolong and destroy the thing.

Thus each thing in the world is really an event. A mountain, a wedding and a flash of lightning are the same. They are all events. They all begin and end. They are all unique, yet each is named as belonging to a class.

These characteristics are less important in themselves than they are in contrast with theoretical knowledge because the characteristics of theoretical knowledge are exactly the opposite.

Theoretical knowledge is derived knowledge. It is derived from observed knowledge and deals with what might be called the mechanisms of nature. Theoretical knowledge is sometimes referred to as truths. In fact, it is man's attempt to approximate nature's truths using the medium of written expression.

Whereas things in the real world are time bound, they begin and end, nature's truths are timeless, as far as we know. Also while everything in the real world is unique, slightly different from other things even in the same class, the laws of nature always operate in the same way. There can be no exceptions. All apples are different but they all fall to earth. If one apple fell up, Newton's law of gravitational attraction would have to be reconsidered.

Man makes his own laws but he must discover nature's laws. Man's laws can be orders: "You shall do this," "or that," but when he expresses nature's laws he is expressing what the relationships in nature are. For practical purposes in building safety these are statements of fact. Thus man builds, he manipulates the real world using his knowledge. If the state, using law, wants to influence these manipulations through imperative orders then it must confine its efforts to observed knowledge. "Walls must be stone two feet thick, etc." If the state wants to promote economy to achieve safer, more efficient and more convenient buildings at less cost then it must make provision in the law for the use of theoretical knowledge. The state would have to establish that the professionals are the authorities and that they have responsibility and it would have to provide the means of checking and accrediting the systems of knowledge including education, research, publications, testing, etc., that the professional peer groups use.

It is evident that there are considerable advantages in applying the laws of nature, including the laws of human nature, as a method of controlling hazard in the built environment. It is an old adage - "Know thine enemy," but there is a conflict, not with intent, but with the mechanics if law is the instrument used. Presently a blind adherence to law as the only instrument is denying the building industry of the advantages to control that theoretical knowledge can bring.

THE NARROWNESS OF THEORETICAL KNOWLEDGE

Theoretical knowledge is expert knowledge. We were talking about apples. One can observe an apple falling to the ground but some expertize is needed, some theory, to explain this phenomenon. Yet the same theory would be useless to explain why the apple is red or its size or many other characteristics. With experience gained by observing, on the other hand, one person can have general knowledge of a multitude of characteristics about apples but he would be unable to develop a new strain, control blight, etc. He would need theoretical knowledge for that but he would probably have to consult a different person to advise him on each of the many fields of expertize involved.

Regulations for walls afford a good illustration of specialization in building control. The 1189 assize based on observed knowledge, or experience required that party walls had to be 3 feet thick. Today using theoretical knowledge we say such walls need 4 hours fire resistance. Under the simple "observed knowledge" system we could regulate walls, roof, floors and any part of a building. Early in this century when we discoverd fire resistance it was special, mysterious, it had scientific status. It became almost the "cure-all" for every fire problem. It was the only theory so the answer to every problem was found in terms of more or less fire resistance. Now there is flame spread, smoke control and many active life safety tools. They are all specialist safety measures, based on knowledge.

The difficulty is that there is, as yet anyway, no complete set of theories which can replace all the aspects which the generalists' view of the world provides for. There are usually gaps. Hence control should be by the generalist and should depend considerably on imperative law, but for specific aspects of the problem where specialist knowledge is available this knowledge should be used. It must be recognized, however, that when the specialist knowledge is applied, a somewhat different instrument, a different balance between law and knowledge must be used.

CUSTOM

Having discussed law and then knowledge it is easier now to talk about custom. Custom is a non-thing. If knowledge is the distinguishing of specific things within the totality of the universe, custom, in the purest sense, was that totality before any "thing" was distinguished. Custom, predates knowledge and is therefore by definition not knowable.

The individual can be involved and participate in a customary way of life. An outsider can observe these ways but must belong, be involved, if he is to act on his observations. Custom is distinct from knowledge therefore in this further sense, it is non-transferrable. It can be shared only by those involved.

Custom has been the principle social control for thousands of years. It lives on today and remains a strong controlling influence in our lives. Really, it is as live and and vigorous a control as ever but other newer controls have been superimposed on top of it. While it may be impossible, strictly speaking, to "know" custom, to know the unknowable, today it can be distinguished from law and knowledge and in this way something can be learned about it. We have said that it is a non-thing, not transferrable and non-knowable. This is all negative. What then can be said in a positive way about it.

We have discussed authority and have seen that law is an instrument used when authority is transferred to the state. Again technical knowledge is an instrument used when authority is taken by special knowledge groups. Custom, on the other hand, is an expression of the original authority of the community. It stays with the community. It cannot be transferred.

In the building world it is more usual to use the word "tradition" as meaning custom. Each part of the world has its traditional ways of building. These ways are passed down from generation to generation and remain essentially unchanged. Tradition is a control. It is a method of preserving cultural values. Before writing, it was possibly the only method.

The traditional way of doing things is handed down from the old to the young in continuous succession. In a traditional context the oldest, non-senile people are the most authoritative. Communication is one way from the old to the young. "Children shall be seen but not heard." There is no feedback. There could be none. Feedback results in change. In fact, feedback is an instrument of change appropriate only to a system of knowledge control.

Custom or tradition is in essence unwritten, and the origin of British Common Law is likewise unwritten and is really the common custom of the people. Despite the evidence of written customs, custom or tradition is communicated, reinforced and perpetuated essentially through involvement and participation. This ensures that it continues without change. The traditions of building are a mixture of process or sequential action, construction standards, and skills. The process and the construction standards can be written in a general way only. If inscribed in law and strictly adhered to the precise general statements that would ensue would be so inhibiting and cause so many problems with the non-typical situations that are constantly rising, that construction would come to a halt.

Tradition controlled the human race and preserved its culture for eons of time before writing was invented. It does not often benefit from being written. Whereas both law and technical knowledge require the written word as their medium, tradition is the opposite. Its medium is participation. Hence tradition may be a valuable control in situations where writing is inappropriate.

Professor Albright, one of the world's foremost orientalists stresses "the fact that oral transmission of tradition is inherently more consistent and logical in its results than written transmission, since it sifts and refines, modifying whatever does not fit into the spirit of the main body of tradition." (17) Masonry and frame construction was used at Jericho at least 6000 years ago and used since then around the world. These are among the oldest building traditions but written standards for masonry and frame construction date from the 1930's although laws written to change these traditions for fire safety reasons have been in effect since Roman times.

There is a modern tendency to put everything down in writing and beyond that to enact it in law. It might be well to ask, "Does this serve any purpose?" Where skills and customary ways are involved it may be well to leave them unwritten as part of the richness of the communities to which they belong. In Canada a wood fire wall is used on the West Coast and a special plank frame construction in Quebec. There is also a tradition of wood shingles in the West and asphalt in the East. These systems are viable in the communities where they belong because of a complex set of conditions both known and unknown. They are not suitable for a national standard. It is undesirable that they be written down for if they are, they could be applied where they do not belong. A worthy tradition in one place may well be a hazard in another.

SKILL

Skill is a form of control that goes hand-in-hand with custom. Skill is doing something, not knowing it. You play golf, do carpentry. One can read about these things but proficiency is possible only through doing. In the middle ages each master craftsman had his mark assigned to him by his guild hall. Today welders require accreditation and must sign their work with their mark. Skill is still an important unwritten control. It is interesting that manual work, because it is doing something lends itself to control by law, to commands. One can say do this rather than that, but there is no way that law can control how well the thing is done, and skill can make the difference between a hazardous and a safe building.

OTHER INSTRUMENTS

The limits of time and space do not permit full consideration of other instruments of control. In the following remarks a few of these are discussed briefly. These are instruments such as money, licensing, goals other than safety, symbolism, fads and function and also the set of local natural conditions including climate, geology and at least the flora if not the fauna of the area.

MONEY

Money may be the most plausible of these other instruments. It is the authority or controlling force used by lending agencies. It is the means or a means by which safety can be introduced into buildings. Money is the instrument and what it achieves is inevitably related to the goals and ethics of the financial source.

Money also has a controlling effect which is dependent for its force on the size of the financial source. Where government building is a significant proportion of the whole building output, the government standards will tend to be used in other areas and can voluntarily become "the" standard over all others. This is sometimes because industrial production is geared to the volume market and sometimes because those responsible for building take "reasonable care" which means using any knowledge or standard that they could reasonably be expected to know about.

Money is the control in yet another sense. It often happens that a permit application is in violation of the municipal by-law and the municipal council has the choice of rejecting an application and losing a development to a neighbouring municipality or waiving the by-law to accept whatever benefits the application brings. Here the issue is money versus the by-law. This raises the question, "Does the by-law really represent the minimum level of risk that is tolerable to the community, or is it an "offering" to safety that can be waived when something really important is at stake.

LICENSING

Every building is designed for use. Many of these uses, particularly commerical uses are licensed and in the case of tourist establishments, restaurants and bars, certain building safety controls become a condition of the license. Hospitals are accredited by the hospital association. This is a form of license and here again safety is a condition of the accreditation.

It is of note that this is one of the best instruments if a performance code is contemplated. In the most simple or basic sense building performance means satisfying the shelter needs of the occupancy. Licensing the occupancy is a way of providing control over the provision of these needs. Through a license to occupy land or space for a given use, a combined control for planning, zoning, building and occupancy is possible. Performance is possible if the control spells out the needs and hazards of occupancy that must be provided or accounted for. If and when these occupancy conditions can be spelled out, building design will be liberated. Any design can be permitted as long as it provides the needs and mitigates the hazards of occupancy - and, of course, does not create any uncontrolled hazards of its own in the process.

GOALS OTHER THAN SAFETY

A good example of this category is the goal to preserve historic buildings. These may have thatched or wood shingled roofs, open stairs and combustible walls. To preserve these features is in conflict with building codes which normally aim to abolish them. If a building is historic it is normal to develop a justification for preservation which has more power than the reasons for following the law. Perhaps being historic places the building in a special class and if there are few in the class then for other than dangers to its occupants it is not a serious hazard.

SYMBOLISM

A symbol is something that stands for something else. The "house" symbolizes the home and the home is the original occupancy and to a degree untouchable by control. Houses contain a greater variety of hazards but have fewer controls than any other occupancy. "The Englishman's home is his castle." This symbolism identifies with a different level of tolerable risk than with other occupancies. It is therefore an important instrument of control.

Another form of symbolic control is the specific development measures placed on the land adjacent to buildings of cultural significance such as national monuments, capital or parliament buildings or the like. (18) The controls are on the land adjacent but the significant buildings which they protect are themselves controls. They are significant for their continuing function of reinforcing the cultural solidarity of the state. Symbolic structures often result in exceptions to the principle of uniform application of law. This need not be seen as an exception. It is really a division of control between two instruments, symbolism and the law.

FADS

Fads in building can be important instruments of control. Historically the fenestration fad has fluctuated back and forth from windowless to all-glass buildings. Another fad is the atrium. These design forms, in themselves have attributes of both hazard and control depending on how and where they are used. To maintain a uniform tolerable level of risk the requirements which supplement the hazard-safety attributes of these forms must differ. The code requirement must be more demanding where the design form is less of a safety measure and less demanding if the design form is more of a safety measure.

FUNCTION

The discussion of "fads" implies that all buildings are, to a degree, safe but due to fads or the blind pursuit of style, some buildings have less intrinsic safety than others and so are subject to more stringent code requirements to raise them to a tolerable standard. The idea of buildings being intrinsically safe is probably the opposite to that which most regulating authorities harbour but it is a sound idea which will be of increasing usefulness.

In effect it implies that the purpose or function of the building is to shelter or protect the occupancy. It is absurd, therefore, to protect the building since this would be protecting the protection. Some buildings may constitute better protection than others but this is an unknown unless we know the occupancy or function that the building is designed to protect. The best protection for concrete block storage might be a wire fence. Function is a good control, not adequately utilized and coupled with licensing, as we have said before, could provide the best building performance and that is in the broadest sense the purpose of control.

A recent situation in a Canadian city illustrates the futility of regulation of the building and the necessity of viewing the function, or occupancy, as the thing to be controlled. In this situation a permit was requested to build a building with a roof garden at the top. The argument centerd around "Where is the roof?" If the roof garden is outside the building, then it is not subject to control, or, if it is part of the building then it is a building without a roof.

These absurd semantic questions evaporate when the function or occupancy is chosen as the thing to be controlled. In this case the roof garden and the occupancies below it would be considered as though the building did not exist. The control question would be "How much building needs to be provided to satisfy the needs of occupancy and make it safe?"

NATURAL CONDITIONS

In certain parts of the world, for example Scotland, there is a tradition of building with stone and slate as against wood and thatch. The reason, other than the availability of these materials, is unknown yet because it is the custom it is, to the extent that stone is non-combustible, a safety control against fire. Against this, Scotland is a cold country and hazards of heating are present that do not exist in locations further south.

Hazards differ in different parts of the world and these and the ways of countering them are due to both cultural and natural reasons. A rational approach to safety must take all of these into account. A satisfactory building must first meet the demands of occupancy, it must provide support and shelter. It is not satisfactory if it is unsafe and to make it safer without undue expense requires that the geotechnical, climatological and human behavioural phenomena be considered conjointly with the space geometry and the structural and mechanical properties of building elements.

CONCLUSION

It is not really sensible to say that a certain thing was put in a building for aesthetic reasons and something else for safety reasons. Every element of a building contributes in either a positive or negative way to safety, economy, convenience, efficiency, durability and looks. The building is the control and the extent that it is positive or negative depends on the choice and use of building safety instruments and the capability of these in coping with the phenomena that relate to safety as well as the other attributes that a building must have in order to perform as its owners, designers and users intended it to.

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PERFORMANCE VS PRODUCER-CONTROLLED CODES

by

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This is intended to speed evaluation and implementation of innovations in standards and codes, which too often await change initiated by large producer corporations. Such producers tend to take such action only when no damage is done to a status quo that favors them and, further, when they stand to benefit from a change.

The writer, a would-be innovator in in-place field evaluation of concrete insulation and strength for twenty years, would leaven producer domination of codes with more vigorous participation of users. Products and methods should be evaluated not under artificial conditions, but under conditions of intended use. Examples include performance vs potential in thermal insulation and nondestructive in-place strength testing by the pullout method.

Key Words: Building codes; concrete testing; evaluation; innovations; in-place testing; performance approach; regulatory domination; standards development.

Innovation in building codes and standards too often is implemented only after producer monopolies are assured no damage will be done to their vested interest and secondly, that they will benefit from any change.

Partial justification for this exists in the producer having the most concentrated investment, experience and expertise in his speciality. Uncritical acceptance of this imbalance, however, tends to continue dominance of less alert personnel, unresponsive to technical advances, contrary to public and in the long run, to the producer's own interest.

As recognized final authorities on their own products, producers in effect control standardization and code development. Regulatory agency personnel are too frequently overly respectful of producer opinion, insufficiently financed and informed to be an effective counterforce in our so-called voluntary concensus standards system. While effort is made to keep producer interests balanced by user- and general-interest ostensible participation in standards-setting organizations, producers call the tune and pay the fiddler.

This pattern impressed me first about twenty years ago, when my faith that a quality product would succeed in the market place was strong. I had just become manufacturer's sales representative for an independent, one-plant lightweight aggregate (perlite) producer. He advised that one of my greatest sales assets was his unique roof-deck roofing specification, recognized by a prestigeous roofing supplier.

I wrote the roofing supplier, who responded, " . . you will be delighted to learn your product may now be treated in the same way as any competitive material." The perlite producer was outraged, but was advised he had no recourse. We were at liberty to continue to recommend the solid, no-gap adhesive method; those who used it saved money initially and avoided several periodic maintenance or roofing replacement jobs over the years, in addition to the savings in fuel economy. But we no longer had the support of the roofing supplier in requiring a superior method of which our competitors' products were incapable, due to relatively inferior strength development in the field.

It was evident that our monopolistic competitors had complained to the roofing supplier and threatened him with loss of business from their multiplant operations across the country. Further, it became apparent that the standard method of test for lightweight concrete strength obscured the fact that our treated perlite behaved well in use, while our competitors' products could "perform" well only under the artificial laboratory conditions of the standard test.

One designer appeared to grasp the advantages of our system and specified it, only to change at the last moment to our competition. "It was like taking candy from a baby," explained one of my new colleagues some months later, after our competition had bought out our operation. In the interim, the designer had complained to me of job delays, before-acceptance modification cost overruns, and excessive fuel requirements which had caused the owner to withhold settlement. My new sales colleague knew nothing of these problems: "They come under different departments." The designer's sad tale had even more point in these days of energy crisis; even then, it comforted no one.

Meanwhile, this innovative, specially treated perlite had gone through several stages of absorbing controversy in standards journals and meetings. Understanding was clouded by nonpublication of research due to apparent national security classification. The classification veil was parted, in part, and briefly, when our competitor was about to take over our plant; but the tri-service study was not published until the perlite patents expired some years later. Then, published discussion of a number of unsettled questions was rejected, officially, as the author had reportedly "answered me personally." "I have never considered you personally dishonest," said another old friend, a standards official; "you just have a communications problem."

A good communicator, like a good standard or code, must establish a high-level record on the side of motherhood, precision and accuracy. If in standard testing of a producer's material for acceptance by a user, it is found that greatest precision is encountered under certain atmospheric conditioning, the standard reaction is to make that conditioning mandatory, within close limits.

Providing that conditioning give also the best (i.e., the highest, most favorable to the producer) test results, as well as the most precise, that method of test becomes the base reference for accuracy. For example, the strength of concrete is that number obtained from breaking a standard-cure 6 x 12 inch cylinder in a laboratory compression testing machine. That is performance.

Performance is not further defined; because it is in the dictionary, say the glossary writers, it need not be further defined. Modifier words such as potential are mentioned more often than field, in-place or use before the word performance. How can one define field, in-place or use? One must use economy in language as well as testing; and standard tests for potential strength are the most precise and therefore the most economical, as the least number of tests is required for acceptable accuracy.

This situation applies to thermal insulation, cement and concrete. Where there are exceptions, they favor producer interests.

Wet insulation is unsuited for acceptance testing because it not only is imprecise - it indicates less efficiency than that confirmed by a thin, easily dried out sample, oven-dried in the standard method. Exception: fire-test ratings may show superior "performance" if difficult-to-drive-out moisture must be turned to steam before temperature limits are exceeded - and if the steam pressure forces are not so explosive as to blow the insulation off the fireproofed structure.

Cement is tested for acceptance in mortar (standard sand) samples. The fact that relative performance of cements in mortars and concretes may not be parallel is controversial, although cement producers are apt to argue their responsibility stops with the mortar acceptance tests: any trouble with the concrete must arise from nonstandard performance of aggregate, water, chemical admixtures or other factors.

As cement is a hydraulic-setting material, extra water must be added to effect the chemical reaction of cement hydration after the concrete had set. The lowest possible quantity of water in the plastic concrete is thought to be essential, based on Abrams' "law," actually an hypothesis. Best (i.e., highest) strengths are obtained by taking a representative sample before tempering water is added to improve workability and following standard methods through moist-room curing. (Producers may well call "Foul!" at this cynical recital, but the sequence is too often practiced.)

The moist-room curing shall be at a standard temperature of 23$\pm$ 1.7°C and relative humidity not less than 95%. The moist room is preferred over immersing cylinders in lime-saturated water, as water vapor can penetrate to aid in cement hydration and strength development better than liquid water. Meanwhile, the high-quality, before-tempering concrete these cylinders "represent" may have insufficient water for hydration, as no curing water may have been added; its low-water content and poor workability probably resulted in bad consolidation and honeycomb voids, while the cylinder had been well rodded into high density.

The performance and precision of such standard curing has recently been improved by requiring minimum humidity be increased from 90 to 95%. Producers of humidity control apparatus have not complained, to my knowledge - although one may have come to ignore agreements to manufacture in-place test equipment capable of determining nonstandard field load-bearing capacity strengths in structures, regardless of ambient relative humidity and temperature.

In-place quality of concrete may be evaluated by testing in compression diamond-drilled cores or CIPPOC cast-in-place-push-out cylinders. The core method has been standard for a number of years, is expensive and has many drawbacks, including the fact that it is not suited to use before the concrete is 14 days old. Thus, the CIPPOC method, which had been in use for about 12 years without standards recognition, will have an increasingly important role in early strength and safe load-bearing capacity tests when it becomes a standard soon.

Nondestructive tests, as officially designated, include the impact-rebound hammer, the explosive-fired penetration probe, the sonic pulse velocity and the pullout methods. Only the last, the pullout method (in which the writer has a patent interest), has not been recognized as standard. Some feel that while all these tests may measure concrete "quality," they may not measure compressive strength. The fact that results from these tests may often be more useful or significant than standard cylinder tests is less controversial.

Although these tests have been available for many years, their initial codification is not the function of this audience. It seems to be the function of the American Concrete Institute (ACI), which, in turn, must cite test methods developed by the American Society for Testing and Materials (ASTM). In similar fashion, jurisdiction among the several committees and subcommittees of each of these organizations must be established. Many other interim issues have delayed code recognition of these methods over a period socn to enter its fifth decade, issues ranging from technical to political and including standard hang-ups, always dominated by producer control of the standardization process.

My own 10-year candidate for in-place concrete strength determination, the pullout method, is a rediscovery and adaptation of a Russian method reported in 1938. A small anchor is cast in the concrete. An inexpensive and hand-portable hydraulic jack is used to pull this anchor and attached small cone of concrete out at any age after the concrete has set. The measured force to failure is divided by the area of the conical surface, giving a strength number relating consistently to compressive strength results - providing the standard specimens are "representative" of the pullout mass in curing, size and other ways.

ASTM in '71 assigned the pullout to its nondestructive subcommittee despite the evident semidestructive break about the small cone, if the test is carried to actual rupture. Now, 5 years later, some who made that assignment may argue that a nondestructive test cannot measure strength.

The standard strength of concrete is based on the 6 x 12-inch cylinder being broken in compression, giving "the usual cone" fracture. Thus the compressive force measures a shear and tensile strength failure, following resolution of that force through cylinder-end friction and adjustment for compressive speciment size and shape under conditions never found in use.

The pullout test, on the other hand, measures directly the tensile strength required to fail a similar cone at a small fraction of the cost and under any curing conditions desired - most importantly, including the structure in use. The pullout cone failure is consistent in size and shape, while the size and shape of the cylinder failures vary with different strength levels and energy requirements for new-fragment surface areas.

The pullout test is so simple and low in cost that those supposed advantages may be a threat to the worth of expensive stationary apparatus and facilities necessary for traditional tests. From another viewpoint, the producer community may decide that prospective pullout apparatus sales and profits are insufficient incentives to pioneer an innovative approach. To the extent the pullout might replace traditional products and services, overall sales volume - and national product! - might suffer.

The outlook for early availability of a pullout standard is mixed: the rules of the game keep changing. The society has developed a new category of publication for the book of standards: a "proposed method," not a standard, but printed "for information purposes only." Even standards of ballotting on a proposed pullout method may be in flux: only a voice vote, as opposed to a letter ballot, may be required. But new rulings, perhaps to be revised at later meetings by producers or their proxies, may affect the issue and effect perpetuation of the status quo.

It is hoped that this recital of some of the obstacles to building code innovation may lead to clarification of ground rules, identification of issues and jurisdictional responsibilities, and improved safety in in-use performance of buildings.

LOGICAL ANALYSIS OF BUILDING CODE PROVISIONS

by

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The paper describes a systematic analysis of a set of related building code provisions. The analysis is a part of an overall methodology being developed for the systematic formulation and expression of clear, correct, and complete building regulatory documents. Provisions for the allowable size of buildings are represented with decision tables and networks. The analysis shows the complete hierarchy of decision making necessary to arrive at the final answer. Alternate schemes of arranging the information are developed, and the relation of the information content to the overall organization of the document is shown. The applicability of the analysis for various factions of the building regulatory system is evaluated.

Key words: Building codes; computer model; decision table; decision theory; networks; specifications; standards; system engineering

INTRODUCTION

This report presents a case study examining the internal consistency of selected building code provisions using a logical and systematic methodology for the analysis, representation, and formulation of the provisions. Use of the methodology can produce benefits for those who write and maintain codes, standards, and specifications, those who enforce such regulations, and those who design or construct based upon such documents. The goal of using the methodology is to produce complete, clear, and correct documents, and thus to enhance the efficiency and utility of the building regulatory process and to assure that the process is achieving its objective.

Research and development on this methodology is being carried on at the National Bureau of Standards and at least three universities. The work was initiated several years ago with a project to represent a specification for structural design in a form amenable to computer processing (1)*. That project and subsequent work (2, 3, 4, 5) have indicated that the methodology used for establishing such a representation is also very useful in achieving completeness, clarity, and correctness in written documents.

This report contains a brief overview of the methodology and a discussion of the application of some of the aspects of the methodology to the provisions governing the area of a building found in the Uniform Building Code, 1973 Edition (6). More detailed descriptions of the methodology are available in several of the references (2, 3, 4).

OVERVIEW OF THE METHODOLOGY

A specification consists of a collection of provisions and can be modeled as a set of data related in several ways. Examples of items of data are: the status of a provision (satisfied, violated); the type of physical entity being addressed (building, floor, door, etc.); the measure of a physical entity (area, height, etc.); and logical statements (fire extinguishing system present, wall separates buildings with different heights, etc.). Data items can take on numerical values (such as area), arbitrary values from a restricted set (such as type of construction), or the binary logical values of true and false (also termed boolean values). The kinds of relations between data items include functional definitions (total allowable area of a multistory building = twice the allowable area for a single story), logical comparisons (actual height of wall $\geq$ required height of wall), heirarchical categorizations (area is a measure of a floor, which is a part of a building, which is a physical entity), and syntactic rules for placement of data items in sentences.

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*The numbers in parenthesis refer to the citations listed in References.

The methodology addresses the organization and meaning of the data items and their relations over a broad range, from gross grouping of related sets of provisions for easy access and cross reference to detailed rules for the evaluation of a single provision. There are several systematic procedures used to accomplish this work; this case study will illustrate the use of the following two systems:

1) The decision table is used to express the functional and logical relationships that establish the value for each data item that is defined in the dcoument. It is a way of dealing with the meaning of an individual provision. A decision table is simply an orderly presentation of the reasoning controlling a set of decisions. It is easily analyzed to assure that the reasoning process will always lead to a unique result and that no possibility exists for encountering a situation not defined. Another advantage of decision tables is that they require an overall analysis of situations involving parallel thought processes whereas written text, and to some extent, flow charts both describe more of a sequential thought pattern.

2) The information network is used for reference to the other items of data that may be required in the evaluation of any data item. It gives a clear expression of the relations between provisions. Each data item is a point, or node, on the network. The nodes are connected to their ingredient nodes by branches that represent the flow of information through a set of provisions from the input data items to the terminal criteria. The ingredients of a node are defined as all those data items thay may be required for direct evaluation of the node. For example, the allowable story area and the actual story area are ingredients to the provision that ". . . no floor shall have an area greater than the allowable area. . ."

Decision tables and information networks will be described in more detail as they are introduced in the analysis of the case study.

UBC PROVISIONS FOR BUILDING AREA

Excerpts from some of the provisions in the 1973 Uniform Building Code that deal with restrictions on building area are reproduced in Appendix A; Sections 505, "Allowable Floor Area," and 506, "Allowable Area Increases," and Table 5C are taken from Chapter 5, "Classification of All Buildings by Use or Occupancy and General Requirements for all Occupancies."

The most basic provisions that no floor be larger than the allowable floor area and that no multistory building have a total floor area larger than twice the allowable single floor area are contained in paragraphs (a) and (b) of Section 505. The remainder of Section 505 deals with somewhat special situations. Table 5C Section 506, and Chapter 16 are explicitly referenced in Section 505 as containing provisions that affect the allowable area. The last paragraph of Section 505 contains a significant sentence: "See Chapters 6 to 16 inclusive for special occupancy provisions." The sentence is contained entirely within the provisions for area separation walls, yet apparently it is meant to apply to the provisions for floor area. There are at least four locations in those chapters that contain provisions modifying the allowable area that are not referenced at any other place in the basic provisions for area (Sections 702, 802, 1102 and 1109). In this case study the assumption is made that this sentence is indeed intended to serve as a reference to those provisions.

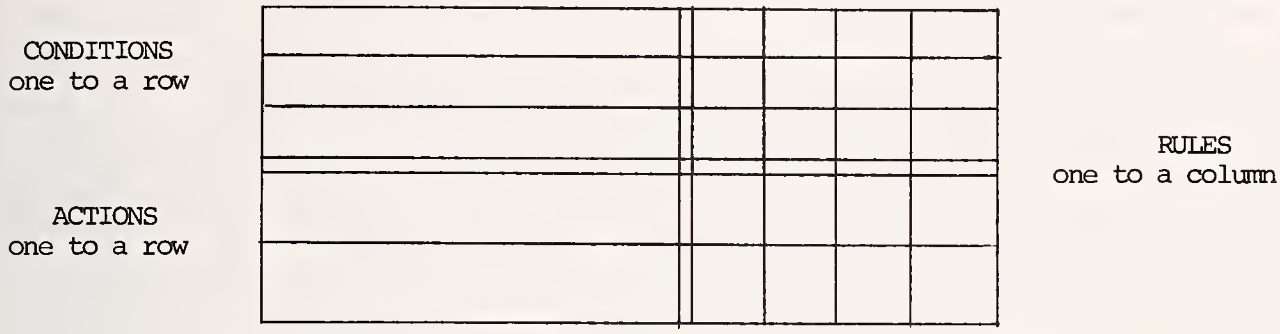
CONDUCT OF THE CASE STUDY

The case study began with the listing of a set of data items. Decision tables were then developed and checked for each of those data items for which an evaluation procedure is defined in the code. This process led to the identification of several new data items. The information network was assembled as the decision tables were developed because the decision table clearly identifies all the ingredients of a data item. The decision tables and information network were analyzed and used to suggest a possible reorganization of the provisions, as described in the remaining portions of this report.

The complete list of data items identified in this case study are shown in Appendix B. Each data item has a name, a short label, and a number. The remaining items shown in the tabulation in Appendix B will be discussed in conjunction with the information network. Several of the data items (most of the ones from 53 to 74) are not mentioned in Sections 505 or 506 or Chapter 16, but are found in those ambiguously referenced sections previously mentioned. The case study is arbitrarily truncated at references to the allowable height and allowable exit distance; that is, the decision tables and ingredients were not developed for them because each of them have significantly large sets of provisions in themselves.

DECISION TABLES

A brief introduction to decision tables will be presented in the context of this case study. A decision table is composed of conditions, actions, and rules, arranged as shown on next page. A condition is a logical statement that may have only one of two values; true or false. An action in a general sense is any operation; e.g., it may be the assignment of a value to a variable by means of a formula or a statement of control that may indicate the next procedure to be initiated. A rule is a statement that prescribes a set of conditions in order that a specified set of actions can be performed. A decision table is essentially a structure for defining a set of related rules. Each rule contains an entry (value) for each of the conditions and an entry to indicate which action is to be executed for the rule. The rule can be thought of as a logical AND function, that is, the rule is not satisfied unless each of the condition entries it contains is matched.



Conventional Structure of a Decision Table

The decision table for data item number 2, single story area check, is an example of a very simple decision table. The only condition is that the actual story area be less than the total allowable story area, and the two possible actions are that the provision is either satisfied or violated. The table is shown below, where T stands for true, F for false, and X for "take this action."

		Rule 1	Rule 2
Condition 1	Actual story area $\leq$ Total allowable story area	T	F
Action 1	Single story area check satisfied	X	
Action 2	Single story area check violated		X

Decision Table for Single Story Area Check

The table is read rule by rule, "If the actual story area is less than the total allowable story area, then the single story area check is satisfied, if it is not, then the check is violated."

The decision table shown below for data item number 46, the allowable area increase for special occupancy situations (506 (b)) illustrates several more features of decision tables: 1) a single condition can be made up of several logical comparisons, 2) decision tables can have many conditions, and 3) the condition entries in the rules can be other than T or F. Note that a condition containing several logical subunits that are connected by an and (a logical and) is true only if all of the subunits are true whereas a condition containing subunits that are connected by an or is true if any of the subunits are true. The condition entry "·" stands for immaterial, meaning that either a true or false value for that condition is acceptable for the rule with the "·". The significance is that the condition has no bearing on the rule and consequently need not be checked to verify that rule. The condition entry "-" means implicitly false, or false without testing. It is used to note that the value of that condition is predetermined by the value of some other condition expressed for that rule. Since conditions two and three contain opposing statements about the presence of a fire extinguishing system, they cannot both be true

		Rules 1	2	3	4
Condition 1	All sides have separation and The minimum width of separation is at least 60'	T	T	T	F
Condition 2	Number stories is 2 or less and Occupancy is F, G, or E5 and Fire extinguishing system is present	T	-	F	·
Condition 3	Number of stories is one and Occupancy is G and Fire estinguishing system is not present and Construction type is II, III-H.T., III-1 hr., or IV	-	T	F	·
Action 1	Allowable increase (506 (b)) = unlimited	X	X		
Action 2	Allowable increase (506 (b)) = 0			X	X

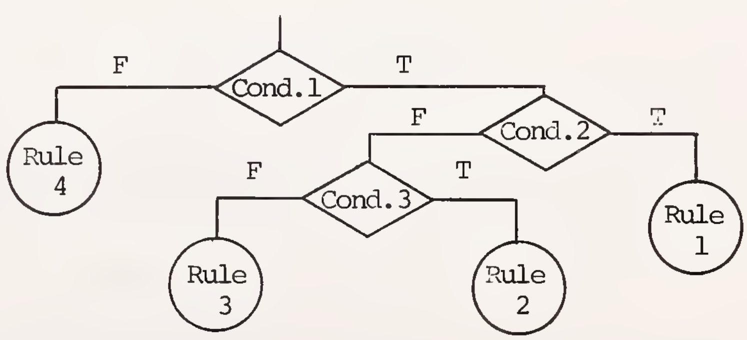
Decision Table for Allowable Increases for Special Occupancy Situations in the same rule. It is also possible to use the symbol "+" meaning implicitly true, but it does not occur in this table. The significance of implicit entries is that they show relations among conditions where such relations exist and they reduce the amount of checking necessary to verify a rule. Reference 4 contains more information on the details of decision tables.

Decision tables for all of the derived values (data items for which an evaluation procedure is defined in the code) in the data list except item number 7 are shown in Appendix C. Data item 7 is the allowable story area shown in Table 5C. The table is not converted from its present tabular format because it is quite concise and easy to analyze. Note that several of the decision tables contain information from widely separated sections of the code, and thus indicate somewhat of an organizational problem.

ANALYSIS OF DECISION TABLES

A great deal is learned about a set of provisions merely by formulating the decision tables for them. A singular advantage of decision tables, however, is that they lend themselves to a systematic analysis for completeness and uniqueness: complete in the sense that every possible set of values for the conditions will match some rule in the table, and unique in the sense that each possible set of values for the conditions will match one and only one rule. The most convenient way to carry this analysis out is to construct a decision tree from the decision table. The upper portion of the rules, generally called the condition entry, of the decision table for the allowable area increase (506 (b)) is shown along with the decision tree derived from it.

	Rules 1	2	3	4
Condition 1	T	T	T	F
Condition 2	T	-	F	•
Condition 3	-	T	F	•



Example Decision Tree

The decision tree is constructed by dividing the table into two subtables each time a condition is tested, one subtable containing those rules for which the condition is true, the other containing those rules for which the condition is false. A rule is isolated when all of its entries that are not either immaterial or implicit have been tested. Thus, dividing this table by testing condition 1 results in two new subtables, one with rules 1 through 3, and the second with rule 4. Since rule 4 contains no other explicit entries, it is isolated from the table and shown as a circle terminating a branch on the decision tree. Testing condition 2 in the first subtable separates rule 3 from rules 1 and 2 in a similar fashion. This decision tree shows that the decision table is complete because no test of a condition yielded a rule that was not in the table and that the table is unique because no test of a condition yielded more than one rule unless there were conditions remaining to be tested.

Many algorithms for developing decision trees exist, particularly for the problem of deciding what order to use in testing the conditions (4, 7). Computer software is available to perform this analysis, but it is very easy to do by hand for all but the largest tables once one has practiced the procedure. All of the decision tables shown in Appendix C were checked using a decision tree and were found to be complete and unique, as defined above.

INFORMATION NETWORK

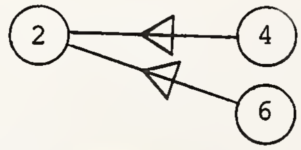
As each decision table is formed, the data items that are its ingredient nodes are found. The entire information network can be constructed one node at a time in this fashion, as shown below.

Data item 2, single story area check

Ingredient nodes:

Data item 4, actual story area
Data item 6, allowable story area

Portion of information network



Computer representation of the network

```
2 SINGLE STORY AREA CHECK
: .......... 4 actual story area
: .......... 6 allowable story area
```

The assembly is generally performed on a computer because of the tedious manipulations involved. Such computer software is available at NBS. Once the assembly is complete, the entire network can be displayed in the same fashion as that shown on the previous page. The dotted lines in the figure are ingredient lines, that is, the node at the right end of a line is an ingredient of the node at the left end. Such figures for entire networks allow one to visualize the second, third and higher generation ingredients of a node.

Appendix D contains two displays of the information network for this case study. The first display (covering two pages) shows all of the nodes and ingredient lines in the entire network in the fashion described on the previous page, except that a few symbols are added to indicate connections that the computer printout could not show otherwise. The nodes shown with a negative sign in front of the number are repeated nodes. To find the original occurrence of the node, go up the figure at the same level until the node is printed without a negative sign. The asterisk following a negative node number indicates that the repeated node has ingredient nodes that are not shown. To find the ingredient nodes, go to the original occurrence of the node. The second display is discussed below.

The assembled network allows determination of other properties of interest. The dependents of a node are all of those nodes for which it is an ingredient. The ingredients and dependents of nodes, as well as, three other properties are listed in Appendix B. The level from output is the number of steps from the node to the terminal criteria, and the level from input is the number of steps from the node to the input values, in both cases going along the longest path that goes through the node. The float of a node is the difference between the longest path from input to output in the network and the longest such path that passes through the node. The levels and float allow the network displays to be reordered by sorting to place those nodes with either large or small level as float first in the network; however, a full discussion of their use is beyond the scope of this case study.

Besides providing the explicit reference for locating the ingredients of any node, the ingredience network is useful for evaluating the entire procedure necessary to drive the value of a node from the input values. As such it can be used to provide alternate orderings of the individual steps in the process. The information network can also be displayed as a dependence network, in which all of the dependents of a node are shown at the right end of the branches connected to it. The dependence network is useful for tracing the effects of a data item throughout a set of provisions. The second display in Appendix D is a dependence network for occupancy group.

DISCUSSION

The first characteristic of these provisions that became apparent as the case study evolved, even before many decision tables were completed, was the complexity on both a small and large scale. On the small scale, for example, a systematic analysis of Table 5C leads one to question why there are so many different values for allowable floor area. The eight construction types and thirteen occupancy divisions can be matched in 104 combinations, but this number is reduced somewhat by the many combinations that are either not permitted or not limited. Between these two extremes, however, there are 30 other values, some of them separated by as little as 0.4%! (11,250 ft^2 vs. 11,300 ft^2). Common sense would indicate that such accuracy can probably not be justified. Any justification behind the provisions in these sections must be inferred, since no performance attributes or physical phenomena are linked to them and no commentary is presented.

On the large scale, the maze of alternative procedures to evaluate the area check seems to overwhelm one. The maze is not apparent on a first reading of Section 505, but begins to grow as the cross references to other sections, both explicit and implicit, are explored. For example, the fairly explicit provisions for area separation walls contained in Section 505 (d) are modified by Section 902 (b) for Group D-1 occupancies with Type III - 1 hour construction. An example of the effect of this complexity is shown by the shaded regions of Table 5C as shown below: all of the shaded values are modified at one or more points in Chapters 6 through 16 (any value can be effected by the allowable increases in Section 506). When such a large table is presented and yet over half of its values are somehow modified or qualified, the worth of the table is severely decreased.

OCCUPANCY	TYPES OF CONSTRUCTION							
	I	II	III		IV		V	
			1-Hour or H.T.	N	1-Hour	N	1-Hour	N
A	Unlimited	22,500	Not Permitted					
B) 1-2	Unlimited	22,500	10,100	Not Permitted	10,100	Not Permitted	7,900	Not Permitted
B) 3-4	Unlimited	22,500	10,100	6,800	10,100	6,800	7,900	4500
C	Unlimited	34,000	15,200	10,100	15,200	10,100	11,800	6800
D) 1	Unlimited	11,300	Not Permitted[1]					
D) 2-3	Unlimited	11,300	5,100	Not Permitted	5,100	Not Permitted	3,900	Not Permitted
E) 1-2[2]	11,250	9,300	4,200	2,800	4,200	2,800	3,300	1900
E) 3-4-5[2]	Unlimited	18,600	8,400	5,600	8,400	5,600	6,600	3800
F) 1-2-3	Unlimited	30,000	13,500	9,000	13,500	9,000	10,500	6000
G	Unlimited	45,000	20,300	13,500	20,300	13,500	15,800	9[illegible]
H	Unlimited	22,500	10,100	6,800[3]	10,100	6,800[3]	7,900	4500[3]
I	Unlimited							
J[4]	See Chapter 15							

Modified Values in Table 5C

A specific problem identified in the analysis is that several cross references between related provisions were missing. This is the kind of problem that might well cause any user of the code to make an incorrect judgement. A solution might be approached two ways: All the provisions for area might be grouped at one location, or the provisions for area might be dispersed to all of the chapters for the various occupancy groups with no provisions in the chapter currently used for general requirements. Taking the first approach, it is possible to use the information network to order the provisions in a style that allows easy progression through the procedure and also provides explicit cross references. Using the complete information network shown in Appendix D, the abbreviated network and outline of provisions shown in Appendix E are obtained (note that the fairly self-contained set of provisions for area separation walls is arbitrarily placed last in the outline).

It is possible to have several different orders for the provisions without changing the meaning or relation between provisions by simply changing the order of placing branches in the information network. The outline shown is just one of many possible arrangements.

It is also possible to use the decision tables and the information network to guide the expression of the provisions. An example of the result of this process is shown in Appendix F. The two rewritten paragraphs correspond to the first two headings of the sample outline shown in Appendix E. It can be argued that these provisions are more clear and complete than the present expression in the UBC because all cross references are explicitly stated and because all related provisions are grouped together rather than scattered about in several different chapters.

CONCLUSION

A logical and systematic methodology for the analysis, representation, formulation, and expression of specifications, codes and standards exists and its use can result in provisions that are more complete and clear and can raise questions about the correctness. The methodology can provide benefits to building designers, and officials and authors of building regulations in several ways. All those involved with building regulations can benefit from the formal representation of provisions in decision table format because the time spent in interpretation would be reduced. Building officials and designers are provided with an important resource for the computerization of checking and design, that is, a self programming and internally consistent set of provisions. Officials can use ingredience networks as a guide for checking while designers can use dependence networks as a guide to parameter studies. Authors of provisions will find the analysis for deficiencies, the formal documentation and the guide to written expression all to be of great aid in formulating provisions. The system also makes revisions easier to accomplish for authors and easier to understand for officials and designers. Computer programs based on a set of decision tables and an information network will be much easier to update then programs written from flowcharts, thus removing one new type of obstacle to progress. Use of the methodology in whole or in part would appear to greatly benefit many phases of the building regulatory system.

ACKNOWLEDGEMENTS

Special thanks are due Richard Wright and Kirk Rankin for the enlightening discussions held during this project, and Charles Culver and George Turner for their thoughtful readings of the manuscript.

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Allowable Floor Areas

Sec. 505. (a) **One-Story Areas.** The area of a one-story building shall not exceed the limits set forth in Table No. 5-C except as provided in Section 506, nor the limits specified in Chapter 16.

For buildings located in Fire Zone No. 3, the basic area may be increased by 33⅓ percent.

(b) **Areas of Buildings Over One Story.** The total area of all floors of multistory buildings shall not exceed twice the area allowed for one-story buildings. No single floor area shall exceed that permitted for one-story buildings.

(c) **Basements and Cellars.** A basement or cellar need not be included in the total allowable area, provided such basement or cellar does not qualify as a story nor exceed the area permitted for a one-story building.

(d) **Area Separation Walls.** Each portion of a building separated by one or more area separation walls may be considered a separate building provided the area separation walls meet the following requirements:

1. Area separation walls shall be not less than four-hour fire-resistive construction in Types I, II or III buildings and two-hour fire-resistive construction in Types IV or V buildings. The total width of all openings in such walls shall not exceed 25 percent of the length of the wall in each story. All openings shall be protected by a fire assembly having a three-hour fire-protection rating in four-hour fire-resistive walls and one and one-half-hour fire-protection rating in two-hour fire-resistive walls.

2. Area separation walls need not extend to the outer edges of horizontal projecting elements such as balconies, roof overhangs, canopies, marquees or architectural projections provided the exterior wall at the termination of the area separation wall and the projecting elements above are not less than one-hour fire-resistive construction for a width equal to the depth of the projecting elements. Wall openings within such widths shall be protected by assemblies having a three-fourths-hour fire-protection rating.

3. Area separation walls shall extend from the foundation to a point at least 30 inches above the roof.

EXCEPTIONS: 1. Area separation walls may terminate at the roof soffit provided the roof is of at least two-hour fire-resistive construction.

2. Two-hour area separation walls may terminate at the underside of roof sheathing provided that the roof has at least one-hour fire-resistive time period for a width of not less than 5 feet on each side of the area separation wall termination.

3. Two-hour area separation walls may terminate at roofs of entirely noncombustible construction.

4. Where an area separation wall separates portions of a building having different heights, such wall may terminate at a point 30 inches above the lower roof level provided the exterior wall for a height of 10 feet above the lower roof is of one-hour fire-resistive construction with openings protected by assemblies having a three-fourths-hour fire-protection rating.

EXCEPTION: The area separation wall may terminate at the sheathing of the lower roof provided the roof is of at least one-hour fire-resistive construction for a width of 10 feet without openings measured from the wall.

See Chapters 6 to 16 inclusive for special occupancy provisions. (See U.B.C. Standard No. 43-7 for fire dampers in air ducts piercing area separations.)

Allowable Area Increases

Sec. 506. (a) **General.** The floor areas specified in Section 505 may be increased by one of the following:

1. **Separation on two sides.** Where public space, streets, or yards more than 20 feet in width extend along and adjoin two sides of the building, floor areas may be increased at a rate of one and one-fourth percent for each foot by which the minimum width exceeds 20 feet, but the increase shall not exceed 50 percent.

2. **Separation on three sides.** Where public space, streets, or yards more than 20 feet in width extend along and adjoin three sides of the building, floor areas may be increased at a rate of two and one-half percent for each foot by which the minimum width exceeds 20 feet, but the increase shall not exceed 100 percent.

3. **Separation on all sides.** Where public space, streets or yards more than 20 feet in width extend on all sides of a building and adjoin the entire perimeter, floor areas may be increased at a rate of five percent for each foot by which the minimum width exceeds 20 feet.

Such increases shall not exceed 100 percent, except for buildings not exceeding two stories in height of Group G Occupancy and one-story buildings housing aircraft storage hangars and as further limited in Section 1002 (b) for aircraft repair hangars.

(b) **Unlimited Area.** The area of any one- or two-story building of Group F, Group G and Division 5 of Group E Occupancies shall not be limited, if the building is provided with an approved automatic fire-extinguishing system throughout, as specified in Chapter 38, and entirely surrounded and adjoined by public space, streets or yards not less than 60 feet in width.

The area of a Group G Occupancy in a one-story Type II, Type III, Heavy-Timber, Type III one-hour or Type IV building shall not be limited if the building is entirely surrounded and adjoined by public space, streets or yards not less than 60 feet in width.

(c) **Automatic Fire-extinguishing Systems.** The area specified in Section 505 may be tripled in one-story buildings and doubled in buildings of more than one story if the building is provided with an approved automatic fire-extinguishing system throughout. The area increases permitted in this Subsection may be compounded with that specified in paragraph No. 1, 2 or 3 of Subsection (a) of this Section. The increases permitted in this Subsection shall not apply when automatic fire-extinguishing systems are installed under the following provisions:

1. Section 507 for an increase in allowable number of stories.

2. Section 3802 (b) 6 for Group E, Divisions 1 and 2 Occupancies.

3. Substitution for one-hour fire-resistive construction pursuant to Section 508.

TABLE 5C

OCCUPANCY	TYPES OF CONSTRUCTION							
	I	II	III		IV		V	
			1-Hour or H.T.	N	1-Hour	N	1-Hour	N
A	Unlimited	22,500	Not Permitted					
B) 1-2	Unlimited	22,500	10,100	Not Permitted	10,100	Not Permitted	7,900	Not Permitted
B) 3-4	Unlimited	22,500	10,100	6,800	10,100	6,800	7,900	4500
C	Unlimited	34,000	15,200	10,100	15,200	10,100	11,800	6800
D) 1	Unlimited	11,300	Not Permitted[1]					
D) 2-3	Unlimited	11,300	5,100	Not Permitted	5,100	Not Permitted	3,900	Not Permitted
E) 1-2[2]	11,250	9,300	4,200	2,800	4,200	2,800	3,300	1900
E) 3-4-5[2]	Unlimited	18,600	8,400	5,600	8,400	5,600	6,600	3800
F) 1-2-3	Unlimited	30,000	13,500	9,000	13,500	9,000	10,500	6000
G	Unlimited	45,000	20,300	13,500	20,300	13,500	15,800	9000
H	Unlimited	22,500	10,100	6,800[3]	10,100	6,800[3]	7,900	4500[3]
I	Unlimited							
J[4]	See Chapter 15							

N. – No general requirements for fire resistance.
H.T. – Heavy Timber.
[1]See Section 902 (b).
[2]For additional limitations in Fire Zones No. 1 and No. 2 see Sections 1602 and 1603.
[3]For limitation and exceptions see Section 1302 (b).
[4]For agricultural buildings also see Appendix, Chapter 15.

DATA NO.	DATA LABEL	DATA DESCRIPTION	INGREDIENTS	DEPENDENTS	INPUT LEVEL	OUTPUT LEVEL	TOTAL FLOAT
1	ACK	AREA CHECK	2 3 43 44 45 53 59		8	0	0
2	SSACK	SINGLE STORY AREA CHECK	4 6	1	7	1	0
3	TBACK	TOTAL BUILDING AREA CHECK	5 6 11 12 13	1	7	1	0
4	AS	ACTUAL AREA OF STORY	14	2 53	3	2	3
5	ATB	ACTUAL AREA OF TOTAL BUILDING	14 16 44 45 51 52 72	3 47 53	3	5	0
6	TASA	TOTAL ALLOWABLE STORY AREA	7 8 9 16 43 44 54 55 56 57 71	2 3	6	2	0
7	AASC	ALLOWABLE AREA FROM TABLE 5C	16 44	6	1	3	4
8	AMS06	ALLOWABLE AREA MULTIPLIER FROM SECTION 506	40 46 47	6	5	3	0
9	AAC16	ALLOWABLE AREA FROM CHAPTER 16	10 16 43 44 45 73 74	6	1	3	4
10	FZONE	FIRE ZONE		9 71	0	4	4
11	BMT	BASEMENT OR CELLAR PRESENT		3	0	2	6
12	ABMT	ACTUAL AREA OF BASEMENT OR CELLAR	14	3	3	2	3
13	BMTSTY	BASEMENT OR CELLAR QUALIFIES AS A STORY		3	0	2	6
14	ASWCK	AREA SEPARATION WALL CHECK	15 19 20 21 27 28 29 38 39	4 5 12	2	6	0
15	ASFRCK	AREA SEP WALL FIRE RESISTANCE CHECK	16 17 18 44	14	1	7	0
16	CTYPE	CONSTRUCTION TYPE		5 6 7 9 15 46 64	0	8	0
17	FRASW	FIRE RESISTANCE OF AREA SEP WALL		15 29	0	8	0
18	FROASW	FIRE RESISTANCE OF OPENINGS IN AREA SEP WALL		15	0	8	0
19	TWOASW	TOTAL WIDTH OF OPENINGS IN AREA SEP WALL IN STORY		14	0	7	1
20	TLASW	TOTAL LENGTH OF AREA SEP WALL IN STORY		14	0	7	1
21	ASWECK	AREA SEP WALL EXTERIOR TERMINATION CHECK	22 23 24 25 26	14	1	7	0
22	ELTS	A S WALL EXTENDS TO EDGE OF HORIZ PROJ ELTS		21	0	8	0
23	FREWAS	FIRE RES OF EXT WALL AT AREA SEP WALL		21	0	8	0
24	WFREW	WIDTH OF FIRE RES EXT WALL AT AREA SEP WALL		21	0	8	0
25	DHPE	DEPTH OF HORIZ PROJECTING ELEMENT		21	0	8	0
26	FROEW	FIRE RES OF OPGS IN EXT WALL AT A S WALL		21	0	8	0
27	ASWFDN	AREA SEP WALL EXTENDS TO FOUNDATION		14	0	7	1
28	ATOASW	ACTUAL TOP OF AREA SEP WALL		14	0	7	1
29	RTOASW	REQUIRED TOP OF AREA SEP WALL	17 30 31 32 33 34 35 36 37	14	1	7	0
30	FRRCOF	FIRE RESISTANCE OF ENTIRE ROOF		29	0	8	0
31	FRRASW	FIRE RES OF ROOF WITHIN 5 FT OF A S WALL		29	0	8	0
32	COMBRF	COMBUSTIBILITY OF ROOF CONSTRUCTION		29	0	8	0
33	ASWDHT	AREA SEP WALL SEP BLDGS WITH DIFF HEIGHT		29	0	8	0
34	FREWLR	FIRE RES OF EXT WALL 10 FT FROM LOW ROOF		29	0	8	0
35	FROELR	FIRE RES OF OPGS IN EXT WALL AT LOW ROOF		29	0	8	0
36	FRLRAS	FIR RES OF LOW ROOF 10 FT FROM A S WALL		29	0	8	0
37	OPLRAS	OPGS PRESENT IN LOW ROOF 10 FT FROM A S WALL		29	0	8	0
38	ASWDCT	AIR DUCTS PIERCE AREA SEP WALLS		14	0	7	1
39	FDCK	FIRE DAMPERS IN AIR DUCTS MEET UBC STD 43-7		14	0	7	1
40	AINSEP	ALLOWABLE AREA INCREASE FOR SEPARATION	41 42 43 44 45	8	1	4	3
41	NOSSEP	NUMBER OF SIDES WITH SEPARATION MORE THAN 20 FT		40 46	0	5	3
42	MWSEP	MINIMUM WIDTH OF SEPARATION		40 46	0	5	3

43	STORY	NUMBER OF STORIES		1 6 9 40 46 47 53	0	5	3
44	OCCGP	OCCUPANCY GROUP		1 5 6 7 9 15 40 46 47	0	8	0
45	OCCNM	OCCUPANCY NAME		1 5 9 40 53	0	6	2
46	AINOCC	ALLOWABLE AREA INCREASE FOR OCCUPANCY	16 41 42 43 44 48	8	I	4	3
47	AINFES	ALLOWABLE AREA INCREASE FOR FIRE EXT SYS	5 43 44 48 49 50	8	4	4	0
48	FESP	FIRE EXTINQUISHING SYSTEM PRESENT		46 47	0	5	3
49	FESHT	FIRE EXT SYS USED TO INCREASE ALLOWABLE HEIGHT		47	0	5	3
50	FESFR	FIRE EXT SYS USED TO SUBSTITUTE FOR 1 HOUR FIRE RES		47	0	5	3
5I	HEIGHT	HEIGHT		5	0	6	2
52	FROSEP	FIRE RESISTANCE OF OCCUPANCY SEPARATION		5	0	6	2
53	HOCCK	CHECK FOR AREA OF H OCCUPANCY	4 5 43 45 55 58	1	4	1	3
54	CNAME	CONSTRUCTION NAME		6	0	3	5
55	FRBLDG	FIRE RESISTANCE OF ENTIRE BUILDING		6 53	0	3	5
56	MAXED	ACTUAL MAXIMUM EXIT DISTANCE		5	0	3	5
57	ED3302	ALLOWABLE EXIT DISTANCE FROM 3302		6	0	3	5
58	FRSPAH	FIRE RES OF APT HOUSE EXCL NONBRG & NONPTY WALLS		53	0	2	6
59	AOPGCK	AREA CHECK FOR OPEN PARKING GARAGE	60	1	4	1	3
60	TOPGCK	AREA CHECK FOR A TIER OF OPEN PARKING GARAGE	61 62 63 65 66 68 69 70	59	3	2	3
6I	ATROPG	ACTUAL AREA OF A TIER OF OPEN PARKING GARAGE		60	0	3	5
62	ATLOPG	ACTUAL AREA OF TOTAL OPEN PARKING GARAGE		60	0	3	5
63	AATOPG	ALLOWABLE AREA OF TIER OF OPEN GARAGE	64 67	60	2	3	3
64	BATOPG	BASIC AREA FOR TIER OF OPEN GARAGE	I6	63	1	4	3
65	NTIERS	ACTUAL NUMBER OF TIERS IN OPEN PARKING GARAGE		60	0	3	5
66	ATIERS	ALLOWABLE NUMBER OF TIERS IN OPEN PARKING GARAGE		60	0	3	5
67	PCTOPN	PERCENT OF PERIMETER OF OPEN PKG GAR WITH OPEN SIDES		63	0	4	4
68	NSQOPN	NUMBER OF SIDES OF OPEN PKG GAR WITH QUALIFIED OPENINGS		60	0	3	5
69	HOQOPN	MAX HORIZ DISTANCE FROM NEAREST QUAL OPENING		60	0	3	5
70	STPIPE	STANDPIPE PROVIDED ON TIER		60	0	3	5
7I	AINFZ	AREA INCREASE FOR FIRE ZONE	I0	6	1	3	4
72	AH5D	ALLOWABLE HEIGHT FROM TABLE 5D		5	0	6	2
73	DPL	MAX DISTANCE FROM WALL TO PROPERTY LINE		9	0	4	4
74	EXW5A	EXTERIOR WALL IN ACCORD WITH TABLE 5A		9	0	4	4

APPENDIX C - DECISION TABLE

DECISION TABLE 1 - AREA CHECK

		1	2	3	4	5	6	7	8
1	Single Story Area Check (2) = Satisfied for all stories	T	T	T	T	T	F	F	F
2	Number of Stories (43) > 1	F	T	T	T	T	·	·	·
3	Total Building Area Check (3) = Satisfied	·	T	T	T	F	·	·	·
4	Occupancy Group (44) = H	·	F	T	T	·	·	·	·
5	Occupancy Name (45) = Open parking garage	·	·	·	·	·	F	T	T
6	Check for Area of H Occupancy (53) = Satisfied	·	·	T	F	·	·	·	·
7	Area Check for Open Parking Garage (59) = Satisfied	·	·	·	·	·	·	T	F
	Area Check (1) = Satisfied	X	X	X				X	
	Area Check (1) = Violated				X	X	X		X

DECISION TABLE 2 - SINGLE STORY AREA CHECK

	1	2
Actual Area of Story (4) $\leq$ Total Allowable Story Area (6)	T	F
Single Story Area Check (2) = Satisfied	X	
Single Story Area Check (2) - Violated		X

DECISION TABLE 3 - TOTAL BUILDING AREA CHECK

		1	2	3	4	5	6
1	Actual Area of Total Building (5) $\leq$ 2* Total Allowable Story Area	T	F	F	F	F	F
2	Basement or Cellar Present (11) = True	·	T	T	T	T	F
3	Basement or Cellar Qualifies as a Story (13) = True	·	F	F	F	T	·
4	Actual Area of Total Building (5) - Actual Area of Basement or Cellar (12) $\leq$ 2* Total Allowable Story Area (6)	·	T	T	F	·	·
5	Actual Area of Basement or Cellar (12) $\leq$ Total Allowable Story Area (6)	·	T	F	·	·	·
	Total Building Area Check (3) = Satisfied	X	X				
	Total Building Area Check (3) = Violated			X	X	X	X

DECISION TABLE 4 - ACTUAL AREA OF STORY

	1	2
Area Separation Wall Check (14) = Satisfied	T	F
Actual Area of Story (4) = Area of story across entire building		X
Actual Area of Story (4) = Area of story within area separation walls	X	

DECISION TABLE 5 - ACTUAL AREA OF TOTAL BUILDING

	Condition / Action	1	2	3
1	Occupancy Group (44) = F1 in first story and Occupancy Group (44) = F2 or H above first story and Construction Type (16) = I for F1 occupancy and Occupancy Name (45) of first story = storage of passenger cars and Height (51) ≤ Allowable Height from Table 5D (72) and Fire Resistance of Occupancy Separation (52) ≥ 3 hours	T	F	F
2	Area Separation Wall Check (14) = Satisfied	·	T	F
	Actual Area of Total Building (5) = area of entire building			X
	Actual Area of Total Building (5) = area within area separation walls		X	
	Actual Area of Total Building (5) = area of entire building excluding F1 occupancy	X		

DECISION TABLE 6 - TOTAL ALLOWABLE STORY AREA

	Condition / Action	1	2	3	4	5	6	7	8	9
1	Allowable Area From Chapter 16 (9) = Unlimited	F	T	T	T	T	T	T	T	T
2	Occupancy Group (44) = B4	·	F	T	T	T	–	–	–	–
3	Construction Name (54) = Open skeleton frame	·	·	F	T	F	·	·	·	·
4	Fire Resistance of Entire Building (55) < 1 hour	·	·	F	·	F	·	·	·	·
5	Occupancy Group (44) = D1	·	F	–	–	–	T	T	–	–
6	Number of Stories (43) = 1 and Construction Type (16) = III - 1 hour or IV - 1 hour or V - 1 hour	·	·	·	·	·	F	T	·	·
7	Occupancy Group (44) = C	·	F	–	–	–	–	–	T	T
8	Actual Maximum Exit Distance (56) ≤ 0.50* Allowable Exit Distance From 3302 (57)	·	·	·	·	·	·	·	F	T
	Total Allowable Story Area (6) = Allowable Area From Chapter 16 (9) * Area Increase For Fire Zone (71)	X								
	Total Allowable Story Area (6) = Allowable Area From Table 5C (7) * Allowable Area Multiplier From Section 506 (8) * Area Increase for Fire Zone (71)		X	X			X		X	
	Total Allowable Story Area (6) = Unlimited				X					
	Total Allowable Story Area (6) = 400 ft^2 * Area Increase for Fire Zone (71)					X				
	Total Allowable Story Area (6) = 3900 ft^2 * Area Increase for Fire Zone (71)							X		
	Total Allowable Story Area (6) = 1.5* Allowable Area from Table 5C (7) * Allowable Area Multiplier from Section 506 (8) * Area Increase for Fire Zone (71)									X

DECISION TABLE 8 - ALLOWABLE AREA MULTIPLIER

	T	F
Allowable Area Increase For Occupancy (46) = Unlimited	T	F
Allowable Area Multiplier From Section 506 (8) = Unlimited	X	
Allowable Area Multiplier From Section 506 (8) = (1 + Allowable Area Increase For Separation (40))* (1 + Allowable Area Increase For Fire Ext Sys (47))		X

DECISION TABLE 9 - ALLOWABLE AREA FROM CHAPTER 16

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Fire Zone (10) = 1	T	T	T	T	T	T	T	T	T	T	-	-	-	F
2	Fire Zone (10) = 2	-	-	-	-	-	-	-	-	-	-	T	T	T	F
3	Construction Type (16) = IV-N	-	T	T	T	T	T	T	F	F	F	•	•	•	•
4	Construction Type (16) = III-N or V	T	-	-	-	-	-	-	F	F	F	•	•	•	•
5	Occupancy Group (44) = E1 or E5	•	•	-	-	-	-	-	T	-	F	T	-	F	•
6	Occupancy Group (44) = E2	•	•	-	-	-	-	-	-	T	F	-	T	F	•
7	Occupancy Group (44) = F or G or J	•	F	•	T	T	T	T	-	-	•	-	-	•	•
8	Occupancy Name (45) = Open Parking garage	•	F	T	F	F	F	F	-	-	-	-	-	•	•
9	Number of Stories (43) = 1	•	•	•	T	T	T	F	•	•	•	•	•	•	•
10	Max Distance From Wall to Property Line (73) < 20 ft.	•	•	•	T	T	F	•	•	•	•	•	•	•	•
11	Exterior Wall in Accord With Table 5A (74) = Satisfied	•	•	•	T	F	•	•	•	•	•	•	•	•	•
	Allowable Area From Chapter 16 (9) = 0	X	X			X		X	X			X			
	Allowable Area From Chapter 16 (9) = 1500 ft^2									X			X		
	Allowable Area From Chapter 16 (9) = 2500 ft^2				X		X								
	Allowable Area From Chapter 16 (9) = Unlimited			X							X			X	X

DECISION TABLE 12 - ACTUAL AREA OF BASEMENT

	T	F
Area Separation Wall Check (14) = Satisfied	T	F
Actual Area of Basement or Cellar (12) = Area of entire basement		X
Actual Area of Basement or Cellar (12) = Area of basement between are separation walls	X	

DECISION TABLE 14 - AREA SEPARATION WALL CHECK

		1	2	3	4
1	Area Separation Wall Fire Resistance Check (15) = Satisfied and Total Width of Openings in Area Separation Wall in Story (19) ≤ 0.25 * Total Length of Area Separation Wall in Story (20) and Area Separation Wall Exterior Termination Check (21) = Satisfied and Area Separation Wall Extends to Foundation (27) = True and Actual Top of Area Separation Wall (28) ≥ Required Top of Area Separation Wall (29)	T	T	T	F
2	Air Ducts Pierce Area Separation Walls (38) = True	F	T	T	•
3	Fire Dampers in Air Ducts Meet UBC STD 43-7 (39) = Satisfied	•	T	F	•
	Area Separation Wall Check (14) = Satisfied	X	X		
	Area Separation Wall Check (14) = Violated			X	X

DECISION TABLE 15
FIRE RESISTANCE CHECK FOR AREA SEPARATION WALLS

		1	2	3	4	5	6
1	Construction Type (16) = I, II, or III	T	T	T	T	F	F
2	Fire Resistance of Area Separation Wall (17) ≥ 4 hr. and Fire Resistance of Openings in Area Separation Wall (18) ≥ 3 hr.	T	F	F	F	•	-
3	Fire Resistance of Area Separation Wall (17) ≥ 2 hr. and Fire Resistance of Openings in Area Separation Wall (18) ≥ 1 1/2 hr.	+	T	•	F	T	F
4	Occupancy Group (44) = D1 and Construction Type (16) = III - hr.	•	T	F	T	•	•
	Area Separation Wall Fire Resistance Check (15) = Satisfied	X	X			X	
	Area Separation Wall Fire Resistance Check (15) = Violated			X	X		X

DECISION TABLE 21
AREA SEPARATION WALL EXTERIOR TERMINATION CHECK

		1	2	3
1	A Separation Wall Extends to Edge of Horizontal Project Elements (22) = True	T	F	F
2	Fire Resistance of Exterior Wall at Area Separation Wall (23) $\geq$ 1 hr. and Width of Fire Resistance Exterior Wall at Area Separation Wall (24) $\geq$ Depth of Horizontal Projecting Element (25) and Fire Resistence of Openings in Exterior Wall at A Separation Wall (26) $\geq$ 1 hr.	.	T	F
	Area Separation Wall Exterior Termination Check (21) = Satisfied	X	X	
	Area Separation Wall Exterior Termination Check (21) = Violated			X

DECISION TABLE 29
REQUIRED TOP OF AREA SEPARATION WALL

		1	2	3	4	5	6	7	8
1	Area Separation Wall Separates Buildings With Different Height (33) = True	F	F	F	F	F	T	T	T
2	Fire Resistance of Entire Roof (30) $\geq$ 2 hr.	T	F	F	F	F	.	.	.
3	Fire Resistance of Roof Within 5 Feet of an Area Sep. Wall (31) $\geq$ 1 hr.	.	.	T	F	F	.	.	.
4	Fire Resistance of Area Separation Wall (17) = 2 hr.	.	F	T	T	T	.	.	.
5	Combustibility of Roof Construction (32) = Entirely noncombustible	.	.	.	T	F	.	.	.
6	Fire Resistence of Exterior Wall 10 feet from Low Roof (34) $\geq$ 1 hr. and Fire Resistance of Openings in Exterior Wall at Low Roof (35) $\geq$ 3/4 hr.	.	.	.	.	.	F	F	T
7	Fire Resistance of Low Roof 10 Feet from A S Wall (36) $\geq$ 1 hr. and Openings Present in Low Roof 10 Feet from A S Wall (37) = False	.	.	.	.	.	F	T	.
	Required Top of Area Separation Wall (29) = 30" above roof		X			X	X		
	Required Top of Area Separation Wall (29) = soffit	X							
	Required Top of Area Separation Wall (29) = Underside of sheathing			X					
	Required Top of Area Separation Wall (29) = "at roof"				X				
	Required Top of Area Separation Wall (29) = 30" above low roof								X
	Required Top of Area Separation Wall (29) = at sheathing of low roof							X	

DECISION TABLE 40
ALLOWABLE AREA INCREASE FOR SEPARATION

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Number of Sides with Separation More than 20 Feet (41) = 2	F	T	T	-	-	-	-	-	-	-	-	-	-	-
2	Number of Sides with Separation More than 20 Feet (41) = 3	F	-	-	T	T	-	-	-	-	-	-	-	-	-
3	Number of Sides with Separation More than 20 Feet (41) = All	F	-	-	-	-	T	T	T	T	T	T	T	T	T
4	Minimum Width of Separation (42) < 40 ft.	·	·	-	·	-	T	F	F	F	F	F	F	-	F
5	Minimum Width of Separation (42) < 60 ft.	·	T	F	T	F	+	·	·	·	·	·	·	-	·
6	Minimum Width of Separation (42) < 120 ft.	·	+	·	+	·	+	·	·	·	·	·	T	F	·
7	Number of Stories (43) = 1	·	·	·	·	·	·	·	·	·	T	F	T	T	F
8	Number of Stories (43) ≤ 2	·	·	·	·	·	·	·	T	F	·	·	·	·	·
9	Occupancy Group (44) = G	·	·	·	·	·	·	F	T	T	-	-	-	-	-
10	Occupancy Name (45) = Aircraft storage	·	·	·	·	·	·	F	-	-	T	T	-	-	-
11	Occupancy Name (45) = Aircraft repair	·	·	·	·	·	·	F	-	-	-	-	T	T	T
	Allowable Area Increase For Separation (40) = 0	X													
	Allowable Area Increase For Separation (40) = 0.0125 *(Minimum Width of Separation (42) - 20)		X												
	Allowable Area Increase For Separation (40) = 0.025 * (Minimum Width of Separation (42) - 20)				X										
	Allowable Area Increase For Separation (40) = 0.05 * (Minimum Width of Separation (42) - 20)						X		X		X		X		
	Allowable Area Increase For Separation (40) = 0.5			X											
	Allowable Area Increase For Separation (40) = 1.					X		X		X		X			X
	Allowable Area Increase For Separation (40) = 5.													X	

DECISION TABLE 46
ALLOWABLE AREA INCREASE FOR OCCUPANCY

		1	2	3	4
1	Number of Sides with Separation More Than 20 feet (41) = All and Minimum With of Separation (42) $\geq$ 60 ft.	T	T	T	F
2	Number of Stories (43) $\leq$ 2 and Occupancy Group (44) = F, G, or E5 and Fire Extinquishing System Present (48) = True	T	-	F	•
3	Fire Extinquishing System Present (48) = False and Number of Stories (43) = 1 and Occupancy Group (44) = G and Construction Type (16) = II, III-H.T., III-1 hr., or IV	-	T	F	•
	Allowable Area Increase for Occupancy (46) = Unlimited	X	X		
	Allowable Area Increase for Occupancy (46) = 0			X	X

DECISION TABLE 47
ALLOWABLE AREA INCREASE FOR FIRE EXTINQUISHING SYSTEM

		1	2	3	4	5
1	Fire Extinquishing System Present (48) = True	F	T	T	T	T
2	Fire Extinquishing System Used to Increase Allowable Height (49) = True or Fire Extinquishing System Used to Substitute for 1 hour Fire Resistance (50) = True	•	T	F	F	F
3	Occupancy Group (44) = E1 or E2 and Actual Area of Total Building (5) $\geq$ 1500 ft.^{2}	•	•	T	F	F
	Number of Stories (43) = 1	•	•	•	T	F
	Allowable Area Increase For Fire Extinquishing System (47) = 2				X	
	Allowable Area Increase For Fire Extinquishing System (47) = 1					X
	Allowable Area Increase For Fire Extinquishing System (47) = 0	X	X	X		

DECISION TABLE 53 - AREA CHECK FOR H OCCUPANCY

		1	2	3	4
1	Fire Resistance of Entire Building (55) < 1 hr.	F	T	T	T
2	Acutal Area of Total Building (5) - Acutal Area of Story (4) of first story $\leq$ 3000 ft.^{2}	•	T	F	F
3	Number of Stories (43) = 2 and Occupancy Name (45) = apartment house and Fire Resistance of Apartment House Excluding Non-barring and Non-party walls (58) < 1 hr.	•	•	T	F
	Check for Area of H Occupancy (53) = Satisfied	X	X	X	
	Check for Area of H Occupancy (53) = Violated				X

DECISION TABLE 59
AREA CHECK FOR OPEN PARKING GARAGE

		1	2
1	Area Check for a Tier of Open Parking Garage (60) = Satisfied for all tiers	T	F
	Area Check for Open Parking Garage (59) = Satisfied	X	
	Area Check for Open Parking Garage (59) Violated		X

DECISION TABLE 60
TIER AREA CHECK FOR OPEN PARKING GARAGE

		1	2	3	4
1	Actual Area of a Tier of Open Parking Garage (61) $\leq$ Allowable Area of Tier of Open Garage (63)	T	F	F	F
2	Actual Number of Tiers in Open Parking Garage (65) < Allowable Number of Tiers in Open Parking Garage (66)	•	F	T	T
3	Number of Sides of Open Parking Garage with Qualified Openings (68) $\geq$ 3 and Maximum Horizontal Distance from Nearest Qualified Opening (69) $\leq$ 200 ft. and Actual Area of Total Open Parking Garage (62) < Allowable Number of Tiers in Open Parking Garage (66)* Allowable Area of Tier of Open Garage (63) and Standpipe Provided on Tier (70) = True	•	•	T	F
	Area Check for a Tier of Open Parking Garage (60) = Satisfied	X		X	
	Area Check for a Tier of Open Parking Garage (60) = Violated		X		X

DECISION TABLE 63 - ALLOWABLE AREA FOR A TIER

		1	2	3
1	Percent of Perimeter of Open Parking Garage with Open Sides (67) $\geq$ 75%	F	T	+
2	Percent of Perimeter of Open Parking Garage with Open Sides (67) = 100%	·	F	T
	Allowable Area of Tier of Open Garage (63) = Basic Area for Tier of Open Garage (64)	X		
	Allowable Area of Tier of Open Garage (63) = 1.25 * Basic Area for Tier of Open Garage (64)		X	
	Allowable Area of Tier of Open Garage (63) = 1.5 * Basic Area for Tier of Open Garage (64)			X

DECISION TABLE 64 - BASIC ALLOWABLE TIER AREA

		1	2	3	4	5
1	Construction Type (16) = I	T	-	-	-	F
2	Construction Type (16) = II	-	T	-	-	F
3	Construction Type (16) = IV - 1 hr.	-	-	T	-	F
4	Construction Type (16) = IV - N	-	-	-	T	F
	Basic Area for Tier of Open Garage (64) = Unlimited	X				
	Basic Area for Tier of Open Garage (64) = 125,000 $ft.^2$		X			
	Basic Area for Tier of Open Garage (64) = 50,000 $ft.^2$			X		
	Basic Area for Tier of Open Garage (64) = 50,000 $ft.^2$				X	
	Basic Area for Tier of Open Garage (64) = 0					X

DECISION TABLE 71 - AREA INCREASE FOR FIRE ZONE

		1	2
1	Fire Zone = 3	T	F
	Area Increase for Fire Zone (71) = 1		X
	Area Increase for Fire Zone (71) = 1.33	X	

APPENDIX D

Information Networks

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GLOBAL INGREOIENCE OF COMPLETE NETWORK

UNSORTEO

EXTREME LEVEL FROM OUTPUT

 0         1          2          3          4          5          6          7          8
 I  AREA CHECK
 :.........2  SINGLE STORY AREA CHECK
 :          :.........4  ACTUAL AREA OF STORY
 :          :          :.......................................14  AREA SEPARATION WALL CHECK
 :          :                                                 :.........15  AREA SEP WALL FIRE RESISTANCE CHECK
 :          :                                                 :          :.........16  CONSTRUCTION TYPF
 :          :                                                 :          :.........17  FIRE RESISTANCE OF AREA SEP WALL
 :          :                                                 :          :.........18  FIRE RESISTANCF OF OPENINGS IN AREA SEP WALL
 :          :                                                 :          :.........44  OCCUPANCY GROUP
 :          :                                                 :.........19  TOTAL WIDTH OF OPENINGS IN AREA SEP WALL IN STORY
 :          :                                                 :.........20  TOTAL LENGTH OF AREA SEP WALL IN STORY
 :          :                                                 :.........21  AREA SEP WALL EXTERIOR TERMINATION CHECK
 :          :                                                 :          :.........22  A S WALL EXTENDS TO EDGE OF HORIZ PROJ ELTS
 :          :                                                 :          :.........23  FIRE RES OF EXT WALL AT AREA SEP WALL
 :          :                                                 :          :.........24  WIDTH OF FIRE RES EXT WALL AT AREA SEP WALL
 :          :                                                 :          :.........25  DEPTH OF HORIZ PROJECTING ELEMENT
 :          :                                                 :          :.........26  FIRE RES OF OPGS IN EXT WALL AT A S WALL
 :          :                                                 :.........27  AREA SEP WALL EXTENDS TO FOUNDATION
 :          :                                                 :.........28  ACTUAL TOP OF AREA SEP WALL
 :          :                                                 :.........29  REQUIREO TOP OF AREA SEP WALL
 :          :                                                 :          :........-17  FIRE RESISTANCE OF AREA SEP WALL
 :          :                                                 :          :.........30  FIRE RESISTANCE OF ENTIRE ROOF
 :          :                                                 :          :.........31  FIRE RES OF ROOF WITHIN 5 FT OF A S WALL
 :          :                                                 :          :.........32  COMBUSTIBILITY OF ROOF CONSTRUCTION
 :          :                                                 :          :.........33  AREA SEP WALL SEP BLOGS WITH DIFF HEIGHT
 :          :                                                 :          :.........34  FIRE RES OF EXT WALL 10 FT FROM LOW ROOF
 :          :                                                 :          :.........35  FIRE RES OF OPGS IN EXT WALL AT LOW ROOF
 :          :                                                 :          :.........36  FIR RES OF LOW ROOF 10 FT FROM A S WALL
 :          :                                                 :          :.........37  OPGS PRESENT IN LOW ROOF 10 FT FROM A S WALL
 :          :                                                 :.........38  AIR OUCTS PIERCE AREA SEP WALLS
 :          :                                                 :.........39  FIRE DAMPERS IN AIR OUCTS MEET UBC STO 43-7
 :          :.........6  TOTAL ALLOWABLE STORY AREA
 :                     :.........7  ALLOWABLE AREA FROM TABLE 5C
 :                     :          :................................................-16  CONSTRUCTION TYPE
 :                     :          :................................................-44  OCCUPANCY GROUP
 :                     :.........8  ALLOWABLE AREA MULTIPLIER FROM SECTION 506
 :                     :          :........40  ALLOWABLE AREA INCREASE FOR SEPARATION
 :                     :          :          :.........41  NUMBER OF SIDES WITH SEPARATION MORE THAN 20 FT
 :                     :          :          :.........42  MINIMUM WIDTH OF SEPARATION
 :                     :          :          :.........43  NUMBER OF STORIES
 :                     :          :          :.................................-44  OCCUPANCY GROUP
 :                     :          :          :.................45  OCCUPANCY NAME
 :                     :          :........46  ALLOWABLE AREA INCREASE FOR OCCUPANCY
 :                     :          :          :.................................-16  CONSTRUCTION TYPE
 :                     :          :          :........-41  NUMBER OF SIDES WITH SEPARATION MORE THAN 20 FT
 :                     :          :          :........-42  MINIMUM WIDTH OF SEPARATION
 :                     :          :          :........-43  NUMBER OF STORIES
 :                     :          :          :.................................-44  OCCUPANCY GROUP
 :                     :          :          :.........48  FIRE EXTINQUISHING SYSTEM PRESENT
 :                     :          :........47  ALLOWABLE AREA INCREASE FOR FIRE EXT SYS
 :                     :                     :.........5  ACTUAL AREA OF TOTAL BUILDING
```

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:                   :                   :         :.......-14* AREA SEPARATION WALL CHECK
:                   :                   :         :..........................-16  CONSTRUCTION TYPE
:                   :                   :         :..........................-44  OCCUPANCY GROUP
:                   :                   :         :.......-45  OCCUPANCY NAME
:                   :                   :         :........51  HEIGHT
:                   :                   :         :........52  FIRE RESISTANCE OF OCCUPANCY SEPARATION
:                   :                   :         :........72  ALLOWABLE HEIGHT FROM TABLE 5D
:                   :                   :.......-43  NUMBER OF STORIES
:                   :                   :....................................-44  OCCUPANCY GROUP
:                   :                   :.......-48  FIRE EXTINGUISHING SYSTEM PRESENT
:                   :                   :........49  FIRE EXT SYS USED TO INCREASE ALLOWABLE HEIGHT
:                   :                   :........50  FIRE EXT SYS USED TO SUBSTITUTE FOR 1 HOUR FIRE RES
:                   :.........9  ALLOWABLE AREA FROM CHAPTER 16
:                   :         :........10  FIRE ZONE
:                   :         :..............................................-16  CONSTRUCTION TYPE
:                   :         :.................-43  NUMBER OF STORIES
:                   :         :..............................................-44  OCCUPANCY GROUP
:                   :         :........................-45  OCCUPANCY NAME
:                   :         :........73  MAX DISTANCE FROM WALL TO PROPERTY LINE
:                   :         :........74  EXTERIOR WALL IN ACCORD WITH TABLE 5A
:                   :........................................................-16  CONSTRUCTION TYPE
:                   :..........................-43  NUMBER OF STORIES
:                   :........................................................-44  OCCUPANCY GROUP
:                   :........54  CONSTRUCTION NAME
:                   :........55  FIRE RESISTANCE OF ENTIRE BUILDING
:                   :........56  ACTUAL MAXIMUM EXIT DISTANCE
:                   :........57  ALLOWABLE EXIT DISTANCE FROM 3302
:                   :........71  AREA INCREASE FOR FIRE ZONE
:                             :.......-10  FIRE ZONE
:.........3  TOTAL BUILDING AREA CHECK
:         :....................................-5* ACTUAL AREA OF TOTAL BUILDING
:         :.......-6* TOTAL ALLOWABLE STORY AREA
:         :........11  BASEMENT OR CELLAR PRESENT
:         :........12  ACTUAL AREA OF BASEMENT OR CELLAR
:         :         :....................................-14* AREA SEPARATION WALL CHECK
:         :........13  BASEMENT OR CELLAR QUALIFIES AS A STORY
:....................................................-43  NUMBER OF STORIES
:............................................................................-44  OCCUPANCY GROUP
:..............................................................-45  OCCUPANCY NAME
:........53  CHECK FOR AREA OF H OCCUPANCY
:         :.......-4* ACTUAL AREA OF STORY
:         :....................................-5* ACTUAL AREA OF TOTAL BUILDING
:         :....................................-43  NUMBER OF STORIES
:         :................................................-45  OCCUPANCY NAME
:         :.................-55  FIRE RESISTANCE OF ENTIRE BUILDING
:         :........58  FIRE RES OF APT HOUSE EXCL NONBRG & NONPTY WALLS
:........59  AREA CHECK FOR OPEN PARKING GARAGE
          :........60  AREA CHECK FOR A TIER OF OPEN PARKING GARAGE
                    :........61  ACTUAL AREA OF A TIER OF OPEN PARKING GARAGE
                    :........62  ACTUAL AREA OF TOTAL OPEN PARKING GARAGE
                    :........63  ALLOWABLE AREA OF TIER OF OPEN GARAGE
                    :         :........64  BASIC AREA FOR TIER OF OPEN GARAGE
                    :         :         :....................................-16  CONSTRUCTION TYPE
                    :         :........67  PERCENT OF PERIMETER OF OPEN PKG GAR WITH OPEN SIDES
                    :........65  ACTUAL NUMBER OF TIERS IN OPEN PARKING GARAGE
                    :........66  ALLOWABLE NUMBER OF TIERS IN OPEN PARKING GARAGE
                    :........68  NUMBER OF SIDES OF OPEN PKG GAR WITH QUALIFIED OPENINGS
                    :........69  MAX HORIZ DISTANCE FROM NEAREST QUAL OPENING
                    :........70  STANDPIPE PROVIDED ON TIER
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GLOBAL DEPENDENCE OF NODE 44

UNSORTED

EXTREME LEVEL FROM INPUT

```
  0         1         2         3         4         5         6         7         8
 44  OCCUPANCY GROUP
  :...............................................................................1   AREA CHECK
  :.............................5  ACTUAL AREA OF TOTAL BUILDING
  :                             :.................................................3  TOTAL BUILDING AREA CHECK
  :                             :                                       :........-1   AREA CHECK
  :                             :........47  ALLOWABLE AREA INCREASE FOR FIRE EXT SYS
  :                             :         :.........8  ALLOWABLE AREA MULTIPLIER FROM SECTION 506
  :                             :                   :.........6  TOTAL ALLOWABLE STORY AREA
  :                             :                             :.........2  SINGLE STORY AREA CHECK
  :                             :                             :         :........-1   AREA CHECK
  :                             :                             :........-3* TOTAL BUILDING AREA CHECK
  :                             :........53  CHECK FOR AREA OF H OCCUPANCY
  :                                       :......................................-1   AREA CHECK
  :..........................................................-6* TOTAL ALLOWABLE STORY AREA
  :.........7  ALLOWABLE AREA FROM TABLE 5C
  :         :................................................-6* TOTAL ALLOWABLE STORY AREA
  :.........9  ALLOWABLE AREA FROM CHAPTER 16
  :         :................................................-6* TOTAL ALLOWABLE STORY AREA
  :........15  AREA SEP WALL FIRE RESISTANCE CHECK
  :         :........14  AREA SEPARATION WALL CHECK
  :                   :.........4  ACTUAL AREA OF STORY
  :                   :         :......................................-2* SINGLE STORY AREA CHECK
  :                   :         :.......-53* CHECK FOR AREA OF H OCCUPANCY
  :                   :........-5* ACTUAL AREA OF TOTAL BUILDING
  :                   :........12  ACTUAL AREA OF BASEMENT OR CELLAR
  :                             :......................................-3* TOTAL BUILDING AREA CHECK
  :........40  ALLOWABLE AREA INCREASE FOR SEPARATION
  :         :......................................-8* ALLOWABLE AREA MULTIPLIER FROM SECTION 506
  :........46  ALLOWABLE AREA INCREASE FOR OCCUPANCY
  :         :......................................-8* ALLOWABLE AREA MULTIPLIER FROM SECTION 506
  :.....................................-47* ALLOWABLE AREA INCREASE FOR FIRE EXT SYS
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Appendix E

Sample of Re-ordering of Provisions

Abbreviated Information Network

- Area Check
  - Single story area check
    - Actual area of story
      - Area separation wall check
    - Total allowable story area
      - Table 5C
      - Area multiplier
        - Increase for separation
        - Increase for occupancy
        - Increase for fire extinguishing system
      - Restrictions in Chapter 16
  - Total building area check
  - Check for area of H occupancy
  - Area check for open parking garage

Possible Outline of Provisions

	Paragraph	Present Section
1	Restrictions on Building Area	---
2	Allowable Story Area	505 (a)
3	Allowable Area Increases	506
	3.1 Increase for Separation	506 (a)
	3.2 Increase for Occupancy	506 (b)
	3.3 Increase for Fire Extinguishing System	506 (c)
4	Area Restrictions in Fire Zones 1 and 2	1602, 1603
5	Allowable Area for Multistory Buildings	505 (b), (c)
6	Area Restrictions for Multistory Building with H Occupancy	1302 (b)
7	Area Restrictions for Open Parking Garages	1109
8	Provisions for Area Separation Walls	505 (d)

Appendix F

Sample Re-expression of Provisions

1. <u>Restrictions on Building Area</u>. Except for open parking garages, no floor of a building shall have an area larger than the total allowable story area defined in paragraph 2, and no buildings over one story in height shall have a total area of all floors larger than the total allowable building area defined in paragraph 5. Multistory buildings with H occupancy and a fire resistance of less than one hour shall also satsify the provisions of paragraph 6. Open parking garages shall satisfy the provisions of paragraph 7. The actual area of buildings may be divided by area separation walls that satisfy the provisions of paragraph 8.

2. <u>Allowable Story Area</u>. The total allowable story area shall be the product of the area from Table __ (Table 5C) and the area multiplier from paragraph 3 with the following exceptions:

   (1) The allowable story area for buildings in fire zones 1 and 2 shall not exceed that given in paragraph 4.

   (2) The allowable story area of Buildings in fire zone 3 shall be increased by 33 1/3%.

   (3) The allowable story area of buildings with B4 occupancy constructed of an open skelton frame with no enclosed space shall be unlimited.

   (4) The allowable story area of buildings with B4 occupancy that are not open frame construction and that do not have a fire resistance of at least one hour shall be 400 ft^2.

   (5) The allowable story area of buildings with C occupancy that have a maximum exit distance of not more than 50% of the exit distance allowed in __ (Section 3302) shall be increased by 50%.

   (6) The allowable story area of one story buildings with D1 occupancy that are of Type III - 1 hour, IV - 1 hour, or 1 - hour construction shall be 3900 $ft.^2$

THE EVOLUTION OF THE PERFORMANCE APPROACH IN PLUMBING

by

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The performance approach is reviewed as it relates to plumbing. The approach described provides for the systematic development of performance criteria, reproducible evaluation or test methods, and inspection guidelines, with significant benefits derived for innovators, contractors, code administrators, and the consumer through the utilization of new methods and materials for water supply and drainage in buildings. Performance specifications are seen as complementary or supplementary to the traditional prescriptive-type language of standards and code documents. They have the primary purpose of simplifying, systematizing, and hastening the process of acceptance of innovation. Traditionally, acceptance has occurred through a lengthy trial period during which satisfactory service history is accumulated with great difficulty and considerable expense to the proponents. The gradual movement to performance concepts in the requirements for sanitary drain-waste-vent systems is discussed. An example is described in which planned laboratory and subsequent field research with a performance orientation have provided a technological basis for acceptance of reduced-size venting. This economically attractive new method has only recently been considered by the prescriptive codes and is not yet fully accepted by them.

Key Words: Performance approach; performance characteristics; performance criteria; performance evaluation; performance testing; plumbing research; plumbing research needs; reduced-size venting

HISTORICAL RESEARCH BACKGROUND

The first plumbing drainage systems in the United States originated in buildings not over three stories in height and generally consisted of a 50-mm (2-inch)-diameter waste stack for sinks located in public hallways. A similar system of 100-mm (4-inch) diameter collected the wastewater from hopper toilets located in closets with access from public hallways. The criteria for the adequacy of the performance of these systems were rapid drainage of the wastewater and the absence of odors from sewer gas. These early single-stack drainage systems were prone to failure of the trap seal by siphonage and back pressure. About 1874, secondary ventilation through auxiliary air pipes was proposed as a means of protecting the water seal in the trap by maintaining atmospheric pressure on both sides of the seal. The theory was checked empirically and the principle of secondary venting was established. Prescriptive rules for the design of these continuous waste and vent systems, often modified on a local basis, led to a complex, non-uniform structure of regulations nationally.

The benefits demonstrated through the development and utilization of product standards in industrial production, together with the pressures of the housing needs following World War I, encouraged the standardization of building and plumbing regulations. A Building Code Committee made up of representatives of industry, academia and government was established in 1921 under the auspices of the U.S. Department of Commerce. Laboratory studies on the hydraulics and pneumatics of plumbing were conducted by the National Bureau of Standards (NBS) under the committee's general supervision. Two significant reports [1, 2] were issued, with the final product known as the Hoover Code. This was widely utilized by state and local regulatory bodies, because it provided for the first time significant theoretical and experimental data that could be utilized in semirational design of plumbing drainage and venting systems. The first report [1] contained experimental data on the hydraulic and pneumatic performance characteristics of one-and two-story drain, waste and vent (DWV) systems, and presented a procedure for estimating peak hydraulic loads for design purposes involving the "fixture-unit" concept and the theory of probability. The 1932 report [2] benefited from further research stimulated by the 1924 report [1], including additional scientific information on matters such as gas diffusion in drains, terminal velocities in tall drainage stacks and flow depths in building sewers. The Hoover Code was the forerunner of the widely accepted American Standard National Plumbing Code, ASA A40.8-1955 [3].

Studies were made between 1932 and 1941 to provide additional scientific basis for DWV system design, in response to needs defined by Federal Government agencies concerned with building construction, and by plumbing installation contractors and code administrators. Perhaps the most significant work during this period was that which produced the "Hunter Curve" (see Figure 1), a method proposed initially for estimating momentary peak hydraulic loads on water-distributing systems for design purposes [4]. The method was soon adapted to the prediction of peak loads for sanitary drainage systems, as an essential step in the computation of pipe-sizing tables for drainage and vent piping. This method was reflected in design manuals and codes of the late 1940's and early 1950's for water supply and sanitary drainage, and has been carried over into the present model plumbing codes [5, 6, 7, 8, 9, 10].

In response to the increasing need for cost-effective design in building following World War II, renewed attention was turned during the period ending in the early 1960's to investigations of trap self-siphonage, stack venting, wet venting and capacities of stacks and horizontal drains [11, 12, 13, 14, 15]. These investigations provided a basis for design improvements and better definition of the performance capabilities and limitations of components and systems with which fairly widespread field experience had already been obtained. Some of this work is reflected in the present model codes. Although these studies were concerned with performance characteristics, the findings were mostly utilized as the basis of greater precision and sophistication in the traditional prescriptive specifications, not for the objective evaluation of proposed new solutions.

More recently, beginning in the mid-sixties, efforts were undertaken to develop procedures for evaluating innovative (i.e., "non-code") solutions, particularly proposed new designs of sanitary DWV systems. This trend led to the identification of a significant need for improved, definitive criteria and evaluation procedures that would determine the satisfaction of essential functional and safety requirements (user needs) based on an adequate knowledge of the important performance characteristics, regardless of the particular design, material or method of fabrication used. For a detailed discussion of the performance approach as related to water supply and drainage for buildings and for selected references, see reference [16].

THE NBS ROLE AND THE RELATIONSHIP BETWEEN NBS AND THE BUILDING COMMUNITY

Agencies of the Federal government, as well as industry groups concerned with construction of buildings and with the furtherance of uniformity in design requirements for plumbing, have generally reacted favorably to NBS activity in plumbing research, and on a number of occasions have sought support from NBS and/or have supported research at NBS as a part of the development of minimum requirements for plumbing.

The first such instance was the development of the aforementioned Hoover Code, a program resulting in recommended minimum requirements for plumbing [2]. This work established a precedent for the use of objective scientific data and set a format for plumbing codes that has been widely used as a model by other code-writing groups for over fifty years. Other instances of NBS input to significant Model documents on plumbing requirements include (1) the ASA[1] A40 (subsequently ANSI[2] A40) project that produced the ASA A40.4/6-1942/1943 standard on air gaps/vacuum breakers [17]; and ASA A40.7-1949 [18] and ASA A40.8-1955 [3] recommended minimum requirements for plumbing codes.

A current proposed revision of A40.8-1955 is being developed under the procedures of ANSI, sponsored by ASME[3] and APHA[4] (an earlier, unsuccessful effort was terminated in 1969). The ANSI A112 project, sponsored by ASME and ASSE,[5] is responsible for developing or keeping up to date a number of standards for plumbing materials and equipment. NBS has made significant technical input to these programs, based largely on its laboratory research expertise and findings. It is widely recognized that NBS activity has had considerable influence on the technical content of these model codes and voluntary standards.

In response to needs expressed over the years by the U.S. Department of Commerce, the Veterans Administration, agencies of the Department of Defense, several of the housing agencies, and the Environmental Protection Agency, NBS has studied, in addition to the subjects mentioned above, evaporation of trap seals [19], fixture unit load ratings [4, 20], hydraulic performance of plumbing fixtures and drainage stacks [19], frost closure of roof vents [21], and backflow protection of potable water supply systems [22, 23, 24, 25]. The results of much of this work have been utilized in the design procedures employed by plumbing engineers, and in the updating of model codes and voluntary standards.

The plumbing research program of the National Bureau of Standards has always been characterized by a high degree of collaboration with national codes and standards organizations and by responsiveness to the needs of the construction agencies of the Federal government. The central objective of this program has been to provide optimum criteria assuring functional adequacy and safety in the design of plumbing systems. The program has provided substantial long-term national leadership, and the technical data developed through the years have had wide international recognition and usage.

THE PERFORMANCE CONCEPT AT NBS--BACKGROUND

Historically, NBS plumbing research involved consideration of the physical performance characteristics of components and systems. The tendency was to emphasize studies of items or classes of equipment, fixtures and systems, many of which had achieved a degree of acceptance through service history. A prominent objective was to improve the precision of the design procedure for familiar designs and to examine the performance of designs with relatively minor modifications. Although significant technical progress has been made using this approach, important applications of the research findings in evaluating sweeping, novel designs that clearly violated the existing standards were often ignored. The tendency

[1]American Standards Association

[2]American National Standards Institute

[3]American Society of Mechanical Engineers

[4]American Public Health Association

[5]American Society of Sanitary Engineers

was to evaluate new approaches largely in terms of the predominant favorable characteristics of the proven solutions.

More recently, however, this situation has begun to change. For example, builders have postulated that traditional DWV systems are over-vented. Simplified DWV systems have been developed and used widely in Europe which are considered by the European national authorities as suitable for their intended use. None of these solutions satisfy the prescriptive requirements of the traditional American codes. This influenced NBS in turning to performance concepts for a resolution of this seeming inconsistency. Two relatively recent developments occurred that especially influenced the trend to performance evaluation in relation to plumbing studies at NBS: (1) the sponsorship by the National Association of Home Builders (NAHB) in the mid-1960's of a study of reduced-size venting (RSV), and (2) the sponsorship of programs by the Department of Housing and Urban Development (HUD) and agencies of the Department of Defence (DOD) since 1968 to review and apply the performance concept to the development of criteria for the design and evaluation of a range of innovative building systems and subsystems, including plumbing. Also contributing to this trend was a study of performance characteristics of sanitary plumbing fixtures under the auspices of the National Academy of Sciences [26].

Difficulties have been encountered in the acceptance of innovative, performance-oriented solutions proposed for water supply and drainage systems under the provisions of contemporary American plumbing codes and similar governmental requirements. These difficulties are due largely to the characteristic prescriptive nature of the existing codes and of the standards referenced by them, and to the absence of adequate methodologies for predicting or testing for essential performance. Adequacy of performance is considered dependent on the continuing adequacy of the health, safety, sanitary and physiological functions deemed essential to satisfy user needs and public welfare. Historically, reliance upon prescriptive codes, which require certain configurations and designs, pipe sizes and materials, has inhibited the implementation of innovative solutions for water supply and drainage systems and for water conservation practices, and has limited the opportunities for materials resource conservation and energy conservation. Although most codes provide for variances at the discretion of the Administrative Authority[6], acceptance criteria for innovations are generally lacking or inadequate and do not provide much definitive guidance. The consequences are overdesign of traditional systems and difficulty and delay in gaining acceptance of innovative approaches. The interest in the performance approach results from a recognition of the expanded opportunities that it can provide for fulfilling the essential needs for building services in terms of user requirements. It offers an avenue for satisfaction of these requirements through relatively unencumbered engineering design

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[6] Administrative Authority. The individual official, board, department, or agency established and authorized by a state, county, city, or other political subdivision created by law to administer and enforce the provisions of the plumbing code as adopted or amended.

to suit the particular circumstances and through a more expeditious and systematic acceptance procedure that might be utilized by the Codes.

One of the difficulties in implementing performance concepts is that of evaluating innovative materials. Traditionally, specification writers attempted to identify and specify the properties of materials and products that were known from service trials to provide satisfactory performance under normal usage conditions over a lengthy period of time. In contrast, the concept of the performance approach is based upon short-term measurements that signify the degree to which user requirements are fulfilled without imposing limitations on any particular combination of physical and chemical properties or on the design or method of manufacture.

It is helpful to distinguish between systems and materials in discussing the performance concept. System performance relates to the functional and safety adequacy; materials performance relates mainly to the durability feature; i.e., the permanence of the essential functions and safety of the system in which the material is utilized.

The problem of performance evaluation for a component made from an innovative material poses considerable difficulty because of uncertainty in the ability to simulate the effects of the service environment in tests for durability. (See Figure 2.) Some of the difficulties are illustrated in a report on a study of performance characteristics for sanitary plumbing fixtures [26]. This problem is also the predominant one in the traditional specification-type approach where the difficulty is the long period of service history required to permit a meaningful evaluation. Under either approach, findings may fall somewhere between the "clearly satisfactory" and "clearly intolerable" categories. In this area, the acceptance decision may require additional data and/or informed judgment based on a consideration of realistic performance levels for the satisfaction of user requirements.

The performance concept and the problems of performance evaluation and related acceptance protocol have been the subjects of a great deal of study in the United States in recent years. This has led to a growing recognition that the implementation of the performance concept can facilitate an orderly, systematic approach to the whole building process. If adequately developed and utilized, it could furnish a framework within which strong incentives could be accommodated for the introduction of new systems, components, and materials.

The performance concept centers on the idea that products, devices, systems or services can be described and their performance can be measured in terms of user requirements without regard to their particular combination of physical and chemical characteristics, their design or the method of their construction. The key to the development of performance standards is the identification of significant criteria which characterize the performance expected and the subsequent generation of methodologies for measuring the extent to which these criteria are satisfied.

The implementation of the performance approach leads to recognition of a need to consider life-cycle costs. This is especially important since life-cycle costs are frequently affected by new methods and materials, and should be a significant consideration in the implementation of a new technology. The potential long-term economic impact is frequently not clear from traditional evaluation methods.

The terminology adopted in this discussion of the performance approach refers to a "performance statement." (See Figure 3.) A performance statement identifies a relevant attribute, and contains a requirement, a criterion and a method of evaluation. Sometimes a commentary is added for rationale or explanation. The universal attributes of adequacy of function, health/safety, and durability (continuity of essential functional capability and health/safety) are suggested. The term "requirement" is adopted to signify a meaningful, qualitative indicator of a generally recognized user need associated with the relevant universal attribute. The "criterion" is a quantitative measure that can be used as the basis for a "method of evaluation" (preferably a test) to determine if the requirement has been satisfied.

Performance evaluation methodology does not address specific details of hardware per se, nor is it concerned with just which particular engineering solution is employed. The capability must therefore be provided to predict or test for the adequacy of performance of various different proposed solutions by calculation or measurement. To satisfy such needs, a systematic and reproducible procedure must be provided. The procedure may be analytical (as by computation from theory or by extrapolation from test data), or it may comprise a definitive reproducible test of a prototype or a systematic inspection procedure applied to a built element or system. Due to the difficulties and high costs of field verification tests or demonstrations, suitable laboratory tests and computational procedures are preferred. This need dictates efforts to develop suitable procedures for scale-model testing and component assembly testing through identification of the non-dimensional controlling parameters applicable to full-scale system simulation. From the data obtainable from experimentation with physical modeling it may be possible under some circumstances to perfect the ultimate evaluation technique--an adequate mathematical model, suitably verified, with empirically determined constants. Such a model could be used to predict specific performance in terms of agreed-upon physical or chemical criteria, provided the appropriate input is furnished with respect to representative loads and environmental conditions, dimensions and configuration, and relevant properties of materials.

PRESENT STATUS OF PERFORMANCE EVALUATION METHODOLOGY FOR PLUMBING

Presently performance evaluation methodology for water supply and drainage for buildings is in the initial stages preparatory to broader development and acceptance. A few well-developed elements of performance evaluation already exist as statements in plumbing codes or generally recognized standards. Other elements are implicit in existing documents, but are not actually stated in performance language. Still other elements have not been effectively defined or developed, and it is in these areas that the most important research needs can be identified. For a detailed discussion and examples, see reference [16].

In reviewing existing codes, standards or other technical documents, one occasionally finds a partial or even a complete performance statement. One such familiar example is the leak statement appearing in the plumbing codes, as illustrated in Figure 3. But, unfortunately not all statements in the present generally accepted standards, and in design manuals and codes of practice, are as definitive or as complete as this one.

Nevertheless, a number of existing <u>implied</u> performance statements can be identified and sometimes these can be restated in performance terms, wholly or in part. For example, a restatement can be made of the specifications in American plumbing codes relating to the venting of sanitary drainage systems. The performance measures implied (but usually not specifically stated) seem to be:

- Adequate trap-seal retention with suction ($\geqq$ 50%, equivalent to 38 mm WG suction, approx.)
- No emissions with back pressure (back pressure $\leqq$ 38 mm WG)
- Minimum water rise or flow interference from hydrodynamic or hydrostatic effects (water rise $\leqq$ 1.0 D, interfixture discharge retardation $\leqq$ 10%)

To complete these criteria a consensus on quantification and test procedures is required. This exemplifies a significant problem with implied performance statements: standard test procedures or other suitable evaluation techniques do not exist in many instances. It appears, however, from a review of various recent documents describing test procedures for drainage system performance evaluation, that early standardization of full-scale physical test methods may be possible in this particular area (DWV system hydraulics and pneumatics). Similarly, standard tests may be possible in other areas in the near future, such as tests for measuring the hydraulic and flushing performance characteristics of plumbing fixtures and appliances.

The least well-developed performance statements, either stated or implied, seem to be in the areas of water conservation, adequacy of water services, and durability as affected by materials. Perhaps the greatest research needs are in these areas.

The reader will find further detail in references [16, 27].

SOME TECHNICAL IMPEDIMENTS TO PERFORMANCE EVALUATION

The principal, broad technical impediments to a viable performance evaluation approach in the field of water supply and drainage in buildings at this time and in the near future are:

1. Incomplete knowledge of the fundamental physical and chemical processes involved in the representative operation of the various components and systems that might be utilized in innovative approaches.

2. Inadequate information on the service environment, particularly with respect to load patterns involving:
   (a) hydraulic and pneumatic demands
   (b) forces, both transient and continuous
   (c) temperatures of fluids transported
   (d) chemical composition of fluids transported

3. Poor correlation between short-term tests and representative service conditions in relation to the prediction of continuity of essential function and safety (durability) of innovative methods and materials in the service environment.

For example, the traditional mathematical models for gravity drainage systems are inadequately defined for the purposes of performance evaluation. Knowledge of the laws of air circulation, air-water "slippage," air demand, and of the correlation between trap-seal reduction and vent pressure fluctuation under typical dynamic conditions is incomplete. Consequently large "safety" factors are used in the application of these models to traditional designs, and they have limited applicability to innovative designs.

The inadequacy of existing information on the service environment is exemplified by recent reports on the deficiencies of the Hunter model for design hydraulic loads [28,29]. However, for the present the Hunter model [4] remains the principal basis of the generally accepted U.S. practice. There is general worldwide acknowledgement of the need for a comprehensive program to update or replace this model.

The problem of correlation between laboratory tests and the service environment has been exemplified by the difficulties and long period involved in establishing general acceptance of thermoplastics piping in appropriate applications. Significant elements of this problem have related to insufficient definition of representative temperature and chemical composition of fluids transported in service, and to inadequate correlation between accelerated test results and long-term service effects.

ANSI A40 PERFORMANCE STANDARD PROGRAM

The development of a performance standard was recently authorized by the Sponsors and the Standards Committee of the A40 Project on Minimum Requirements for Plumbing, under ANSI procedures. (See Figure 4.) The performance standard is expected to be complementary to the updated specification-type model code revision that is being developed, not in competition with it. In fact, the expectation is that a performance standard would be a useful aid in the administration of specification-type codes by establishing a methodology for acceptance of innovations, an area in which the traditional codes are deficient. Conceivably, as familiarity and experience are gained in the concept and utilization of the performance standard, the specification-type code would gradually adopt more and more of the performance language and format or optimal substitution could be made.

The initial activity on the performance standard program has been to begin the development of a consensus on the specific steps to be taken, on the sequence in which they are to be taken and on the identification of feasible means for carrying the work to a suitable conclusion. This has been described in some detail in reference [16]. Once format, terminology and basic philosphy are agreed upon, the first major task is to index existing codes and standards for actual or implied performance statements in the agreed-upon format. It is expected this exercise will be quite informative in identifying several technical and administrative impediments to an early limited general application of the performance approach, but at the same time will identify those areas in which early success is possible. Long-range impediments may also be more clearly identified.

BENEFITS AND CONSEQUENCES OF PERFORMANCE EVALUATION

The consequence of movement toward performance evaluation for plumbing is that it could furnish the framework within which innovations could be accommodated for new systems, components and materials. The generally recognized incentive is that an engineered solution rather than a prescribed solution can evolve for each installation, at least theoretically. In stressing the satisfaction of user requirements through the performance approach, it must be recognized that there are a variety of users. The primary emphasis is upon the ultimate occupant employing the installed plumbing for its intended purposes. However, to deliver the operating systems, it must be recognized that a team of "users" must be involved. These include the developer, the financier, manufacturers, designers, installers and regulatory officials.

In initial implementation of the performance approach and the performance evaluation methodology, the procedures adopted must indicate acceptance if applied to historically proven, traditional systems. The evaluation methodology must be adequate to provide a reasonable prediction of the ability of the plumbing system to satisfy the user's needs for its intended lifetime as installed in the building. This requires definitive knowledge of the characteristic hydraulic, structural, thermal and chemical load patterns, and of the manner in which these loads may affect longevity of the materials under representative exposure conditions and installation practices. Test methods must be correlated with the service exposure conditions and their effects. Potential economic benefits from innovative approaches are often cited as a primary motivation for implementation of the performance approach. This is an important point, but an expanded base of information is required to bring about widespread implementation while assuring that user needs are provided for in terms of function, health/safety, and durability.

With the broadening awareness of the need for conservation and of the opportunities for cost reduction provided by innovative solutions, the performance approach is becoming an increasingly pressing issue. Reductions in usage of traditionally accepted materials and the substitution of alternate materials can sometimes result in economic savings as well as conservation of critical resources. At present there is increased public concern for preservation of ecological and environmental safety. New measurement instruments of extremely fine resolution and accuracy now provide testing capability for traces of compounds which are of concern because of toxicity hazards. Therefore the capability for screening of materials for initial acceptance purposes has been improved. But the long term influences of contaminants in water often remain unpredictable due to the lack of epidemiological studies.

Innovative approaches are being offered for water conservation, water-related energy conservation and the conservation of critical materials. Again, the concern is not only with the ability to evaluate initial performance in terms of function and health/safety (even this capability is presently inadequate), but also with the long-term capability (durability) to continue to provide the essential services over a reasonable life expectancy of the system.

THE REDUCED-SIZE VENTING EXAMPLE

Background

The earliest work on this innovation was sponsored by the National Association of Home Builders [32, 33] and more recently by the Department of the Air Force and the Tri-Services Investigational Committee on Building Materials of the Department of Defense [34], with assistance from the NBS. The analysis of traditional venting theory was the first step in the development of performance criteria for venting systems for designs with short drainage stacks (water wall distance less than 20 ft (6.1 m)). The basic assumptions in accepted venting theory [14, 30, 31] assumes neither air circulation within the vent network nor relief from the building sewer as a source of air for venting, and air demand with a given hydraulic load and drainage stack diameter is assumed the same for systems of all heights. Current designs are believed to be unnecessarily restrictive for many residential (short-stack) applications. For this reason, a planned laboratory study of hydraulic and pneumatic parameters in systems with reduced-size venting (RSV) was undertaken. The National Bureau of Standards has participated in work on evaluation of reduced-size vents (smaller than those presently allowed by model plumbing codes) over a number of years. (See Figure 5.)

Recent Laboratory Investigations

In the recent NBS laboratory work [34], a system comprising an 18-ft (5.5m) long, 3-inch (75mm)) PVC drainage stack with back-to-back flushometer water closets at the top was studied. Test conditions for studying reduced-size venting could be controlled in this simple configuration. An adjustable butterfly valve was used to simulate different sizes and lengths of vent pipe. From such tests a preliminary empirical correlation under dynamic conditions was obtained between the peak vent suction, the peak air flow rate and the trap-seal reduction. This represents a performance approach because for the first time data were obtained simultaneously relating the traditional design criteria (air flow rate and suction in a vent adjacent to an idle trap) and a significant performance criterion (trap-seal reduction or retention). The results showed that the peak air flow at a suction of 1-in (25mm) WG[7] (as allowed by codes) is appreciably less than predicted by traditional models [14], and that trap seals can withstand repeated transient peak suctions significantly greater than the traditional 1.0-in (25mm) WG design limit. The air flow vs. suction data obtained were essentially comparable with those obtained in an earlier NBS study of RSV [35] utilizing a similar, 20-ft (6.1 m) cast-iron drainage stack. In the earlier study, the peak air flow at a suction of 1-in (25mm) WG with water fall-distance of 5 ft (1.5m) or less (as in one-story field installation) was very dramatically below the values predicted by the traditional models. These results support a relaxation in the traditional design criteria.

Upon completion of tests with the simplified system, a full-scale two-story 2 1/2-bath townhouse system was evaluated in the laboratory. Reduced-size vents were installed beginning 6 in (150 mm) above the flood rims of the fixtures. Vent-sizing criteria derived from the earlier study [33] were utilized. The system was tested over a variety of conditions, including one with the main vent terminal closed and the building drain submerged. Trap-seal retention was adequate under all test conditions considered realistic. The water closet traps were much more resistant to seal depletion from suction than were the smaller P-traps used for the waste fixtures. Empirical data were obtained indicating significant beneficial air circulation within the DWV network, and indicating significantly less air demand from a load discharged at the first-floor level than from the same load discharged at the second-floor level.

Subsequently, a test of reduced-size vents was conducted on a 10-story, 20-bath system with a 4-in (100 mm) soil stack [36]. All the dry vents (with the exception of the stack vent) were sized from an empirically extrapolated version of the current NBS

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[7] WG - water gage. A measure of pressure, with reference to atmospheric pressure, expressed in terms of equivalent height of water column.

recommendations [34] for one- and two-story systems with reduced-size venting. Trap-seal performance was found adequate in all cases with respect to suction. Performance with respect to back-pressure (emissions) was judged adequate in a modification wherein standard-size venting was employed for the lowest branch interval and a relief vent to atmosphere was installed on the building drain. Further work is needed to perfect the high-rise RSV criteria before they can be recommended for general application.

Field Tests

To verify the utility of the laboratory findings NBS is currently conducting a field study in military single-family housing units at Andrews Air Force Base, Camp Springs, Maryland. The criteria derived from the laboratory work were used in resizing the standard vent systems originally planned for three types of homes: a 3-bedroom townhouse, a 4-bedroom townhouse, and a 4-bedroom duplex ranch house. Size reductions ranging from one to four commercial pipe sizes were obtained. Measured parameters include trap-seal retention of P-traps, time of vent pressure over range, dwelling unit water consumption (hot and cold), time and spatial distribution (pattern) of water usage, (hot and cold), by fixture, and time distribution of energy used for heating water. The data are recorded on magnetic tape by an automatic data acquisition system. (See figures 6 and 7). The needed measurements of energy and water supply parameters were "piggy-backed" on the DWV program and have no direct relationship to the study of RSV performance.

The principal expectation from the post-occupancy data on the DWV system is the confirmation of the adequacy of the reduced-size vents. Pre-occupancy field tests using hydraulic loads derived as in laboratory tests have indicated adequate performance. It is also expected that the data will contribute to the knowledge needed to update the present method for predicting peak hydraulic loads [4] and to improve the present procedures for selecting simulated loads for laboratory tests [9, 37, 38].

Economic Significance

Potential cost savings from substituting RSV for conventional venting have been estimated for selected DWV systems for one-and two-story residential systems [39, 40], and currently a study is being made of potential cost savings from RSV for Veterans Administration hospitals. Cost savings are anticipated from reduced materials costs and possibly from reduced labor for installation. No sacrifice in terms of higher maintenance costs or reduced performance or durability is expected for properly designed and installed systems.

In this early stage of the development of RSV, exact predictions of cost savings cannot be made. The estimates of costs for the different plumbing system designs, estimates of RSV plumbing code adoption rates, assumptions of which standard venting designs are required in particular geographic regions, and some of the other information needed to make precise cost savings estimates are without detailed empirical verification, although the information utilized is based on consultation with industry experts. However, the model used for evaluating cost savings is reasonably well established and therefore should provide a reasonably accurate preliminary view of the economic viability of RSV (for one- and two-story housing systems).

Savings will be influenced not only by the kind of pipe material which is used, but also by the particular venting design that is required by the code in force. This is because pipe materials vary in cost (e.g., copper tube is more expensive than plastic pipe) and because venting designs vary in the amount of piping they require. Furthermore, some codes require larger "standard" - size vent piping in some applications than others. The cost saving than can be expected from substituting RSV for conventional venting is a function of the material used, the labor for its installation, and the sizes and number of units of pipe and fittings used for the reduced-size design in comparison with the number of units used for the standard-size design.

The labor component of the cost model used in the aforementioned study [39] was based on the "Labor Calculator," intended for use with standard plumbing systems and published by the National Association of Plumbing-Heating-Cooling Contractors [41], and on consultation with experienced contractors concerning the details of the procedures that might be used to apply the calculator to RSV systems.

Estimates of savings in the United States realizable from the adoption of Reduced-Size Venting in one- and two-story single-family dwellings in the period 1975-1985 range from $50 million to $150 million [39]. The wide range results from uncertainties in the assumptions regarding the rates of acceptance and utilization of RSV in the time period and the assumed rate of building construction.

The utilization of RSV, and hence the national cost savings realizable, depends on the acceptance of RSV in the plumbing codes and, once authorized, on the rate at which builders, plumbing contractors, and buyers will implement the new technology. The incentive to employ RSV in plumbing installation work will be affected by the availability and cost of the smaller-sized pipe and the required size - transition fittings, on the degree of experience in design and installation practices for RSV, on material and labor cost estimating procedures used by contractors, and on labor attitudes. The establishment of RSV as an accepted alternative to standard venting for various types of sanitary gravity drainage systems will gain from field demonstrations showing that RSV meets the essential venting performance and from the formulation of appropriate code requirements and installation standards.

TRADITIONAL ACCEPTANCE MODEL FOR INNOVATIONS

Experienced has shown that, typically, acceptance of new approaches in plumbing system design occurs when the following four steps are completed:

(1) A technical analysis is made of the problem, incorporating conceptual and mathematical correlations with state-of-the-art design methodology and prevailing code provisions.

(2) Laboratory experiments relating to the principal parameters in step (1) are designed and carried out, involving typical components and systems, and design and evaluation criteria appropriate to the innovative approach are proposed based on the laboratory data.

(3) Systematic field trials are conducted on systems designed in accordance with the laboratory-based criteria, and measured performance is reported. Pre-occupancy tests are made with hydraulic loads computed as in the laboratory, and ideally, post-occupancy performance with natural loadings is measured automatically.

(4) Appropriate code language and recommended practical design and installation guidelines and inspection procedures based on the scientific findings obtained in steps (1) through (3), are prepared.

This can be a long and expensive path, as indicated in Figure 8. Improvements in the first step (analytical procedures), along with improvements in the other steps would simplify and expedite the process [27, 29].

In the case of RSV, the first three steps have been carried out, and the fourth is presently in process. The present interest of ANSI Committee A40 and the BOCA Basic Plumbing Code Committee [7] in draft code language for RSV, developed with NBS assistance, lends encouragement to the expectation that model code bodies are moving toward acceptance of RSV with appropriate limitations and controls.

The technical feasibility and the economic incentives indicated above will spur movement toward needed code changes, installation standards, and product development. These actions are needed to facilitate a uniform, safe and orderly transition to reduced-size venting. Perhaps the RSV example will be helpful as background in planning a realistic approach to the more expeditious acceptance of future innovations in plumbing.

CONCLUSIONS

Performance Evaluation - Potential and Approach

For some time, performance standards will have to be supplemented by the studied judgment of informed, technically qualified persons, and consensus-type performance standards arrived at in this way should be considered, for the transition period, as complementary to the traditional specification-type standards. But even with these limitations, there is an increasing awareness that early benefits can accrue from the utilization of the performance approach as a format and a tool for systematically identifying, classifying and relating the existing preformance-type statements that actually appear or that are implied in the specification-type standards. It can also provide benefits in the meaningful definition of the research needed to realize the full potential of the performance approach.

The performance approach is beneficial because it provides an orderly, entirely different non-prescriptive means for considering the entire building process, from design and evaluation through fabrication and installation in buildings. It appears that the performance approach is going to be in a continuous state of development for some time simply because all of answers are not available. There exists, then, the requirement for a deliberate and uniform process of development relying upon sound professional judgment for some time but with a transition to creating quantitative evaluation methodologies as our knowledge expands. Ideally, a comprehensive knowledge would exist of the relevant physical and chemical phenomena and of the representative intensity and distribution of physical and chemical loads in the service environment, and this knowledge would be systematically applied through analytical models or test procedures to provide definitive and meaningful criteria and evaluation techniques. The simplest method of performance evaluation could comprise a mere visual inspection that might require the use of a ruler or a level. A higher-order method might take the form of a full-scale test of a component or of the complete system, requiring the use of instruments to measure changing discharge rates, pressures, etc. The most sophisticated method is the utilization of a valid mathematical model that permits the accurate prediction of the service performance, given the input values that represent the service conditions.

It is recognized that some basic problems are involved in the performance approach that were more or less avoided in the traditional specification approach, largely because of the long-term, service-history basis of the latter. These problems are in the areas of (1) predicting performance of systems or assemblies (rather than of individual parts), (2) installation standards (because the nature of the installation work may affect the performance, and because this is a greater difficulty with an innovation than with a traditional component or system with which installers have had ample experience), and (3) acceptance protocol (a generally recognized approval system and accredited testing agencies must be identified). (See Figure 9.)

In brief, the addition, to an adequate technical data base, of practical considerations and studied judgment of informed persons acting as a group can result in a consensus performance standard. (See Figure 10.) Finally, some form of acceptance protocol is necessary to assure widespread implementation of such a performance standard. That is, one or more decision-making, evaluation or interpretation groups supported by accredited testing laboratories will be needed. If this can be achieved, under the procedures of a generally recognized standardizing organization, the performance standard can be of great value in the uniform administration of state and local plumbing codes. A recent voluntary laboratory accreditation program has been offered that should be considered in developing a viable protocol. (See Figure 11.)

Action Requirements and Implementation Approaches for Performance Evaluation Methodology

References [28, 29, 42, 43, 44] provide some definition of a number of specific research needs in hydraulics and pneumatics of plumbing systems, alternative methods of waste disposal and other technical areas. It is not the primary purpose of this paper to dwell on these details, but rather to suggest meaningful actions needed to facilitate broad implementation of the performance approach.

Broad actions that are needed to adequately define research requirements and to develop viable approaches to implementation of performance evaluation methodology for water supply and drainage for buildings can be categorized as follows:

1. Cataloging and analysis of the requirements of a variety of users, in a suitable performance format.
2. The identification of the essential measures (criteria) for performance and the establishment of realistic levels of performace of the installed system that will satisfy the user's essential requirements. These measures and performance levels must relate the functions and properties of the system and its components to the essential characteristics of the services delivered to the user.
3. The development of reproducible, reliable test procedures, model laws and mathematical models involving the key measures in (2) and including guidelines for interpretation of results to determine conformance with the requirements in (1).
4. The establishment of a consensus performance standard derived in accordance with the above steps, and its acceptance by appropriate regulatory bodies. However, this should be supplemented by steps 5 to 8 for the desired impact.
5. The development of protocols for submission of supporting data to the approval authorities and for its processing to determine acceptance.
6. The establishment of viable, accredited testing laboratories to fulfill the need for conducting tests called for in the performance standard.
7. The provision of inspection procedures and installation standards suitable for innovations.
8. The establishment of training and education programs to facilitate performance specifications interpretation and the examination of designs and installations represented as in accord with the performance specifications.

Summary

The steps delineated immediately above are considered essential for full integration of the performance approach. The traditional specifications describe the properties of materials and products which are known from service history to provide satisfactory performance under conditions of normal use over a period of time. On the other hand, performance evaluation centers on establishing what functions must be provided and on the methodology for measuring the adequacy of performance of these functions under representative service conditions. There are common elements in both approaches since performance measures and test methods deal with structural, thermal, mechanical, acoustic, chemical and biological properties. Some of these same properties are dealt with in the traditional specification standards. The principal difference is that the traditional standards are concerned with these properties largely for identification of the product (usually a component) and for manufacturing quality control, whereas the performance standard is concerned with selected properties that can be used as significant measures or indicators of the probable ability of the installed system to satisfy essential user needs. Service correlation is through a lengthy period of service history in the case of the traditional standard. This correlation must come through an adequate knowledge of the service environment and meaningful simulated service tests in the case of the performance standard, if early acceptance is to be determined. Performance standards are not restrictive to historically proven solutions but generate the opportunity for innovative solutions. However, for optimum benefits and a broad implementation of the performance approach in water supply and drainage for buildings, research and test development is needed relating to the simulation of service environments in testing, to techniques of life-cycle and cost-benefit analysis, and to the correlation between accelerated aging test results and service conditions.

The present performance standard program within the ANSI A40 project[8] offers a significant opportunity to begin the systematic development and implementation of the performance approach in plumbing, and the A40 Committee and its Sponsors deserve widespread support in their program to emphasize this worthy endeavor during the next several years.

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[8] Subcommittee 17, Plumbing Performance. Standards Committee A40, Minimum Requirements for Plumbing, sponsored by The American Society of Mechanical Engineers and The American Public Health Association under procedures of The American National Standards Institute.

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Names and addresses of Depository Libraries are contained in Appendix A, NBS Special Publication 305, Publications of the National Bureau of Standards, Supplement 7, June 1976. SD Catalog No. C13.10:305 Suppl. 7. Available for $7.55 from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

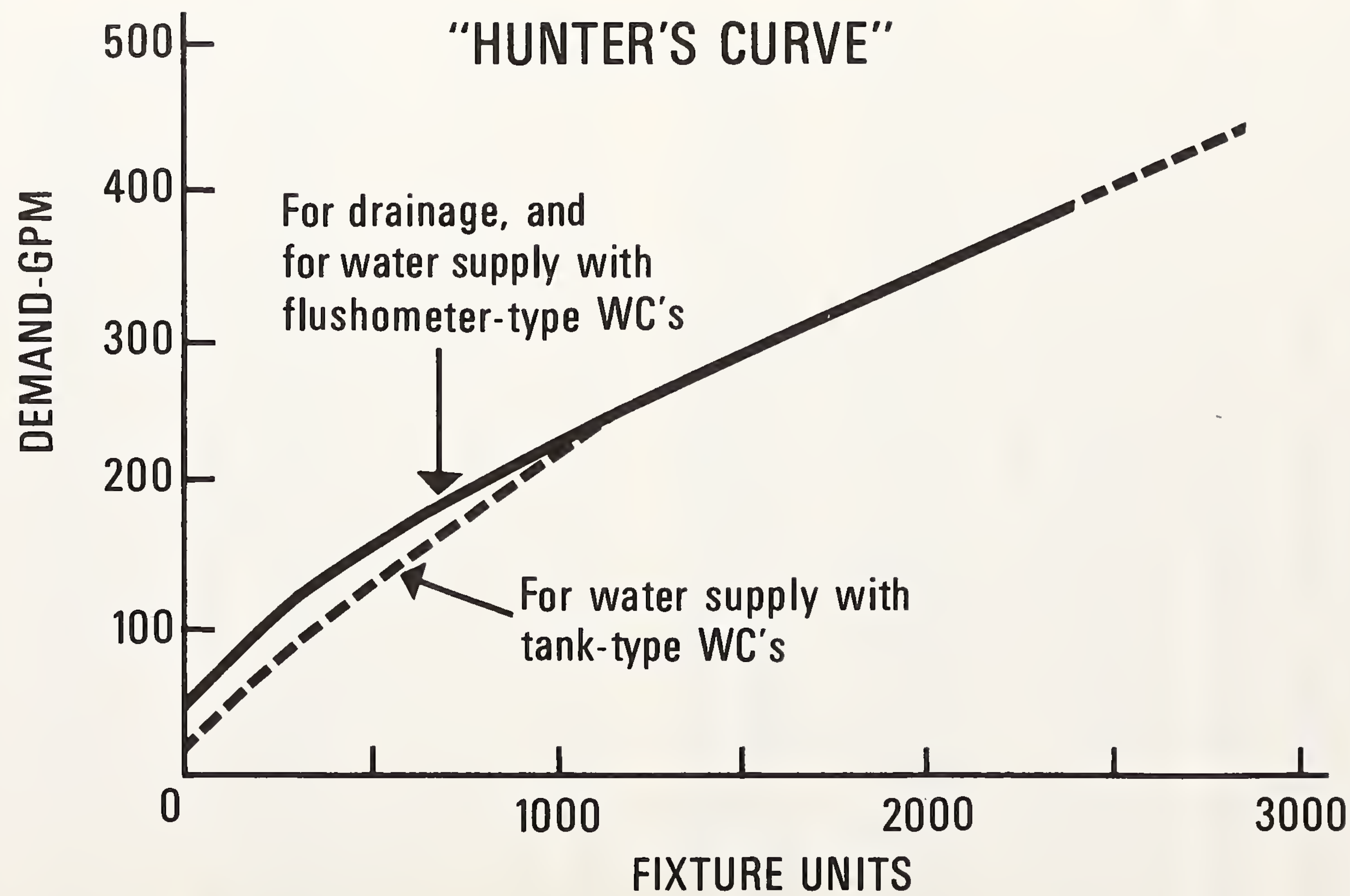


FIGURE 1. THE HUNTER CURVE FOR COMPUTING DESIGN FLOW IN PLUMBING SYSTEMS

Center for Building Technology

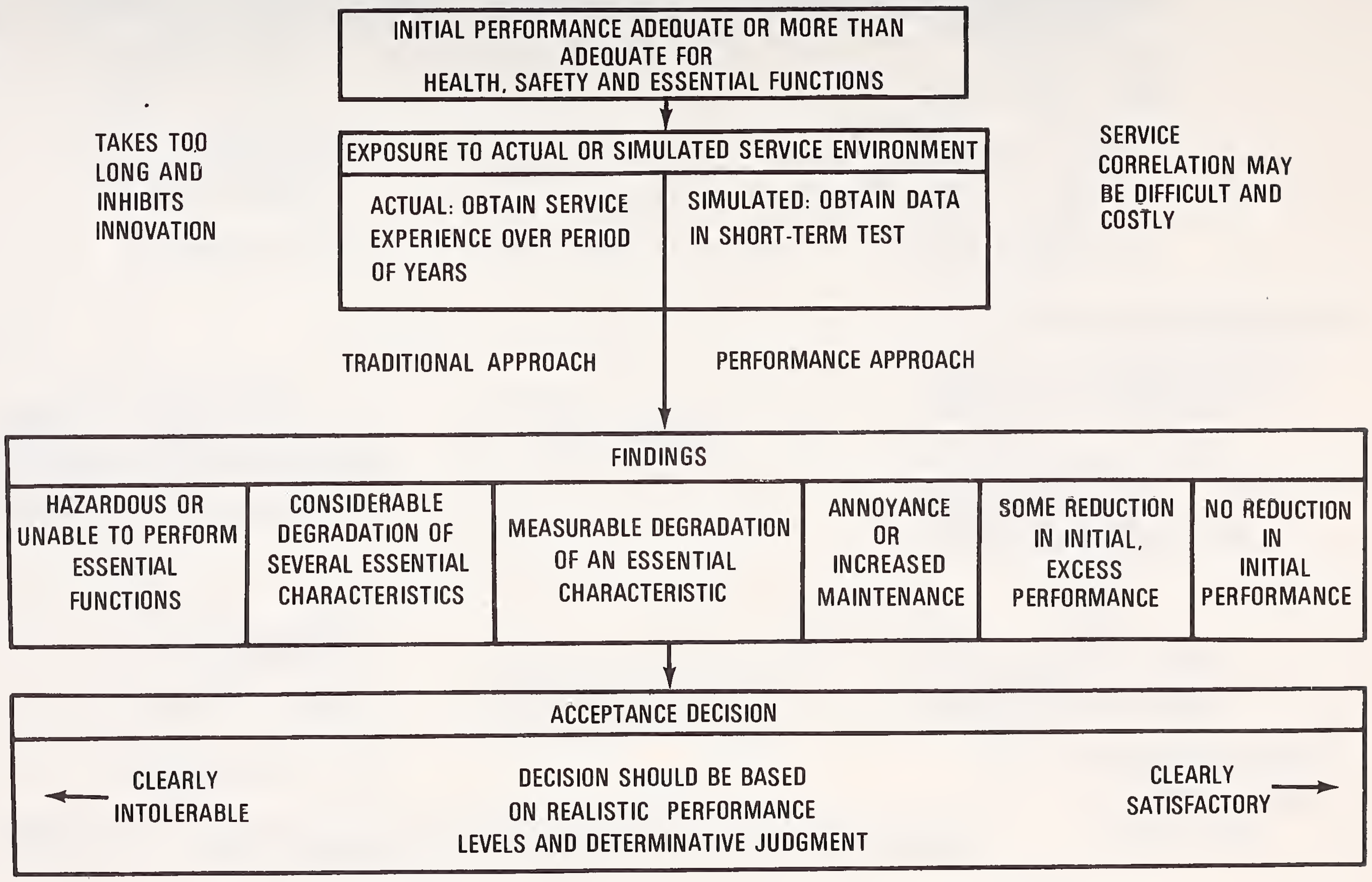


FIGURE 2 THE PROBLEM OF DURABILITY EVALUATION

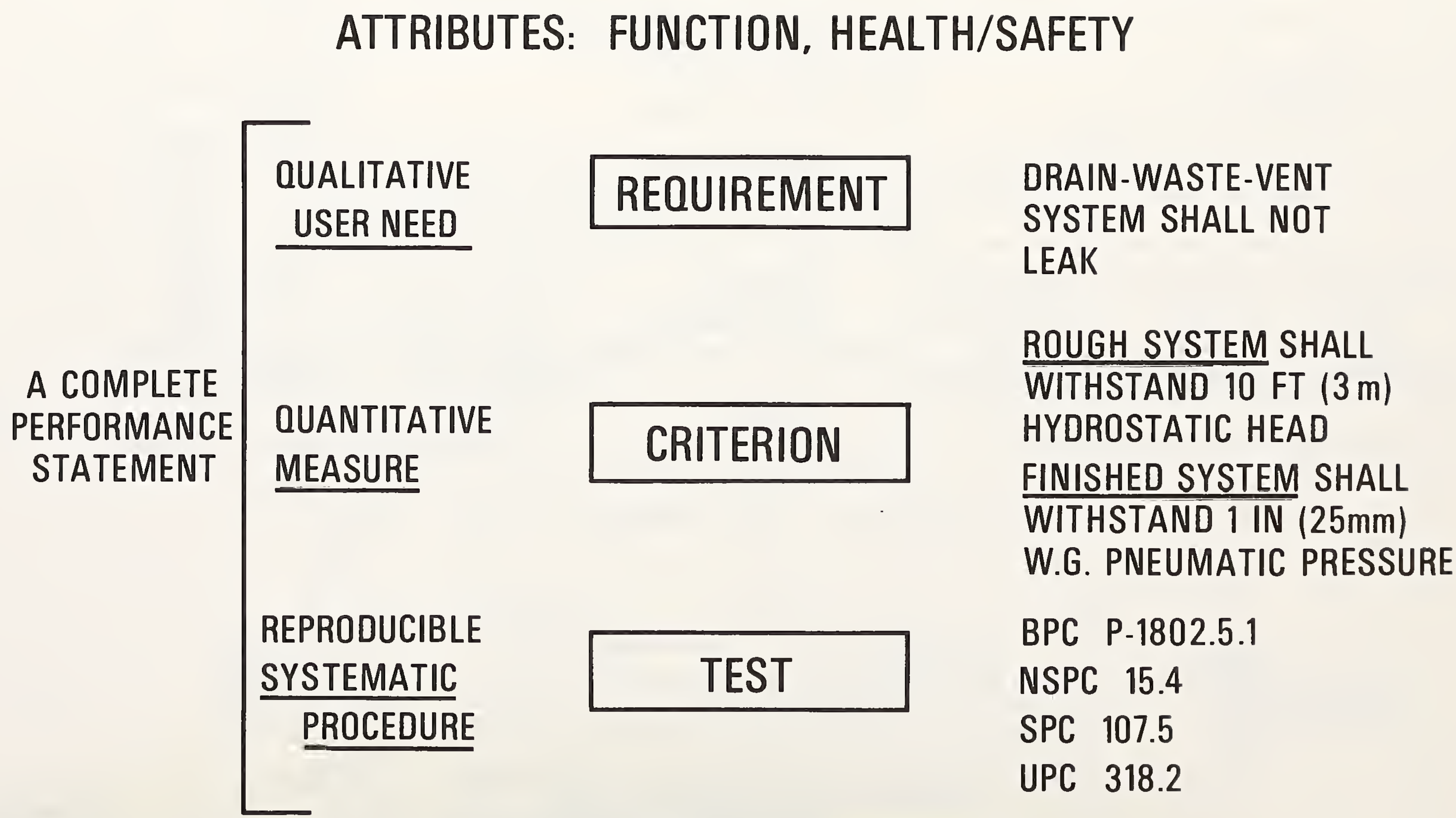


FIGURE 3. THE ESSENTIAL ELEMENTS OF A PERFORMANCE STATEMENT

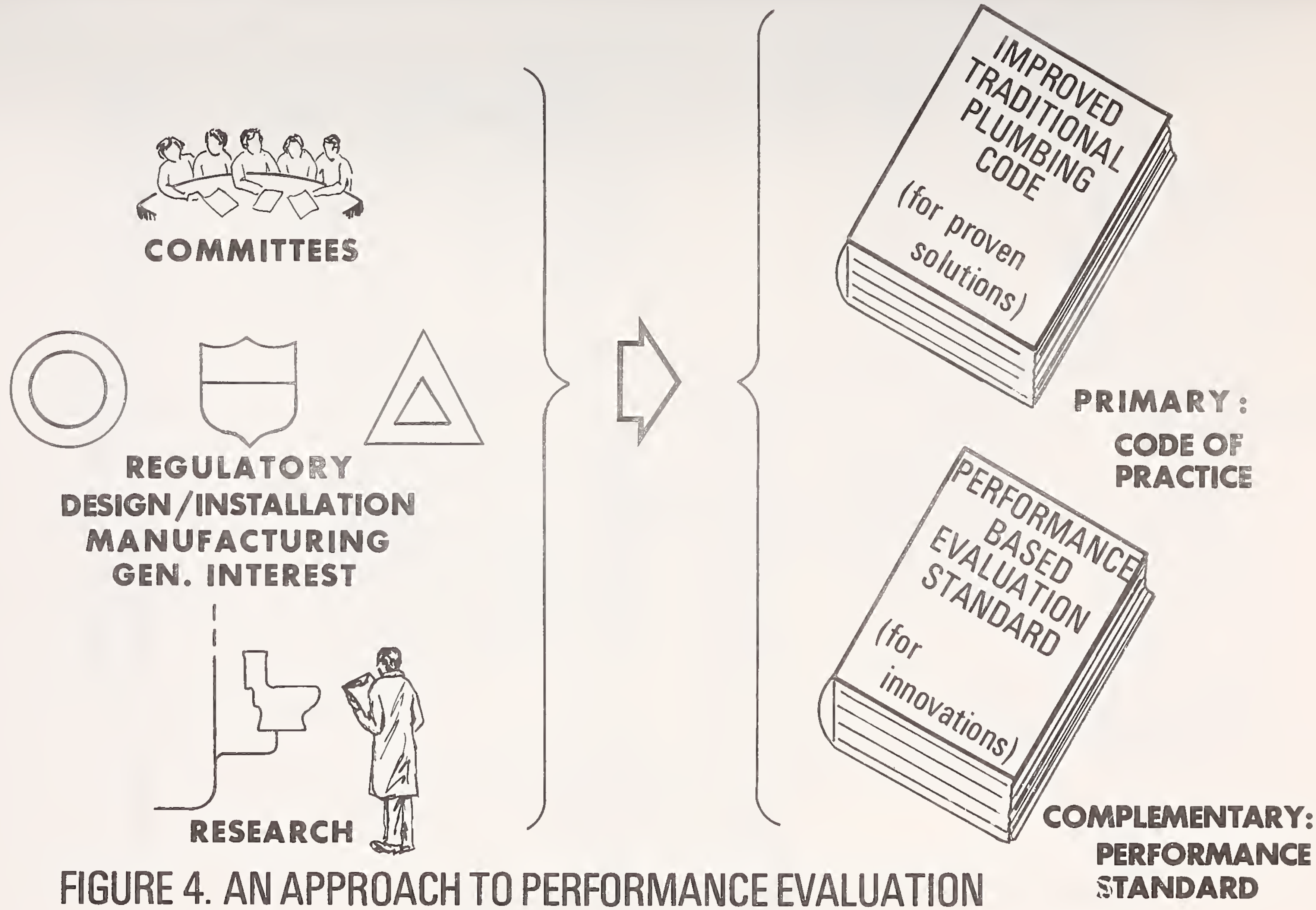


FIGURE 4. AN APPROACH TO PERFORMANCE EVALUATION

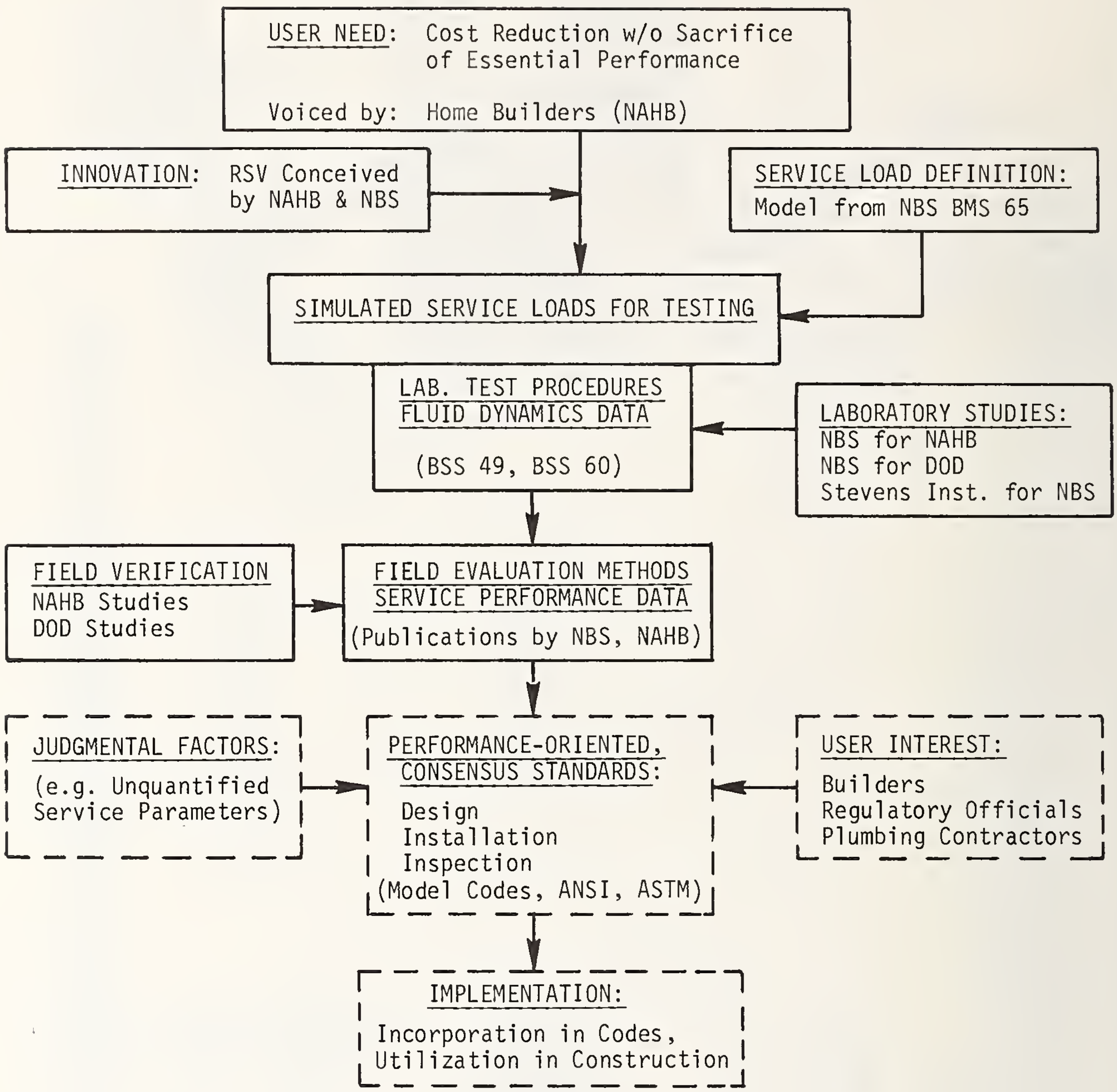
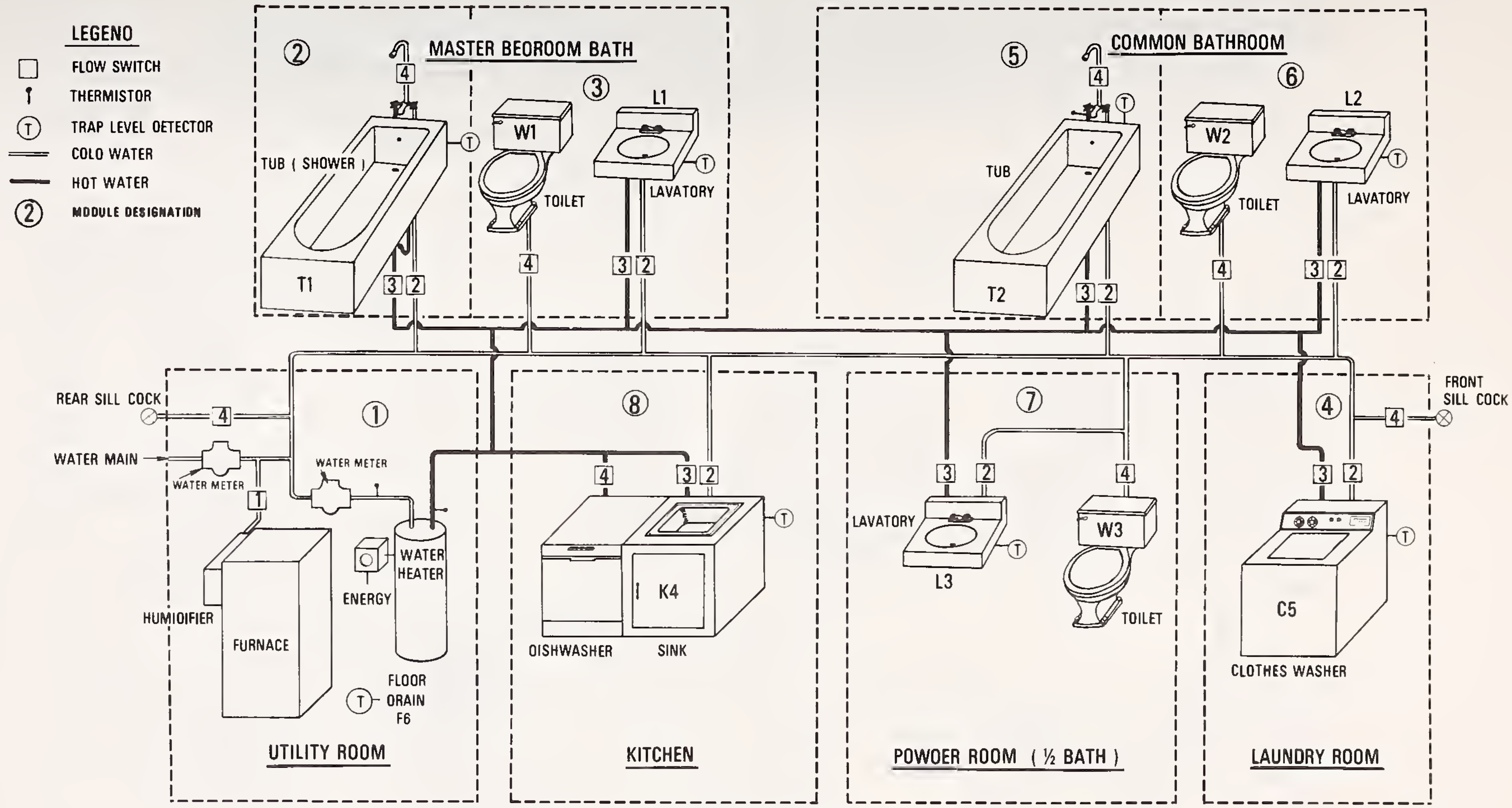


FIGURE 5. CHRONOLOGY OF EVALUATION OF REDUCED-SIZE VENTING



NOTE: NOTSHOWN HERE, SUCTION AND BACK-PRESSURE OVER RANGE SWITCHES WERE INSTALLED IN SELECTED FIXTURE VENTS.

FIGURE 6. SCHEMATIC OF INSTRUMENTATION FOR PLUMBING SYSTEMS IN FIELD STUDY

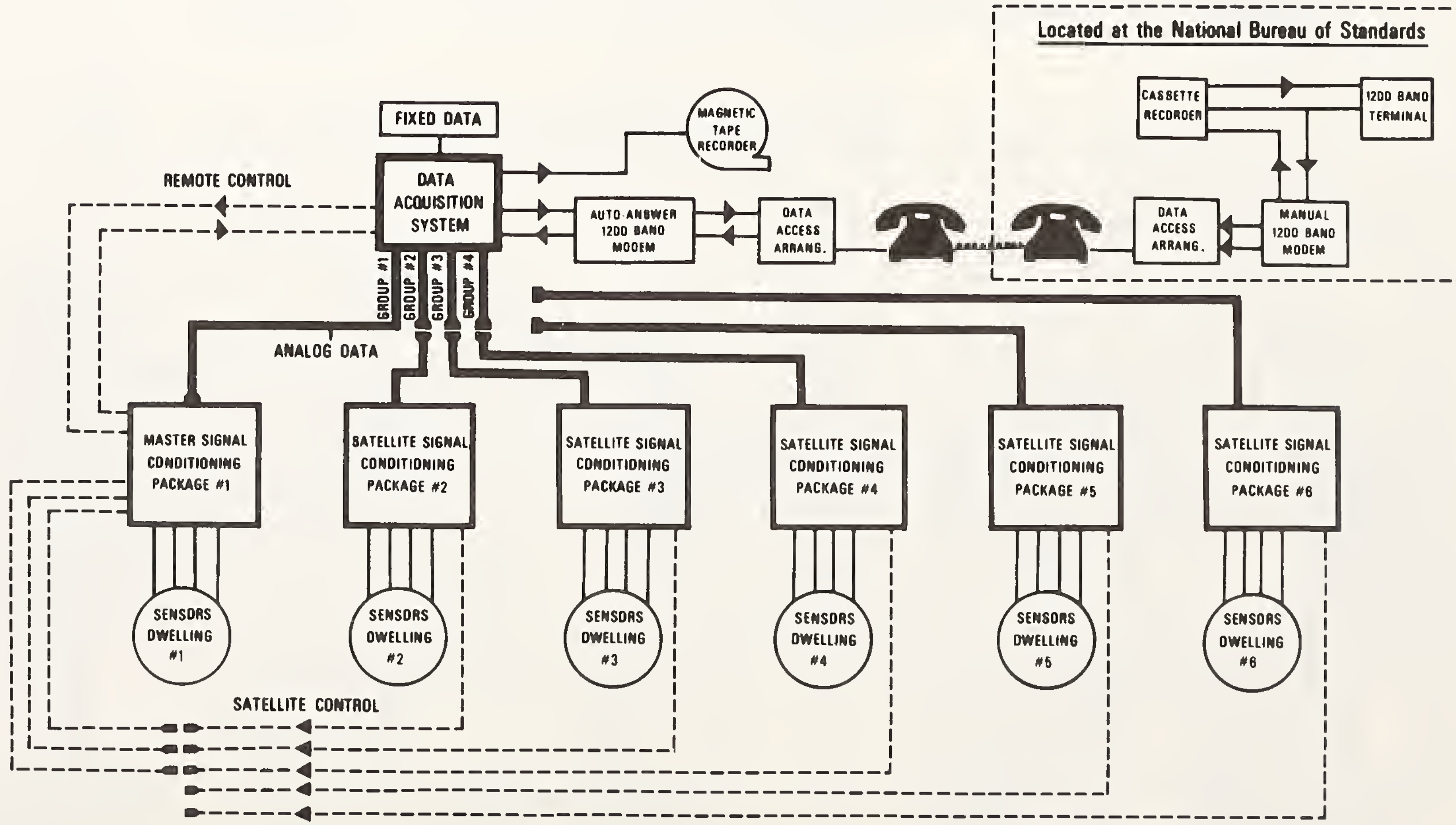


FIGURE 7. SCHEMATIC OF POST-OCCUPANCY FIELD DATA ACQUISITION SYSTEM FOR MONITORING PERFORMANCE OF REDUCED-SIZE VENTING, DISTRIBUTION OF WATER USE AND ENERGY FOR HEATING WATER

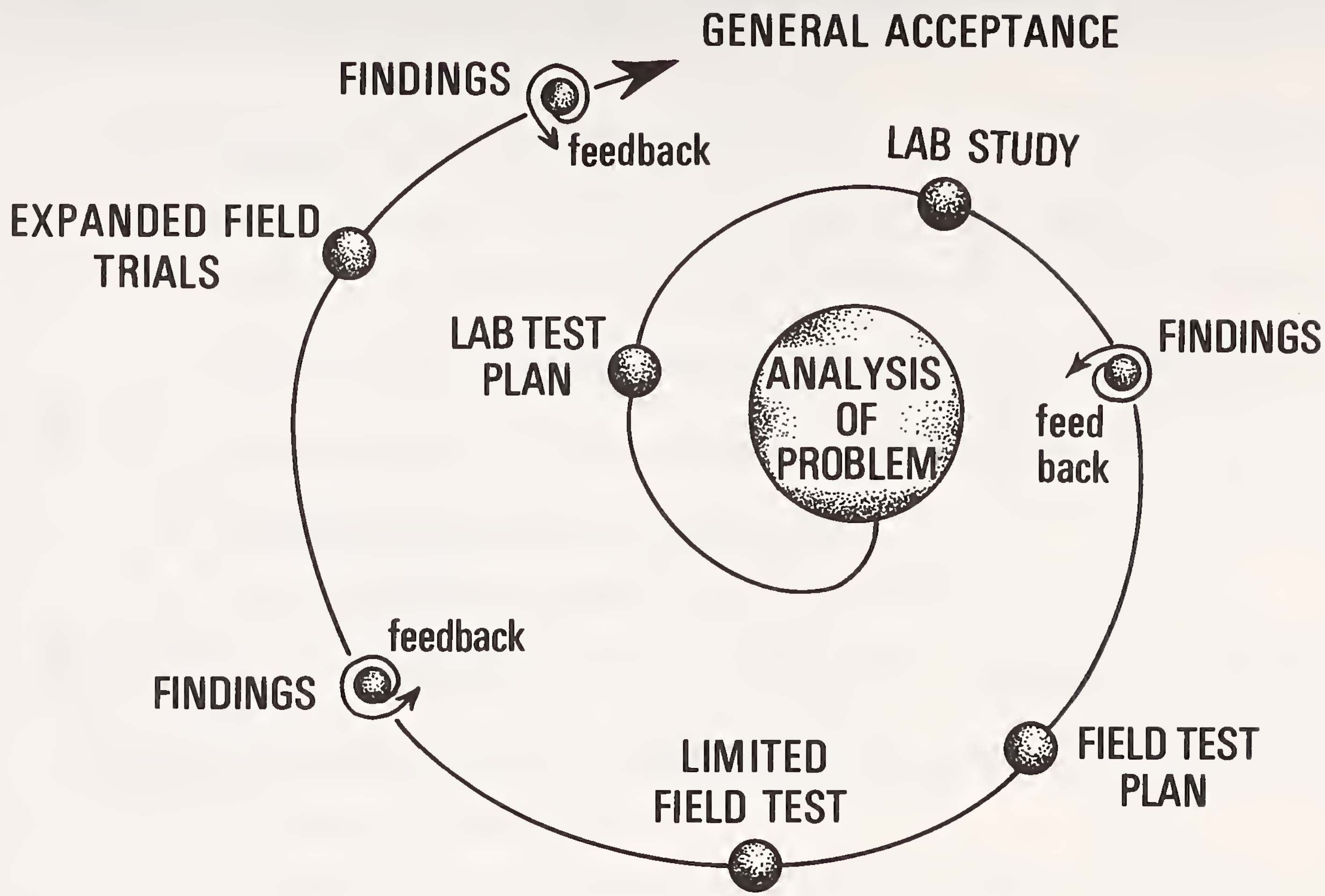


FIGURE 8. TRADITIONAL MODEL FOR ACCEPTANCE OF PLUMBING INNOVATIONS

- PREDICTION OF PERFORMANCE OF INNOVATIONS: APPROACHES
  - BY COMPUTATION (FROM THEORY OR MATHEMATICAL MODEL)
  - BY SIMULATIVE SERVICE TEST
  - BY SOME OTHER SUITABLE, SYSTEMATIC EVALUATION PROCEDURE
- SPECIAL NEEDS FOR INSTALLATION STANDARDS: COMPONENT INTERACTION
  - SYSTEM PERFORMANCE DEPENDS ON INTERACTIONS BETWEEN PARTS
  - INTERACTIONS DEPEND ON INSTALLATION DETAILS
- ACCEPTANCE PROTOCOL NEEDS: CONCEPT IMPLEMENTATION
  - PERFORMANCE LANGUAGE SUPPLEMENTING THE TRADITIONAL SPECIFICATION LANGUAGE OF THE CODES
  - GENERALLY RECOGNIZED STANDARDS DEFINING/MEASURING ESSENTIAL PERFORMANCE
  - A VIABLE CERTIFICATION SYSTEM AND ACCREDITED TESTING AGENCIES
  - DESCRIPTIVE CATALOG OF ACCEPTABLE SOLUTIONS

FIGURE 9 APPROACHES AND BASIC NEEDS IN IMPLEMENTING THE PERFORMANCE CONCEPT

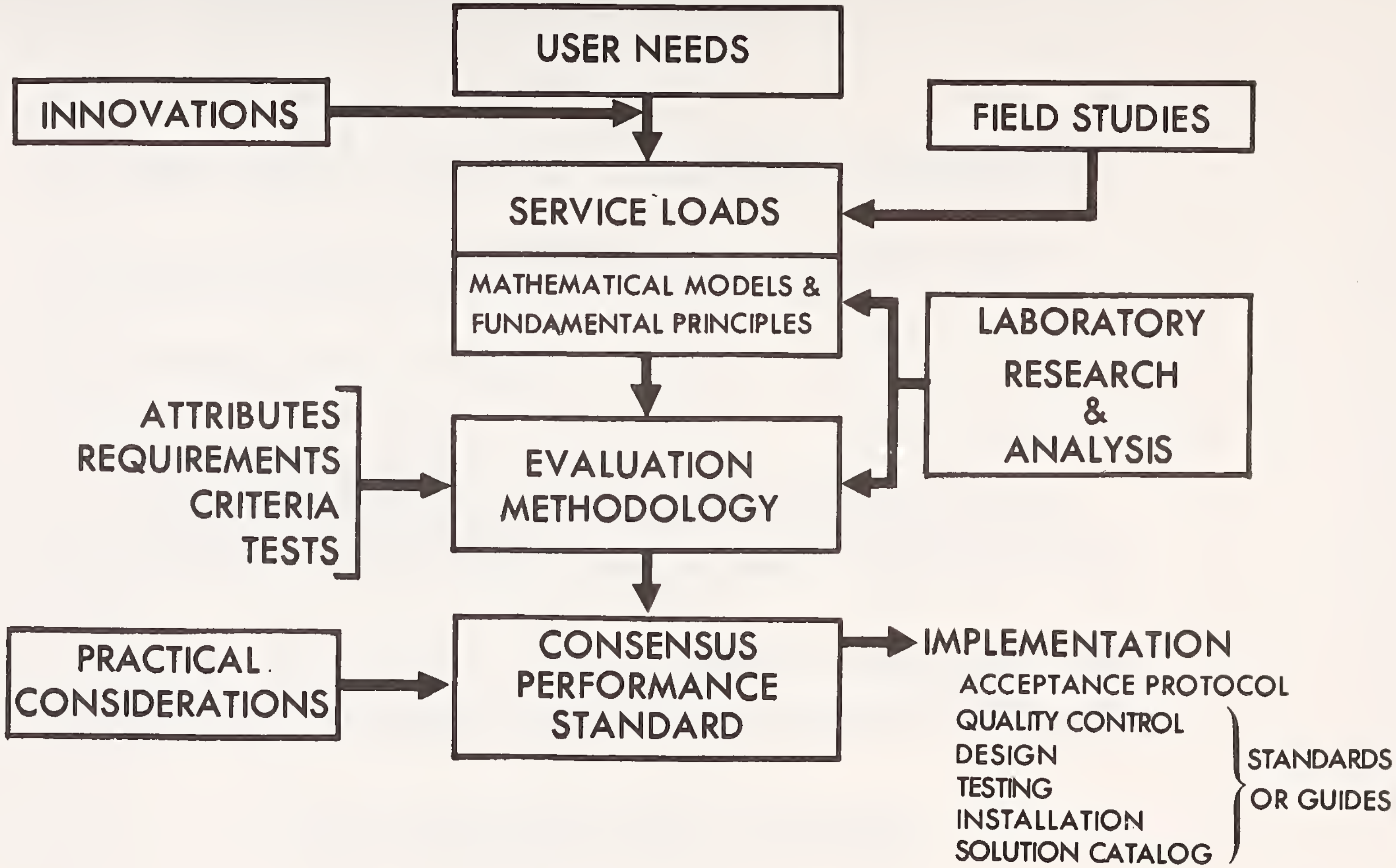


FIGURE 10. MODEL FOR EVALUATION OF INNOVATIONS

AN ACCREDITATION PROGRAM

- INITIATED - PROMULGATION, FEDERAL REGISTER PUBLICATION February 25, 1976 (Part 7 Title 15 Commerce and Foreign Trade)
- EXAMINES - PROFESSIONAL AND TECHNICAL COMPETENCE OF TESTING LABORATORIES FOR PRODUCT EVALUATION AND CERTIFICATION NEEDS
- ACCREDITS LABORATORIES
- QUALIFICATION MAINTAINED THROUGH PERIODIC CHECKS
- SERVE NEEDS OF INDUSTRY, CONSUMERS, GOVERNMENT(S)

FIGURE 11. VOLUNTARY NATIONAL LABORATORY ACCREDITATION PROGRAM

A THEORETICAL BASIS AND IMPLEMENTATION FOR COMPUTER ASSISTED ARCHITECTURAL DESIGN EVALUATION

by

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and
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SEARCH: Systematic Evaluation And Review of Criteria for Habitability (SEARCH) is an automated architectural criteria maintenance and design evaluation system. A prototype system is now in the Office of the Chief of Engineers (OCE). SEARCH is used in two phases of Corps of Engineers design work. First, performance type architectural design criteria and selected building code requirements are checked for consistency, documented as to information location, and stored for later use. Second, design layouts produced by Architect/Engineers (A/E) are put into SEARCH. The result is full, unbiased evaluation based on the previously checked and stored criteria. SEARCH is intended to be used by OCE personnel for both criteria maintenance and design evaluation type of work. An example of criteria maintenance would be in checking and storing criteria of the Design Guides now being developed. Design evaluation use will involve evaluating selected architectural designs submitted by Corps Districts as well as design layouts and relationship diagrams in the Design Guides.

Key words: Architectural criteria; automated system; buildings; building codes; computer applications; criteria maintenance design evaluation; design guides.

INTRODUCTION

The Construction Engineering Research Laboratory (CERL) in Champaign, Illinois was established in 1968 by the U.S. Army Corps of Engineers. CERL's mission is to provide the military user and other Federal agencies with solutions to design construction and Operation and Maintenance problems.

The Military Construction building delivery process consists of six interrelated phases which cover the full range of project activities from planning/programming, Architect/Engineers (A/E) selection, concept design, final design, and contracting through construction. There are four general groups of participants; funding authorities, Corps of Engineers design professionals, private design professionals and the facility user.

CAEADS (Computer-Aided Engineering and Architectural Design Systems) addresses solutions of problems in the Military Construction process in order to expedite and improve the constructed products of this system. With goals of "increased effectiveness" and "improve quality" the CAEADS team was charged to "provide an integrated set of computer tools for professionals who accomplish Military Construction planning and design."

Over the past four years, work has progressed in three areas, specifications, cost estimating, and architectural design. SEARCH (Systematic Evaluation And Review of Criteria for Habitability) is the architectural module of CAEADS. One of the principal theoretical problems that faces the developers of CAEADS is the design of an appropriate format for building description that will serve a wide variety of application programs. The work on SEARCH addresses a significant subset of this problem; providing a theoretical basis for further design.

BACKGROUND

In 1974, an interim report was published containing a thorough survey of the available computer-aided architecture tools and an indepth review of Corps needs.[1] Subsequent work included monitoring the use of two potential systems. Although an overall system to aid in the architecture design portion of the facility delivery process was desired, the main conclusion drawn was that no integrated design systems existed which would meet the needs of the Corps of Engineers[2]. No adequate systems were found because: first, Corps Divisions

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[1]Dains, Kelley, An Evaluation of Computer-Aided Architectural Systems, (Construction Engineering Research Laboratory, Champaign, Illinois, August, 1974.)

[2]Ibid, p. 7.

and District offices are involved in the administration, contracting, review, and evaluation of design more often than the actual development of designs and second, most of the systems surveyed dealt with other portions of the design process.

Following the recommendations that computer aids to architectural design be built up of application programs starting with those of greatest benefit to the Corps, one of the systems surveyed was adapted and tested; the design evaluation portion of IMAGE[3] (developed over a period of five years at MIT) was modified to become the SEARCH prototype.

The emphasis on design evaluation as opposed to design generation recognizes that the Corps, while managing the largest building delivery process in the world, accomplishes about 80% of its design through outside A/E contracts. Therefore, design evaluation is of greater immediate benefit. Further, the results of CERL's monitoring of existing systems, demonstrated that generation of building designs used excessive computer time, was limited to unrealistically small buildings and yielded mediocre results!

The SEARCH prototype system is now in the Office of the Chief of Engineers (OCE). A redesigned system being developed will be released in January for field testing at OCE and two Corps District offices.

SEARCH is used in two phases of Corps of Engineers design work. First, performance type architectural design criteria and selected building code requirement documents are checked for consistency, documented as to information location, and stored for later use. Second, design layouts produced by Architect/Engineers (A/E) are put into SEARCH for a full, unbiased evaluation based on the previously checked and stored criteria.

Office of the Chief of Engineers personnel will use SEARCH for both criteria maintenance and design evaluation type of work. In contrast, the District will use SEARCH mainly for design evaluation. Corps concept design evaluators are expected to be primary users of SEARCH. For Corps "in-house" designs it will be used to evaluate layouts during the design process. For work being performed by outside A/E's it will be used to aid evaluators in the district. The possibility of an A/E firm that has access to computing equipment using SEARCH in their own office has been considered.

Since SEARCH handles complex criteria (relationships between spaces and certain building code requirements), the districts are expected to use it to evaluate medium to

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[3] Timothy E. Johnson, Guy Weinzapfel, et al., IMAGE: An Interactive Graphics-Based Computer System for Multi-Constrained Spatial Synthesis, Cambridge: (MIT Department of Architecture, September, 1970.)

large buildings or those with many different kinds of spaces. Buildings for which a Design Guide has been published or is being prepared are prime candidates, as they will be among the first to have criteria stored for evaluation use. Examples which fall in these catagories include Army Service Schools, General Education Centers and Libraries, Criminal Investigation Facilities, NCO and Officer Clubs, and Recreation Centers.

Use of SEARCH is also expected to extend to smaller buildings for limited evaluations. This will include checking certain building code requirements such as fire code distances and corridor widths, areas within fire zones and rise and run of stairways. Traffic flow requirements between public and private spaces (entrances, lobbies, corridors) will also be checked.

The two sections of this paper that follow describe in detail Building Description and Design Evaluation with particular emphasis on SEARCH implementation.

BUILDING DESCRIPTION

The usefulness of any computer-aided design system depends heavily on the way the object being designed is described to the machine. In the non-machine environment there are many techniques for describing buildings. Two dimension orthographic drawings and section views of structures are the most common.[4] Namely floor plans (horizontal sections taken looking downward 4' -0" above each occupiable floor), elevations (exterior orthographic views) and building sections (vertical sections taken arbitrarily within a structure. Other drawings that are also commonly used are reflected ceiling plans (mirror images of horizontal sections looking upwards to ceilings), details (large scale drawings of joints, trim, operable parts and decorations that are cross referenced with other drawings) and perspective or isometric projections. Non-graphic descriptors include construction specifications, door, window, plumbing, hardware and electrical schedules, which are also cross referenced with the basic drawings.

The function of these documents is to communicate an unambiguous three-dimensional model from one set of designers to a builder and another designer. They are limited to one or two-dimensional representation due to the cost of the media and preparation effort.

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[4]Roark, Ivan W., Positions in Space, (The University of Tulsa, 1965,) pp. 53-55.

Add the computer and two things become evident: 1) computers can't "see" to read drawings[5] or text[6] and 2) there are a plethora of mathematical models that could be useful to describe buildings that haven't been used before due to our lack of the computation power to manipulate them. To the researcher who is seriously investigating computer-aided design, graphic output in the form of conventional plans, elevation and sections must become secondary to the mathematical representation that underlies the drawings. A good mathematical representation will, among other things, permit straightforward graphic interpretation.

Three-dimensional mathematical representation of buildings have been put forward by several researchers[7] and most CAD systems that have been developed have used some variation of these schemes. By and large they rely on representing physical units of the building in three spaces by storing x, y, and z coordinates and a variety of transformations that place one element in space relative to other elements and to a global coordinate system.

The emphases in Eastman's BDS system are on complete description of a building, data compression (by use of templates to repeat topologies in a variety of transformations), the ability to perform the Boolean operation of intersection, union and symetric difference on volumes, and recently the development of a problem oriented language (POL) called GLIDE which facilitates the description of buildings in the BDS.[8]

The emphasis in Coon's work was toward the mathematics of describing the complicated curved surfaces commonly encountered in automotive and aircraft design. The work done in attempting to solve (and solving) the "hidden line" problem in perspective drawing led to other useful data structures.

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[5]Scanners are available, but they are experimental and consequently relatively unreliable and expensive, see: Williams, C.M. "The Automatic Transduction of Drawing Into Data Bases," Proceedings of AFIPS 1973 National Computer Conference, (June, 1973), pp. 635-7. See also: Negroponte, Nicholas, Soft Architecture Machines, (MIT press, 1975), pp. 55-91.

[6]Recognition of hand drawn characters is also experimental though possible, see: Ray, Robert M. III, On Direct Methods for Direct Quantification Of Pattern Associations, (Center for Advanced Computation, University of Illinois, CAC document #139, Nov., 1974).

[7]Charles Eastman, Steven Coons, Ivan Sutherland and others such as Braid, have advanced various mathematical schemes for 3-D data structures.

[8]Eastman, Charles M., Language for a Design Information System, IPPR report #58, (Carnegie-Mellon University, Feb., 1976.

The systems mentioned above all describe actual physical objects. While it is true that the physical object is the least common denominator of the design representation, it is also true that the designer, whether he be an architect, a structural engineer or an acoustician, nearly always works with an abstraction of the building rather than with a complete physical description. Indeed when many important design decisions are being made there is no physical description, there are only a collection of abstractions!

The engineering disciplines have developed specific abstractions of buildings and components of building which suit the purposes of their design and analysis. The structural engineer is interested in center-lines, physical properties of members, loads, and stiffness of connections; all of which are abstractions of real physical objects. Mechanical Engineers are concerned with networks of pipes and ducts. To calculate flow in a network for example valves and elbows are made mathematically equivalent to additional lengths of pipe. Only in the architectural problem of the interference of one system with another does the 3D physical representation become important.

An adequate 3D representation must therefore be sufficiently rich to allow each discipline to abstract from it the pertient data to solve it's own unique problem.

The next section of this paper deals with three abstractions that are used by architects. The final section describes a computer implementation which explicitly uses these abstractions to aid designers and design evaluators in the Corps of Engineers.

DESIGN EVALUATION

Building Description Abstractions

Three abstractions that are useful for design evaluations will be described: 1) design criteria, 2) volumes of space, and 3) functional relationships. No two of these abstractions deal with exactly the same elements, but they can all be applied to a single design project and must all reference a common project description. Each abstraction is in reality a particular "point of view" that helps an architect understand a project.

They are not uniquely architectural concerns as for example acoustical and thermal engineers are also interested in volumes of space, industrial engineers often deal with functional relationships and regulatory officials and specification writers deal daily with various kinds of criteria. In fact it is because of the requirement to automatically evaluate designs against design criteria that we are concerned with volumes and functional relationships.

The emphasis in this research has been architectural. The design criteria that directly concerns the project team is that which specifies, size, shape, and functional relationships of activity spaces (rooms) in a building.

The design process has been variously described by absolutely everybody who has written a paper on CAD. Quite simply it has two steps: 1) generation of candidate design solutions and 2) evaluation of the candidate solutions. All the rest of the work simply supports these activities. Although early attempts at CAD tried to automate both parts of the problem it now seems prudent to assume that trained designers are best at design generation while computers may be useful in providing tools fcr design evaluation. Computers have shown their usefulness in a support role in graphics, specification editing, bookkeeping and engineering analysis, which is, of course, a form of design evaluation.

Design Criteria

One point of view of building description avoids the actual building altogether, but rather considers the design criteria that controls the final design. The collection of design criteria for a particular project constitutes a program or conceptual model of the future design. Whether design criteria are specific as with building code or zoning restrictions or where they are more general as with functional or economic considerations they are rarely simple and are often complex and highly interrelated.

A successful design seldom satisfies all of its criteria but rather represent intelligent trade-offs between potentially conflicting requirements (e.g., cost vs. quality). Serious consideration of computer-aided design evaluation leads to the necessity of defining a design criteria language which is rich enough to allow the computer to consider subtle variations in solutions to problems and to recognize potential trade-offs between requirements.

Computer aided architectural design systems have all approached the design evaluation function to some degree. In the cases where the purpose of the program was to automatically generate design solutions, evaluations had to be kept very simple due to the necessity of performing the evaluation several thousand times for a single design. These simplications often limited the evaluation to area, distances between spaces, or adjacency only. A typical input to such a system is a matrix listing the required spaces along each axis. The matrix contains such information about desired relationships between pairs of spaces as can be coded by a single number and can be evaluated by a simple algorithm (e.g., adjacency, nearness, farness). No systems that the SEARCH team studied allowed a requirement to specify an <u>alternative</u>. An example of this type of requirement is where a pair of spaces are to be acoustically isolated from one another. They could either be located some distance apart <u>or</u> share a wall with a specified acoustical rating! Indeed a high proportion of design criteria involve similar alternatives.

The purpose of design criteria is to provide a measurable means of expressing user requirements. In the Corps it must be expressed in performance terms. Situations or circumstances under which the building is to be built cannot be presumed since criteria is generated completely apart from the programming of a particular building. The Corps develops standardized criteria by facility type. This material which is published as Design Guides, combines criteria for modernization of existing facilities as well as criteria for various sizes of facilities (usually determined by troop strength).

The abstraction developed by the SEARCH team to describe architectural design criteria is a language based on normal arrangement of logical and arithemetic statements. Through a hierarchy of simple commands, in which elementary statements are combined, complex requirements are described.

Statements are made up of identifiers, arithemetic operators, functions, and keywords. Identifiers are the rudimentary terms found in text, such as space names, item names, square footage measure, counts of items, walking distance measures, etc. Arithmetic operators consist of all the basic operations, = (equal), + (plus), x (multiply), / (divide), etc. Functions, in addition to standard ones (square root, sine, cosine, etc.), include named architecture constraints such as near, between, far, enclosure, etc. Key words are built into the language to indicate a process that the statement is to execute; these include define, require, assign, and report. The following are two typical statements.

```
REQUIRE BETWEEN (administration, conference, personnel);

REQUIRE number_parking_spaces = 200;
```

The first is a requirement that a "conference" area be located between the "administration" space and the "personnel" space.

The second requires that 200 parking spaces be included in the design.

Complex requirements are produced by connecting elementary statements with logical expressions. "AND," "OR," "NOT," and IF-THEN-ELSE" are logical operators. The following is an example of the complex statement - "if a faculty office exists then the faculty offices should be near the directors office, however, closer proximity is required between the faculity office and the classrooms."

```
IF EXIST (faculty_office);

    THEN REQUIRE NEAR (faculty_office, directors_office);
    AND REQUIRE BETWEEN (directors_office, faculty_office, classrooms);
```

Figure 1 shows an even more complex expression of an actual requirement for parking spaces. It is taken from a government document, DOD 2740 I-M "Construction Criteria Manual," p.4-13, - Parking Spaces Authorized for Non-Organizational Vehicles for Military Hospitals.

FIGURE 1

```
BEGIN PARKING DOD 4270 I-M - p. 4-13;
          B=NUMBER (BEDS)
          IF B <= 100 THEN X= 2*B;
     ELSE IF B >  100 AND B <= 500 THEN X= 200 + B
     ELSE IF B >  500 THEN X= 600 + (B-500)*0.6;
          A=AREA (CLINIC);
          IF A < 30000 THEN X=X+ (A/1000)*2;
     ELSE IF A > 30000 THEN X=X+60+(A-30000)/1000
          NUMBER (PARKING_SPACES) + X;
END PARKING;
```

Elementary statements and complex statements are separated and identified by grouping them as "BLOCKS." A block is defined by a group of statements (elementary or complex) which begin with the title - "BEGIN, block title, document page numbers" and which end with "END, block title." The block title usually refers to an area of common interest such as "PARKING" in figure 1. The document page number is a reference to the document and page where the criteria is found. This enables convenient future referencing and updating. Checking for some conflicts in criteria as well as inconsistencies in the criteria language, however, is accomplished at the time the criteria is entered. Reports listing "raw" block data can be printed at any time.

Volumes of Space

To the casual observer an abstration of a building into volumes of space, might appear to be equivalent to the typical three-dimensional coordinate computer graphics approach found in most all computer-aided architectural design programs. This is not true as will be pointed out below.

To be sure, a three-dimensional coordinate system is referenced by most programs. Those that develop building models in sufficient detail to plot perspective drawings or produce working drawings deal with points in three-space, polygons, and planes (surfaces). Those that deal with spatial layout deal with two-dimensional blocks that can assume a variety of positions and orientations. Whereas the detailed systems can describe spaces of any shape or complexity as for industrial design etc. they explicitly represent only solid objects. The spatial layouts systems explicitly represent spaces (voids between solid objects), but they are usually limited to rectangles or combinations of rectangles, or are confined to a pre-defined grid system.

A major concern of an architect is not the solids that make up the mass of the building, but the voids that are left over between the masses of materials. From an aesthetic and maintenance point of view the outside millimeter of the solid material is the most important aspect of the mass. Philip Thiel chooses to call the surfaces that we view as we exist in a space SEES (Space-Establishing Elements).[9] In fact these SEES are the principal evidence of the existence of the building to the user. A rectangular space has six SEES; four walls, a ceiling and a floor.

The basic element of the SEARCH three-dimensional model is a SEE, or more precisely half of a wall. SEARCH has been developed under the constraint that it must be able to model buildings containing non-rectilinear spaces. For this reason and because the concept of the SEE is consistant with an architectural abstraction of a building the following procedure is used for describing rooms in a building.

SEARCH prints a list of the spaces that are required in the building from the criteria data base. This list may then be attached to a digitizing surface beside a drawing of the building plan. After defining a "Z" coordinate for the particular floor plan level, and establishing a standard wall thickness, the terminal operator touches a room name with the digitizer pen and the inside corners of the named room. SEARCH matches the set of "half walls" so defined with other "half walls" that are a distance of one wall thickness away. Pairs of "half walls" become "walls." Fig.2

The operator continues in this manner unitl he has described all of the required spaces and the exterior perimeter of the building. SEARCH can then combine all remaining "unmatched" half walls with new ones that it generates to define the common or corridor space in the building. The operator can then use the digitizer to locate doors and windows or other features of the building. As the model is built it is displayed and room areas and perimeters are calculated. When the model is complete SEARCH can evaluate the design against the criteria stored in the criteria data base.

Functional Space Relationships

Another useful abstraction of a building describes the functional relationships of one room to another. In a realistic analysis of traffic patterns, interdepartmental

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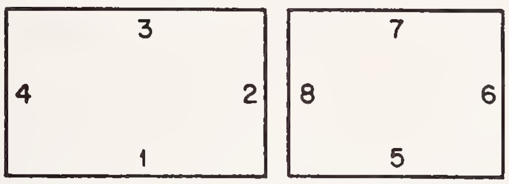
[9]Thiel, Philip; "Notes on the Description, Scaling, Notation and Scoring of Some Perceptual and Cognitive Attributes of the Physical Environment," <u>Environmental Psychology</u>, pg. 593-618. (Holt, Reinhart and Winston, New York, 1967.)

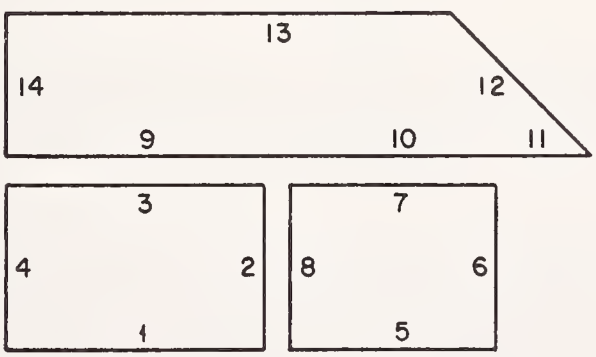
Figure 2

IDENTIFICATION OF HALF-WALLS AND WALLS

A ROOM MADE OF 4 "HALF-WALLS" (1,2,3,4)



TWO ROOMS FORMING A "WALL" (2,8)



THREE ROOMS FORMING 3 "WALLS"
(2,8), (3,9), & (7,10)

communications, emergency egress and movement efficiency of material and personnel, a graph (network) representation of the building provides the necessary information for computer analysis.[10]

Most computer aided space layout design evaluation systems address the interdepartmental distance problem, but none that the SEARCH team have reviewed consider the locations of doors and corridors when calculating walking distance. Rather, most of the systems utilize straight line distances which disregard walls altogether, and several systems calculate distances from the center of one space to another either by a straight line.

$$\text{DIST} = \sqrt{(X_2-X_1)^2 + (Y_2-Y_1)^2}$$

or by what is called the "rectangular" distance

$$\text{DIST} = |X_2-X_1| + |Y_2-Y_1|$$

A variation measures the distance between the nearest pair of corners of two spaces.[11] One early variation of CRAFT[12] called SLAP II[13] measured distances via corridors, however, the program only considered buildings configured along a single double loaded corridor and ignored locations of doors.

Grason suggested an interesting graph representation[14]. He points out that if one considers the graph represented by the building walls themselves, then the dual of the graph represents the room adjacency! Although this allows one to distinguish between rooms that allow traffic to flow and those that do not accept traffic, it unfortunately fails to take into account the existance or positions of doors.

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[10] Bryant, Dale A., A Graph Representation of Functional Space Relationships in Buildings, (University of Michigan, June, 1969.) (unpublished.)

[11] Johnson, Weinzapfel, Ibid, p. 22.

[12] Gordon C. Armour and Elwood S. Buffa,"A Heuristic Algorithm and Simulation Approach to Relative Location Of Facilities," Management Science, Vol. 9, #2, (Jan., 1973.)

[13] Anderson, Thomas, "Layout Planning for Minimum Circulation Cost," (University of Washington, 1962.) (unpublished.)

[14] Grason, J., Methods for the Computer-Implemented Solution of a Class of Floor Plan Design Problems, (Carnegie-Mellon University, 1970.) (Ph.D. thesis.)

If one is designing a functional relationship model for automatic design generation rather than design evaluation, then it is reasonable to ignore doors, since their location introduces an additional level of complicity to the design parameters. Because SEARCH always assumes that a design that was manually produced is being evaluated, the recognition of the locations of doors adds needed realism rather than new level of complication.

The graph chosen for SEARCH represents doors as its nodes, and rooms as its arcs. (Fig. 3) The value of an arc is the linear distance between two doors in the same room. The adjacency matrix and the initial lengths of arcs are calculated directly from the geometric data that is obtained by digitizing the drawing. From this basis the distances between other pairs of doors can be calculated. (Fig. 3)

The design criteria relating to functional relationships can specify required maximum or minimum distances between pairs of spaces, or require that the distance beweeen a pair of spaces be greater or less than the distance between another pair of spaces or above or below the average of all spaces. One might require that a space be "between" two other spaces, or that no traffic between a particular pair of spaces be permitted in another space or set of spaces.

Multi-story buildings can be evaluated by including stairways and/or elevators as nodes in the graph. A "difficulty" factor can be applied to vertical distance to equate it with horizontal distance. By using a directed (directional) graph, one-way passage through a particular arc, say an escalator, or turnstyle can be accommodated.

The use of this graph allows convenient evaluation of most functional space relationship problems that involve flows of people and materials. Obviously, where other considerations are important, other abstractions are required.

SEARCH

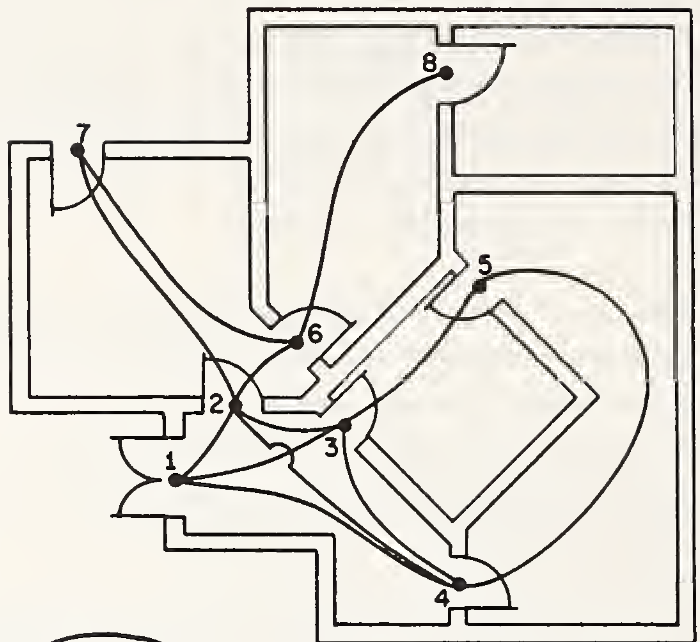
Structure

SEARCH is a computer program that combines the three building description abstractions described above with a data base, a user interface and various criteria evaluation algorithms. Figure 4 shows the principal components of SEARCH as they relate to one another.

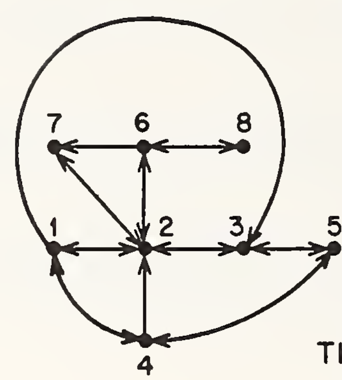
The SEARCH data base handles three types of data corresponding to the three description abstractions, criteria, geometry, and functional network. The names of the parts of buildings are held constant across the three data subsets, so that all applications subprograms communicate data by name rather than by location.

Figure 3

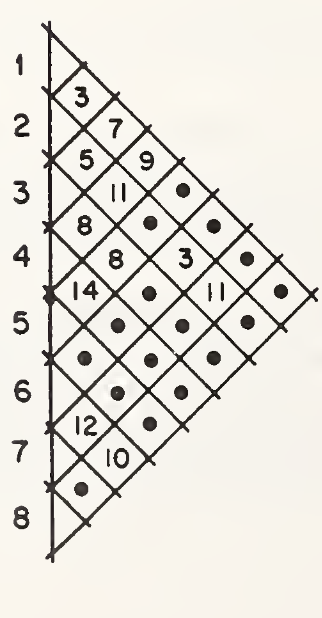
FUNCTIONAL GRAPHS



PLAN WITH GRAPH



THE GRAPH



THE ADJACENCY MATRIX WITH DISTANCES BETWEEN DOORS EXPRESSED IN FEET.

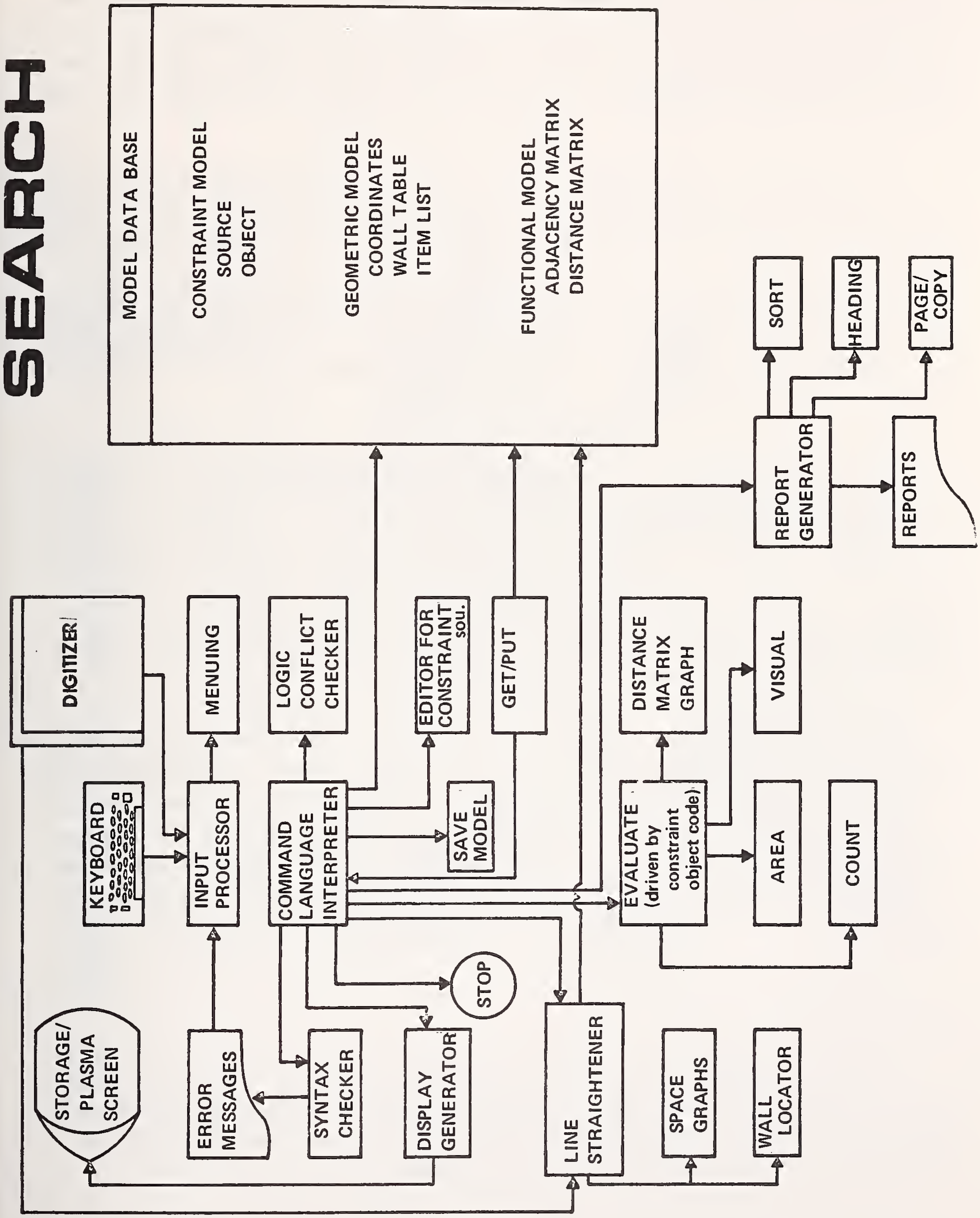

SEARCH
MODEL DATA BASE
CONSTRAINT MODEL
SOURCE
OBJECT
GEOMETRIC MODEL
COORDINATES
WALL TABLE
ITEM LIST
FUNCTIONAL MODEL
ADJACENCY MATRIX
DISTANCE MATRIX
SORT
HEADING
PAGE/ COPY
REPORT GENERATOR
REPORTS
DIGITIZER
MENUING
LOGIC CONFLICT CHECKER
EDITOR FOR CONSTRAINT sou.
GET/PUT
DISTANCE MATRIX GRAPH
VISUAL
KEYBOARD
INPUT PROCESSOR
COMMAND LANGUAGE INTERPRETER
SAVE MODEL
EVALUATE (driven by constraint object code)
AREA
COUNT
STOP
STORAGE/ PLASMA SCREEN
ERROR MESSAGES
SYNTAX CHECKER
DISPLAY GENERATOR
LINE STRAIGHTENER
SPACE GRAPHS
WALL LOCATOR

Figure 4

Since the standard design criteria that SEARCH uses applies to many projects, the first step in using SEARCH to evaluate a particular design is to select the appropriate design criteria for the particular project. These criteria may originate directly from the specific requirements for the project or be drawn from the standard Army documents previously stored in the data bank. Criteria is, in any case, used by SEARCH only after it has been coded using the criteria language described above.

The second step in using SEARCH involved describing the building design (floor plan) to the computer using a graphic digitizer as described in the section concerning volumes of space. The resulting geometric model is stored and the functional graph is generated.

The third step provides for printouts of selected evaluations of the building. The user is also afforded an opportunity to edit any portion of the data base, display any part of the building at any scale, and request printed summaries of selected portions of the data base at any time.

The user interface software allows for free format terminal input and an extensive use of the digitizer for selecting commands from menus attached to the digitizing surface. Input from the digitizer if first analyzed to determine whether it represents a hit on a menu item, and if it does, then the value associated with the menu item is passed to the using program rather than the digitized coordinates. New menus can be generated and printed at any time and hand written menu's can even be made by the user "on the fly" should he desire to make them. The using program need not anticipate whether a command will originate from the keyboard or from a menu.

The user communicates with SEARCH on several levels. Figure 5 indicates the relationship of the several languages of SEARCH. The "job control language" allows direct access to the host computer. The SEARCH command language communicates with the SEARCH main program as do the MACRO's which generate code in the criteria language. The user may also generate criteria language code. The criteria language compilor as well as the command interpreter are equipped with error detection routines, and error traps which make it nearly impossible for an erroneous user input to cause the program to inadvertantly terminate.

Implementation

SEARCH is implemented in a combination of FORTRAN and PL/1 languages on the AMDAHL V470 at the University of Michigan in Ann Arbor, Michigan. The source code consists of approximately 6000 80 column card images. When loaded in the virtual machine SEARCH occupies close to 180 pages (4096 bytes/page) of memory.

THE LANGUAGE OF SEARCH

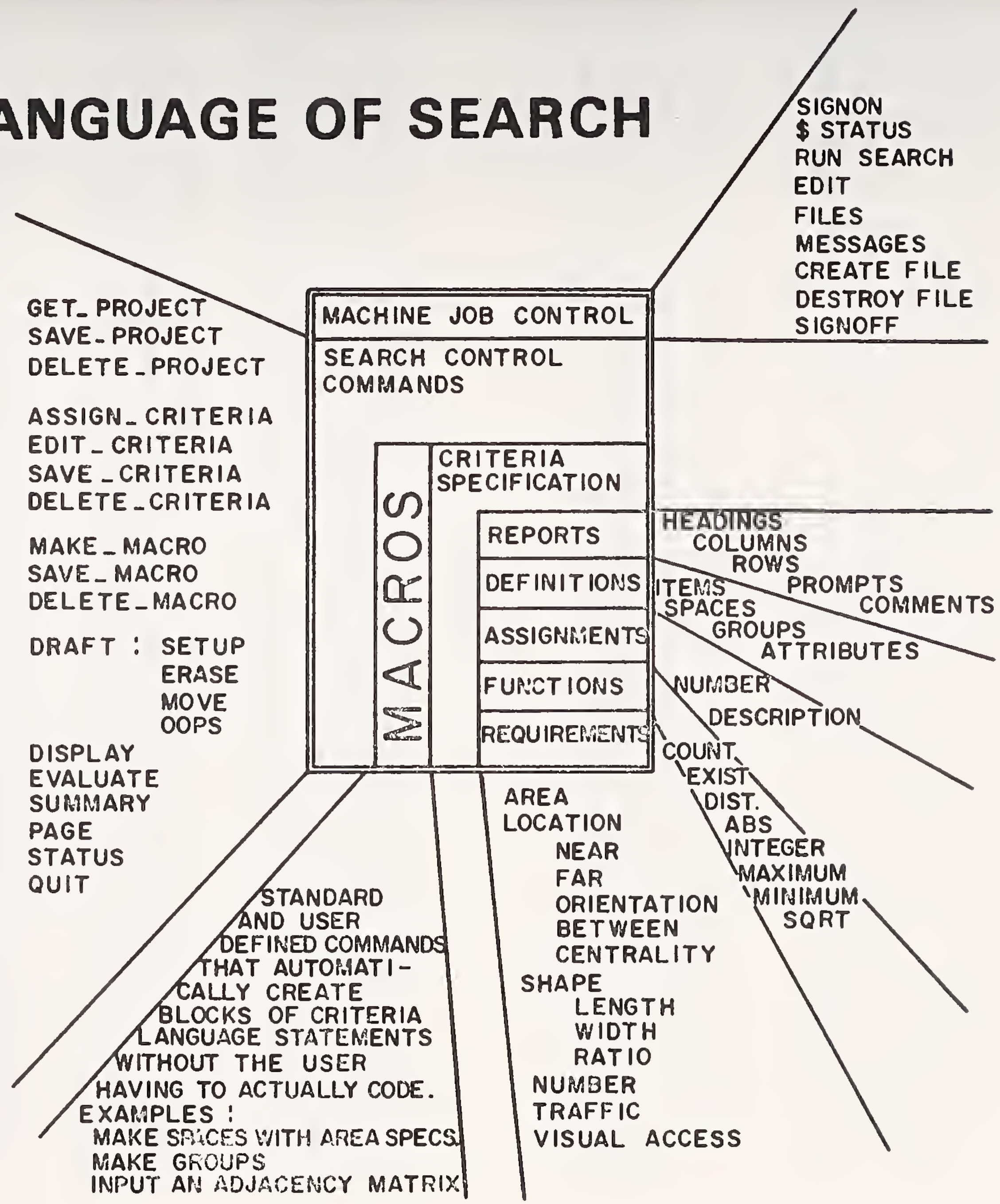


Figure 5

In October of this year the first two CRITS (Criteria Review Interactive Terminal Stations) terminals will be delivered. They consist of five basic I/0 elements built around an LSI 11 microprocessor. The five CRITS elements are an ASCII keyboard, and 8 1/2" x 8 1/2" plasma display panel, an impact printer, a cassette tape drive, and a 36" x 48" digitizing surface.

Development Status

The SEARCH prototype, a variation on the Image system, has been operational at the Office of the Chief of Engineers for two years. In January, 1975 work began on a new version of SEARCH. This development is 90% complete to date. A field test is scheduled to begin in January, 1977 at three locations; the Office of the Chief of Engineers, Washington, D.C.; Norfolk District, Corps of Engineers, Norfolk, Virginia; and Sacramento, District, Corps of Engineers, Sacramento, California.

Upon the completion of these field tests (approximately one year) SEARCH will be integrated into a larger system that is under development at CERL. This system, the Computer-Aided Architectural and Engineering Design System (CAEADS), includes architectural criteria checking, cost estimating, specification, preparation, thermal simulation and many other applications.

CONCLUSIONS

The choice of a format for building description can contribute greatly to the success or failure of a computer-aided architectural design evaluation system. Since certain types of desirable analysis require particular abstractions of a building, the appropriate building description format is one that allows for the widest variety of abstractions.

The SEARCH program, although not offering a solution to the problem of generalized building description introduces three useful abstractions - one for describing a building by its design criteria, a second for describing a building by volumes of space, and a third for describing a building by its functional layout.

The lessons to be learned from the SEARCH field test in 1977 will greatly increase the knowledge about how the architecture design team is able to communicate with a machine about a building design.

SEARCH is expected to have a significant effect on the Corps of Engineers field offices in their role of designers and design evaluators. Improvement of their capability to respond to a growing workload with limited personnel, increased control over design criteria, more thorough and timely design evaluations and consequently better designs and buildings are the expected results of this work.

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Mr. R. Porter is Chief, Architecture Branch, and Dr. R. Dinnat, is Chief, HP Division. Colonel J. E. Hays is Director of CERL and Dr. L. R. Shaffer is Deputy Director.

THE DEVELOPMENT OF COMPUTER BASED SYSTEMS FOR BUILDING CODES

by

Charles Masterson
The AIA Research Corporation
Washington, D.C.

The Purpose is to explain, in a brief fashion, the most important aspects of four years of research into computer-based systems for building regulation. The topics of automated plan review and performance evaluations through computer technology are covered. And, the basic strategies of a master plan for applications oriented development are outlined. The basic thrust of the argument is that computer-based systems can provide major assistance in moving the regulatory process towards a performance-oriented basis.

Key Words: Building regulation; computer-based systems; computer technology; information processing; performance evaluation; plan review; research and development.

A SCENARIO OF REGULATORY IDEALS

I think that we all understand the major problems of building regulation --modernization, uniformity, accuracy, adequacy, timeliness, and fairness are all required. So I will not dwell on regulatory difficulties in any detail. Rather, I will discuss the opportunities of attacking these old difficulties anew in a different way.

Let me begin by sketching a seemingly far-fetched, but as I'll demonstrate attainable, scenario of ideals in the regulatory process that goes something like this

> If we had sufficient information about the nature of the hazards impinging upon buildings, and...
>
> if we could define in humane terms according to human requirements acceptable degrees of risk, and...
>
> if we were able to formulate our policies of building regulation from this point-of-view, and...
>
> if we were able to translate those policies into performance measures, and...
>
> if we are able to assess and to predict the performance of alternative building technologies, and...
>
> if we were able to cast aside existing predispositions and make performance based decisions on the best set of available knowledge rather than on a current set of beliefs, and...
>
> if we were able to establish an on-line system of monitoring, evaluation, and feedback so that the regulatory system would continually enrich our building knowledge, and...
>
> if we were able to use this new information to constantly improve the regulatory process
>
> ...then we would have a building regulatory process that was performance oriented, operating cost-effectively, in the interest of public health, safety and general welfare.

My scenario is based upon a quantum improvement of our capacity to process information for decision and control in the public interest in the built environment. It is an improvement that is attainable through the proper application of computer technology to the regulatory process.

INFORMATION PROCESSING IN CODES AND COMPUTERS

Our regulatory problems stem from complexity -- a layering of new human requirements, a layering of new technological capabilities, a layering of new building and better understood natural hazards. We cut through this complexity by our ability to process information -- to improve our understanding, to guide our action. We do the best that we can and we could use better tools.

The contemporary tool of information processing is the computer. It is most often poorly used, like a file clerk and his files, to store, to retrieve, and to manipulate data. In regulation, we deal not in data but in its human interpretations -- each datum must be embodied with meaning. We deal in information which has been defined as "a difference that makes a difference."

A computer is an information processing device and so is a building code system. A computer processes information for a purpose through a program -- a structured routine, an analytical process for manipulating certain data in certain ways. When you put the data in, the computer runs through the program, and prints-out or displays the result. Interpretations are "hard-wired" in or they are made after the fact.

A building code consists of a structure for organizing information. It and a series of related manuals are followed by code officials when they are enforcing a code. In a way, these manuals are programs. A plan examiner takes a set of building plans and following the structure of the code he knows and the examination process he has been taught, he compares the data in the plans to the data in the code. Interpretations of meaning are made all along the way.

The computer works bits of data at high speed within a limited conceptual structure. The code official works bits of data at slow speed within a broad conceptual structure. The computer calulates. The code official judges. And, that is a difference that makes a difference.

THE OPERATING SYSTEMS OF BUILDING REGULATION

The regulatory process, as I have implied in my scenario, consists of at least six formally linked systems which (1) formulate regulatory policy, (2) manage the implementation of that policy on a daily basis, (3) develop and update regulations, (4) evaluate building proposals against applicable regulations, (5) enforce the code in the processes of building construction and use and, (6) maintain required records. These operating systems are found at the national, state and municipal level, and computer based systems can play an important role in each of these.

The development of powerful and reliable computers coupled with the exponential growth of the information processing industry has lead to considerable applications oriented research and development in the fields of building and building regulation. There are, up and running, applications of computer technology to building code administration and record keeping. For the most part, these systems are exactly what they were designed to be -- automations of existing practices. There developers asked the question: "How can the computer be applied to regulatory tasks?" There is a better question and code officials must ask it: How can this system improve the delivery of public health, safety and welfare?"

RESEARCH INTO COMPUTER-BASED BUILDING CODE SYSTEMS

Four years ago, at the School of Architecture and Environmental Design of the State University of New York at Buffalo, we asked: "When computer-based systems become available for use in the regulatory process, in what ways can we take advantage of the power of the computer to increase the scope and sophistication of building code requirements?" Our research, first in Buffalo, and subsequently at the AIA Research Corporation in Washington, D.C. has provided an answer to that question and a plan for realizing that answer in a physical form. Stated quite simply, the development of computer-based systems for building codes will provide major assistance in the development of an enforceable performance code. My evidence for this somewhat presumptious statement is as follows.

PLAN REVIEW WITH COMPUTER TECHNOLOGY

In 1965, a research group at the National Bureau of Standards, demonstrated that it was possible to develop a series of computer programs that would review plans for hospital construction against the Hill-Burton requirements, a set of standards not unlike a building code. They found that approximately 80 percent of the standards were machine readable (the 20 percent that were not, were ambiguous and required judgement on the part of the reviewer). They found that building plans were, at a high cost, communicable to the machine. And, that plans could be compared to requirements and exceptions noted in a relatively straight-forward manner.

The high cost of current machine communication is avoidable if you are willing to make changes in the nature of the regulatory process. For example, the bulk of computer-aided structural design programs incorporate code-checking routines to deal with such things as member sizing. That is, they already use national reference standards to evaluate design alternatives. Why not, as New York City has done, certify computer programs and qualified users and waive plan review in this area. We have demonstrated, in an architectural office, that it is possible to check as a fundamental part of the design process, the egress requirements of the New York City Code on a computer-based Design System. Such actions not only radically reduce the costs of plan review, they also reduce the costs of design. Moreover, they help designers to understand the intent of the code.

Those requirements that are ambiguous are troublesome to the computer -- it can only compute, it cannot judge. But they are more troublesome to society in that they are distressingly indicative of a deeper underlying difficulty in the regulatory process. Many building code requirements that seem to be crystal clear on the surface turn out to have a murkey and unsubstantiated foundation.

EVALUATING PERFORMANCE

One of the more familiar egress requirements specifies that, in schools for example, no classroom may be more than so many feet (usually between 150-200 feet) from a designated means of egress. This specification is a rule of thumb with a great deal of common sense. It is implicitly based on some sense of required performance. In this case the required performance might be a sense of the time that it takes reasonably healthy children, in a state of more than mild panic, to run, holding their breath, down a smoke-filled corridor, to a protected area of refuge or means of egress before the fire catches them. My explanation is, of course, facetious and unverifiable. But, that is the point. The degree of life safety provided by such a requirement is also not subject to verification. The distance requirement is not a helpful fact. It is a convenience to measurement gained at the expense of understanding.

The problem of developing performance requirements for life safety from fire is a problem of prediction: What will happen if a fire occurs? The answer is not obtainable, because of the human factor, through physical testing. Prediction is dependent upon understanding the complex interaction of many factors including human condition and behavior, fire development, flame spread, smoke development, structural integrity, availability and capability of fire protection devices, design configurations, fuel contribution, and a wide range of environmental conditions of both a physical and social nature. After many years of dealing with these complexly interrelated factors there is a good understanding of how a building will perform in times of fire. Based on empirical evidence the allowable time spans for egress are known. While the allowable time spans are known, it is not known whether or not the occupants will actually make it out of the building. There is no way of predicting their behavior in an emergency condition. If we were asked to accurately specify the probability that a certain building could be safely evacuated in a certain kind of fire, which is a way of subjecting the entire regulatory process to a kind of cost-effectiveness analysis, we could not do so. Consequently, existing building codes are improved following disaster, on a crisis model at high cost, after code requirements are proved to be inadequate.

The computer has been used, in a preliminary way, to simulate the complex variables of fire development and spread. Additionally, we have demonstrated how the computer might be used, again in a preliminary way, to simulate human behavior -- egress under emergency conditions. This means that the computer can be used to structure a model of proposed building designs and to flesh out that model with scientific principles derived in the laboratory of how fires develop, the fuel contribution of various building materials, the alternative levels of protection provided by alternative building techniques, and with empirical evidence from the field with respect to the reactions of human inhabitants to a wide range of fire conditions. Such a model once constructed may be economically used over and over again with the required changes in its significant variables to simulate the degree of life safety provided by a wide range of alternative building designs. Its use would result in a quantum improvement in understanding, in accuracy, in fairness and in protection over the existing set of incomplete building regulations. In the hands of the regulatory authority, the use of the computer in this way would be a powerful tool of performance evaluation.

CHANGING THE NATURE OF BUILDING REGULATION

The introduction of computer technology into building regulation does not have to mean the automation of existing practices. If used wisely computer-based systems will change the rules and tradition of building regulation. The use of performance evaluations will explicitly illustrate the potentials of building failure. This explicitness will force a more informed, more articulate, public discussion of regulatory policies. The use of performance evaluations would demand that we develop a better understanding of people, hazards and buildings. And this, in turn, would demand that we organize and manage the building regulatory process in such a way that we continually develop in a timely and orderly fashion the information we need to regulate buildings well. In short, if we choose to develop computer-based systems for building codes in a way that assists in moving the regulatory process towards a performance orientation, then along the way we will realize my initial scenario of regulatory ideals.

A MASTER PLAN FOR DEVELOPMENT

It will not be easy. The development of these computer-based systems will be difficult and time consuming -- a task fraught with constraints and difficulties too numerous to mention. We believe, however, that it is well worth the effort.

The AIA Research Corporation has defined a Master Plan for the Development of Computer-based Systems for Building Codes. This Master Plan contains short and long term strategies that will

1. encourage the development of standard data elements, languages, and algorithms to facilitate communication between designers and regulators who use computer technology;

2. encourage and direct the coordinated development of computer-based administrative and management systems that can increase regulatory efficiency and effectiveness;

3. encourage and coordinate the development of various information systems in building regulation;

4. enable designers to become certified and to use certified programs as an alternative to lengthly code review by regulatory agencies;

5. enable the computer to be used as a sophisticated tool of performance evaluation in such areas as life safety, energy conservation, environmental quality, and general building livability; and

6. enable the existing participants of both the building and the regulatory process to actively define, guide, and participate in these research and development efforts as these participants will be the users of computer-based systems for building codes.

In a very special way, it is perhaps the last of these strategies that is the most important. Since the beginning of recorded time, man has regulated the building efforts of man in the interest of man. He has always brought to this task, in a variety of ways, the best of his expertise. The only purpose of developing computer-based systems for building codes is to provide the participants of the regulatory process with a new expertise in carrying out their public mandate. And, it is only when these systems can be usefully used by these participants, when computers become an extention of their skills and capabilities, that computer technology can make a difference in regulation and, more importantly, make a difference in the provision of public health, safety and welfare.

NOTE:

The references are too detailed to cite, detailed information may be obtained by writing to:

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THE USE OF COMPUTERS AND MICROFILM IN THE CODE ENFORCEMENT PROGRAM OF THE CHICAGO DEPARTMENT OF BUILDINGS

by

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The Chicago Department of Buildings uses three principal types of computer-supported systems. 1) Several systems use automated devices to issue documents to the public. Notices of violation are prepared on minicomputers using stored violation texts. "Certificates of Inspection" for buildings and elevators are prepared by computer. 2) Computers are used extensively for information retrieval. An on-line system allows access to selected information on specific buildings via CRT display and hard copy. Monthly reports summarizing building permit activity are generated from computer files. 3) Management control reporting is an important computer-based application. Permits, complaints, and follow-up inspection requests are aged by computer; and items open beyond a control age are listed on exception reports. A system to report on inspectional performance is currently in development. About eight years ago the Department was literally forced by the volume of its paper to convert its files to microfilm. We now have approximately 10 million documents on film and are expanding at a rate of approximately 1.5 million documents per year.

Key Words: Building code; building permits; computers; enforcement; information retrieval; inspection; management control; microfilm.

COMPUTER APPLICATIONS

Judging from the papers we have heard delivered so far in this Conference and from the abstracts of other papers published in the program, we, being involved in code enforcement, have a unique point of view among the speakers here. Still, it seems appropriate for us to be here, since, after all, code enforcement is an essential part of the building regulatory process.

Today effective code enforcement requires that code enforcers by provided with the effective support of various management tools. Among the most important of these are computers and microfilm. Our plan of attack will be to use roughly the first half of our allotted time to discuss in broad terms the ways in which we use computers in code enforcement, then to move on to the use of microfilm.

Due to time constraints, the discussion of computer applications will have to be very broad indeed. It might, however, still be of use to those of you who are now involved in code enforcement, to those who might be so involved in the future, and even to those of you who, although you will never have direct code enforcement responsibility yourselves, might find yourselves in a working situation together with others who do have such responsibility.

This paper will have served its purpose if it can suggest to you potential areas of computer application that you can explore more fully when the concrete situation arises. The word "areas" is stressed because detailed approaches to be taken change with the technical state-of-the-art, which in the computer business changes very rapidly. The basic idea is that, if someday you find yourself in a position where similar computer applications are appropriate, you might contact us (at City Hall, Chicago) for more detail. It's not that we are technologically advanced (we're really not), or, that we're so conceptually slick. Rather, it's for two reasons. For one thing, computers honestly make a substantial contribution to our code enforcement effort. For another, as these things go, we've really been at it for quite a long time; and frankly you'll probably find that we've already made, and learned how to avoid most of your start-up mistakes for you.

Our computer applications can be, somewhat arbitrarily, divided into three classifications: document issuance systems, information retrieval systems, and management control systems. We have several of each type of system, so we'll have to settle for illustrating each by example.

One of our most important document issuance systems is the one we use to generate notices of violation. The key to this system is the use of a battery of minicomputers, which have access to a file containing short paragraphs describing practically any possible violation of our Code.

Each paragraph is identified by a six-digit number. When an inspector finds a violation he only needs to enter the six-digit number and the location of the violation on his inspection report. Notices of violation are prepared from this report using the minicomputers, which retrieve the descriptive paragraphs represented by the six-digit numbers from storage and automatically type the texts on the notice. This results in a significant increase in speed and accuracy, in comparison with manual preparation.

Another result of this method of preparation, a by-product of sorts, is that we are able to capture on a computer-readable medium (magnetic tape) various data which are used to feed one of our key information retrieval systems. This latter system allows us almost instantaneous access via terminals to descriptive and status information on every building which we've inspected since the system started (in 1968). The number of buildings covered by this system is still gradually increasing; at last report it stood at some 220,000.

Whenever we can, we combine our document issuance with automated data capture. We have already seen one example of this above. In a similar fashion, the system which produces building permits also captures selected data items, such as the number of new dwelling units constructed, dwelling units demolished, dollar values of various categories of work, etc. Each month we use the captured data to produce a series of reports summarizing permit activity in a variety of ways. These reports are used internally and are also distributed to various governmental agencies and financial institutions, who use them for forecasting and planning.

The third, and perhaps most important, type of computer application is that which supports management control systems. Basically, these are systems which keep management informed as to what their employees are doing, for performance evaluation, staffing decisions, and such. For example, every complaint received by the Building Department is recorded on magnetic tape by our minicomputers. Each night the tape file created during the day is input into a series of programs run on the mainframe computers of the City's centralized data processing facility. There a record of each complaint is stored on an "aging file," whose use we will see in a moment. Various computer files, mainly containing information which was captured during some form of document issuance, are accessed; and from them a report is generated giving any open complaints, already received on the addresses cited by the day's complainants, our last inspection date on each address, and our most recent action (such as a court hearing), if any. This is valuable information, since it allows us to kill those complaints whose alleged violations are already covered by some previously initiated action of the Department. Some 27% of the 120,000 complaints we receive annually are kept from resulting in a reduplicative inspection by this system.

The management control aspect of the system enters the picture when, on a weekly basis, the aforementioned aging file is passed and a report is produced listing those complaints which remain unanswered past a certain control age (currently four weeks). The report is structured along the lines of our organization chart -- open complaints are listed by first-line supervisor, supervisors are grouped under District Directors, etc. The report shows, among other things, the age of each complaint in weeks. The idea is that the older a complaint gets, the better the explanation to upper management will have to be.

This has been a general overview of the sorts of things we do with computers. At least as important to our systems redevelopment program has been the revolution in our manual filing which has come with the use of microfilm. We will now turn our attention to this.

MICROFILM

The City of Chicago's Building Department now has 240,000 buildings on its 16 MM microfilm files and these files are copies of notices, correspondence, and court orders and may consist of anywhere from one document to six or seven hundred documents. An 8" x 5" microfilm jacket holds approximately 100 documents. Less than 10 years ago all these were paper files in file folders. We had a file room 60' x 30' that was packed to capacity and a backlog of paper to be filed that would create a stack 36' in height. It took 16 months and $250,000 to convert that mass of paper to microfilm but it was worth it. In addition we have over 900,000 permits on 35 MM film. Since 1956 all blue prints or plans have been filmed and are available for reference or copies. I would like to compare the old paper system and the new microfilm system. The first and most obvious comparison is SPACE. The paper files took up twenty times as much space as the microfilm files. However when you allow for the equipment for filming and viewing your records, a 50% savings in space would be more accurate.

The second advantage is SECURITY. If a file jacket containing one hundred documents is taken from your central file by an inspector or by office personnel and is later returned, how do you know that all 100 documents originally contained in the file are still there?

MISFILING is another situation that causes office procedures to go awry. Misfiling of a file folder and all of its contents can cause hours of frustrating searching. This rarely happens in a microfilm system for two reasons:

1. The jackets are color coded based on the third letter of the street name. There are ten possible colors.
2. The jackets are also notched based on the first number of a four digit number. If there are less than four digits we complete the number by adding zeros. There are ten notch positions across the top of the jacket.

Between the color coding and the notching, it is difficult to grossly misfile a microfilm jacket. You might be off several addresses but if your first digit is a higher or lower number the mistake will be obvious.

Now that I have described the advantages, what are the costs? Let us take a hypothetical figure of 100,000 files each having ten documents for a total of one million documents. You would need the following equipment:

One Rotary Camera	$5,000.00
One Jacket Loader	1,600.00
One Lektriever or Cardveyor	5,000.00 to $10,000.00
One Diazo Processor	4,300.00

Either by carelessness or design several documents may have been removed and you would be unaware of the fact. Some of the documents may have been altered and you would have no way of knowing it. This cannot happen in a microfilm system since the original microfiche is NEVER given out. A diazo, a duplicate copy is created in approximately thirty seconds at a cost of 7 cents. This copy may be viewed or used to make paper copies. The original is always retained in the microfilm section.

No matter what happens to the diazo the integrity of your files is insured. A third consideration is if you have a hundred documents in a file folder in date sequence and someone finds the particular document that they need and then merely stuffs it back in the file folder, not in sequence, it is very possible that even though you have the document in the proper folder, someone looking for it will probably not find it.

This cannot happen in a microfilm system since the documents are inserted in date sequence and once in the jacket they are never moved.

Another problem is that when you need a paper file, someone has already signed out for it and you have to trace it down or wait for it to be returned. This does not happen in a microfilm system since a second request merely means that you create another diazo.

The labor involved in the transition would be approximately 832 hours of filming at 1,200 documents per hour. Three hundred and thirty three (333) hours of loading and inserting at 300 files or 3,000 documents per hour. 840 hours of labelling at a rate of 120 jackets per hour. 100,000 microfilm jackets would cost $10,000.00. In addition to this you would have to purge your paper file to eliminate duplicates, pull staples and insert target sheets. This cost would vary with the condition of your files. You would need 360 rolls of film at $6.00 per roll including developing. This comes to a total of $33,060, plus 6,000 man hours in preparation and filming. The amount of time involved in the transition depends on how active your files are since obviously you have to service your ongoing needs during the transition period. The result of this would be as follows: you will probably not reduce the number of personnel you now have but this is dependent on the number of updates and inquiries per day. We were able to train the personnel we had in the skills necessary for our microfilm system. We did not reduce the number of personnel involved but we have substantially improved our performance in maintaining accurate and readily accessable files.

Our next step is to utilize COM, Computer Originated Microfilm. We are experimenting with this system in which the computer reports are flashed on a video screen and then microfilmed and a hard or paper copy is never created.

These copies are reduced at a ratio of 42 to 1, and you have 208 images on a 4" x 6" card. You may make copies from these images or you can view them on a screen. If you are now receiving computer reports you know how rapidly stacks of computer printouts can accumulate in your office, and a 10" card file on your desk can store 1,000, 4" x 6" microfilm jackets which can contain 208,000 pages of computer printouts which should be adequate for any reference papers you may have to access. COM is definitely the coming thing for anyone who is receiving computer reports, and microfilm is the present method for anyone who has a large number of records to keep.

IMPROVED COMMUNICATIONS BETWEEN CODE OFFICIALS AND BUILDING DESIGN AND CONSTRUCTION GROUPS THROUGH EDUCATION

by

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This paper stresses the necessity of developing educational programs in order to provide more effective communication between code enforcement officials and the various branches of the building construction field - architects, engineers and building contractors. The major premise is that code enforcement officials must be elevated to a professional status to communicate more effectively with the building construction groups. To accomplish this, educational background criteria and professional requirements must be established through educational and certification programs. These programs can be offered through two channels: continuing education courses and formal degree programs. The Pennsylvania State University's continuing education program is presented as a model of how educational programs can be offered effectively to upgrade the status of building code officials. Included is a review of Penn State's certificate programs wherein code officials, through evening courses and seminars, are provided the technical background needed to increase their professional competence. Also covered are examples of the development of special programs utilizing the information obtained through the above educational programs, specifically, the Energy Conservation Seminar which provides terminology and principles of heat gain and loss. The program includes a workshop session on the ASHRAE 90-75 requirements. This enables code enforcement officials to interpret and apply ASHRAE 90-75.

Key Words: Building construction groups; certification; code enforcement officials; communications; criteria; education programs; professional competence.

BACKGROUND

The construction process is a team effort. A successful team effort is the result of positive communication between all members of the team. A key member of this team is the code official who maintains contact with the project starting with design and following through the construction. Unfortunately, most design professionals and contractors do not consider them as part of the design/construction team. This attitude stems in part from the fact the majority of code officials currently reviewing the design/construction process do not have formal training or education in the field and few are required to complete certification or licensing programs. In short, political appointees who may hinder rather than aid the construction process. Another barrier to positive communication is an apparent lack of knowledge of building systems and materials and the reasoning behind certain code requirements by the code official requesting compliance because "the code says so."

With the advent of performance oriented codes, new standards for energy conservation design and possible future requirements for noise control in buildings, team communication takes on an even more important role in the completion of construction projects. The implementation of these requirements eliminates the construction industry as a possible source of code personnel as they require a more theoretical knowledge and background of construction systems and materials rather than the applied one established by most journeymen training programs.

Because of these developments and with the proper training and education, code personnel will become the key link in the communication chain of construction projects. Contractors will need to rely on their interpretation and evaluation of the new requirements. With the proper theoretical knowledge and vocabulary, they will be able to communicate with the design professionals in the interpretation and evaluation of designs in accordance with the new requirements. They will then be able to assist contractors in the application of these requirements in the construction phase.

EDUCATION AND TRAINING

In order for the code enforcement officer to be able to contribute to the construction process and attain his position on the construction team, valid educational and certification programs must be established. The educational programs, once developed, can be offered through two channels: continuing education and formal degree programs. The most pressing need at this moment is the education of existing code enforcement officers and their certification. Once this process establishes a "profession," then formal programs can be developed to educate individuals for the code enforcement field. The main focus of this paper is the development and offering of continuing education programs for existing code enforcement personnel. The Pennsylvania State University's program is used as a model to indicate how education can effectively upgrade the status of code enforcement officers and improve communication between the various design/construction groups.

In 1971, the University's Department of Architectural Engineering formed an advisory committee comprised of design professionals, code enforcement officials and representatives of the state and federal government to provide information as to the educational and training needs of code enforcement officers. Utilizing this information, the Department projected a stepped concept of basic and advance courses and programs that would meet the needs. The Department then applied for a Title I High Education Act Grant from the Department of Health Education and Welfare to develop and offer the first level of programs.

Certificate Program I was developed to provide information on certain fundamental areas of code enforcement. The program is intended to present existing code enforcement officers with information which they can immediately apply to their day-to-day activity and to build confidence in their ability to continue in more advanced formal training and educational programs. Hopefully, this will overcome the tendency of individuals who have been away from an educational situation for long periods of time to be hesitant about getting involved in such programs.

CERTIFICATE PROGRAM I

Evening Courses

Plan Reading
Building Construction and Technology
Structural Systems Evaluation
Fire Protection
Building & Housing Code Administration

Seminars

Seminar A - Basic Communication, Public Relations & Professionalism
Seminar B - Basic Inspection Principles, Code Principles and Legal Awareness Considerations

After sucessfully completing the first program, the Department applied for additional grants to develop two more programs.

Certificate Program II was created to extend and apply the knowledge gained in Program I to interpreting building codes and to provide code enforcement officers with a fundamental background in specialty areas of code enforcement. This enables them to provide improved service to their communities by increasing their liaison capabilities with electrical, plumbing and fire code inspectors.

CERTIFICATE PROGRAM II

Evening Courses

Plan Reading and Code Interpretation

Plumbing Code Inspection

Electrical Code Inspection

Fire Code Inspection

Seminar

Advanced Plan Reading and Code Interpretation

The last certificate program, Certificate Program III, was developed to assist code enforcement personnel in understanding and recognizing new emerging national problems - High-Rise Fire and Energy Conservation. Each topic is the subject of a four-day conference. The High-Rise program presents and discusses requirements for compartmentation, heat and smoke detectors, alarm systems, smoke control, suppression systems and elevators. The Energy Conservation program acquaints code personnel with basic heat loss and heat gain principles, definitions, insulation types and placement, ventilation principles, moisture problems and evaluating building designs in conjunction with the ASHRAE 90-75 Standard.

ENERGY CONSERVATION WORKSHOP

The Energy Conservation Workshop will be examined to show how a specific educational program can improve communication between construction and design professionals. This is an example of a new element in code enforcement where previous experience in the construction industry is of little value in understanding the terminology or requirements involved.

Design professionals are well versed in the heat gain and heat loss terminology and process and should be able to interpret and meet new energy design standards. To be able to intelligently review and comment accordingly on designs/plans submitted for approval, the code enforcement officer also requires a knowledge of the design terminology and process. This is consistant with the Penn State philosophy of providing a background of information on definitions, systems, material manufacture, assembly and basic principles of design which will enable code enforcement officers to better evaluate building designs through code requirements. It is felt that before individuals can enforce the new energy provisions, they should understand certain definitions and principles of heat loss and heat gain. In addition, this background will enable code personnel to provide assistance to contractors in meeting and interpreting the energy design/construction requirements.

The overall workshop content is as follows:

ENERGY CONSERVATION IN BUILDINGS

- Moisture/Condensation
- Comfort Conditions
- Relative Humidity
- Insulation Requirements
- Degree Day Concept
- Principles of Heat Loss
- Guidelines for Heat Loss Analysis
- Principles of Heat Gain
- Guidelines for Heat Gain Analysis
- Heat Loss Workshop
- Heat Gain Workshop
- ASHRAE 90-75 Standard
- ASHRAE 90-75 Workshop

The following is an example of specific program content:

- Heat Transfer
  - Conduction
  - Convection
  - Radiation
- R-Factor vs. U-Value
- Building Materials-Heat Flow Coefficients
- Heat Loss Formulas
- Climate Effect on Heat Gain
- Heat Gain Formulas

The program participants also completed heat gain and heat loss calculations for a residence type structure which enabled them to apply and more fully understand the principles presented. Finally, they evaluated the design of a five-story apartment building to determine whether or not it met Section Four of the ASHRAE 90-75 Standard as it applies to building envelopes. The individuals completing this program not only gained the necessary background to enable them to discuss designs intelligently with architects and engineers, but through the workshop sessions they also gained confidence in their own ability to understand, interpret and enforce the new energy standards.

To determine whether or not the programs helped improve code enforcement in Pennsylvania, questionnaires were forwarded to the participant's employers. The following is a sample of the questions and responses.

From a standpoint of your community, has the program been beneficial? Why?

> "Yes. The nature of the courses has given him a greater professional outlook. The work in the seminars and the contacts and viewpoints of fellow-workers has enhanced his vision and hence benefits the Community."
>
> "We feel our inspector is one of the best inspectors in the area, and it would be difficult for his quality to improve. However, we feel attendance in classes such as this, always result in improvement, as it permits the inspector to reacquaint himself with the basics of the construction industry as well as introducing him to new building techniques and materials."
>
> "Steve's increased ability through better understanding has made him more efficient, thereby providing a better service to property owners with whom he works."
>
> "The program has been beneficial. Anytime an individual can be further educated in his field, the community has to benefit. Until recently, persons in code enforcement had very little opportunity to obtain any kind of education outside of their office."

Should all code enforcement personel be required to complete similar educational programs as a condition of employment? Why?

> "Currently many building officials are not of professional caliber; so, some sort of training is necessary to improve the field. However, we must also be wary of unnecessary credentialism. Programs such as PSU's may provide an avenue for the prospective building official to gain the requisite education needed to perform his duties."
>
> "All code enforcement personnel should have the advantage to acquire the knowledge provided by the certificate programs. Such knowledge would provide consistency and

uniformity in the interpretation of codes requirements
rather than individual interpretations based on
insufficient knowledge."

"Regardless of the expenses of the code official there
is need for update. Due to new materials, improved
methods of construction, new design methods as well as
code changes, make it mandatory for refresher courses."

"I believe it should be required in order to provide
the Community with trained personnel."

Has there been an improvement in working relations with the general public and dealings with architects, engineers and contractors?

"Yes. Greater rapport with builders because of an
increased understanding of the intricacy of the Code."

"Through a better understanding of the codes requirements,
he speaks more authoritatively on the subject, thereby
creating an improvement in working relations with the public
and contractors."

"There has been a closer working relation with the inspector."

REGULATION AND THE HOUSING INDUSTRY

by

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The National Association of Home Builders (NAHB) has become increasingly aware of the disproportionate increase in the cost of owning a new home, in relationship to the general increase in consumer prices. These increases are rapidly raising the cost of housing out of the reach of an ever increasing percentage of the population. What are the reasons for this inordinate increase in housing costs? NAHB has embarked on a major national study effort to answer this question. The study is intended to pinpoint the causes of this cost escalation, and in particular, determine the impact of increasing state, local, and Federal regulations on spiralling housing costs. It is a growing feeling among consumers and homebuilders alike, that a significant portion of the increased regulations associated with housing construction, do not provide benefits in relation to the overall costs incurred by the builder, which of course are ultimately passed on to the home buyer.

Key Words: Builder-developer; cost analysis; cost benefits; construction; consumers; housing; regulation.

The National Association of Home Builders (NAHB) is a trade association with over 79,000 members in 603 state and local associations across the United States. Its membership represents approximately 85 percent of the housing starts in this country, and consists of all segments of the residential construction industry. Additionally, we feel strongly that we represent, in many ways, the interests of the general public in securing a decent home for every American.

One of the most nagging problems facing the builder-developer today is the rapidly escalating price of housing. In 1965 the price of the median home was $20,000. By 1975 this had climbed to $39,000. More importantly, however, increases in taxes, interest rates, insurance and utilities have combined with the increased sales price to more than offset rising incomes, and have resulted in a decrease in the percentage of families eligible to buy. Based upon the latest figures available, the median sales price has risen to $43,000 and the percentage of families eligible to buy has dropped to 16 percent.

As supplier of housing to a market whose ability to purchase is being severely eroded, NAHB has attempted to analyze the factors contributing to the dramatic rises in housing costs. One of these, obviously, has been inflation. But, further investigation reveals that there are additional costs which are not inflationary in nature. Of these, costs directly and indirectly attributable to government regulation appeared to be primary candidates for the role of villian. Preliminary estimates indicated that as much as 10 to 15 percent of the purchase price of a new home is attributable to regulation.

Because of the severe impact of cost increases of this magnitude, at its Spring 1976 Board of Directors meeting, NAHB's President, John Hart, instructed the NAHB Special Committee on Housing Costs to undertake a careful analysis of the "costs of regulation" in the housing industry. As a result of this charge, the NAHB staff embarked on several projects.

First among these was an attempt to collect and review all current literature and information relating to the cost of regulation on residential construction. That material which was thought to be most beneficial and informative was edited and reprinted in a 163-page information kit entitled, "Fighting Excessive Government Regulations." The kit consists of material in three main categories: Economic Data; News Articles; and Studies and Reports.

Upon conclusion of this activity it was determined that a pilot study would be an ideal method for quantifying regulation costs while simultaneously uncovering those areas which required the commitment of additional resources. The pilot study was to have had three main purposes:

1) To determine the feasibility of actually assessing the specific cost of

individual regulations or requirements on a specific case basis.

2) To determine the feasibility of developing a uniform methodology for implementing a nationwide data gathering effort.

3) To gain first hand field study exposure for developing alternative courses of action for a national study.

This pilot study was conducted in Anne Arundel County, Maryland, and proved to be a sometimes rewarding and frequently frustrating experience. Anne Arundel County was selected for its proximity to our Washington office and characteristics typical of a rapidly developing, moderately regulated suburban jurisdiction.

Initially, an attempt was made to base the cost analysis on a comprehensive checklist or breakdown of various cost items contributing to the total purchase price of the house. The checklist was based to a large extent on NAHB's "Accounting System for All Builders," a standardized financial accounting and reporting system for the home building industry which itemizes in detail the cost factors for land development, construction, financing, marketing, etc.

Data was to be compiled for similar residential development projects completed in 1970 and 1975. By comparing this data, cost changes for each item could be determined. The regulation effecting the cost item, if any, and its contribution to the cost increase would be largely determined through interviews with builders, developers, and local government agencies.

It was decided, however, that adherence to the above methodology for the pilot study was not practical, in view of the limited time and resources available. It was, therefore, necessary to abandon the use of a pre-determined checklist and the concept of comparing projects from 1970 to 1975.

The use of a pre-determined or standardized checklist presents a problem since most builders use an individualized accounting system that meets their own specialized needs. Translating these costs into a detailed standardized listing would be a time consuming task. Instead, a generalized list of costs based on broad classifications of expenses was used for the pilot study. By breaking costs into general areas (fees, electrical, foundations, etc.), the data sorting was a less cumbersome task.

The "then and now" (1970 to 1975) approach was also deemed impractical for this study. The problems of obtaining data for a project recently completed is extensive. Finding data 5 to 10 years old is even more difficult. Other studies such as that conducted by the

Home Builder's Association of Colorado, indicate this is a major difficulty. Also, if one is to only determine the costs incurred due to additional or increased regulations, it would not identify costs attributable to excessive regulations which may have been in existence during the earlier project.

For example, if there was a requirement in the earlier project for a 32' side street, and the same requirement is still imposed on the current project under study, no cost due to an "increased" regulation would be evident. If, on the other hand, it is established that 28' side street is suitable for the application, it would be reasonable to identify the additional cost due to an excessive requirement. It was, therefore, decided that comparisons would be made against what was assessed to be a reasonable standard or requirement.

The determination of the reasonable standards and requirements just mentioned is in itself a major issue and provides the focal point of arguments as to whether or not government requirements are "over-regulation" or simply "protection of the public welfare." These standards and requirements must be debated individually and utilize separate and distinctive techniques. In the case of a fee, for example, the law is quite clear that the fee is excessive if it is utilized to provide revenue above and beyond the costs associated with the services which the fee provides. Unfortunately, not all attempts at determining appropriate levels of regulation are so easily resolved.

Based upon the pilot study conducted the following conclusions have been reached:

1) The impact of government regulations on housing costs is a complex and diverse issue which is actually composed of a series of more specific and specialized problem areas. There seems to be no single research project which can evaluate all the factors associated with this issue and provide an attainable and immediate solution. Each problem area requires separate investigation and its own set of solutions.

2) Without a uniform standard with which to compare the requirements and procedures of jurisdictions around the country, it will be extremely difficult to quantify costs resulting from regulation on a national basis.

3) Although staff was able to compile a list of most of the cost items that make up the sales prices of the homes in our study, a portion of the data is either incomplete or inconsistent and needs to be supplemented before firm conclusions can be drawn regarding the costs of regulation in Anne Arundel County, Maryland.

4) There is a cost associated with every lot in Anne Arundel County, due to excessive regulations and no-growth policies which is a result of:

   a) a need for greater return on investment because of the greater risk of the builder-developer capital.

   b) the law of supply and demand and the diminishing supply of developable land.

While it is impossible to quantify these two variables it was substantiated in the study that lots which were among the smallest and lowest priced in the County and which sold for $8,000 in 1974 are currently selling for $11,200.

In an attempt to begin dealing with the cost of regulation problem, a 14-point program has been developed. Work is beginning on the first seven of these which I would like to outline for you. They are as follows:

1) Development of broad based support among trade and professional groups for a program aimed at reducing the cost of regulation. This goal includes development of a list of organizations to be contacted, with strong emphasis on those groups closely related to local government and regulatory agencies (i.e., Conference of Mayors, American Society of Planning Officials, Public Works Associates, etc.) and preparation of a basic policy position on regulation for presentation to these organizations.

2) Conduct a fee survey designed to provide hard data for several specific types of fees. The study must be carefully conducted to insure meaningful and useable data, and should concentrate on selected, well defined fees. Additionally, the data base should be sufficiently large to maintain statistical validity while categorizing the data according to population of the jurisdictions surveyed. Orientation of data collection should be towards comparison of fees between municipalities with similar characteristics.

3) Development of a "Ten Most Wanted List" of overly restrictive code items. The list would incorporate the ten code items enforced nationally, which are costing the consumer the greatest amount of money. This list would be published periodically and would provide a focal point for a national campaign to eliminate the items from the model building, plumbing, and electrical codes, and thereby reduce the cost of housing.

4) Conduct a cost survey on a "benchwork" or "index" house, of approximately 1200 square feet in size. The NAHB survey would be conducted in a number of selected communities around the country, and would include data on financing, taxes, utilities, and other factors contributing to monthly costs of homeownership. The survey would also incorporate economic data from each area on spendable income to illustrate the impact on the public's ability to purchase housing. Use of the Boeckh Cost Indexes, which are published bimonthly and offer a good barometer of construction changes in over 200 cities, could also be considered for use in this survey.

5) Conduct a moderate scale survey to determine customer willingness to spend money for regulated items. This study offers the possibility of providing powerful ammunition for the argument that the public does not want many of the items prescribed by regulations. Such things as street width, sidewalks, ground fault current interruptors, etc., would be ideal subjects for this survey.

6) Prepare for a national conference on the cost of regulation, to be conducted in the spring of 1977. This symposium would serve as a public forum for a campaign against over-regulation. It is envisioned that well known national figures would attent the symposium, thereby assuring large scale press coverage. If possible, this conference will be conducted jointly with Rutgers University and other groups engaged in developing hard data related to the cost of regulation.

7) Develop a packaged kit for local and state Home Builders Associations to enable them to conduct their own regulation studies. The kit would provide a simple format, with detailed instructions on:
   a) typical areas of regulation to be investigated
   b) collection of data
   c) sources of data
   d) resources required
   e) management of the project

Additionally, the kit would provide methodologies for comparison of actual local costs to base line costs, so that the true "cost of regulation" could be determined.

The debate as to the level of regulation appropriate for any industry will always be spirited. Yet there is much more than a debate involved in the over-regulation of the housing industry. What is involved is the question of whether or not millions of Americans will be kept from purchasing decent homes because of the over-zealous and often arbitrary actions of government officials. Elimination of needless regulations is an absolute necessity in any program designed to reduce the cost of housing in America.

ECONOMIC IMPACTS OF BUILDING CODES

by

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This paper presents an impact evaluation approach for building officials faced with making building code decisions. Types of building code impacts are defined and categorized. A standardized method to measure and evaluate the potential benefit and cost impacts of a specific building code provision is described. The approach is intended to be a relatively simple, easy to apply system which uses available, or easily obtainable information. Benefit and cost impacts of code provisions intended to reduce the risk of death from a building hazard are examined. The paper concludes with case study of the 1975 National Electric Code requirement for the use of Ground Fault Circuit Interrupters (GFCI) in residences to illustrate the approach.

Key Words: Accidents; Benefit-cost analysis; Building codes; Building economics; Building regulations; Economic impact; Electric shock; Ground Fault Circuit Interrupters; National electric code; Safety regulations; standards.

I. INTRODUCTION

There is a wide variety of opinion concerning the impact of building codes upon building safety, the cost of construction, and upon efficiency in the construction industry. Critics allege that building codes promote inefficiency in the construction industry and increase construction costs by limiting choice in design, materials, and construction methods; and by impeding innovative building technology.[1] In contrast, other experts, while acknowledging that such impacts exist, place a higher priority on building safety, and believe that the impact of building codes on efficiency and costs is relatively small.

Differing opinions over the economic impact of building codes exist for several reasons. Perhaps the most important reason is that building codes are only one of a set of interrelated factors which influence efficiency and productivity in construction. Other important factors include weather, cyclical and seasonal fluctuation of demand, sensitivity to monetary policy, regional shifts in demand and in composition of output, supply influences in the construction materials industries, the smallness of firms in the industry, the separation of design from production, union restrictions, jurisdictional disputes among contractors or among unions, and regulations other than building codes such as zoning, HUD minimum property standards, or the Hill-Burton Act requirements. This complexity, combined with relatively poor construction statistics, makes it difficult to separately identify and measure building code impacts.

A second reason for conflicting opinions concerning the impact of building codes is that different members of the building community have different perspectives, and they are concerned about different types of impacts. A third, closely related reason is the lack of a consistent language or set of specific definitions concerning building codes and their impacts.

The research reported here is one part of a larger research project at the National Bureau of Standards whose purpose is to analyze the economic impact of building codes.[2] To give a general overview and background of what is meant by building code impacts, Section II summarizes the framework developed in that project to define and classify economic impacts. Three general categories are suggested; (1) benefit and cost impacts associated with specific building code provisions, (2) building code impacts which affect income distribution, and (3) aggregate impacts of the building code system upon the construction industry as a whole.

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[1]For a recent indictment of building codes see Charles G. Field, and Steven R. Rivkin, The Building Code Burden, Lexington Books, Lexington, Mass., 1975.

[2]John McConnaughey, An Economic Analysis of Building Code Impacts, forthcoming, National Bureau of Standards.

This paper primarily concerns the first category of impact. A standardized method to measure and evaluate the potential benefit and cost impacts of specific code provisions is developed in Section III. The discussion is made more specific by examining the benefit and cost impacts of building code provisions which are intended to reduce the risk of death from a building hazard. The objective of this research is to provide a useful tool for building officials faced with making building code decisions. Ideally benefit-cost, life-cycle cost or cost effectiveness analyses can be used to evaluate alternative building code choices to identify and rank the most economically efficient code provisions. In practice, it would be difficult if not impossible for code making organizations to require or undertake such a complete type of analysis for every proposed building code change.

The approach developed in this paper is intended to be a simpler, more quickly and easily applied system which can provide information about the potential magnitude of benefits and costs, and their distribution. It uses available or relatively easily obtainable data. The approach can act as an initial screening device to identify and rank those code provisions which will have the greatest net beneficial effect on building safety and construction cost. Often sufficient information may be made available so that more complex or costly analysis is not needed.

To illustrate the use of this approach the paper concludes with an illustrative case study of a code provision intended to protect against electric shock death--the 1975 National Electric Code requirement for the use of Ground Fault Circuit Interrupters (GFCI) in residences.

II. DEFINITIONS AND CATEGORIES OF ECONOMIC IMPACT

Defining and classifying what we mean by building codes and their impact is necessary before we can examine those impacts. We define a building code as a particular state or local government statute or ordinance which regulates the construction of buildings to protect public health, safety, and general welfare. We include in this definition mechanical codes which regulate the installation of mechanical systems in buildings. Each building code contains a set of building code provisions or requirements which regulate specific building practices.

The term "building code system" refers to the institutional system which has evolved in the United States to regulate building construction through building codes. In addition to building codes, major elements of the building code system are model codes, voluntary standards which are referenced in codes, and the public and private testing, research, and coordinating organizations which are specifically concerned with building codes and standards such as the National Conference of States on Building Codes and Standards (NCSBCS), Underwriters' Laboratories (UL), or the National Bureau of Standards (NBS).

The building code system is a major subset of the "building regulatory system." The building regulatory system refers to the institutional system which has evolved in the United States to influence or regulate building construction. Major elements of this system include other state or local statutes and ordinances such as health codes, architectural codes, housing codes, environmental regulations, and zoning or subdivision regulations. In addition to state and local regulations, other major elements are federal government actions which affect construction. These include; (1) Federal regulations issued by agencies, such as the Mobile Home Standards issued by the Department of Housing and Urban Development (HUD), (2) Federal Conditions of Participation such as the HUD Minimum Property Standards (MPS) or the Hill-Burton Act requirements, and (3) Federal procurement or construction criteria by agencies such as the General Service Administration (GSA) or the Department of Defense (DOD).[3]

There is no established procedure used in the building code literature for classifying the economic impacts of building codes. Impacts are examined from many perspectives. Building contractors may be most concerned about the inconvenience and higher costs associated with building code provisions. Building Code Officials may stress technical and safety characteristics associated with a code provision. Labor unions or building material producers appear most concerned with the impact of a particular code provision upon them--that is upon employment or sales. Other members of the building community (architects, industrialized builders, sub-contractors, etc.) have somewhat different concerns. Impacts may be local, regional or national. Some impacts are direct and relatively easy to assess while other building code impacts are indirect, hidden, or closely interrelated with other building regulations or factors affecting construction. We can illustrate some of the different perspectives and ways of viewing the magnitude of building code impacts in Figure 1.

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[3]I wish to thank Robert Kapsch of the National Bureau of Standards Office of Building Standards and Codes Services for suggesting this break-down of Federal actions which affect construction.

FIGURE 1

IMPACT MAGNITUDE MATRIX

	One Unit	All Units
Single Code Provision	A	C
All Code Provisions	B	D

Block A concerns the impact of a single code provision upon one building or residential unit while block D represents the other extreme which is concerned with the impact of all building code provisions upon a group of buildings or residential units aggregated to a regional or national level. Blocks B and C are intermediate positions. Blocks A and B more closely correspond to a local impact while Block C and D more closely correspond to social or national impacts. Direct impacts are more prominent in Blocks A and B while indirect impacts are of greater concern in Blocks C and D.

Different members of the building community may be concerned with impacts in different blocks of the matrix. One code provision, for example the requirement for Ground Fault Circuit Interrupters in new housing, may be primarily viewed by builders as an increase in direct construction cost (Block A), by electrical manufacturers as a new or expanded national market (Block C), and by a voluntary standards or model code committees as a social benefit, i.e. total number of lives saved from electric shock (Block C). The above discussion gives some idea of the complexity involved in defining and classifying the different types of impacts. However, it also points out some of the more important factors which should be considered in any classification scheme.

Benefit-Cost Impacts

This category refers to the positive and negative impacts upon society (the nation) as a whole which result from requiring a particular code provision (Block C in Figure 1). We define benefits as positive impacts and costs as negative impacts which may be measured in monetary or non-monetary terms.

The general benefits of a code provision can be further subdivided into (1) code provisions which reduce the risk of death, injury, illness, or property damage, from some hazard, (2) code provisions which reduce building costs by allowing improved building technology, and (3) codes which meet some other welfare objective such as energy conservation, improved building facilities for the handicapped, historic restoration, or improved safety conditions for fire-fighters.

Both the cost and benefit impacts of a building code provision should most appropriately be examined from a life-cycle context. The potential benefits which accrue to building owners and occupants generally last for many years, often for the life of the building. The potential costs of a code provision are separated into initial (or first) construction costs and recurring annual costs. Initial costs are direct labor, materials, equipment, overhead and profit costs. Recurring costs are future maintenance, repair, and operating costs. A code provision which has the highest first cost may have the lowest life-cycle cost among several alternatives because it requires more durable or reliable components, or reduces future maintenance, repair, or operating costs.

Income Distribution Impacts

This category refers to the distribution of the benefit and cost impacts which result from a particular code provision. Particular code provision changes involve income transfers. That is, one group's welfare may be increased at the expense of another group. The benefit-cost category refers to impacts upon the nation as a whole. The income distribution category refers to impacts upon particular groups smaller than the nation as a whole.

An example may help explain the difference between these two categories of impacts. Consider a code provision which allows plastic pipe for sewage. This would be classified as that type of benefit-cost impact, where the benefit is the difference in cost between installing plastic pipe and the existing type of pipe used for sewage--in this case cast iron pipe. If such cost savings are realized, plastic pipe producers (and their suppliers) may gain a new market and cast iron pipe producers (and their suppliers) may lose a market. Since plastic pipe is generally considered to be easier and faster to install, installation workers may lose employment. Such impacts may have special regional importance (on employment, for example) if cast iron pipe producers are major employers in small communities.

Persons familiar with the building code system recognize the importance which income distribution impacts have upon various groups in the building community. Explicitly identifying such impacts can provide useful information to building officials faced with making code decisions. The method outlined in Section III for identifying and measuring benefit-cost impacts can also help identify and measure some of the income distribution impacts.

Aggregate Impacts of the Building Code System

The first two categories treat the impact of a single code provision. This category concerns the aggregate impact of the building code system. Examples of such impacts are (1) excessive administrative, enforcement, testing, or marketing costs due to the non-uniformity of codes, (2) impacts which affect the ability of the construction industry to achieve economics of scale in the production of buildings, (3) technological change impacts which affect the diffusion of new building products and innovations, and (4) code provisions which duplicate or contradict other building regulations. Although difficult to measure, such impacts may be substantial, especially when one is concerned about increases in the efficiency of the construction sector over time.

III. IDENTIFICATION AND MEASUREMENT OF BENEFIT-COST IMPACTS

This section outlines the general approach or framework used to identify and measure the benefit-cost impacts associated with code provisions intended to reduce the risk of loss from a building hazard. The economic resources to be used for safety are scarce. Accordingly, up to a certain point to achieve some higher level of protection normally involves some reasonable increase in cost. Much of the controversy over specific code provisions centers upon the definition of "reasonable." A minimum criterion for "reasonableness" would require that the benefits from a specific code provision exceed the costs. Economic theory suggests that under certain conditions the optimal (most reasonable) level of a code provision would be where the net benefits (total benefits-total costs) are maximized (i.e., where marginal benefits = marginal costs).[4] A more general criterion for "reasonableness" requires comparison of different code alternatives. We will show later how analysis of the benefit-cost impacts can provide a decision rule to rank code provisions by identifying provisions which provide the largest benefit per dollar spent. An even broader criteria for "reasonableness" would be to compare the building code provision rankings with similar rankings of other building safety policy alternatives such as fabric flammability standards, increased expenditures for fire protection services, earthquake prediction research, or regulations concerning insurance or product liability.

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[4] These criteria of reasonableness are based upon cost-benefit analysis. For an example of a cost-benefit model applied to a building hazard see Robert E. Chapman and Peter F. Colwell, Economics of Protection Against Progressive Collapse, National Bureau of Standards Interagency Report 74-542, September 1974.

It is not possible to actually measure all the benefits and costs associated with a specific building code provision. Part of this measurement problem is inherent in the very nature of construction, since buildings serving the same function are unique in many characteristics such as design, size, location, or materials used. Another part of this measurement problem is due to imprecise or incomplete code language which allows substantial latitude for interpretation and enforcement in different code jurisdictions. A third reason for this measurement problem is that statistics on building safety are imprecise, not available, or not in a form which can be easily used. Another reason is that some benefit and cost impacts are intangible; that is, although they can be identified, there is no known or accepted method available to measure their magnitude. In addition, the degree of accuracy and precision of measurement also depends upon the degree of complexity associated with each particular code provision.

To acknowledge that not all benefit and cost impacts are easily measured does not imply that better decisions are not possible using the limited information available. Even when certain vital data are not available, it may be possible to evaluate the influence of benefits or costs which are not easily measured upon the ranking of code provisions by using sensitivity analysis. An example of the use of sensitivity analysis will be given in the case study section.

To measure costs, a common base for evaluation is required. To do this a typical design incorporating the code provision is needed. Often a code provision applies to more than one building type or allows more than one method to meet the requirement so that more than one typical design should be used. For a performance based code, typical designs could be based upon a manual of accepted practice. To completely identify and define the code provision, it is also necessary to define an alternative in the same manner. Normally this is a "before and after" or a "with and without" comparison, where the alternative considered is the existing building practice.

The next step is to estimate the initial installation costs from the typical design or designs. Several methods can be used such as industry cost estimating guides, specific estimates from professional cost estimators, or actual cost information gathered from construction sites. Whichever cost estimating method is used, it is important to clearly explain the steps taken to arrive at a final dollar figure. This means that the types of materials, labor, and equipment should be specified in terms of quantities. The material prices, wage rates, equipment rental fees, and overhead and profit charges used to arrive at the dollar estimate should be specifically identified whenever possible.

Life-cycle cost information on durability, maintainability, reliability, repair/replacement costs, and operating costs are often more difficult to obtain. Some of the technical information is available from laboratory testing conducted by manufacturers, independent testing laboratories, or other building research organizations such as the

National Bureau of Standards. Performance in the building may also depend upon proper installation so that field test results on effectiveness or failure in use should also be examined if available. This information can be used to estimate the useful life over which the code provision provides its benefits, the reliability of the provision, and the annual maintenance, repair, or operating costs. It should be recognized that professional judgment is also important, and there will often be a good deal of uncertainty associated with such estimates. However, the importance of each estimate upon the ranking of code provisions can also be examined using sensitivity analysis. If the primary benefit of the code provision is a reduction in costs, then estimating the first cost and life-cycle cost characteristics for the code provision and its alternative can provide the information needed to perform the necessary analysis.

Perhaps the most common benefit intended is a reduction in the risk of death, injury, illness, or property damage. These benefits can be assessed using decision analysis framework, which is a method of analyzing decision choices which must be made with incomplete information.[5] Figure 2 is a decision tree which illustrates all of the possible sets of outcomes from a decision to enact or not enact a code provision. Whether we decide to require or not require a code provision, there are only two outcomes--either a hazardous event occurs or it does not occur. If a hazardous event occurs, there can be one or more types of loss outcome. For clarity, we have only shown the potential loss outcome for accidents in Figure 2. A more complete decision tree would contain a set of potential loss outcomes for each hazard. Since building codes normally apply to new construction or major renovation, the lower "no code" branch of the decision tree largely represents the set of loss outcomes which occur in the existing stock of buildings. The upper "code" branch of the decision tree represents the set of potential loss outcomes which occur in new buildings subject to the code. The potential benefit in the upper branch which we would like to measure is the proportion of the losses which can potentially be averted by the code. To do this we need to estimate the effectiveness of the provision. Code provisions can avert loss in two basic ways. First, they may prevent a hazardous event from occurring. Secondly, they can protect against or reduce loss once the hazardous event has occurred. We assume that a code provision will not be completely effective in preventing loss by either of these methods. This assumption seems reasonable since codes are not generally intended or expected to totally eliminate all risk of loss. Moreover, many behavioral aspects which affect loss outcomes are not strongly influenced by codes. Thus a code provision intended to prevent fires may not be effective against arson. A smoke detector intended to reduce loss of life after a fire occurs may not be effective for persons under the influence of drugs or alcohol.

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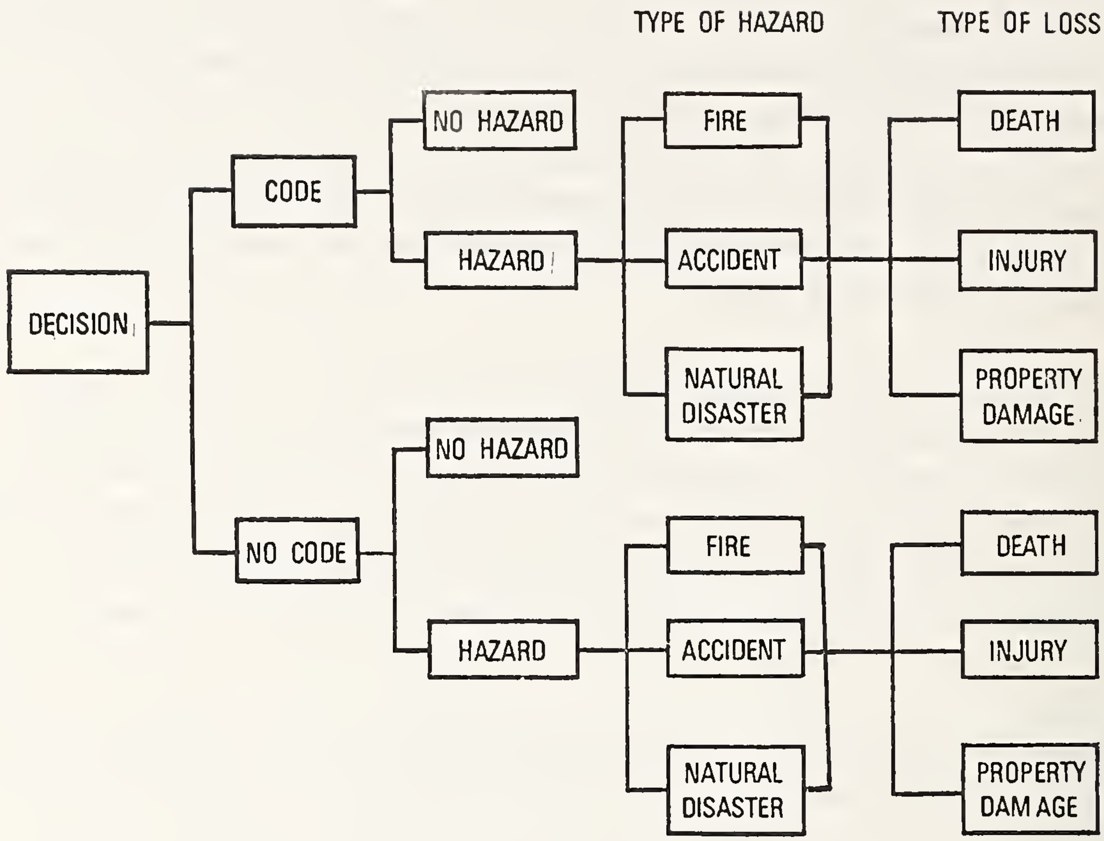
[5]For a description of Decision Analysis see Howard Raiffa, Decision Analysis: Introductory Lectures on Choice and Uncertainty, Addison-Wesley, Reading, Mass., 1968.

FIGURE 2

DECISION TREE



Two major elements are needed in order to estimate the proportion of losses which can be averted by a code provision. The first element is a need to understand how building hazards, and losses from building hazards occur. In addition, we need technical knowledge of how the code provision intends to reduce the risk of loss. The technical knowledge is often available as a result of research undertaken by manufacturers, building researchers, or independent testing organizations. Less is known about causation, or the chain of events which lead up to hazards and losses. One problem is that events which lead to death, injury, or property damage are complex. For example, what is the cause of death if a person falls from a ladder after receiving an electric shock from a power tool? Is the death due to the fall or to electric shock? Was the shock due to a poorly designed or unsafe tool, or because a grounding type electrical receptical was not used? Is this type of accident unique or typical? What is its frequency?

Despite obvious difficulties, progress is being made to examine the causality of hazards. New sources of data are beginning to be available such as the U.S. Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS). Case studies are sometimes available which investigate hazardous events to identify common patterns.[6] Generally no one data source or study contains all the necessary information. Further analysis is needed.

The second element needed in order to estimate the proportion of losses which can be averted is to identify the proportion of buildings which will be protected by the code provision. National statistics on losses are most generally annual estimates. Since building codes are not uniform nationally, we need to make some sort of assumption concerning the number of buildings to be protected. The assumption which we make here is that the code provision is a mandatory nationwide requirement in the year prior to its proposed enactment.

A hypothetical example can illustrate this technique. Suppose we wish to estimate the potential number of lives saved per year if a particular code provision is required in new residential construction. National statistics estimate that the hazard which the code provision is intended to protect against causes an average of 6500 residential deaths per year. If a code provision is to be enacted in 1976 then we would assume that all residences constructed in 1975 incorporated the proposed code provision. Since building construction is subject to building cycles, we will also assume that the number of residences built in 1975 is a 5-year average of the number of residences built between 1971 and 1975. If this number were 2 million residences and the total housing stock was 80 million residences, then the percentage of residences protected in 1975 is 2/80 or 2.5 percent. If deaths are equally distributed over the entire housing stock, then at the most 2.5 percent of the 6500 deaths, or 163 deaths, would potentially be saved by the code provision. Although generally not known, if technical and field studies find that the code provision is effective in preventing 40 percent of those deaths, then the potential number of lives saved in 1975 would be estimated to 163 x .4, or 65 lives.

This example can be extended further to illustrate the method of analysis. The next step in the analysis is to estimate how much it would cost, using the typical design cost estimates, to require the code provision in the 2 million residences assumed to be constructed in 1975. If this were $100 per unit then the total cost in 1975 would be $200 million. To complete this analysis we would have to then consider life-cycle characteristics, i.e., account for the number of years the code provision is expected to be effective,

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[6]One recent study outlines the major chain of events which lead up U.S. fire deaths. See Frederick B. Clarke, III and John Ottoson, "Fire Death Scenarios and Firesafety Planning," Fire Journal, May 1976, pp. 20-22, and 117-118.

and account for any annual repair, maintenance, or operating costs. If a 20 year life were assumed, then potentially 1300 lives could be saved (65 x 20). If there were annual recurring costs, then these future costs would be converted to a present value by discounting. For example, using a discount rate of 10% the present value of a recurring annual cost of $20 million (in 1975 dollars) is approximately $170 million.[7] The final statistic would be an estimate of the life-cycle cost per life saved--in this case about $285 thousand ($270 million/1300 lives). This statistic is important, because code provisions could then be compared and ranked on the basis of the life-cycle cost per life saved.

Other types of losses can also be evaluated using this type of analysis. Injuries, classified by severity, can also be measured by annual number occurrences. Property damage estimates can be measured in dollars.[8] The technique can be applied as long as (1) it is possible to determine the total number of buildings associated with a loss statistic, and (2) it is possible to estimate the number of new buildings to be protected by the new provision.

IV. GROUND FAULT CIRCUIT INTERRUPTERS - AN ILLUSTRATIVE CASE STUDY

The 1975 National Electric Code requires ground fault circuit interrupter (GFCI) protection for all receptacles installed outside or in bathrooms for new residential construction.[9] The GFCI is designed to protect against death from line-to-ground electric shocks. This type of shock occurs when current flows through the body between a voltage source and ground. The GFCI detects this ground fault and opens the circuit rapidly if current above a certain level (5 milliamperes for the GFCIs we are discussing) flows to ground

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[7]Equal dollar expenditures made at different times do not have the same value. Discounting is a way to account for the time value of money by converting future costs to an equivalent dollar base with initial costs. The above computation was made using a discounting formula. Such formulas are explained in most engineering economics textbooks. See, for example, Eugene L. Grant and W. Grant Ireson, Principles of Engineering Economics, 5th. Ed., New York: The Ronald Press Co., 1970.

[8]Since deaths and injuries are measured by occurrence while property damage is measured in dollars, there is no common measure used for all potential code benefits. The forthcoming NBS research report on this topic will also describe a method which can be used to weight different types of benefits using a common measurement system.

[9]Art. 210-8, National Electric Code, 1975 Edition, published by the National Fire Protection Association.

over an unintended path. The GFCI does not protect against line-to-line current flows.[10] Although exact information is not available, experts believe that the vast majority of shock deaths in residences results from a line-to-ground shock.

GFCI Benefit Identification

The average number of deaths in residences from electric shock in recent years has been a little less than 300. In our benefit computation we will use 300 deaths as our loss statistic.[11] We will also assume that all electric shock deaths are from line-to-ground shock. Thus, if our assumptions are in error we will overestimate rather than underestimate the potential number of lives saved by GFCIs.

The National Electric Code only requires GFCI protection for outside and bathroom receptacles, but electric shock also occurs in other locations in residences. Two studies have reported on the location of electric shock deaths in residences. Both studies are based upon analysis of newspaper clippings reporting electric shock death or injury. The studies were performed by researchers at Underwriters' Laboratories.[12] The first study, which is based upon a 3 3/4 year sample in the late 1960's, reported 193 fatalities in homes or apartments (including grounds but excluding outside pools, fountains and wading ponds). A total of 84 fatalities (43.5 percent all fatalities reported) occurred outside or in bathrooms. The second study reports upon electrocutions during the early 1970's involving portable electrical products in the residential area.[13] A total of 92 accidents occurred, 52 of which (56.5 percent) occurred in bathrooms or outdoors. By combining these reports a total of 48.2 percent of all fatalities/accidents reported occurred outside or in bathrooms. It cannot be assumed, however, that the 1975 GFCI requirements

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[10]For a comprehensive survey of Ground Fault Circuit Interrupter Usage, see Robert W. Beausoliel and William J. Meese, Survey of Ground Fault Circuit Interrupter Usage for Protection Against Hazardous Shock, National Bureau of Standards Building Science Series NR 81, Washington, D.C., 1976, hereafter referred to as BSS 81.

[11]Annual statistics on electric shock death are reported in Vital Statistics of the United States, Accident Mortality, U.S. Department of Health, Education, and Welfare, Washington, D.C.

[12]A summary of the results of these studies were presented to the National Electrical Code Panel which reviews proposals for GFCI protection requirements. See the "Preprint" of the Proposed Amendments for the 1971 NEC, p. 45, and "Preprint" of the Proposed Amendments for the 1978 NEC, p. 30, both published by the National Fire Protection Association.

[13]It is not clear whether the number of accidents includes injuries as well as fatalities in the second report.

will prevent 48 percent of these electric shock fatalities. Electric shock fatalities occur outside during the use of electric products such as lawnmowers, hedge trimmers, charcoal starters, and power tools used for automobile repair. The 1975 National Electric code requires only one outdoor receptacle.[14] One receptacle may not be adequate for every location outdoors, and it is likely that homeowners will use receptacles on lighting outlets in the residence, basement, or garage which are not protected by a GFCI to operate such electric products. Additionally, since new houses are also required to have another way to prevent electric shock--provisions for equipment grounding--it is likely that a smaller proportion of deaths will occur in new houses than in older houses. We will assume that GFCIs will be effective in preventing 40 percent of electric shock in new residences. This assumption would also probably overestimate rather than underestimate the potential number of lives saved.

The next step to determine the potential annual number of lives saved is to estimate the number of residences protected relative to the total occupied housing stock (total year round housing units less vacant and seasonally occupied housing units). Using 1975 as the year of installation, there were approximately 72 million occupied housing units.[15] There was a severe housing slump in 1975 and only about 1.2 million units were constructed. Instead of this figure we will use 1.8 million units, which is the average number of units produced over the previous 5-year period (1971-1975). The 1.8 million units are separated into 1.2 million single family (1-4 units) residences and .6 million multi-family (5+ units) residences. Mobile homes are not included in the 1.8 million estimate. If we assume that electric shock deaths are evenly distributed over the total number of units, then the 1.8 million units which we assume are protected in 1975 represents 2.5 percent (1.8/72) of the total number of units in which electric shock deaths occur.

Our estimate of the potential number of lives saved for the GFCIs installed in 1975 is then the product of the annual loss (300 deaths) times the percentage of units protected (2.5 percent) times the effectiveness of each GFCI unit (40 percent). Performing the multiplication (300 x .025 x .4) the potential number of lives saved is 3. This is probably a high estimate due to the assumption about the effectiveness of the GFCIs. The actual number may be much less.

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[14] See Act 225-10, National Electric Code, 1975 Edition, published by National Fire Protection Association.

[15] The Statistical Abstract of the United States, 1975 estimates that there were 69.3 million occupied units, including mobile homes, permanent rooms in rooming houses, etc., in 1973. Using the Annual Housing Survey of 1974, and adding the number of housing starts in 1975 updates the estimate to 72 million.

In this illustrative case study we will not specifically estimate other types of benefits such as protection against injury from electric shock or protection against fire. Available information on injuries suggests that the magnitude of such benefits would be small. The first Underwriters' Laboratory study on location of electric shock fatalities also reported statistics on non-fatal accidents. In the 3 3/4-year period over 80 percent of all accidents were fatal (193 fatal of 235 accidents). Of the 42 non-fatal accidents reported, only 20 percent occurred outdoors or in bathrooms.

Although little information is specifically available upon the effectiveness of GFCIs in preventing fire loss, it is not likely that the magnitude of such benefits would be large. First, electrical circuits protected by GFCIs are only a small proportion of the electrical circuits in a residence. Secondly, the GFCI will not open a circuit which is overheating until a ground fault occurs. Moreover, a fuse or circuit breaker may operate to open the circuit almost as quickly as a GFCI if there is a ground fault under short circuit conditions. Finally, a recent study of fire deaths suggests that the chain-of-events (or scenarios) which involve electrical wiring or equipment is not as common as other types of fire death scenarios.[16] For example, this study estimated that the scenario in which faulty wiring ignites the structural members of a residence accounted for 2 percent of U.S. fire deaths. Electrical wiring or equipment igniting the interior finish in residences accounted for another 2 percent of U.S. fire deaths. In contrast, one scenario not affected by building codes--cigarette smoking igniting furnishings in residences--accounted for 27 percent of U.S. fire deaths.

GFCI Cost Identification

There can be a wide range in the actual installation cost of GFCIs to meet the 1975 National Electric Code Requirements. Costs will vary due to factors such as regional differences in wage rates, the type of GFCI used, type of cable used, and most importantly, building design. Builders in Florida, for example, claim that installation costs range from $60 to $135 per residential unit.[17]

There are two general types of GFCI which may be used in residences. One is a receptacle type which replaces a standard receptacle outlet. The second type is circuit breaker with GFCI which, for some designs, may fit into the conventional circuit breaker

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[16] Frederick B. Clarke, III, and John Ottoson, "Fire Death Scenarios and Firesafety Planning," Fire Journal, May 1976, pp. 20-22, and 117-118.

[17] "Florida Builders Open Fire on Regulations That Up Housing Costs," House and Home, January 1976, p. 40.

panel. It is often possible to place both the bathroom and the outside receptacles on one branch circuit. The size and design of the residential unit determines whether one or two GFCIs are needed. GFCIs are subject to false tripping--that is a current leakage above the 5 milliampere trip level will cause the GFCI to open the circuit. To minimize false tripping the Underwriters' Laboratories Standard 943 limits the length of load conductor.[18] Despite these limitations, false tripping has been reported when (1) other electrical apparatus, such as florescent lights or bathroom exhaust fans are included on the branch circuits, (2) there is excess moisture or humidity, or (3) there are electrical storms.[19]

This case study is termed "illustrative" because cost estimates based upon typical designs have not been completed. Our first assumption is that the installation cost for each GFCI used is $50. This cost includes the cost of the GFCI device, labor charges, other material charges, and subcontractor overhead and profit charges. The listed retail price for GFCIs was in the $40 to mid $50 range in 1975 but electrical subcontractors receive a substantial discount (in one instance investigated about 35 percent) for purchases in volume. We also assume that two GFCIs are installed in single family residences (defined as 1-4 units per building) and one GFCI is installed for multi-family residences (defined as 5+ units per building) to give an example using more than one typical design estimate. Other cost assumptions will be made later in our discussion of sensitivity analysis.

Recall that when we were estimating the GFCI benefits we assumed that 1.2 million single family units and .6 million multi-family units were built in 1975. The total installation cost is then $150 million (1.2 million x $100 + .6 million x $50). In addition to the installation costs each GFCI has a small electrical operating cost. Preliminary laboratory measurements at the National Bureau of Standards of several approved GFCIs indicate that the models tested used between 7 and 9 kilowatt (KWH) hours per year. Using a consumption rate of 8 KWH per year the total usage per year for 3 million GFCIs assumed to be installed in 1975 would be 24 million KWH per year. At a cost of 4¢ per KWH the yearly operating cost in 1975 is about $1 million.

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[18] Ground Fault Circuit Interrupters, Underwriters' Laboratories Standard 943, Table 32.1, December 11, 1972.

[19] See, for example, comments by the NAHB representative in the "Preprint of the Proposal Amendments to the 1978 NEC", pp. 30-31.

Life-Cycle Analysis

It would not be reasonable to evaluate the benefit and cost impacts of the GFCI on the basis of first-year estimates alone. GFCIs can provide benefits for many years. Thus, it is more appropriate to evaluate the benefit and cost impacts over the expected life of the GFCI. Information concerning the effectiveness over time of GFCIs for residential use is not available.[20] The effectiveness over time may be influenced by the incidence of false tripping. There is some controversy concerning the trip level of 5 milliamperes. GFCIs at this trip level were taken off the market in South Africa due to the large number of false trips. A requirement for the use of GFCIs at construction sites was also postponed by the Occupational Safety and Health Administration (OSHA) in part due to the false tripping problem.[21]

Where false tripping is a problem, there may also be maintenance or repair expenses, or the homeowner may remove the GFCI. For the life-cycle analysis we will assume that the GFCIs will have a useful life of 20 years. If the GFCIs remained completely effective over a 20-year period and we assume that the potential number of lives saved is 3 per year, then the estimated total number of lives saved would be 60 by 1995. This assumption again probably overestimates the potential number of lives saved since not all GFCIs will operate effectively for the full 20-year period.

To compare the initial installation costs with future operating costs, future electric consumption costs will be converted to a present value (1975 dollars) using a discount rate of 10 percent. In addition, it is assumed that electricity prices will increase at a rate of 2 percent a year. This computation gives a present value of the future electric consumption for 20 years of about \$9.5 million.[22] Over the assumed life of the GFCI the total life-cycle cost is about \$160 million. The life-cycle cost per life saved is \$160 million/60, or about \$2.7 million.

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[20] See BSS 81, pp. 7-8, for a history of GFCI usage.

[21] See BSS 81, pp. 8-12.

[22] This is computed using the following formula

$$\text{Present Value} = \text{First year electrical cost} \times \left[\left(\frac{1 + P}{D - P}\right) \left(1 - \left(\frac{1 + P}{1 + D}\right)^{L}\right]$$

where P is the average annual rate of electricity price increase (2 percent), D is the real discount rate of 10 percent, and L is the life assumed (20 years). For a more complete discussion of the concept of life-cycle costing and the determination present values see Rosalie Ruegg, Solar Heating and Cooling in Buildings: Methods of Economic Evaluation, National Bureau of Standards, NBSIR 75-712, 1975.

Sensitivity Analysis

The above estimate of the life-cycle cost per life saved depends upon several sets of basic assumptions. The accuracy of these assumptions are subject to a good deal of uncertainty. One method to handle such uncertainty is sensitivity analysis. In sensitivity analysis one of the basic assumptions is changed to examine how sensitive the final outcome is to the change in that assumption. Figure 3 illustrates this technique. The left column contains the set of key assumptions used in our analysis. For reference, the case study which we have just described is listed as Case Number 1. In this case study we made several assumptions which probably overestimated rather than underestimated the potential number of lives saved. In Case Number 2 we have changed our estimate of GFCI effectiveness from 40 percent to 20 percent. This reduces the potential number of lives saved from 3 to 1.5 per year. Over the 20-year period the life-cycle cost per life saved becomes $5.32 million.

In Case Number 3 we change our original assumption that 2 GFCIs are required in single family houses. The number of GFCIs actually required depends upon the specific design of the house and the electrical layout used. In most cases probably only one GFCI is needed to meet the National Electric Code requirements. We now assume that only one GFCI is required for a single family unit. In addition, we will also use an estimate of $60 as the installation cost for each dwelling unit (the lowest cost cited in the Florida builders range of costs referenced earlier). These assumptions change both the total installation costs and the annual energy costs. Over the 20-year assumed life the new estimate of the life-cycle cost is $113.7 million and the life-cycle cost per life saved becomes $1.9 million.

Additional sensitivity analysis was also performed. Since the annual energy cost is small relative to the initial costs, differences in assumptions concerning these costs did not have a large affect upon the results.[23] Case Number 2 demonstrates that one of the more important assumptions is GFCI effectiveness. Effectiveness over time, or the useful life over which the GFCI provides its benefits is also very important. A reduction in the useful life to 15 years in Case Number 1 increases the life-cycle cost per life saved to $3.52 million. An increase to 25 years reduces the statistic to $2.14 million. The difference between Case Number 1 and Case Number 3 due to changes in cost assumptions should serve as a reminder that this case study is "illustrative" and not based

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[23] Energy costs might be a more important consideration in an analysis which sums the impact of GFCIs installed over a future time period. For example, if one GFCI were installed in each residential unit, and 1.8 million units are built each year, then by 1995 36 million GFCIs would be installed. Assuming energy usage of 8 KWH annually per GFCI, the energy usage in 1995 would be 288 million KWH.

FIGURE 3

SENSITIVITY ANALYSIS

Key Assumptions	Case Number 1	Case Number 2	Case Number 3
Annual NR. Deaths	300	300	300
GFCI Effectiveness	40%	20%	40%
Housing Stock Protected	2.5%	2.5%	2.5%
Annual Lives Saved	3	1.5	3
NR. of Single Family Units	1.2M	1.2M	1.2M
Installation Cost per Dwelling	$ 100	$ 100	$ 60
Subtotal	$ 120M	$ 120M	$ 72M
NR. of Multi-Family Units	.6M	.6M	.6M
Installation Cost Per Dwelling	$ 50	$ 50	$ 60
Subtotal	$ 30M	30M	35M
Total Installation Cost	$ 150M	$ 150M	$ 108M
Annual Energy Use Per GFCI	8 KWH	8 KWH	8 KWH
NR. of GFCI	3M	3M	1.8M
Annual Energy Use	24M KWH	24M KWH	14.4M KWH
Cost Per KWH	$ .04	$ .04	$ .04
First Year Cost	$960,000	$960,000	$576,000
Discount Rate	10%	10%	10%
Electrical Price Escalation	2%	2%	2%
Useful Life	20 Yrs.	20 Yrs.	20 Yrs.
Present Value of Future Costs	$ 9.5M	$ 9.5M	$ 5.7M
Life-Cycle Cost	$ 159.5M	$ 159.5M	$ 113.7M
Live Saved Over Useful Life	60	30	60
Life-Cycle Cost Per Life Saved	$ 2.66M	$ 5.32M	$ 1.9M

upon cost estimates from actual typical diagrams. Case Number 3, which uses the optimistic set of benefit assumptions of Case Number 1, but lower cost assumptions probably represents a lower bound estimate. This estimate would be higher if we dropped the assumption that all GFCIs installed in 1975 worked reliably for the full 20-year period without maintenance, repair, or removal of GFCIs where there is a false tripping problem. If a pessimistic set of assumptions were used, the estimate for the life-cycle cost per life saved would be higher than estimates given in Figure 3.

Sensitivity analysis can also be used to examine changes in the future cost of installing GFCIs. As the market for GFCIs expands, the price for the devices may decline due to economics of scale in production or increased competition by producers. This has apparently occured for smoke detectors and might likely occur for GFCIs. Using sensitivity analysis we can ask the question "By how much would the 1975 installation cost of GFCIs have to decline in order to reduce the life-cycle cost per life saved to $1 million?"[24] The answer for the set of assumptions listed in Case Number 1 is almost $17 per GFCI installed, for Case Number 2 almost $7 per GFCI installed, and for Case Number 3 about $30 per GFCI installed.

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[24] $1 million as a cost to avoid the loss of a life is picked as a benchmark. There is not agreement on any specific method to place a statistical value on human life. Economic studies which do estimate the statical value of a human life have produced a wide range of estimates, although most such estimates fall below $1 million. For example, V. L. Broussalian, " Risk Measurement and Safety Standards in Consumer Products" in Household Production and Consumption, National Bureau of Economic Research Studies in Income and Wealth Vol. 40, Columbia Univ. Press, 1976, used a value of $100,000 for a child under 6 years of age. This value was based upon an analysis of injury settlements. The U.S. Department of Labor has used a value of $300,000 in some of its technical studies. G. Fromm, "Aviation Safety", Law and Contemporary Problems, 33, 1968, pp. 590-618, estimates that in 1966 a value of $450,000 is estimated for an air carrier fatality. This estimate, which is based upon the median income and age characteristics of the passenger is about double that of the average person.

V. CONCLUSION

This paper summarized one part of the research being done by the National Bureau of Standards to analyze the economics impact of building codes. A standardized method to measure and evaluate the potential benefit and cost impacts of a specific code provision was described. Special emphasis was placed upon code provisions intended to reduce the risk of death from a building hazard. The GFCI case study, although confined to the benefit-cost category of impact, illustrated how the approach might be a useful tool to decision makers concerned with building codes. The forthcoming NBS report extends the approach to examine injury and property loss, and to evaluate potential cost-saving code provisions.

How can this type of analysis be used by building officials? First, as we have suggested, a similar analysis can be used for other code provisions and a ranking of life-cycle cost per life saved statistic can be made. By enacting those provisions having the lowest life-cycle cost per life saved, more lives could potentially be saved at a given cost. A second potential use of this type of analysis is to examine trade-offs between different types of benefits. For example, a code provision which reduces costs, or provides a welfare benefit such as energy conservation may potentially increase the risk of injury or death. This type of analysis can help to quantify the loss associated with such potential risks.

However, the approach is not a cure-all. It is easier to apply to some code provisions than to others. This research should be viewed as a first step. Additional work is needed before such analysis can be used on a regular basis. For example, simple working documents and user handbooks containing a step-by-step methodology are needed. Source data for cost parameters and for building hazards and losses need to be collected and compiled for easy use by building officials. Decisions need to be made on who does the analysis and on which code provisions to analyze.

Perhaps the primary advantage of the approach is that it provides a framework for analysis. Even when formal analysis is not carried out, it provides a way to assemble and organize available information in a format which can be of greater use to decision makers. Each step is explicit. Assumptions are clearly spelled out. There is room for debate, but sensitivity analysis can help to focus such debate away from side issues. From sensitivity analysis, key assumptions and research/information needs can be identified.

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IMPLICATION OF METRIC CONVERSION ON BUILDING
DESIGN AND CONSTRUCTION STANDARDS AND REGULATION

by

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As the United States prepares to join the "metric" world in the use of the International System of Units (SI), the impact of the proposed change will affect the construction industry and related professional enterprises -among others- and first of all the architectural, engineering and construction standards and building regulations involved. The conversion process offers a number of opportunities for unification and improvements, while potential harm and damage can be mitigated or eliminated by careful planning and collaboration between affected industries, institutions and professional organizations.

Such planning is being carried on by the American National Metric Council and its coordinating committees and sectors. Presently, the United States Metric Board -to be appointed by the President- will assume the oversight of the metrication process.

Key Words: American National Metric Council; building codes; construction specifications; dimensional coordination; International System of Units (SI); metric conversion; regulations; research.

PREFACE

Among the major governmental agencies which provide assistance and expertise in the preparation of useful data and systems planning is the National Bureau of Standards which through the years has gained increasing experience in the use of metric units. In response to a demonstrated need for identification of typical standards and regulations which will have to be converted into metric terms in preparation for the proposed change, research is being conducted at the National Bureau of Standards on the appropriate use of SI units in design and construction standards, specifications and building codes, in a dimensionally coordinated system.

This paper is based on the research conducted by the author during the Summer, 1976.

INTRODUCTION

The Public Law 94-168, 94th Congress, H.R. 8674, signed into law by the President, on December 23, 1975, designates the United States Metric Board as the administrative instrument to be responsible for an orderly plan of a voluntary conversion to the metric system. While no exact date is set at which the metrication would take effect, the directive is in some ways similar to those issued for metric conversion in the United Kingdom, Australia, and Canada.

It may be of interest to learn how our English speaking neighbors are accomplishing this task and what the implications may be to the building industry, design and construction standards, building codes and regulation.

For improvements to and unification of building codes and standards, impressive efforts have been made in the past, including the study made by the Advisory Commission on Inter-governmental Relations which in its January 1966 published report encouraged maximum uniformity in building codes and made eleven specific suggestions for improvements. While a number of steps have been taken to implement these recommendations, the metric conversion process offers a new opportunity to accomplish the aims of the Commission.

Model building codes, special codes, State and local building codes normally are not considered as reference documents on measurement systems. However, all of them contain dimensional and other measurement information which ultimately must be converted into metric terms. The researcher has reviewed the Standard Building Code (SBCC), Basic Building Code (BOCA), Uniform Building Code (ICBO), and National Building Code. In addition, ASTM Standards in Building Codes, ASHRAE Handbook on Fundamentals, and UL Building Materials List have been reviewed. The National Bureau of Standards recently has completed a computerized list of standards that appear in model codes, special and State codes, and in the thirty largest cities' building codes. They all face the same problems and opportunities offered in metric conversion.

TIME FRAME FOR METRIC CONVERSION

Good planning practice requires setting a time budget or "frame" together with personnel and ecnonomic considerations.

In the time frames projected by the United Kingdom, Australia and Canada, certain preparatory information was scheduled to be completed very early. The British allotted time for "key dimensional recommendations based on user studies" and metrication of essential reference publications for a two-year period, to be completed four years in advance of the M-Day, the day on which constructors would begin using metric measurement. The Australians and Canadians performed the same tasks during the first two years of their preparatory periods of not more than three years.

By comparison, then, a "reasonable period for preparation" in the United States could be as short as three years and not more than six, as we also can benefit from the pioneering work done by our English speaking cousins. This means that an effective date for metrication could be as early as 1980, or at least by 1982.

After the "M-Day," a follow up period of approximately three years is anticipated for total completion of the conversion.

OPPORTUNITIES IN METRICATION

Although there still exists some reluctance in the United States to adopt the metric system, the opportunities and benefits that can be derived from the use of the metric system are numerous and outweigh the inconveniences that may occur during the transfer period.

In the area of Codes and Regulation, for instance, the opportunities include:

- -unification of model codes, State and local codes,
- -having codes based primarily on performance, and developing proper criteria for performance of materials and equipment,
- -unification of Standards, by accredited organizations, in an international system,
- -increasing competence of code officials and building inspectors through education and training in metric measurement,
- -reduction of errors in plan reviews and document examination after the initial unfamilarity with metric terms is overcome,
- -improved coordination and collaboration between code officials, standards developers, and building inspectors at all governmental levels.

The design professionals sometimes have shunned modular coordination as being restrictive to their freedom to create new forms. However, the use of dimensionally coordinated, horizontal and vertical multiples of preferred dimensions provides ample opportunities for a designer to exercise creative powers.

INTERNATIONAL SYSTEM OF UNITS - SI

The International System of Units of measurement -SI- has been developed through international cooperation. This system has been adopted by the other English speaking nations.

From the basic units of quantity, combination units are derived in the same decimal system. The terms at first may sound unfamiliar, but can be learned without much effort. Some of the unit names are of recent origin, such as newton (unit of force, N) and pascal (unit of pressure or stress, Pa).

Besides the unification of terms and symbols in the SI-system, international agreements are necessary for preferred units of quantity, and the way that they are expressed numerically. For instance, numbers are grouped in threes on both sides of the decimal point, with a space rather than a comma to separate them. And, in construction drawings, short lengths are expressed in millimeters, often without the use of the symbol "mm."

ARCHITECTURAL REFERENCE STANDARDS AND PUBLICATIONS

Application of the SI-units in architectural design and graphic reference standards and publications requires several different conventions. Some measurements are applicable to "soft" conversion's an exact or approximately the same measurement using SI units, i.e., the weight of building materials. In "hard" conversion, a preferred dimension or "rounded" figure is used, based on new material sizes, results of recent research, or adoption of the principal of dimensional coordination. Collaboration between architects, engineers, manufactures, contractors, code officials, and other related professions, institutes, and industrial sectors is required in the selection of such figures in hard conversion. Dimensional coordination implies an agreement that a certain dimensional unit, such as 100 mm, (with multiples of 200 or 300 mm) be used as the basic module throughout a project.

Any new dimensional standard needs to be rational and applicable for use in other building standards and building codes. For instance, in place of the current 22" (559 mm) standard which is used in multiples to designate egress widths in fire codes it may make more sense to adopt a minimum width of 900 mm and adjust the codes to that dimension. For stair dimensions, research is currently being conducted at the National Bureau of Standards in order to define the most accurate formula for stair design.

Required and allowable stresses in brick and mortar, as required by building codes, need to be adjusted to pascals (or kilo- and megapascales). The load tables need to be converted in cooperation with handbook editors, codes officials and standards organizations.

The number of sizes of building materials may be reduced as metric standards are developed. A reduction in the number of sizes of structural steel shapes should result in lower stock and storage requirements while the availability may increase. Some new structural shapes and sizes may be developed as a result of international standardization. As the products are re-evaluated, the aspect of dimensional coordination will be included in the criteria.

The 100 mm module is being accepted as a workable unit for construction. The actual size of the nominal 2" x 4" wood stud and other lumber sizes are still being debated, with 38 x 89 mm being considered as the preferred equivalent of the present $1^{1}/2$x$3^{1}/2$" size, and the nominal metric size being 40 x 90 mm.

The plywood sheets that now measure 4' x 8' could become a bit more narrow and a little shorter, with modular dimensions of 120 x 240 mm. The thicknesses may also vary slightly, depending on industry decisions. The same process will affect the sizes of fiber - and gypsum boards.

Building components associated with openings, such as doors, windows, and curtainwalls, benefit from dimensional coordination. Although basic differences between their uses in wood, metal, and masonry construction will remain, improvement can be made through the development of coordinated metric standards. Hopefully, products of different manufacturers will become interchangeable, in a lesser number of sizes, with variety of design being produced by skillful and sensitive use of dimensions. It is anticipated that, not withstanding patent rights, anti-trust laws, and industrial competition, greater standardization will occur and benefits will be gained from the utilization of national and international sources of test data and research laboratories.

CONSTRUCTION SPECIFICATIONS

In specifications, a minimum use is made of dimensions in order to avoid conflicting with the dimensions shown on drawings and the many revisions that may take place during the planning and preparation of contract documents. However, there are myriad references to certain key dimensions covering manufacturing and installation practices, unit quantities, and standards. These need to be identified and converted into appropriate metric units for the changeover.

There are several model specification in use nationally. The MASTERSPEC of the American Institute of Architects is organized in accordance with the Construction

Specification Institute (CSI) format of sixteen divisions, and is also available as the COMSPEC through the Construction Specifications Institute.

With a program of dimensional coordination, stock sizes of materials may be revised to reduce cutting and fitting and to accommodate the most common standard sizes. However, the specifier needs to learn the metric material property values. Performance specifications, which are increasingly used when many materials and products become available, will be written with greater care and may be based on data by accredited national and international standards publishers. Builders hardware will have to be manufactured in metric sizes, including the templates and reinforcings in the receiving materials, i.e., doors, lock sets to doors.

The MASTERSPEC specification masters are voluminous and will require careful review. However, a short version also is in existence in a single volume. This format has proportionately considerably less references to dimensions, but when they do occur, similar changes will take place. The many standards which are being referred to continuously in both the larger and the shorter version require coordination between the specifying organization and the publishing institutes, including the American National Standards Institute (ANSI) which maintains contact with the International Standards Organization (ISO) for world wide standardization.

Most of the U.S. Federal government agencies have adopted the CSI-format of specifications, with some slightly different titles. They are generally available in computerized form and on microfilm, with updates every three or six months. Their metrication will follow the same pattern as the AIA/CSI format.

CONSTRUCTION AND MATERIALS STANDARDS

Practically all of the products, components, assemblies, materials and construction systems designated by architects, engineers and specification writers, need to conform to certain standards developed by various institutes and testing laboratories for the construction industry. These organizations, and many others, need to review the standards, convert dimensions and other measurements to metric units which are directly applicable, and collaborate with professions, industry and other institutions in providing revised standards for products, components and assemblies subject to "hard" conversion and dimensional coordination. In recent years many of them have started to provide metric information along with the conventional information, - dual units. For instance, the ASTM's recent standards all are published in this manner. ASTM and ANSI are among the leading standards organizations involved in developing proper criteria and steps in the process of metrication of the entire construction industry.

Eighteen of the 432 construction industry standards listed in the ANSI June 1976 catalogue are in metric terms, including 9 involving modular coordination. All eighteen also are ISO standards. This illustrates perhaps the extent to which ISO so far has been involved in the development of international standards for the construction industry. It is difficult to determine how many standards are included in MASTERSPEC specifications (there are 133 standards publishing organizations involved). As previously mentioned, the NBS study lists a total of more than 1850 standards for the construction industry, referenced in model codes, State and major city building codes. The American Society for Testing and Materials lists 523 ASTM standards that are frequently referred to in building codes.

The American Society for Testing and Materials uses a committee method for developing and approving standards. For instance, an ASTM Special Committee on Metric Practice meets frequently on general policy, while a subcommittee (E-6-62) deals with metric standards in construction. ASTM also is represented in various other organizations, the American National Metric Council and its sectors and subsectors, the American National Standards Institute, and very likely in the U.S. Metric Board, when appointed.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers is a professional organization vigorously engaged in setting standards for environmental and energy aspects of construction. The organization operates on a similar committee basis as ASTM and also is actively represented in the ANMC effort. It is one of the organizations comprising the Codes and Standards Sector and the Design Sector of ANMC, has published an S.I. metric practice guide for heating, ventilation and air conditioning, and is in the process of preparing a metric (SI) revision of its four-volume handbook series.

Metrication of 2375 pages of highly technical information is a major task and a credit to the engineering organization. The ASHRAE Metric Committee is working in collaboration with a number of other committees and task groups to cover several other activities involved in metrication, such as education, research, and standards.

The Underwriters' Laboratories publishes standards for hazardous chemicals, electrical equipment, and alarm systems, and establishes fire ratings for various materials components and assemblies. Because of patent rights or otherwise controlled manufacturing processes by different manufacturers, tests made under different basic conditions, or other factors, no two assemblies meet the same certification requirements under these circumstances. As a result, the designer and the inspector must search for product and rating information, guard against unqualified substitution, and make sure that the installation is in accordance with the strict specifications. Metrication and dimensional coordination should help the situation. The National Bureau of Standards, or standards organizations under government or industry contracts, could be engaged to perform the basic tasks of developing the technical data and drafting the necessary metric (SI) construction standards for and requesting industry, while specific product standards would still continue to be tested by the standards organizations to meet the overall standards in dimensionally coordinated system.

The fact that various standards publishers consider their operations as business ventures and depend on the income derived from the sales of the documents, may act as a deterrent to unification of standards. The data retrieval companies that make their livelihood by searching and organizing information on standards in a usable form for their clients, may find that unification of standards and the availability of data from a single or at least a reduced number of free sources will reduce their business in this field. The optimization of national goals always may not coincide with the interests of the private sector. Selection of standards and setting priorities may produce market situations favoring some and being unfavorable to other industries. Through mutual cooperation between industries, professions, government, and the standards organizations, a consensus solution may be obtained.

BUILDING CODES AND REGULATIONS

While the problems are similar, the degree of impact of metrication differs between the various model codes: For instance, the Uniform Building Code (ICBO) contains practically all the information, lists of symbols, formulas, and calculations which are contained in various structural engineering handbooks for wood structures, concrete, steel and other structural materials. The sequence for revision of that code must include the engineering handbook revision, so that the appropriate information to be included in the Uniform Building Code may be coordinated and correct.

Work towards unification of model codes is being done, and some common definitions have been drafted. Metrication is just another function that should be included in the joint effort. The National Conference of States on Building Codes and Standards (NCSBCS) also must tackle metrication in addition to its own efforts towards unification. The National Institute of Building Sciences may become the vehicle to untangle the unification problems.

A cursory examination of the codes reveals a wide range of numerical references, especially in dimensions, areas, mass weights, and stress. Most of them are based on past and current construction practices, while some others appear purely arbitrary. Systematic reduction of reference figures could be one of the results of metrication.

The Standard Building Code is prepared and published by Southern Building Code Congress International, Inc. and first was adopted in 1945. Its stated purpose is "to provide minimum requirements to safeguard life, health and public welfare and the protection of property," within its scope. In the 1976 edition, there are 194 standards published by 29 different organizations.

Since the purpose of the building code is to provide for greater safety to the public, uniformity of building laws, and "full justice to all materials on a fair basis of the true merits of each material," it is rational to look for performance criteria in terms of how well a certain material fulfills a set of reasonable requirements.

This means on one hand that the user requirements must meet some minimum standards of safety, convenience, economy of purchase and maintenance, quality of life and beauty. On the other hand, the designer, manufacturer, contractor, building inspector, and others involved in the construction process need to have corresponding measurements or quantities of these requirements or values, in order to meet these minimum requirements. The merit system is by far the easiest to use in quantification, and the use of SI units on a worldwide basis makes the largest possible number of choices available for the builder as well as the user. Standardization, simplification and unification of building codes, user requirements, and numerical references, will result in lesser cost and better performance. As far as the Standard Building Code of the SBCC is concerned, metrication and simplification of this code does not seem to involve excessive efforts.

The Basic Building Code of BOCA, Building Officials and Code Administrators, International, Inc. is quite definitive in its claim to being based on measured performance rather than rigid specifications. It further states that "in this way, [it] makes possible the acceptance of new materials and methods of construction which can be evaluated by acceptance of new materials and methods of construction which can be evaluated by accepted standards, without the necessity of adopting cumbersome amendments for each variable condition." Since 1950, this model code has been adopted by a large number of communities by reference. It is being kept up to date through a procedure of review and changes as issued annually, with a new and revised edition being published every three years. The code references 139 standards developed by 21 organizations, of which ASTM is the most representative (74).

Metrication of the Basic Building Code should be a relatively simple matter, as numerical values in references have been kept at a minimum.

The National Building Code is a model code published by the American Insurance Association, and is best described in its own words: [(It is)]... "a code prescribing regulations governing the construction, alteration, equipment, use and occupancy, location and maintenance, moving and demolition of buildings and structures." It originated in an effort to improve the life safety and fire prevention aspects of local building codes. Metrication problems for the National Building Code essentially are similar to those facing the Standard Building Code, although the National Building Code is simpler and numerical values in its references are fewer. There are fewer tables (which are shorter) and no appendices.

The Uniform Building Code, published by the International Conference of Building Officials (ICBO), is one of the oldest model codes and has been in use since 1927. The code itself is only a part of a series which includes a Uniform Mechanical Code, Uniform Housing Code, Uniform Code for the Abatement of Dangerous Buildings, Uniform Sign Code, Uniform Fire Code, Uniform Building Code Standards, and several other publications of similar nature.

Because of the handbook-like contents of the code, the Uniform Building Code will be the hardest to metricate, and the work has to be done primarily first by the handbook publishers and their engineering staffs and consultants. Training of personnel should not be a big problem, as anyone who is able to master the formulas and calculations may welcome the change to the easier metric system. The Uniform Building Code contains 143 references to standards (some of them referring to rule books or to several standards as in Chapter 27-1, 2701, where it refers to 28 ASTM standards); its accompaniment, the Uniform Building Code Standards, is a formidable instrument with 901 pages of even more detailed information.

Since the Uniform Building Code and the standards that it contains is only one of several model codes in national use, the coordination of codes and standards information with architectural and engineering design standards and construction standards and specifications becomes difficult, especially as they relate to a single national MASTERSPEC and its computerized version, COMSPEC. It may not be feasible to produce a metric guide that would equally well serve all of the existing model codes, State and local codes, standards organizations, specifications systems, design professions and construction industry. However, the willingness of the organizations to work toward a national and/or international set of metric specifications and standards would be of great help.

What has been said about the metrication problems regarding the model building codes is generally applicable to State and local codes (including the zoning ordinances) as most of them are based on model codes. Some of the independently developed codes, such as the City of New York Building Code, will have to face their own problems and perhaps follow the example to be set by the model codes in making the necessary revisions. At the same time, each code authority may use the opportunity to evaluate the effects and effectiveness of the code now in use, and make new decisions for the future. In this respect, services of an "impartial" national organization i.e., the National Institute for Building Sciences could be utilized.

Regarding the standards which are incorporated in the various codes a national effort, perhaps under the leadership and guidance of the Construction Industries Coordinating Committee of the American National Metric Council, seems necessary to develop universally acceptable sets of standards which would be applicable to all codes and specification. The American National Standards Institute would have to be involved in that task, together with the International Standards Organization and the Model Codes Standardization Council.

POLICY DEVELOPMENT AND RESEARCH OPPORTUNITIES

Metrication and codes and standards unification programs may be carried to a successful conclusion only with the cooperation and collaboration of all the parties involved. The scopes of partial programs, time schedules, priorities, and division of work must be decided with an appropriate consensus. Who is to do what, how it is to be done, what is to be included in the documentation, and how the information will be distributed to the users, are just some of the questions that come to mind. To date the fact that international trade will eventually demand that all products imported by metric nations to be in metric (SI) measurements, presently does not cause too much concern to a large part of construction industry yet not involved in that trade. Solutions favoring "soft" conversion still are being sought; however, the principles of dimensional coordination are of such importance that initial "hard" conversion to industry-wide preferred sizes should be insisted upon. The time schedule for these activities stretches well through the actual metrication program as it unveils during the coming years. When one examines all the various problems and solution alternatives that may be available as the United States moves to adopt the metric system, there appear immense opportunities for policy development and research. This could be compared to a "bicentennial" event, but its effects will be with us for the next millennium. It will be up to the American construction industry and related professions to decide what course to follow.

The research opportunities opening before us are almost endless. When Gutenberg set his first book in type, it opened up a means of communications which augured the modern technological development. The adoption of the metric system can mean a similar boost of technical and professional development to the American construction industry. But the research opportunties are not limited to the technological aspects. The following are only some of the areas that should be investigated and the results of which could benefit the overall results:

- the roles of private and public sectors in metrication efforts and in future responsibilities for professional, industrial, and codes and standards development,

- optimizing the metrication effort and opportunities for dimensional coordination,

- equalization of costs and benefits in proportion to the efforts and magnitudes of the economic sectors and subsectors involved in metrication,

- long term economic impacts of metrication,

- coordinating quality control of the voluntary metrication effort,

-methods of coordination of the time schedule and "M" dates for various sectors.

Mid-winter dates may prove to be the most suitable. Besides often being the beginning date for a fiscal year, January 1 represents in many cases the low point of planning and construction activity. It is also a suitable publication date for changeover information. And should it come as early as 1980, it may challenge us with opportunities of not only a new decade, but the next century of development in the United States.

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BUILDING CODES: PRESERVATION AND REHABILITATION

by

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There has been a large rise in interest in the last ten years in building reuse, rehabilitation and preservation projects. This trend is expected to continue in the foreseeable future. Such projects pose difficulties for the building regulatory system since many of these buildings were originally constructed prior to the existence of building codes. Most of these buildings do not meet modern levels of building regulation and application of building regulations to them poses difficulties as these regulations are essentially designed for new construction. The potential impact of these regulations includes the increase of project costs and damage to the fabric of the building intended to be preserved. Yet safety and health must be achieved in existing buildings as well as new. This paper summarizes studies and other activities that are presently being conducted by a number of organizations on this subject. One such study conducted by NBS has indicated that numerous State and local jurisdictions and model code organizations are adopting historic building waiver clauses and similar regulations as a partial answer to this problem. The National Trust for Historic Preservation sponsored the first national conference, in 1974, on this question and is currently cooperating with NBS in a study of the effectiveness of selected historic building waiver clauses. The National Endowment for the Arts has sponsored a grant that would identify tradeoffs that could be used in building regulations. NBS has also sponsored a study, reported in a separate paper in these Proceedings, on how a standard designed for existing buildings might be structured and formatted. NBS is also studying, for the Department of Housing and Urban Development, technological aspects of neighborhood conservation, including the role of building regulations. As of this writing, no final or definitive answer has been developed for the problem of achieving contemporary levels of safety and health in existing buildings.

Key Words: Adaptive reuse; architecture; building codes; building regulations; building safety; construction; performance; preservation; rehabilitation; renovation.

INTRODUCTION

The last ten years has seen an increasing interest in the reuse, rehabilitation and preservation of existing buildings. This is a trend that is having a great impact on the building regulatory community--particularly those who write and enforce building codes and standards. The purpose of this paper is to summarize:

--The nature of this trend toward the reuse, rehabilitation and preservation of existing buildings,

--The building regulatory response to this trend,

--The building regulatory research presently being conducted in this area.

Terms that are becoming more and more frequently used in the building community are:

--Preservation,

--Restoration,

--Rehabilitation, and

--Recycling/Adaptive Reuse.

These terms are related to each other through their common concern for retaining and reusing existing buildings, but differ significantly in what actions and uses they imply for these existing buildings.

PRESERVATION

Preservation can perhaps be considered the oldest of these terms, the first preservation movement being that begun by the Mount Vernon Ladies Association, over 100 years ago.[1/] Traditionally, preservation efforts have been directed at retaining individual buildings of historic or aesthetic merit. Recently, this direction has been broadened to include a concern for the retention of those buildings that enhance and enrich the urban fabric. This can be seen in the current widespread interest in historic districts. Traditionally, preserved buildings have been used as house museums, such as Mount Vernon. But this too has been broadened in recent years; preserved buildings now may be put to any number of uses--including the originial intended use. Thus, the building regulatory official is increasingly faced not with single house museums that will be only open during certain hours, but with a range of preserved buildings being used for housing, restaurants, retail stores, auditoriums, and other uses.

1/Charles B. Hosmer, Jr., "Presence of the Past: A History of the Preservation Movement in the United States Before Williamsburg," G. P. Putman's Sons, New York, 1965. This book is considered the standard history of preservation in the United States up to 1926.

RESTORATION

Restoration, the second of these terms, can be considered a small subset of preservation--the modification of an historic building so as to recreate the building as it appeared at some earlier data. This is a small portion of the preservation projects encountered by regulatory official since restoration is very expensive--for example the restoration of the Carlisle House in Alexandria, Virginia, and the restoration of the William Paca House in Annapolis, Maryland, each cost over $1 million for restoration.2/ But restoration projects pose particular problems to the building regulatory official as historic and architectural authenticity are of the utmost importance. These restoration projects can be, and frequently are, as technologically advanced as new construction, including modern electrical, plumbing, heating, ventilating and air conditioning, structural and fire detection and suppression systems--all of which must be concealed to preserve the historical "fabric" of the building.

REHABILITATION

The term rehabilitation, the third of these terms, has been used in two contexts in the 1970's. The first is the rehabilitation of the 19th century rowhouses in the central cities for an increasing number of young professionals returning to the city. The second context within which rehabilitation is found is housing for the urban poor. In this second context, rehabilitation is related to conservation; rehabilitating existing buildings, so as to maintain urban areas that have not yet experienced significant physical decline. Conservation's primary thrust is to maintain jobs and housing in situ, usually in areas of little historical or architectural distinguishment. Whereas restoration projects usually have large budgets and are under the direction of trained architects, rehabilitation usually operates under extremely tight budgets and is usually undertaken by contractors or homeowners who are frequently largely unaware of pertinent building code requirements or alternative methods of satisfying these requirements.

RECYCLING/ADAPTIVE REUSE

The last of these terms are recycling and adaptive reuse. Many building professionals object to the term recycling as it tends to equate buildings with aluminum cans. But despite these potential associative shortcomings, the term clearly conveys its intended meaning--the reuse of existing buildings to meet current needs. Perhaps a more widely used term is adaptive reuse. Under the concept of adaptive reuse, old buildings are

2/The Washington Post, "A Grand House Restored," Sunday, August 29, 1976, p. L1.

given new functions--and thus must adhere to the requirements of the building code. Although adaptive reuse projects usually do not have the restoration project's strict requirements for authenticity, particularly in the interior spaces; neither do they have the large budgets or professional assistance usually associated with restoration projects.

GROWTH OF INTEREST IN EXISTING BUILDINGS

There is considerable evidence of the growth of interest in existing buildings during the 1970s. For example, the Urban Land Institute Study of 1975 concluded the following:

- "...Private-market renovation is fairly extensive."
- Private-market renovation, "appears substantial in relation to the amount of both subsidized and unsubsidized housing which has occurred in the past."
- "Private-market renovation, "is reported to be increasing."
- "The survey findings also demonstrate the attractiveness of older, and particularly, historic areas to a segment of the population which has grown rapidly in recent years--the relatively affluent professional and office workers...."[3/]

Most American cities can point to one or several areas within the central core that are presently undergoing such private renovation.

Other evidence of this growth of interest in existing buildings includes Congressional action. For example, Congress recently passed the Public Buildings Cooperative Use Act of 1976[4/] encouraging the General Services Administration to utilize existing buildings to meet their space needs and the Tax Reform Act of 1976[5/] containing special provisions for those who preserve designated historic resources.

That existing buildings have taken on new importance in the 1970s can be judged by statements of responsible public officials. For example, Secretary of HUD Carla Hills, has stated:

> "...The era of clearing out whole blocks of buildings to erect new housing is ending. Instead, cities and the Federal Government should stress rehabilitating existing buildings."[6/]

3/J. Thomas Black, "Private-Market Housing Renovation in Central Cities: A ULI Service," Urban Land, November 1975, p. 7.

4/Public Law 94-451, signed by President Ford on October 18, 1976.

5/Public Law 94-455, signed by President Ford on October 4, 1976.

6/The Washington Post, "Carla Hills Stresses Rehabilitation," Saturday, February 7, 1976, p. D38.

The Advisory Council on Historic Preservation, in a report prepared for the Senate Committee on Interior and Insular Affairs, identified the growing emphasis in the last ten years on preservation. This report states:

> "The proliferation of history and preservation groups in towns and cities throughout America - from less than 2,500 in 1966 to more than 6,000 in 1975, also evidences the public conviction about the importance of historic preservation. The American Government reflected this upsurge of popular interest when, in 1973, it become the first government to ratify the World Heritage Convention. Adopted by the UNESCO General Conference of November 1972, the Convention affirms that it is the "duty" of each national government to preserve and conserve the cultural resources that collectively are the heritage of all mankind,"[7/]

Other evidence could be cited to substantiate the rise of interest in existing buildings in the 1970s. The fact remains that the building regulatory officials of the U.S. are reviewing more existing building projects, be they preservation, restoration, rehabilitation or adaptive reuse projects, than was the case in the past.

In general, existing buildings come under the purview of building codes when (1) there is a change of occupancy or (2) the value of alteration or damage repair work to be accomplished exceeds certain designated limits, or when the building is expanded.[8/]

For example, the Basic Building Code, one of the three widely used model building codes in the U.S.,[9/] requires code compliance for change of occupancy:

7/Advisory Council on Historic Preservation, "The National Historic Preservation Program Today," prepared at the request of Henry M. Jackson, Chairperson, Committee on Interior and Insular Affairs, United States Senate, 94th Congress, 2nd Session, U.S. Government Printing Office, Washington, D.C., January 1976.

8/This discussion is limited to building codes. Many jurisdictions enforce housing codes which remain applicable to the buildings in that jurisdiction at all times. Building codes typically include, usually by reference, approximately 300 nationally recognized standards produced by such organizations as the American National Standards Institute (ANSI), the American Society for Testing and Materials (ASTM), and similar organizations. Some jurisdictions do have retroactive requirements in their building code, such as the District of Columbia. In these cases, existing buildings would come under the purview of building codes.

9/Produced by the Building Officials and Code Administrators International, Inc., and used in the Northeast and Midwest. The other model building codes in the U.S. are the Standard Building Code (produced by the Southern Building Code Congress), used in the South, and the Uniform Building Code (produced by the International Conference of Building Officials), used in the West. Although these model building codes are not legal documents, they frequently serve as the technical basis for building codes promulgated by the States, cities and local jurisdictions.

"105.2 Change in use: It shall be unlawful to make any change in the use or occupancy of any structure which would subject it to any special provision of this code without approval of the building official, and his certification that such structure meets the intent of the provisions of law governing building construction for the proposed new use and occupancy, and that such change does not result in any greater hazard to public safety and welfare."10/

Similarly, code compliance is also required for major alterations:

"106.1 Application: Except as provided in this section, existing structures, when altered or repaired as herein specified, shall be made to conform to the full requirements of this code for new structures."

"106.2 Alterations exceeding 50 per cent: If alterations or repairs are made within any period of twelve (12) months, costing in excess of fifty (50) percent of the physical value of the structure, this code's requirements for new structures shall apply."

"106.3 Damages exceeding 50 per cent: If the structure is damaged by fire or any other cause to an extent in excess of fifty (50) per cent of the physical value of the structure before the damage was incurred, this code's requirements for new structures shall apply."

"106.4 Alterations under 50 per cent: If the cost of alterations or repairs described herein is between twenty-five (25) and fifty (50) per cent of the physical value of the structure, the building official shall determine to what degree the portions so altered or repaired shall be made to conform to the requirements for new structures."11/

And, similarly, code compliance is required for additions.

"106.6 Increase in size: If the structure is increased in floor area or number of stories, the entire structure shall be made to conform with the requirements of this code in respect to means of egress, fire safety, light and ventilation."12/

What is the impact of these building codes and standards on preservation, restoration, rehabilitation and adaptive reuse projects? It must be recognized that many, if not most, of these existing buildings do not meet modern accepted levels of safety and health--in fact, many of these buildings were constructured prior to the existence of building codes. Even those built according to existing building codes at the time of construction may not meet modern levels of safety and health as there has been a general and widespread upgrading of these levels in building codes throughout the 20th century. This general upgrading of building codes in the U.S. continues today and includes the adoption of new code provisions

10/The BOCA Basic Building Code, 1975 Edition, Building Officials and Code Administrators International, Inc., p. 3.

11/Ibid., pp. 3-4.

12/Ibid., p. 4.

and standards for areas such as fire safety, structural safety, physical safety and security, energy conservation, and others. Although these new, and generally higher, levels of building regulation provide more safety and health for the building user; they also provide a larger impact on preservation, restoration, rehabilitation and adaptive reuse projects. This impact is of two general types: (1) larger project costs for existing building projects, and (2) disruption or destruction to the building fabric--the architectural integrity of the building that is intended to be preserved.

That modern levels of building codes impose additional project costs is apparent to all those who have participated in preservation and rehabilitation projects--enhanced safety and health for the building user usually can only be achieved at some cost. That these building regulations might also disrupt or destroy the building fabric intended for preservation may not seem as obvious. Modern building regulations are primarily written for new construction projects. These regulations contain prescriptive and performance statements. Prescriptive statements specify the allowable materials, combinations of materials, components, assemblies, or configurations and dimensions that can be included in the construction of that new building. These prescriptive statements thus prescribe building solutions and are relatively easy to meet in new construction projects since none of the building is yet existing. Yet for preservation and rehabilitation projects the building is existing and thus not amendable to the application of prescriptive statements--although it may have to be minimally or substantially modified to meet building code requirements. These same prescriptive statements, when thoughtlessly applied to existing buildings, can needlessly add additional project costs and destroy many of the essential architectural features of the building. For example, the building code prohibition, "(on) the use of winders or circular stairways...in stairways serving as required exits,"[13/] and the related building code requirement that, "The minimum width of any stair serving as a means of egress shall not be less than forty-four (44) inches, except that stairs serving an occupancy load for less than fifty (50) people may be thirty-six (36) inches in width,"[14/] may have a tremendous impact on the large number of older buildings that use circular stairways, primarily or exclussively. In fact, what usually has to be done in such buildings is to construct a new structure adjacent to the existing building to house a new stairway or to create a space within the existing building for the required stairway.

Thus it can be seen that the objectives of safety and health can conflict with the objectives of preservation. Nevertheless, the answer to this problem is not to waive building regulations in the case of preservation, restoration, rehabilitation or adaptive reuse projects

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13/Standard Building Code, 1976 Edition, Southern Building Code Congress International, Inc. Section 1115.3(c).

14/Ibid., Section 1115.6(c).

--society has indicated a clear need for safety and health in buildings which they use, including existing buildings. The final or definitive answer is to seek out solutions in which society can attain the objective of preservation as well as the objectives of safety and health.

Toward this end, the first conference on preservation and building codes was held in Washington, D.C., in May 1974 by the National Trust for Historic Preservation. This conference was cosponsored by a number of professional, preservation and code organizations including:

--Advisory Council on Historic Preservation
--American Institute of Architects
--American Insurance Association
--Association for Preservation Technology
--Building Officials and Code Administrators International, Inc.
--International Conference of Building Officials
--National Conference of State Historic Preservation Officers
--National Fire Protection Association
--Society of Architectural Historians
--Southern Building Code Congress

The papers presented at this conference were published by the National Trust in 1975.[15/]

Perhaps the feelings of the conferees were best summed up by Giorgio Cavaglieri, a practicing architect and a specialist in the restoration and adaptive use of urban public structures:

> "Laypersons frequently suggest that preservation commissions or design boards should obtain special waivers from the various building departments so that original designs may be preserved. Any serious technical and artistic judgment, however, must recognize that even if the requirements of the code are oppressive or disturbing at times, the safety and comfort of the users cannot be disregarded. It therefore becomes the restoration architect's duty to make preservation compatible with code requirements and when selecting the design items of secondary importance to carefully choose those that can be changed in order to permit the required or desired protection. Only when this is done can preservation for adaptive reuse be considered successful."

In the autumn of 1975, NBS sponsored a study conducted by Melvyn Green Associates to determine what actions regulatory bodies were taking with respect to preservation projects.[16/]

15/National Trust for Historic Preservation, "Preservation and Building Codes: Paper from the Preservation and Building Codes Conference Sponsored by the National Trust for Historic Preservation, May 1974," The Preservation Press, Washington, D.C., 1975.

16/Melvyn Green and Patrick W. Cooke, "Survey of Building Code Provisions for Historic Structures," National Bureau of Standards, Technical Note 918, U.S. Government Printing Office, Washington, D.C., September 1976.

Responses were solicited from:

--Delegates to the National Conference of States on Building Codes and Standards (NCSBCS)
--State Historic Preservation Officers (SHPOs)
--Regulatory officials of the member cities of the Association of the Major City Building Officials (AMCBO)
--Model Building Codes (Basic Building Code, Standard Building Code, Uniform Building Code)
--Other interested jurisdictions and organizations.

This study revealed a growing adoption and use of:

--Historic preservation waiver clauses in building codes
--Administrative regulations contained in historic district legislation and similar regulations containing similar provisions as the building code waiver clauses.

This survey revealed that of the forty-seven (47) State responses, eleven (11) reported special code provisions in effect and five (5) reported special administrative regulations (see Figure 1). This is particularly significant as twenty (20) States now have mandatory or voluntary statewide building codes.

Of the sixteen (16) States reporting special code provisions or administrative regulations for preservation, nine (9) reported special boards to regulate preservation. On many of these boards, the State Historic Preservation Officer was represented. It is also significant to note that the first such provision was only recently adopted, in 1971, by the State of Alaska.

The survey also indicated that of the twenty-four (24) Association of Major City Building Officials (AMCBO) city responses that seven (7) reported special code provisions in effect and that eight (8) reported special administrative regulations (see Figure 2).

Perhaps most significantly, the survey also indicated that two (2) of the model building codes have adopted historic preservation building code provisions, the Uniform Building Code and the Basic Building Code, and that the third, the Standard Building Code, has a similar provision under consideration (Figure 3). These code provisions were only added in the last two years. A fourth model building code, the National Building Code, just recently added special provisions for existing buildings. These model code survey results are significant as these model codes serve as the technical basis for many, if not most, of

STATES WITH BUILDING CODE PROVISIONS OR ADMINISTRATIVE REGULATIONS FOR HISTORIC PRESERVATION

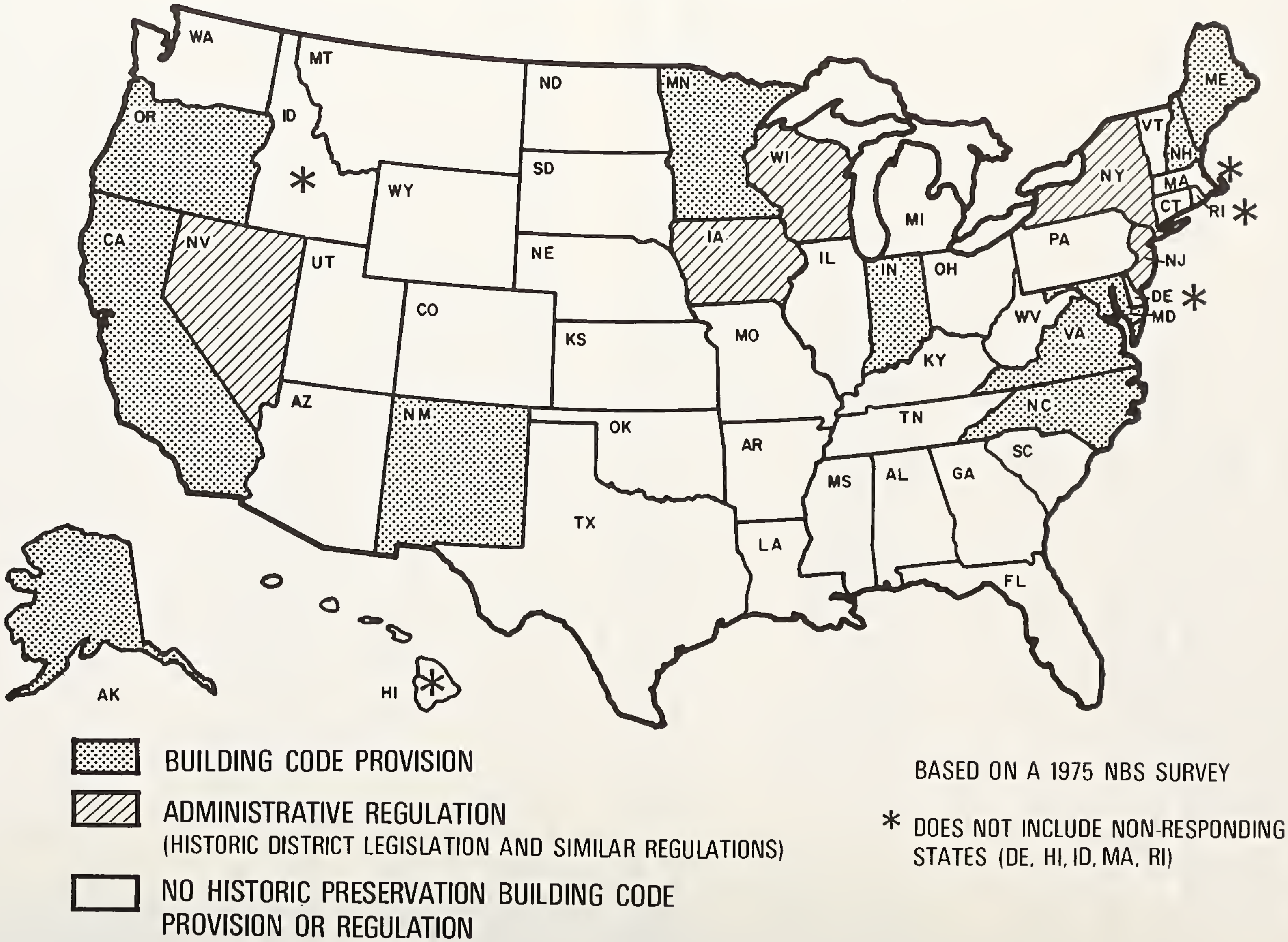

FIGURE 1

CITIES WITH BUILDING CODE PROVISIONS OR ADMINISTRATIVE REGULATIONS FOR HISTORIC PRESERVATION

● BUILDING CODE PROVISION

* ADMINISTRATIVE REGULATION (HISTORIC DISTRICT REGULATIONS OR SIMILAR REGULATIONS)

■ NO HISTORIC PRESERVATION BUILDING CODE PROVISION OR REGULATION

BASED ON A 1975 NBS SURVEY OF THE 30 MAJOR U.S. CITIES

DOES NOT INCLUDE NON-RESPONDING CITIES OF BOSTON, CLEVELAND, DETROIT, NEW ORLEANS, PITTSBURGH, SAN FRANCISCO.

FIGURE 2

MODEL BUILDING CODES WITH HISTORIC PRESERVATION PROVISIONS

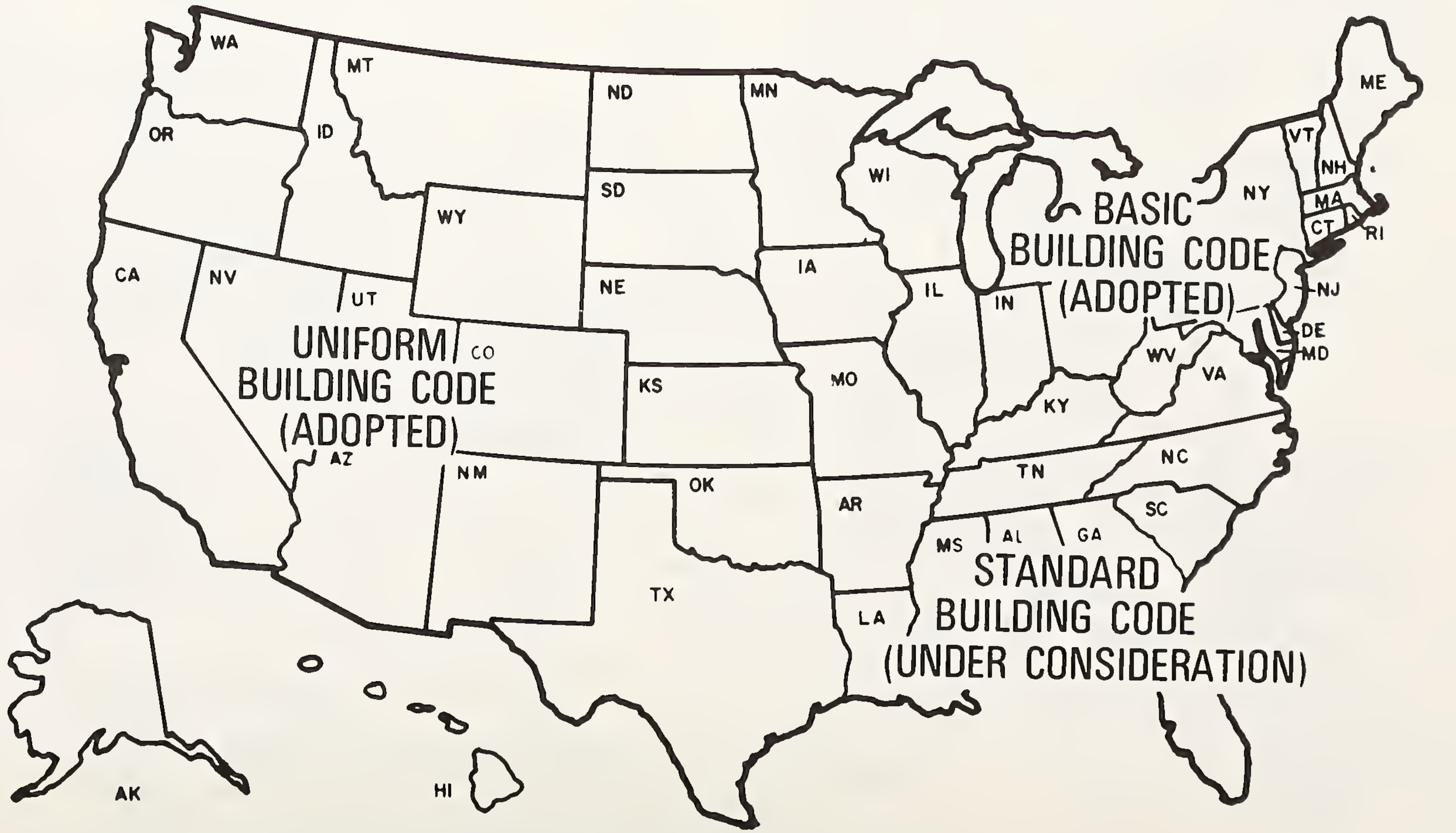

FIGURE 3

the building codes used in the United States. New provisions in the model building codes are usually adopted by State and local jurisdictions. Thus, the addition of historic preservation waiver clauses to these model building codes may well indicate a further, future use of such provisions by all building codes.

The Uniform and Basic Building Codes illustrate what typical historic preservation building code provisions contain:

Uniform Building Code

"(j) Historic Buildings. Repairs, alterations and additions necessary for the preservation, restoration, rehabilitation or continued use of a building or structure may be made without conformance to all of the requirements of this Code, when authorized by the Building Official provided:

1. The building or structure has been designated by official action of the legislative body as having special historical or architectural significance.

2. Any unsafe conditions, as prescribed in Section 203, will be corrected in accordance with approved plans.

3. Any substandard conditions will be corrected in accordance with approved plans.

4. The restored building or structure will be less hazardous based on life and fire risk, than the existing building."17/

Basic Building Code

"SECTION 317.0 SPECIAL HISTORIC BUILDINGS AND DISTRICTS

317.1 Approval: The provisions of this code relating to the construction, repair, alteration, enlargement, restoration and moving of buildings or structures shall not be mandatory for existing buildings or structures identified and classified by the state and/or local government authority as historic buildings, subject to the approval of the board of appeals when such buildings are judged by the building official to be safe and in the public's interest of health, safety and welfare regarding any proposed construction, alteration, repair, enlargement, relocation, and location within the fire limits. All such approvals must be based on the applicant's complete submission of professional architectural and engineering plans and specifications bearing the professional seal of the designer."18/

17/Uniform Building Code, 1976 Edition, International Conference of Building Officials, Section 104.

18/Basic Building Code, 1975 Edition, Building Officials and Code Administrators International, Inc.

However, the existence of historic building code waiver provisions may not resolve the difficult problem area. As one building regulatory official has stated:

> "It (historic building code waiver provision) is nebulous, arbitrary and in places that have adopted it, they have found it to be unworkable...."[19/]

What are the problems posed by historic building code waiver provisions? The answer to this question is not known definitely, particularly since these provisions are relatively recent on the building regulatory scene. However, it is widely suspected that there is inadequate existing technical information that would assist the building regulatory officials and others in making the critical decisions that affect safety and health on the one hand and preservation on the other. By far the preponderance of existing technical information, including the numerous building codes, referenced standards and other technical information, is oriented toward the needs of new construction rather than the needs of renovation and preservation of existing buildings. Moreover, building research, the basis of these codes and standards, has also been primarily oriented to new construction. Thus, the technical bases upon which to base decisions of safety and health in preservation, rehabilitation and adaptive reuse projects, although available for new construction, are almost totally lacking for existing building projects.

There are other perceived difficulties. Tradeoffs, the substitution of one adequate design solution for another, are rarely specified in the available technical information. Such tradeoffs would be particularly useful in existing building projects. Further, the effect of historic preservation waiver clauses on the professional liability of building designers engaged in such projects is presently unknown. Requiring the professional seal of a designer in instances when adequate technical information is lacking may well increase liability. Finally, the reliance of existing building codes on prescriptive requirements (adequate for new construction) effectively masks the intent or goal of the same regulations when applied to existing building projects. Making determinations of building safety and health under such conditions, as one senior building regulatory official has expressed it, "...is why building regulatory officials lose sleep at night."

Performance requirements, those regulatory statements that specify end objectives rather than allowable solutions, would better meet the needs of existing building projects. Performance requirements would tend to minimize the disruption of existing building elements in achieving safety and health. Unfortunately, little building research has been directed toward the development of performance requirements for existing buildings, so little information presently exists.

19/Melvyn Green and Patrick W. Cooke, "Survey of Building Code Provisions for Historic Structures," NBS Technical Note 918, September 1976, p. 22.

Little information also presently exists on how historic preservation waiver clauses are working in practice. NBS, in cooperation with the National Trust for Historic Preservation, is undertaking a study of the effectiveness of these historic preservation waiver clauses from the preservation point-of-view. This study will select and examine selected case studies so as to document problem areas encountered and the needs for technical information. The results of this cooperative effort will be available in the autumn of 1977. Another related effort is the National Endowment for the Arts grant to Melvyn Green Associates to identify tradeoffs that could be included in building regulations so as to alleviate the conflict between the objectives of safety and health and the objective of preservation. The results of this study are expected in mid-winter.

The results of these and other studies might well indicate a need for a building standard designed specifically for existing building projects. The Douglas Commission recommended that model standards be developed for incorporation into local building codes with special reference to rehabilitation. The Commission reported:

> "There is widespread recognition among code experts that current code standards, which are intended for new construction, should not be applied literally to the alteration of existing buildings."[20]

Although this recommendation was made in 1968, little work has been done in this area; largely due to a lack of applicable building research and technical information. However, with the recent establishment of the National Institute of Building Sciences (an organization recommended for establishment by the same Douglas Commission) and with the widespread interest in the problems of existing buildings the time may be ripe for the building community to address this subject area.

In the spring of 1976, NBS sponsored a study conducted by Baird Smith to investigate alternative methods of structuring and formatting a standard specifically designed for the needs of existing buildings. This study identified eight (8) problem areas in applying building codes to existing building projects and proposed a performance-based approach to structuring and formatting a standard designed for the needs of existing building projects. The results of this study are included as a separate paper by Baird Smith in these Proceedings of the NBS/NCSBCS Regulatory Research Conference.

Other studies have been undertaken. NBS is presently studying technological aspects for achieving neighborhood conservation. This study is being undertaken for the Department of Housing and Urban Development and will, among other subjects, examine the role of building regulations in achieving the objectives of conservation.

20/Douglas Commission, "Building The American City: Report of the National Commission on Urban Problems," House Document No. 91-34, 91st Congress, 1st Session, December 12, 1968, p. 269.

Other work is being accomplished to better acquaint preservationists and others involved in reuse, rehabilitation and preservation projects with the building regulatory system and its requirements for existing buildings. The National Trust for Historic Preservation is sponsoring a special supplement to its publication, Preservation News, to acquaint its membership with building codes and historic preservation waiver clauses. The National Trust is also developing a brochure that will inform preservationists of the importance of including regulatory provisions in their building plans and the need for communications with the building regulatory official to overcome potential problem areas.

The adoption and growth of historic preservation waiver clauses, the development of similar administrative regulations and the conducting of conferences and studies on existing building regulations are relatively recent actions--most having been initiated in the last several years. These actions offer promising approaches to the problem of achieving adequate safety and health in existing building projects. Since most of this work is relatively recent, final and definitive answers have not been arrived at. To develop these final answers will require additional work and study on the part of the building community.

INFORMATION STRUCTURE OF BUILDING CODES AND STANDARDS FOR THE NEEDS OF EXISTING BUILDINGS

by

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With the increased occurrence of rehabilitation and preservation projects, the problem of code compliance for these buildings is growing in magnitude. We are no longer dealing with isolated historic buildings, but with both entire historic districts and an ever increasing number of recycled, adaptively used buildings. The problem of code compliance for these projects frequently causes the destruction of the historic integrity of the building, the replacement of serviceable materials and, at the same time, increases project costs. The compliance problems may stem from the organization and format of the model codes which are based on new construction materials and techniques. This study examines the present organization and format of the three model codes, and develops a decision flow chart which analyzes how these model codes are used. The regulatory problems facing rehabilitation and preservation projects are then reviewed. From this investigation, a proposed decision process, based on the needs of rehabilitation and preservation projects is developed. Such a decision process could be used if and when building regulations are developed for the unique needs of these type projects.

Key Words: Building codes and standards; building code structure; existing buildings; historic preservation; performance attributes; performance evaluation.

There is currently a great increase in the amount of construction activity in the area of rehabilitation and preservation of the built environment. This effort to preserve old buildings goes far beyond the old concept of the restoration of a grand old mansion into an historic house museum. This enlarged effort, involving the whole spectrum of existing buildings, includes the rehabilitation, adaptive use and recycling of these valuable physical resources.

The term existing building is not interchangeable with the term historic building. The latter have been identified or recognized by some public or private organizations as having important historical or architectural merit. These historic buildings have been granted special consideration by two of the model building codes and by a number of State and City building codes.[1] Because of their status as historic buildings, full compliance with the building code is left to the judgment of the local code official or a designated review board. The degree of compliance, for these buildings, is decided on a case by case basis.[2]

This study, although concerned with those buildings, is primarily concerned with the much larger group of ordinary old buildings which do not have a historic building designation, but do face building code problems. They represent a true physical resource which people are beginning to turn to more and more to fill the need for housing, business and commerical space. These buildings are soundly constructed, but, using the current model codes, face very real compliance problems.

These problems are manifested in three common complaints which preservationists raise. First, they feel compliance to building codes cause the unnecessary destruction of aesthetically and architecturally important building features, both interior and exterior. Secondly, compliance seems to require the replacement of perfectly serviceable old materials with their modern counterparts. Finally, code compliance increases the cost of these rehabilitation and preservation projects without a proportionate increase in building performance.[3]

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[1] Melvyn Green and Patrick W. Cooke, Survey of Building Code Provisions for Historic Structures, NBS Technical Note 918 (Washington: GPO, 1976), pp. 9-10.

[2] For code provisions relating to historic buildings see: The Building Officials and Code Administrators, Basic Building Code (Chicago: National Conference of Building Officials) Section 317; Uniform Building Code (Whittier, Ca.: I.C.B.O., 1976) Section 104 (j).

[3] National Trust for Historic Preservation, Preservation and Building Codes (Washington: The Preservation Press, 1975), pp. 15-26.

The purpose of this investigation is threefold. The basic questions of the inquiry are:

1. What is the structure of the model building codes and are they geared toward new construction projects or can they be used with similar ease with projects in existing buildings? In other words, is the structure of the codes one of the inherent causes of the problem?

2. Are standards in the codes, which are generally prescriptive in nature, applicable to existing buildings with old materials and systems?

3. Is there an alternative structure and set of standards which would more directly satisfy the conditions present with existing buildings?

The model codes with which the study concerns itself are the most recent editions of the Uniform Building Code,[4] The Basic Building Code[5] and the Standard Building Code[6] which will be referred to as the model Codes. Analysis of mechanical, electrical or other speciality codes, as well as the various State and City building codes, is beyond the scope of this study.

Certain terms used in discussing this topic need to be defined. These definitions are commonly used by those in the building regulatory process and are understood by most code officials.

Building regulations are the total set of all legal requirements which a building project must meet. These legal requirements include those promulgated by the State or local governments (usually collected together into one building code) and all other requirements--for instance, those promulgated by the Federal government through the Occupational Safety and Health Administration and the Environmental Protection Agency.

A building requirement can be one of two types, or, what is more common, a combination of the two. They are prescriptive building requirements and performance-based building requirements.

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[4]International Conference of Building Officials, Uniform Building Code, 1976 Edition (Whittier, Ca.: I.C.B.O., 1976).

[5]Building Officials and Code Administrators International, Inc., Basic Building Code/1975 (Chicago: B.O.C.A., 1975).

[6]Southern Building Code Congress International, Inc., Standard Building Code, 1976 Edition (Birmingham, A.: S.B.C.C., 1976).

A prescriptive building requirement gives the allowable or permitted dimension, size, engineering type, assembly method or material which must be incorporated into the building project. These prescribe allowable design solutions.

A performance-based building requirement gives the allowable or desireable end goal to be achieved. These requirements differ from the prescriptive building requirements in that they set forth the results expected rather than the means of achievement.

A code provision is a statement in a building code setting forth a legal building requirement.

A building standard is a document, usually included by reference in a building code, covering a specific subject and developed by a nationally recognized standards organization. Two such organizations of the more than 150[7] are the American National Standards Institute (ANSI) and the American Society for Testing and Materials (ASTM).

A performance attribute is a statement which indicates the desirable goals to be accomplished to satisfy certain basic human needs. Principle performance attributes include safety, health and general welfare. Other, secondary attributes, vary according to different building regulatory philosophies.

This investigation was undertaken from the viewpoint of the designer engaged in preservation, rehabilitation or adaptive use projects. The results will tend to focus on the needs of the designer as he uses the code, not on the needs of the code official or building code producer. Hence, this study deals most directly with the decision process one follows as one uses the code when involved with code compliance in a project involving an existing building.

PART I

ANALYSIS OF THE STRUCTURE OF THE MODEL CODES

The three model codes share the same purpose: to provide for the safety, health and general welfare of the public regarding buildings and building construction. To accomplish this, each of the codes contain building code provisions and referenced standards. These regulations govern certain physical entities of the building such as height, area, configuration, structural design criteria and materials selection. The Code provisions tend to be prescriptive in that they identify the dimensions or materials which are per-

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[7] David Falk, "Building Codes in a Nutshell," Real Estate Review, Fall, 1975, p. 83.

mitted. Full compliance to the building codes is a fusion of the allowable physical entities, with the allowable materials, to achieve the desirable levels of performance with respect to safety, health and general welfare.

The model codes are arranged according to various chapters. Although each of the model codes have a different format and organization of chapters and provisions, the overall content and structure of the three are very similar. The decision process which the designer uses with the three is even more similar. The following discussion explains that desicion process.

USE OF THE MODEL CODES
A DECISION PROCESS

Use of the building codes begins with the determination by the designer of whether or not the project falls under the jurisdiction of the building code. All new construction and most projects in existing buildings must comply to the code. The conditions for application to projects in existing buildings using the Standard Building Code, are as follows.

101.4 - Existing Buildings

(a) If, within any twelve (12) month period, alterations or repairs costing in excess of fifty (50) percent of the then physical value of the building are made to an existing building, such building shall be made to conform to the requirements of this code for new buildings, also that for buildings located in fire districts the provisions of Section 302.1 and 302.2 shall apply.

(b) If an existing building is damaged by fire or otherwise in excess of fifty (50) percent of its then physical value before such damage is repaired, it shall be made to conform to the requirements of this code for new buildings.

(c) If the cost of such alterations and repairs within any twelve (12) month period or the amount of damage as referred to in paragraph (b) is more than twenty-five (25) but not more than fifty (50) percent of the then physical value of the building the portions to be altered or repaired shall be made to conform to the requirements of this code for new buildings to such extent as the Building Official may determine.

(d) For the purpose of this section physical value of the building shall be determined by the Building Official.

(e) If the occupancy of an existing building is entirely changed the building shall be made to conform to the requirements of this code for the new occupancy. If the occupancy of only a portion of an existing building is changed and that portion is separated from the remainder as stipulated in Section 403, then only such portion need be made to conform.

(f) Repairs and alterations, not covered by the preceding paragraphs of this section, restoring a building to its condition previous to damage or deterioration, or altering it in conformity with the provisions of this code or in such manner as will not extend or increase an existing non-conformity or hazard, may be made with the same kind of materials as those of which the building is constructed; but not more than twenty-five (25) percent of the roof covering of a building shall be replaced in any period of twelve (12) months unless the entire roof is made to conform with the requirement of this code for new buildings.

302.1 - Existing Building Within the Fire District

An existing building shall not be hereafter increased in height unless it is of the type of construction permitted for new buildings within the Fire District or is altered to comply with the requirements for such type construction. Nor, shall any existing building be hereafter extended on any side unless such extensions are of the type of construction permitted for new buildings within the Fire District.

302.3 - Moving Buildings

Buildings shall not hereafter be moved into the Fire District or to another lot in the Fire District unless it is of a type of construction permitted in the Fire District.[8]

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[8]For reference to similar provisions in the Basic Building Code see Sections 106.1 through 106.8. See also in the Uniform Building Code, Section 104 (a) through 104 (g) and Section 105.

Obviously, the designer has to have a pretty good idea of what work is anticipated in the existing building before he knows under which of the above cases the project falls. He would have to know the value of the building and the value of the anticipated work, whether the occupancy type were to be changed and if the height or area were to be increased.

Assuming that full compliance with the code is required, the designer begins the decision process explained here. Through this procedure, the designer will discover what actions he must initiate with respect to the building to achieve the desired levels of performance for the attributes of safety, health and general welfare. This procedure does not relate in any way to the order in which the provisions occur in the code. The procedure dictates that one jump from chapter to chapter to accomplish the task. In the Standard Code and the Uniform Code the procedures are well outlined. In the Basic Code, the requirements are obvious, but the procedure for use is less distinct.

The decision process explained here is a simplification and combination of the actual procedures found in the three model building codes. Although the decision process has been simplified, the concepts outlined are applicable to all three model codes.

Figure A illustrates the first stage of the decision process. In this stage, essentially, the level of risk is determined. In the two steps, the determination of the occupancy classification and the verification of the location of the building with respect to the city fire zones, the apparent level of risk is confirmed. Each of the two decision steps include code requirements which are here called primary requirements. These are requirements which are peculiar to the occupancy type and the fire zone and account for the degree of risk. The occupancies with the highest risk have the most restrictive primary requirements, as does the fire zone nearest the center of town.

These primary requirements can restrict the type of construction used, limit the building height or area or require fire extinguishing or fire alarm systems. As a rule, these primary requirements are of a general nature, establishing the allowable building size, configuration and type of construction. The detailed requirements which further define the physical entities come later in the decision process.

After that stage, the decision process moves into the second one, as shown in Figure B. This stage is one in which the physical entities are fully defined to bring building performance to a level high enough to counter the level of risk confirmed through the choice of occupancy in the first stage.

The two decision steps of this stage include the determination of the type of construction and the determination of the allowable height and area. The type of construction fixes the allowable degree of combustibility of the structural components. The structural frame, and the floor, wall and ceiling assemblies comprise the components.

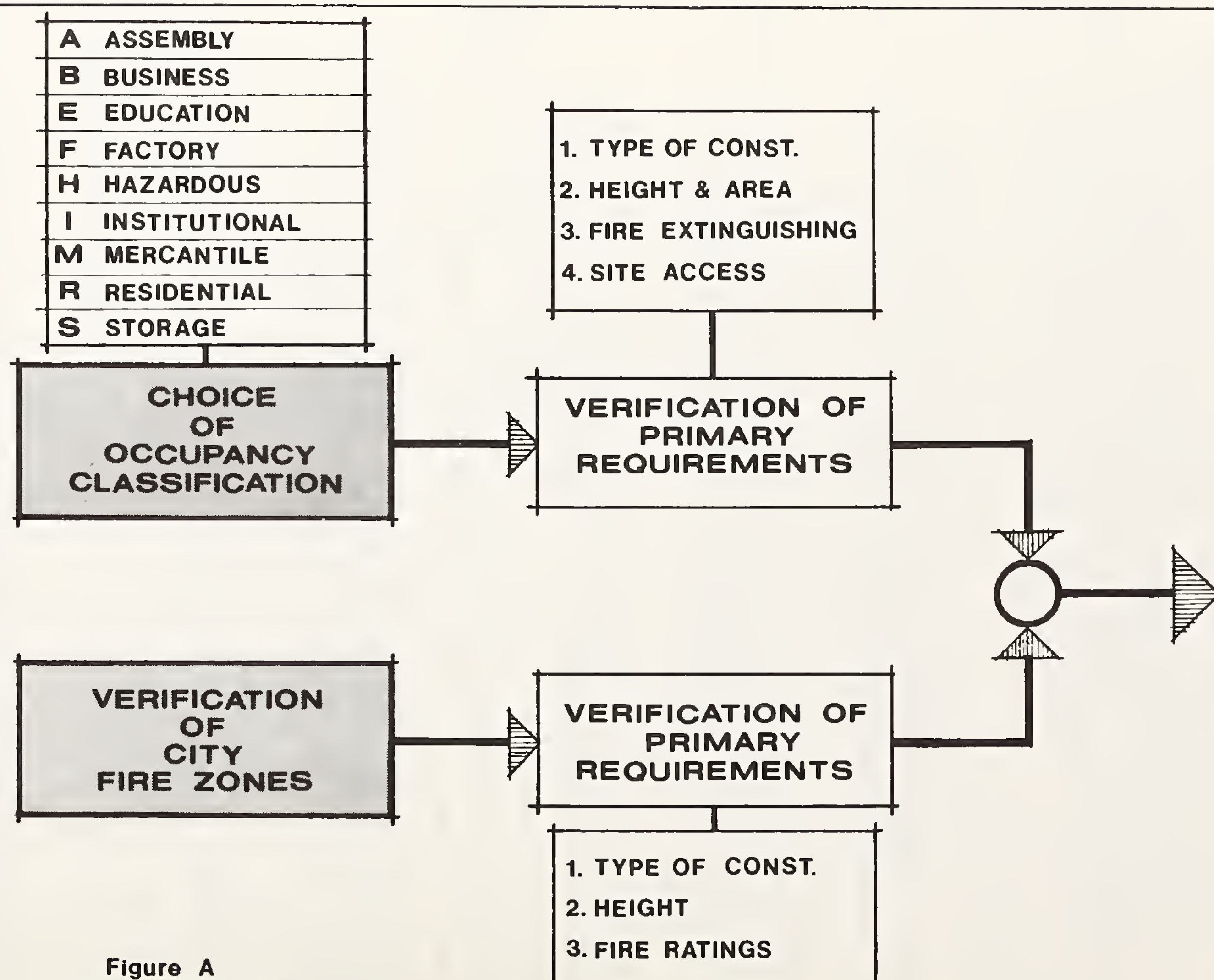

Figure A
FIRST STAGE
DECISION PROCESS IN THE MODEL CODES

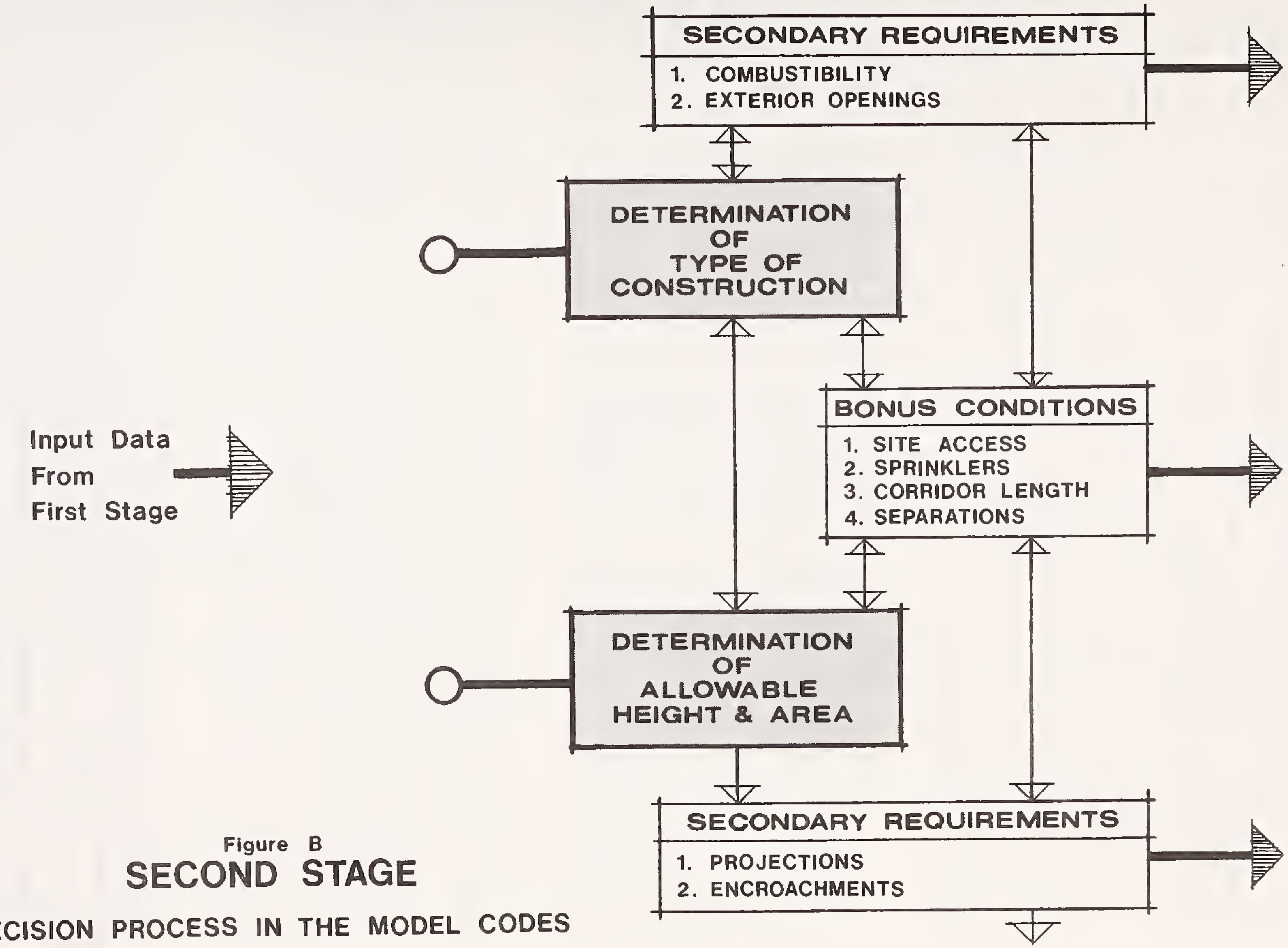

Figure B
SECOND STAGE
DECISION PROCESS IN THE MODEL CODES

Although each of the model codes differ on how many types of construction there are, each does have a specific definition which identifies the required fire resistivity of the structural components. The allowable height and area are given in a table in the codes which compares the occupancy classification (apparent risk) with the type of construction (apparent building performance). As the height and area increase, the risk factor increases which requires an equivalent increase in the performance of the building, hence the degree of non-combustibility for the type of construction is increased.

If the type of consturction and the building height and area were primary requirements of the occupancy, then the designer in this stage is merely verifying the detailed requirements of the type of construction. If that is not the case, he can use the tables for allowable height and area, to determine what type of construction he must use to attain a pre-determined area.

The final determination of the allowable building height and area is complicated with a set of bonus code provisions which allow an increase in the height or area if the overall building performance is increased accordingly. This increase is allowed if a physical entity, a trade-off, is added to the design. A good example of a common trade-off is the addition of a fire extinguishing system. With its installation in a building which was not required to have such a system, the codes permit a doubling and in some cases trebling of the building area. This trade-off is recognized as increasing the building safety performance, therefore, an increase in building area is awarded which brings the building into a new balance of risk versus performance.

Other bonus conditions include increasing aocess to the building site from public roadways, reducing corridor length and increasing the fire separation between buildings.

This stage has accomplished two important facets of the decision process. By establishing the allowable height and area and the type of construction, the building codes have, in effect, determined basic design criteria for the designer. Secondly, these two entities together contribute directly to achieving the desired level of performance for the attribute safety, or more specifically, fire safety.

The third stage of the process is essentially comprised of the many detailed code requirements which further define the physical entities. Some are directed toward the performance attribute of safety, while the others are to satisfy the requirements for the attributes of health and general welfare. The decision process given here has created groupings of these secondary, miscellaneous requirements. In reality, these provisions are spread throughout the model codes and often the performance attribute which they satisfy is not distinguishable. Grouping these provisions together does help to clarify the decision process.

Figure C illustrates the three decision steps of this stage. The first is the verification of safety requirements. The physical entities which are included in this element are: the fire resistivity of the surface materials, the number and size of the exits and a multitude of miscellaneous provisions which dictate various methods of construction.

These secondary requirements are largely made up of detailed concise prescriptive statements. For instance, the following floor assembly will achieve a one hour fire endurance rating. Principle materials are steel joists, concrete and acoustical ceiling tile.

> Top slab - 2" concrete over 10" bar joist spaced 24" o.c. Ceiling - Main tees are spaced 48" or 24" o.c. and supported by hanger tee wires. Cross tees are spaced 24" o.c., perpendicular to main runners. The system supports 1/2", 24" x 24" or 24" x 48" acoustical lay-in panels. Protected light fixtures may be installed in ceiling not to exceed 8% of ceiling area. Air duct openings not to exceed 25 square inches per 100 square feet of ceiling area. Listed by U.L. under Design No. 43-1 Hr., U.L. Test No. R4349.[9]

This perscriptive requirement indicates the material type, size, assembly method, the allowable light fixtures and air ducts and provides the reference for the standard and test which certifies the performance.

Also, in this third stage are the requirements to satisfy the performance attributes of health and general welfare. The former includes requirements for adequate heat, sanitation facilities and access for the handicapped. The latter includes requirements for adequate light, ventilation and the durability of materials. These requirements are also detailed, concise prescriptive statements. The following is the requirement to provide adequate light and ventilation.

> All enclosed portions. . . . used by human beings . . . shall be provided with natural light by means of exterior glazed window openings with an area not less than one-tenth of the total floor area, and natural ventilation by means of openable exterior openings with an area of not less than one-twentieth of the total floor area or

[9] S.B.C.C., Standard Building Code, Table 7, p. B-35.

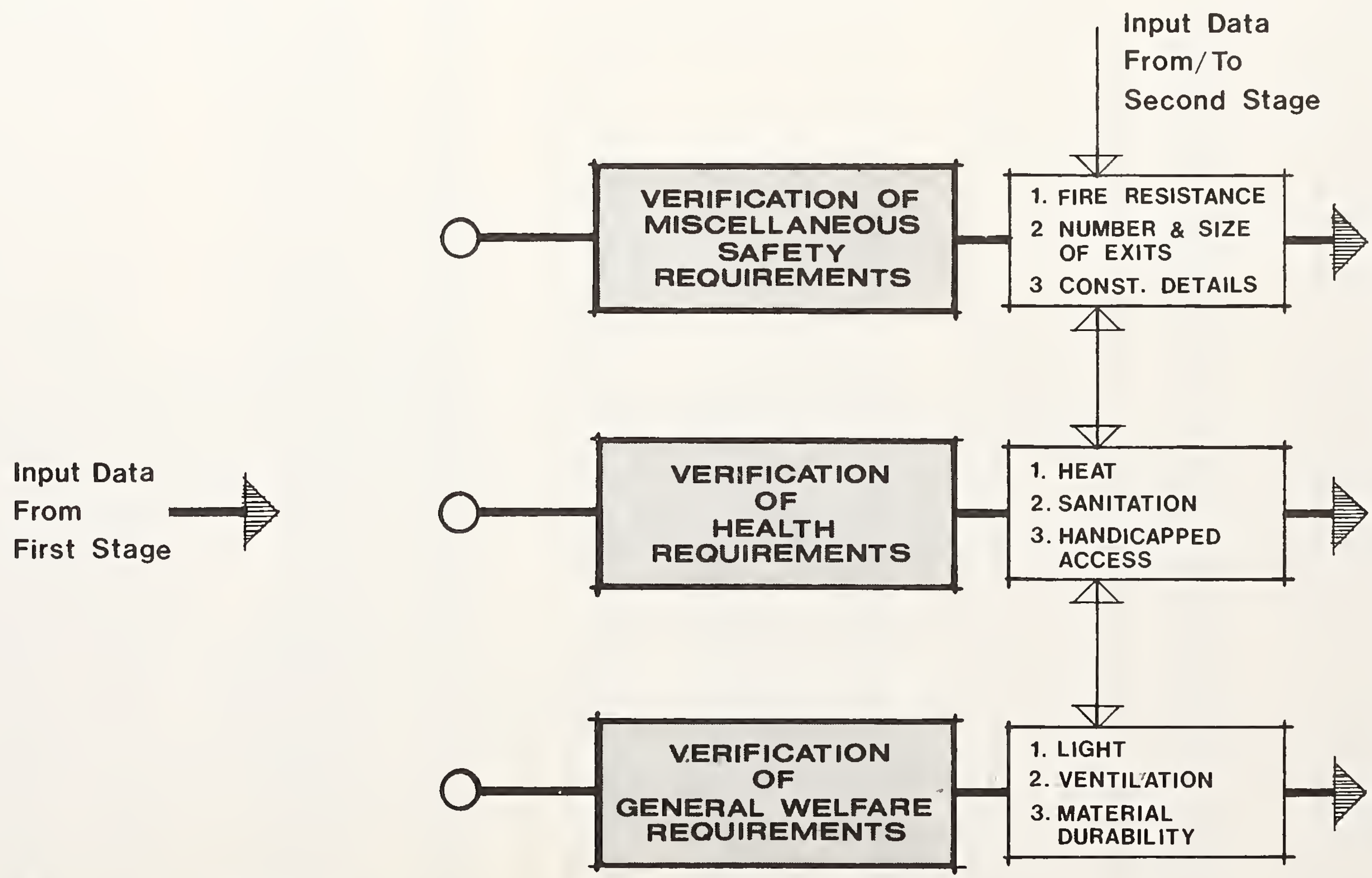

Figure C
THIRD STAGE
DECISION PROCESS IN THE MODEL CODES

shall be provided with artifical light and a mechanically operated ventilating system. . . .[10]

This and other prescriptive requirements are to satisfy the performance attributes of health and general welfare.

The entire decision process is shown in Figure D. The first stage was essentially a complete definition of the occupancy classification which confirmed the apparent level of risk. The second stage was comprised of design criteria which established the overall building size and the type of construction. In the third stage were the secondary, prescriptive requirements which fully defined all the physical entities of the building. The process moves from the general to the specific. First dealing with overall building size and ending with the minutest details of the building materials, assemblies and systems. It has yielded a multitude of prescriptive requirements which would be incorporated into the building design.

The end result is a building, still in the form of drawings and specifications, which fully satisfies all requirements.

This analysis has presented the structure and the decision process involved with using the model codes. Up to this point, this discussion has not indicated the various problems which existing buildings face in code compliance. A full understanding of how building codes work was necessary before the problems which existing buildings face could be dealt with. The following discussion attempts to answer the questions which prompted this investigation.

PART II

PROBLEMS WHICH EXISTING BUILDINGS FACE IN CODE COMPLIANCE

There are a number of problems which existing buildings face in relation to the building codes. These problems relate to the structure, the decision process and the code standards. The major problem areas follow.

1. The performance levels which a building must meet have risen throughout this century.

Many existing buildings were built to comply with performance levels which are now well below the required level.

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[10] I.C.B.O., Uniform Building Code, Section 605, p.62.

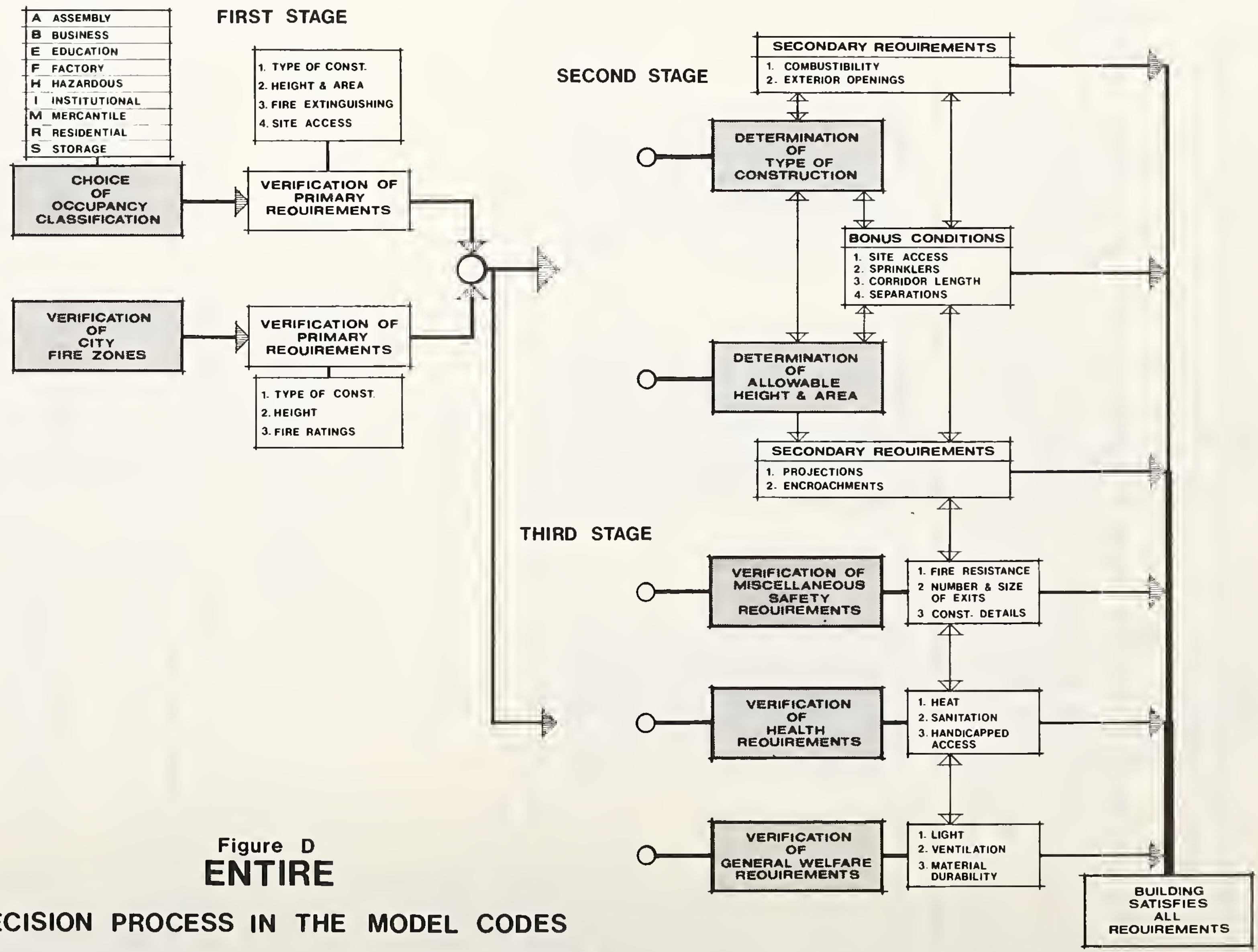

Figure D
ENTIRE
DECISION PROCESS IN THE MODEL CODES

One good example is with the sizes for beams and girders permitted in heavy timber construction. In 1920, a minimum cross-sectional area of thirty-six square inches was required in the Building Code of the National Board of Fire Underwriters.[11] This minimum rose to forty-eight square inches in the 1937 edition of the Uniform Building Code[12] and the same code now requires a sixty square inch minimum.[13] This is a clear example of the significant increases in the minimum levels of performance which have occurred.

2. New performance attributes have been added to the codes for which there are new building code requirements.

Existing buildings must conform to the requirements for newly added attributes such as convenience, (i.e., access for the handicapped) and economic welfare (i.e., conservation of energy and the durability of materials). Since these standards were not in effect until recently, vast numbers of existing buildings would not comply with these new requirements.

3. As new performance attributes were added to the model codes, problems resulted.

Specifically, the model codes do not fully recognize that some performance attributes may actually be in conflict with each other. For example, materials which are flame resistant and meet the standards for fire safety may not begin to meet the standards for energy efficiency or durability. The model codes may not have a mechanism to fully integrate the performance attributes with each other.

4. The decision process of the model codes is applicable only to new construction and does not lend itself to projects in existing buildings.

The model codes achieve the required levels of performance for the attributes of safety, health and general welfare through a process where physical entities (i.e., building height, area, configuration, structure, materials, and systems) are varied in relation to each other to reach a level of building performance. This complete flexibility, to alter any of the physical entities, is possible only in new construction, but does not in any

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[11] National Board of Fire Underwriters, Building Code, Fourth Edition, 1920 (New York: N.B.F.U., 1920), Section 105.

[12] Pacific Coast Building Officials' Conference, Uniform Building Code, 1937 Edition (Los Angeles: P.C.B.O.C., 1937), Section 1908.

[13] I.C.B.O., Uniform Building Code, Section 2106 (c), p. 122.

way correspond to the conditions present with existing buildings, since the physical entities there are largely fixed.

Secondarily, the designer involved with an existing building must use the model codes as if the project were new construction. He must plow through the decision process, trying to determine which provisions are applicable. He may find applicable provisions under the occupancy type, under the type of construction, under engineering regulations, detailed regulations, special regulations or miscellaneous requirements. It is a constant searching effort to determine the requirements.

Perhaps the greatest problem for existing buildings is that there is not a sound method for evaluating the existing level of performance. This is because the building standards are related to the construction of new buildings. The following are characteristics of these standards which create problems for existing buildings.

5. The various prescriptive standards of the codes are based on modern materials and do not include information about older materials.

These prescriptive standards are based on modern materials in common use today. Older materials and assemblies like cast iron, early steel and concrete sections and many early varieties of wood are not included. Many architects and code officials assume that they would not meet the standards given for new materials. Hence, they are often replaced with modern counterparts.

Apparently, as codes have been revised through the years, older materials were dropped from the standards and replaced with modern ones. A good example is wooden lath and plaster.

Information about this wall assembly is not included in any of the model codes. However, a review of out-of-date building codes yields the following. Wooden lath was not allowed in any construction as early as 1920 based on compliance to the National Board of Fire Underwriters Building Code,[14] nor was it allowed in the 1937 edition of the Uniform Building Code.[15] However, it was allowed in certain cases in the 1950 Building Construction Code for New York City[16] and the 1953 edition of the Southern Standard

[14] N.B.F.U., Building Code, Section 190.

[15] P.C.B.O.C., Uniform Building Code, Section 1916.

[16] C. W. Starbuck, Building Construction Code of New York City, Second Edition, 1950 (New York: C. W. Starbuck, 1950), Section 8.4.10.1, p. 164.

Building Code.[17] These facts don't mean much in themselves, except that they point out certain regional differences in the uses of wooden lath and plaster.

A startling fact about wooden lath is in a 1942 publication the the National Bureau of Standards entitled Building Materials and Standards.[18] In this report, which includes extensive tables of the fire resistivity of a broad range of materials, one can find the ratings for wooden lath and plaster. According to those tests, made in accordance with ASTM standards, one-half inch of gypsum or lime plaster on wooden lath on either side of a 2 x 4 wood stud wall is given a one-half hour fire resistance rating. If the void in the wall is filled with mineral wool, the wall is given a one hour rating. The fact that wooden lath and plaster has been reported to achieve a one hour rating is certainly important for existing buildings and it is unfortunate that it is not present in the model codes.

6. The various prescriptive standards are based on what might be called standard modern building configurations.

At the top of the list for this item is the requirement that all interior exit corridors, stairways and doors be 44" wide for most buildings.[19] This minimum standard has been proved to be of little relationship to the performance which is desired, that is, the safe evacuation of the building occupants.[20] However, this standard is rigidly enforced for existing buildings, causing extensive remodeling or the entire replacement of serviceable stairways and doors which only lacked a few inches of width.

7. Reference standards make it difficult to determine exactly what is required.

Reference standards are a necessity with more than 150 organizations producing standards. In new construction, there is little problem because the required standard is merely included in the contract specifications. However, where existing materials are in

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[17] Southern Building Code Congress, Southern Standard Building Code, 1953 (Birmingham, Al.: S.B.C.C., 1953), Section 1803.2.

[18] National Bureau of Standards, Building Materials and Standards, National Technical Information Services, COM-73-10974 (Washington: GPO, 1942), p.34.

[19] B.O.C.A., Basic Building Code, Sections 610.3, 616.2.1, 616.6.1.

[20] J. L. Pauls, "Evacuation and Other Fire Safety Measures in High-Rise Buildings," Research Paper No. 648 of the Division of Building Research, National Research Council of Canada. Reprinted from ASHRAE Transactions, 1975, Vol. 81, Part 1, p. 530.

question, it is frustrating for the designer when he comes to a reference standard. For instance, if the designer is trying to determine if wall plaster on wooden lath meets the code requirement, he finds the statement 'Interior gypsum plastering shall be done in accordance with the procedures as set forth in "Specifications for Gypsum Plastering, ANSI A 42.1'."[21] The reference standards cause problems because the referenced standard may not be available locally or, even if available, adequate testing facilities may not be.

8. Information which is included about older materials, specifically fire endurance ratings, may not be an accurate indication of the performance of the material.

Take, for instance, the fire endurance ratings given to structural systems based on the standard fire test methods. In these tests, most columns are tested with a minimum length of nine feet. These columns and floor framing systems are typically tested in chambers with a floor to ceiling dimension of about nine and a half feet, closely approximating modern structural configurations.

There would seem to be a problem with these test configurations based on the research of a Canadian, T. Z. Harmathy.[22] He reports that room size during a fire is one of the major factors in fire severity. His studies show that high ceilings actually contain the fire, creating a compartment, while low ceilings tend to force the fire out through openings. Therefore, it would seem, that since existing buildings often have ceilings of from twelve to sixteen feet, many of the structural systems and materials now rated with very low fire endurance ratings, may actually perform at a level significantly higher.

These materials and systems need to be retested in the configuration in which they are used, that is with twelve and sixteen foot ceilings, not in standard modern configurations.

The previous discussion reveals several facts. The decision process and the prescriptive building requirements of the model codes are most applicable to new construction. This process does not readily fit projects in existing buildings and the information about older materials and assemblies is either missing altogether or inaccurate. This lack of applicability to existing buildings does not necessarily mean that the model codes need to be revised. They certainly meet the needs for new construction. What is needed is a building code or standard which is based on the special conditions and needs of existing buildings. A proposed concept for that new code follows.

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[21] S.B.C.C., Standard Building Code, Section 1802 (b), p. 18-3.

[22] T. Z. Harmathy, "Design Approach to Fire Safety," Progressive Architecture, April, 1974, p. 85.

PART III

AN ALTERNATE APPROACH FOR EXISTING BUILDINGS

Existing buildings need a building code or standard which would achieve the following. First, provide a decision process which directly relates to the conditions present. Secondly, provide a decision process which includes a mechanism to recognize and improve deficiencies and, lastly, to provide a method for the thorough evaluation of existing materials, assemblies and systems and to provide extensive information about the physical properties, fire resistance and other performance data to aid in the full evaluation. The highest priority would be to achieve the same levels of performance which are now required for new construction for projects in existing buildings.

The structure and decision process for the new code presented here is just a concept and outline. More study and investigation must be undertaken to fully test this decision process for various buildings and to fill in the numerous gaps in what is now the skeleton of an idea. This new code or standard is perceived to be a companion document to the model codes. Whether it is for national use, regional use, or to piggyback the model codes, is a policy decision beyond the scope of this investigation. This is a concept which requires, and deserves, more development.

A POSSIBLE STRUCTURE OF THE NEW CODE OR STANDARD

The basic principle of the new code is that performance of an existing building cannot be based on the manipulation of building height, area, type of construction and choice of materials as is now required by the model codes. Rather, the new code will evaluate the performance of the existing building with respect to performance attributes and require that performance which is below the accepted levels be improved to a satisfactory level. A fuller understanding of the performance attributes is required, therefore, a discussion of that point follows.

There are three fundamental performance attributes: safety, health and general welfare. These can be further defined with the addition of eight secondary attributes. Under safety would be fire safety, structural safety and accident safety. Health would include the attributes of comfort (i.e., heat and sanitation) and convenience (i.e., access for the handicapped). Social welfare (i.e., light and ventilation) and economic welfare (i.e., conservation of energy and durability of materials) and historic preservation (i.e., retention of important building features) would be included under the attribute of general welfare.

Historic preservation is included as a performance attribute because it should be viewed in the same manner as the rest. After all, society is now demanding that old buildings be retained because of their value as a physical resource and that important building features be preserved because of their contribution to our cultural and aesthetic heritage. For these reasons, historic preservation should be included as a performance attribute which must be achieved through a building code.

The structure of the new code is based on building occupancy and would use the same definitions as in the model codes. However, each occupancy would not have a listing of primary requirements, rather, each occupancy would have certain required performance, unique for that occupancy, for the eight performance attributes. This level of performance would be determined through the evaluation of certain physical parameters. A physical parameter is not a code requirement, it is a physical entity which, when measured, indicates the level of performance for that one aspect of the performance attribute. The parameters are the recognizable, principle factors for performance in an attribute.

An example of the use of physical parameters as the measure of a performance attribute can be seen in a publication from the Center for Fire Research, Center for Building Technology, NBS, entitled, "A System for Fire Safety Evaluation in Health Care Facilities."[23] To evaluate performance for the attribute of fire safety, the Center created this list of thirteen physical parameters.[24]

Construction (Combustible, non-combustible, one floor, two and three floors, four floors and up)
Flame Spread (Corridors and exits)
Flame Spread (Rooms)
Fire Resistive (Partitions)
Fire Resistive (Vertical openings)
Smoke Control (Type of system)
Horizontal Exits (Type of exit)
Alarm System, Manual (Type of system)
Detection System (Type of system)
Occupant Door to Corridor (Fire endurance of door)
Sprinklers (Type of system)
Corridor Length (Length of travel in smoke compartment zone)
Fire Fighters, Public (Arrival time)

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[23] A. J. Shibe, I. A. Benjamin, H. E. Nelson and M. J. Slifka, "A System for Fire Safety Evaluation of Health Care Facilities," Draft report, Center for Fire Research, National Bureau of Standards, July, 1976, p. 6.

Each of these parameters has a definition and a set of measured physical entities which describe the parameter. For instance, for the parameter corridor length, the following five entities are given: dead and with three doors, length greater than 150 feet, length between 150 and 100 feet, length 100 to 50 feet, and length less than 50 feet. These are arranged from the least safe condition, the dead end, through a range of conditions to the safest condition. The middle condition, length of travel from 150 to 100 feet, is the minimum level required by the model code. This becomes the baseline for determination of the degree of performance for the parameter.

To determine the performance for the attribute, a weighted numerical value, of from -10 to 10, is attached to each of the physical entities which describe the parameter.[25] When the values which correspond to the various measured physical entities are added together, the level of performance for the attribute is established. Those parameters which exceed the baseline value have the effect of bringing up the performance level of the deficient ones. This means that the performance for the attribute can be at the required level while at the same time having certain individual parameters which are below the baseline value.

This method, which evaluates the performance of the attributes through the evaluation of physical parameters, is the principle concept of the new code or standard presented here. This new code would be arranged according to the various occupancies. The following is a skeleton outline for one such occupancy which includes a definition and a listing of the eight attributes, each with a set of physical parameters.

Occupancy Type: Assembly

- A. Definition
- B. Performance Attributes
    - Safety
        - Structural
            - Physical Parameters
        - Fire
            - Physical Parameters
        - Accident
            - Physical Parameters
    - Health
        - Comfort
            - Physical Parameters
        - Convenience
            - Physical Parameters

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[25] Ibid., p. 21.

General Welfare
  Social
    Physical Parameters
  Economic
    Physical Parameters
  Historic Preservation
    Physical Parameters

Each occupancy type would have a different listing of the physical parameters. Some parameters would be found in all the occupanices, others would be unique for specific ones. The occupancies which represented the higher level of risk would include physical parameters with proportionately higher baseline values. Thus, the resulting building performance could be matched to the apparent level of risk relative to a given occupancy.

HOW THE NEW CODE OR STANDARD MIGHT BE DEVELOPED

This report is not intended to be the definitive work on the subject, but rather, is largely intended to spark further research and development. This study could be developed into technical criteria through research under the auspices of perhaps the National Bureau of Standards of some outside research organization. This research would include:

- o Determining the physical parameters to accompany each performance attribute.

- o Determining the baseline values of each parameter by translating the performance level from the prescriptive requirements of the model code.

- o Matching the baseline values to the apparent level of risk represented for each occupancy type.

- o Interpolating these baseline values so that the performance level for each performance attribute is established.

- o Integrating the performance attributes with each other to ensure that incompatibility and conflicts are reduced to a minimum.

Once this technical criteria is solidified, it could be transformed into one or more final documents by the appropriate technical committees of the voluntary consensus standards organizations, by the code change hearings of the model building codes or, possibly, by the National Institute of Building Sciences (NIBS).

In addition to the full development of the occupancy performance requirements mentioned above, there needs to be an extensive effort to determine the physical properties, fire resistance and performance data on the various materials which are used in old buildings. This could include the many types and configurations of early structural systems; i.e., heavy timber, cast iron, steel and concrete. Also, many surface materials need to be evaluated, such as typical early plaster on wooden lath, wooden paneling, wall papers and fabric wall coverings. Certain historical devices such as dumb waiters, cage-type elevators, gas and oil lamps and a multitude of early industrial machinery should be investigated with clear, fresh thinking.

Some of this data can be uncovered through research into old building codes, standards and test data. Other information must be obtained through retesting. Since there will be little economic incentive for private industry to undertake these efforts, it will probably fall to a governmental agency such as the Department of Housing and Urban Development or the National Bureau of Standards to sponsor the necessary research and material testing.

HOW THE NEW CODE MIGHT BE USED: THE DECISION PROCESS

With the fundamental structure and concept outlined, the decision process involved when using the new code or standard can be presented.

The new code or standard would be used in any project in an existing building. There would be no preconditions for value of work, change in occupancy or increase in size. It is presumed that the new code or standard would be used in the preliminary design stages by the designer. The first is shown in Figure E. In this stage the designer chooses the applicable occupancy classification and familiarizes himself with the physical parameters and the physical entities of each to be measured. The designer is essentially verifying what work he will do in the next stage.

The next three stages of the process would be undertaken for each of the eight performance attributes independently. The process separates the attributes and concentrates on satisfying the requirements of each one, one at a time.

The second stage, as shown in Figure F, includes three functions. Given the listing of physical entities for each parameter from the first stage, the designer must: (1) identify each physical entity to be evaluated, (2) measure the performance of each and (3) evaluate the performance of each.

In the identification function, the architect isolates which physical entities are in question for each parameter. For instance, in the earlier example of the corridor length, the designer would establish which corridors would be evaluated to fulfill the definition of the parameter.

The second function is to measure the performance of the physical entity. Performance information for numerous materials and assemblies will be included in the new code. Thus, the performance for many of the parameters can be determined either by direct measurement or by locating the value in an accompanying table.

Some of the parameters lend themselves to on-site testing or measuring. The performance of existing exit facilities, for instance, can be measured through certain test methods developed by J. L. Pauls in Canada.[26] He has developed many methods for testing how fast people exit buildings under different conditions and with various stair configurations. The parameter for exit facilities would therefore measure how many people could evacuate the building in a fixed amount of time. Each exit facility would be measured to determine those values.

Many other on-site tests could be developed that could capitalize on the fact that the building is in place. For instance, the loading capability of structural frames can be verified and/or tested through a combination of on-site loading and analytical procedures. Thermal conductivity of walls and air leakage can be measured and a measurement can be developed which evaluates the capability of public fire fighters to effectively answer a fire call. These on-site test methods and others could be developed into standard test methods for existing buildings and would become an important and unique part of the new code or standard.

The third function of this stage is to evaluate the performance of each parameter. This means that the performance measured in the previous step is now compared to the baseline value. The performance for each parameter is thereby determined to exceed, be equal to, or less than the baseline value. This data is carried on to the next stage.

In this stage of the process, as shown in Figure G, the designer determines the performance level for each of the performance attributes based on the performance of the individual parameters. Using the numerical tabulation method identified earlier, the weighted values for each parameter are added together. The resulting performance level of the attribute is thus a combination of the high and low performances of the parameters which make up that attribute. With this last evaluation, the levels of performance for all eight attributes will have been determined. Those attributes which meet the required

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[26] J. L. Pauls, "Evacuation in High-Rise Buildings," pp. 529-531.

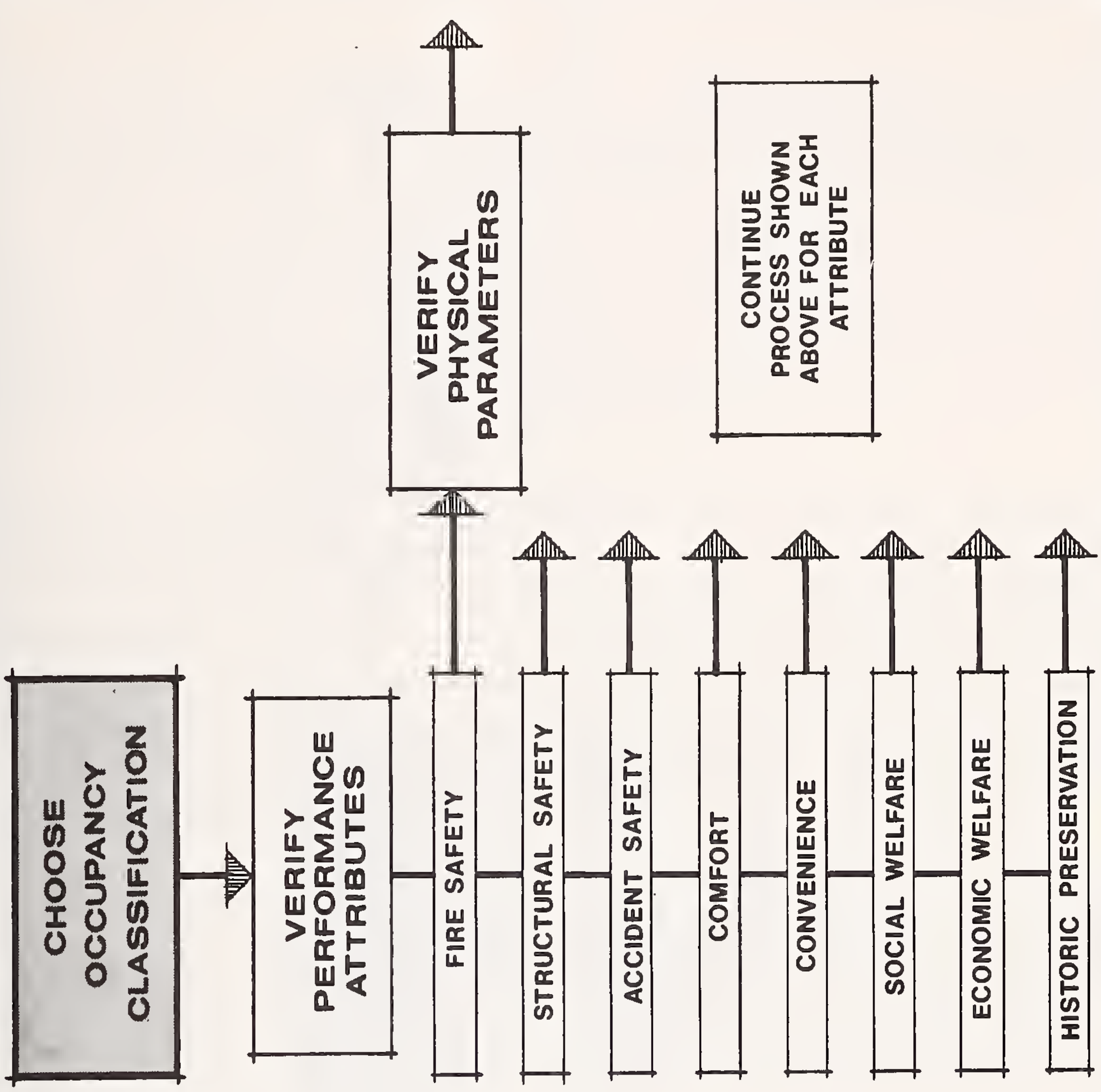

Figure E
FIRST STAGE
NEW CODE FOR EXISTING BUILDINGS

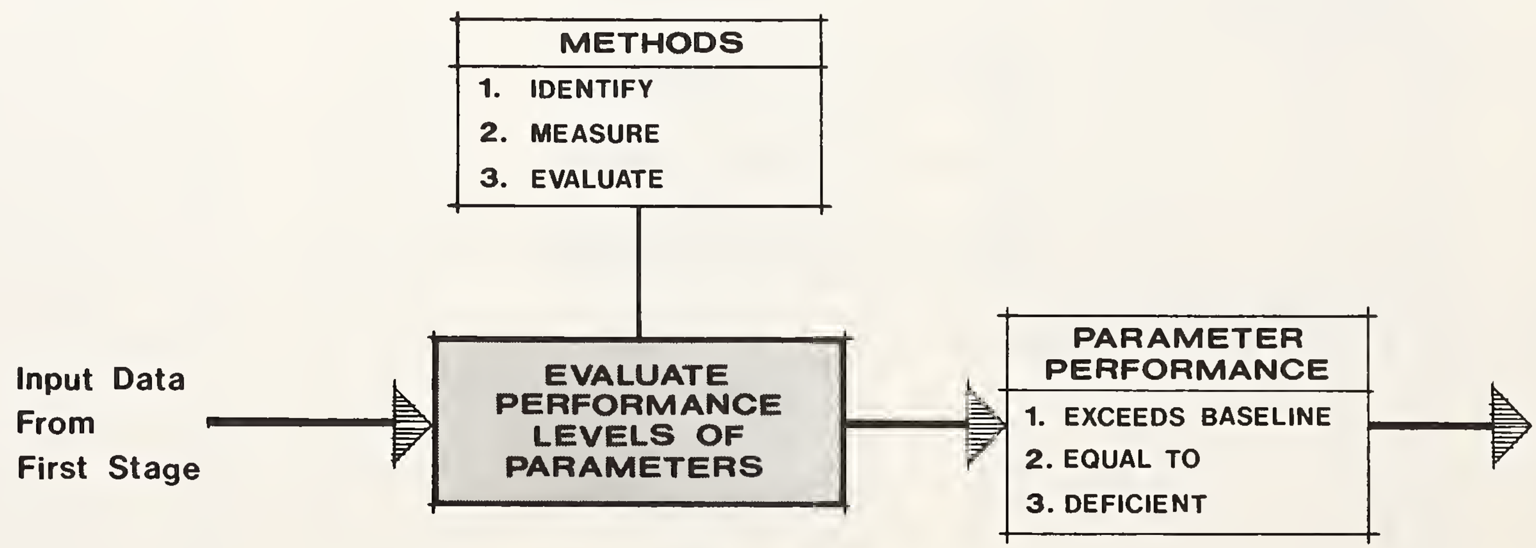

Figure F

SECOND STAGE

NEW CODE FOR EXISTING BUILDINGS

level of performance will not need remedial work. Those which are below the required level, will receive further attention through an improvement method outlined in the next stage.

The fourth stage, as shown in Figure H, includes a mechanism by which the deficiencies can be improved to reach a minimum performance level. Normally, the designer would re-analyze the deficient parameters. In many old buildings, these deficiencies would probably include open wooden stairs, corridor partitions which did not have the necessary fire resistance, exit doors which were not fire resistant, or for instance, an overall low level of illumination. The designer could either improve the deficiency directly, using whatever modern materials and methods he chose, or in the case of the open wooden stair, for example, he could possibly increase the performance level of one of the other parameters under the safety attribute to produce the necessary counterbalancing affect.

This action to improve another physical parameter to counterbalance a deficient one can be accomplished through the addition of trade-offs. These physical entities, when added to the building, increase the performance of a specific parameter and ultimately of a performance attribute. The degree to which the trade-off will increase the performance is poorly understood at this time. One trade-off which is recognized now by the model codes is the addition of a fire extinguishing system. Most code officials will agree that this will counterbalance deficiencies in safety performance, but a quantitative value for this degree of improvement is not known at this time.

The whole topic of trade-offs warrants a good deal of investigation. Trade-offs seem to fall into two groups. The first are sometimes referred to as technical trade-offs. These include the addition of a physical entity to the building. Some items which fall into this category, besides fire extinguishing systems are: smoke detection, heat detectors, the sophisticated alarm communications systems, and chemical treatments which increase the fire resistivity of materials.

The second type of trade-off is the concept of operational controls. Generally this implies the control, guidance or manipulation of people in a building to ensure that if a disaster strikes, such as fire, that the minimum loss of life would occur. These can include the limiting of the number of people allowed in a given space, the training of the occupants in evacuation methods, or the acknowledgement that persons who are habitually in the same space, become familiar with the exit facilities and can exit more quickly than strangers could. Operational controls are, thus, a method of controlling the occupancy of certain portions of the building. Essentially, by controlling the occupancy, the apparent risk for that part of the building is controlled.

These controls have to be tested and given some quantitative value so that their counterbalancing effect on a deficiency can be known. Currently, the model codes recognize very few operational controls. The latest National Building Code, however, does permit one

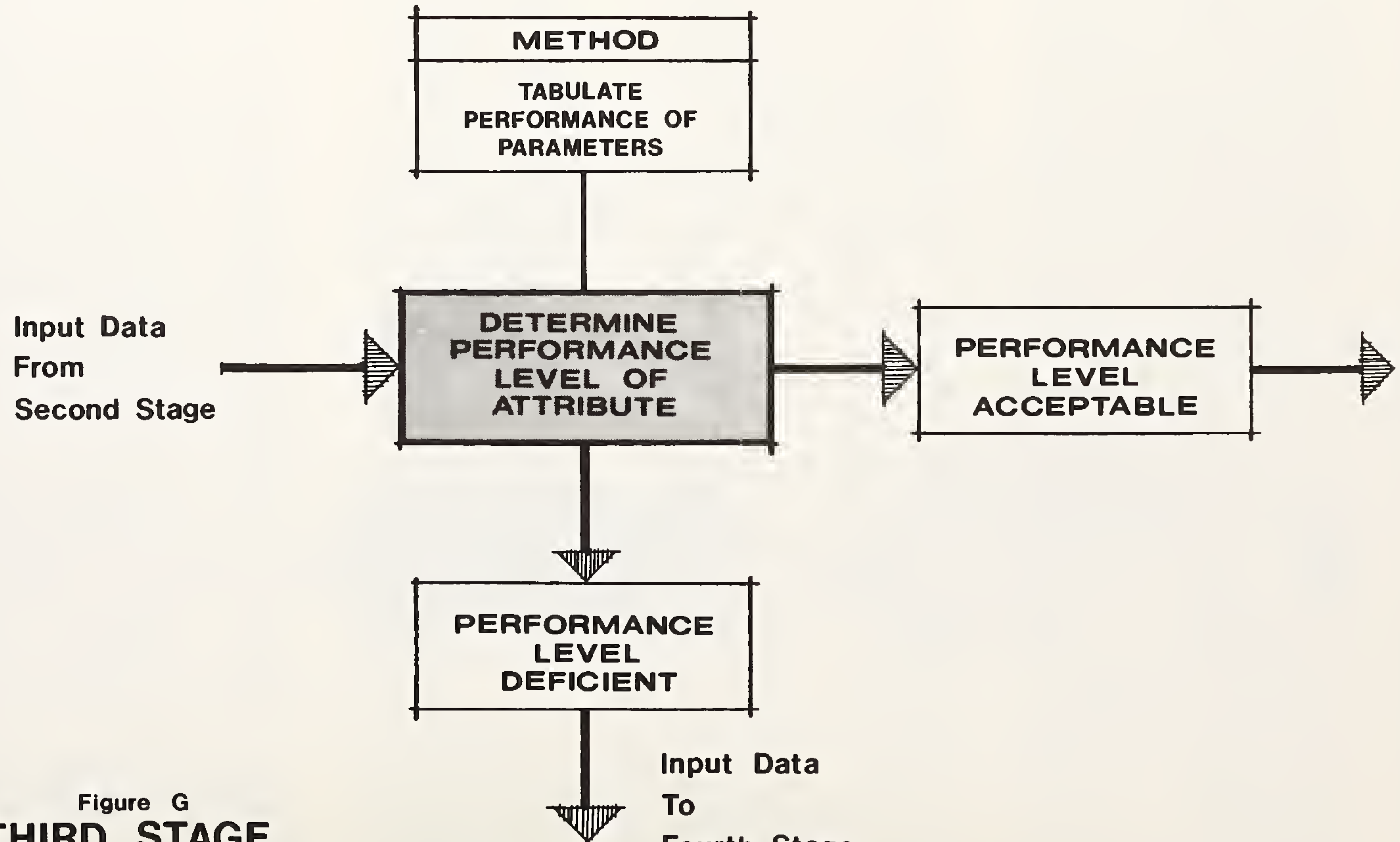

Figure G
THIRD STAGE
NEW CODE FOR EXISTING BUILDINGS

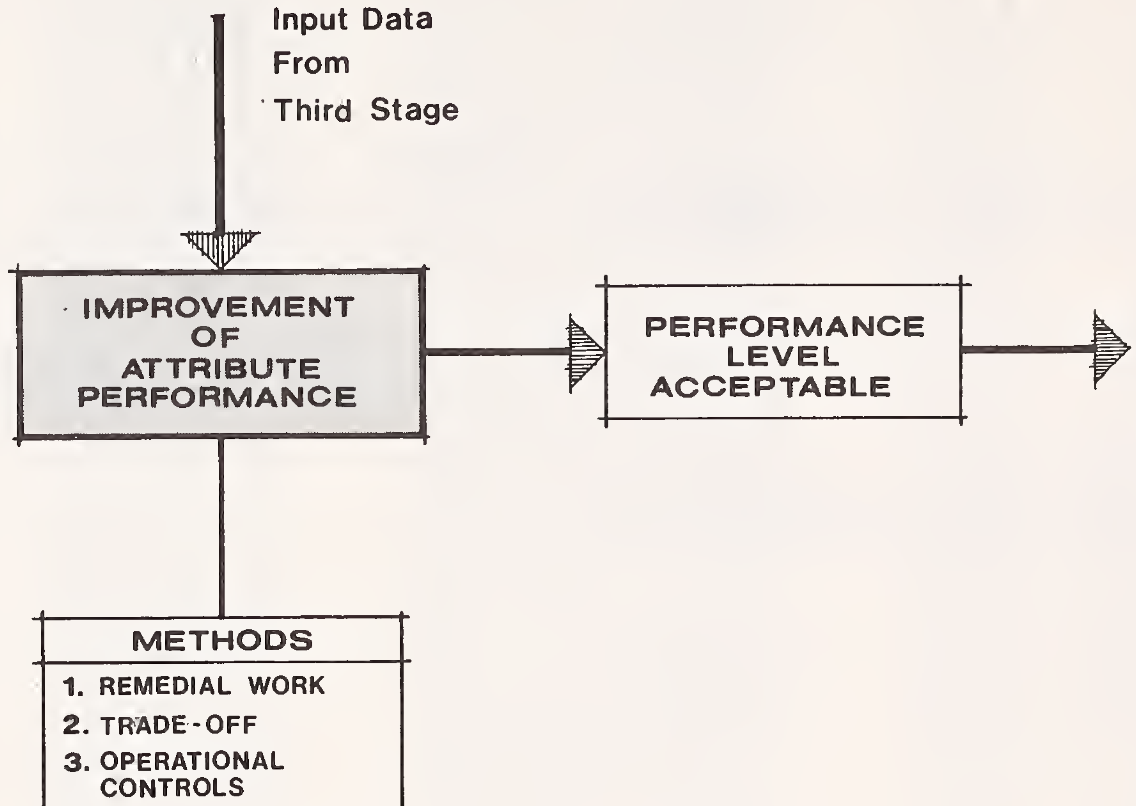

Figure H

FOURTH STAGE

NEW CODE FOR EXISTING BUILDINGS

means of egress from an historic building of less than three stories if the "Visitors are admitted by guided tours or there are supervisory attendants in all the areas accessible to the visitors."[27] These operational controls, and others, need more research and testing to be developed into recognized trade-offs.

This stage of the process provides the mechanism for the designer to improve the deficiencies of the performance attributes. Trade-offs, operational controls, or remedial repair work will increase the deficient performance to a level which meets the minimum standards.

At this point, the entire decision process is complete. That process, shown in Figure J, includes four stages. In the first stage, the designer chose the occupancy classification and verified the performance attributes and the physical parameters of each. Then, in the second stage, each of the physical parameters were identified, measured and evaluated, with the results carried into the third stage. There, the performance levels of the eight performance attributes were determined by tabulating the values of the individual parameters. In the fourth stage, through remedial work, or the addition of technical trade-offs or operational controls, deficient attribute performance was improved. The result was that all performance attributes met the required levels of performance.

SUMMARY

This investigation has made one attempt at analyzing the probems which existing buildings face in code compliance. This compliance causes, from the viewpoint of preservationists, the needless destruction of architecturally and aesthetically important building features, the unnecessary replacement of serviceable building materials and systems and apparently increases the costs of these preservation and rehabilitation projects.

This affect of code compliance on existing buildings seems to stem from the following eight characteristics of the model building codes.

1. The performance levels which a building must meet have risen throughout this century.

2. New performance attributes have been added for which there are new building code requirements.

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[27]American Insurance Association, National Building Code, 1976 (New York: A.I.A., 1976), Section 1709.6 (b), p. 505.

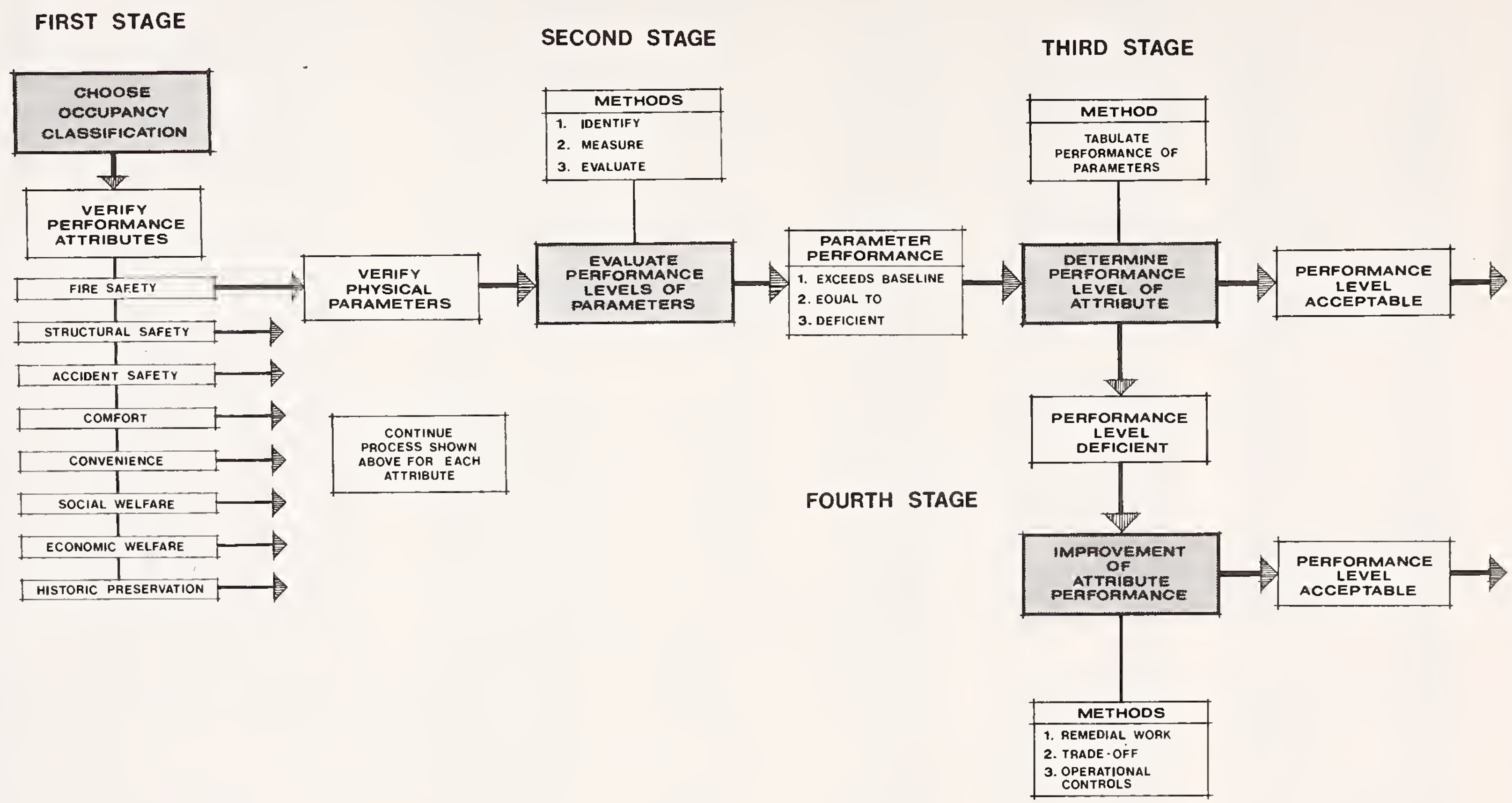

Figure J
ENTIRE
DECISION PROCESS IN THE NEW CODE FOR EXISTING BUILDINGS

3. As new performance attributes were added to the model codes, problems resulted.

4. The decision process of the model codes is applicable only to new construction and does not lend itself to projects in existing buildings.

5. The various prescriptive standards of the codes are based on modern materials and do not include information about older materials.

6. The various prescriptive standards are based on what might be called standard modern building configurations.

7. Reference standards make it difficult to determine exactly what is required.

8. Information which is included about older materials, specifically fire endurance ratings, may not be an accurate indication of the performance of the material.

With these problem areas and cause-effect relationships in mind, this report has presented a concept, structure, and decision process for a possible new code or standard for use with existing buildings.

The decision process of the new code presented here judges the building for its performance in the eight performance attributes, not according to the rigid prescriptive requirements of the model codes. The process was conceived to relate directly to the conditions present with existing buildings, conditions which differ markedly from those present in new construction.

This new code or standard would fully and accurately evaluate all existing materials and systems through numerous standard on-site test methods and through the inclusion of extensive information about the physical properties and performance data for these old materials. This evaluation would hopefully eliminate the needless replacement of serviceable materials, and at the same time, provide an accurate picture of the actual performance capabilities of the existing building.

This evaluation procedure identifies a spin-off value of the new code to the preservationist as he prepares a feasibility study for a project in an existing building. Just as the model codes aid designers in the design of new buildings by fixing building size, configuration and structural systems, this new code would provide a method for the designer to accurately assess the condition of the building and determine the amount of remedial work necessary to bring the building up to the required performance levels. This, in itself, may greatly contribute to, and increase, the preservation of old buildings.

Finally, the new code would include sound, recognized methods for identifying and improving deficient attribute performance. This improvement would be achieved through remedial work, or the addition of technical trade-offs and operational controls. These trade-offs would increase attribute performance, which would allow certain physical entities within the attribute, for instance, an architecturally important open wooden stair, to be retained.

If this concept for the new code or standard for existing buildings were fully developed into a working document, the end result ought to be an existing building, of any type or description, which would fully meet the performance levels established for new construction, while at the same time, retaining historically important building features and reusing serviceable materials, all at a reduced project cost. As was pointed out however, for this concept to be transformed into a working document, a good deal of further study, research and development would have to be undertaken. Hopefully, this investigation will stimulate just such an effort.

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CONTRACTOR UNDERSTANDING RELATIVE TO REHAB COSTS

by

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The nature of rehabilitation, with its nonvisible elements and its potential for self-help, makes it extremely difficult to accurately estimate the costs involved. The uncertainty is passed on by the Contractor in the fees he charges. Uncertainty exists, as well, in the standards for accomplishing the work at hand. Specifications are normally cumbersome, Work Write-Ups lacking in detail. Therefore understanding is diminished, and costs rise, while quality falls below standards.

With the pending increase in neighborhood code rehabilitation projects, there is the need to increase the supply of competent contractors interested and experienced in rehab. This requires both a method for offering standardization of specifications and work-write-ups with more detail, and the ability to assure a steady flow of work into bidding channels.

Key Words: Building codes; community development; construction costs; contractors; housing; standards; rehabilitation.

Local ways of Code Administration make coats of many colors. There is much variety, and much misunderstanding. It has taken the loss of thousands of lives and billions of dollars to get codes where they are today. Yet on a court docket comprising one murder, two rapes, and four auto thefts, a leaking drain does not sound very important!

True, to the family downstairs, that leaky pipe may mean a sinkful of someone else's sewage. To the property owner, however, it has meant harassment, and police type enforcement. To the Contractor, who will eventually be called in to repair the situation, it means simply another job, one with some sticky red tape and possible delay in getting both payment and certification of inspection. Understanding of the code involved has gone astray. Instead, bureaucracy has been given another demerit. The family downstairs? They moved. Better plumbing meant higher rent!

Our subject: "CONTRACTOR UNDERSTANDING," that is his understanding of the reasons behind the code, what the code specifies, and what he must do in order to meet those specifications. All of which is "RELATIVE TO REHAB COSTS."

What does rehab cost, and what is involved? A good example is a recent one-day processing of 57 single family owner-occupied structures by our firm. The rehab dollar in Code Violations alone was $283,536.78. There were 3,445 such deficiencies found in these properties, or an average of 60 per structure, at a repair figure of near $5,000.00 for each homeowner. I might add, these properties were not in a so-called blighted area.

It is interesting to note that there seems to be understanding in some areas regarding the cost of rehab. Major building trade unions in New York City say they'll accept 25 percent cuts in wages and fringe benefits on HUD-sponsored rehab. First okays came from carpenters, roofers, painters, bricklayers, marble masons, plumbers and laborers. Others are considering it. Unions will take time and a half for overtime, instead of double-time, cut out travel time and expenses, and are cutting back on some other items. HUD, by the way, has approved money for rehabbing over 3,000 apartment units in that city. In anybody's book, that is a lot of code problems being cleaned up.

Actually, the nation's stock of housing has been deteriorating faster than it has been replaced or maintained. This is especially the case in core areas of older cities. At the same time, the population is increasing and the nation has goals of higher quality housing for all people. Remember, however, the single most important asset of any community is its existing housing supply. It will be there, for the most part, in the year 2005. The operation of local government, that includes many of your paychecks, is dependent, to a large degree, on residential real estate taxes. Repair and/or maintenance of it must be kept in line financially, as well as in the intent of the codes involved.

In many areas, Code agencies have come to realize that running a complaint bureau and prosecuting lawbreakers in the courts has not kept many dwelling units in good condition. This passive and punitive approach has caused them to fall further behind. Now they are becoming more actively aggressive at establishing routine inspection periods for all dwelling units. In addition, they are shifting the emphasis from court summons to getting the property repaired via Community Development and other programs.

At this point, I hope you understand that rehabilitation programs are spurring the clean-up of major code problems. Contractor understanding is vital here, in order to keep costs at an even keel, and code concurrence of work performed at the highest level, even if sometimes, regulatory agencies must bend a little in standards.

For those of you who can see what is happening through such programs, but point out that you are in the regulation of new construction, I contend the same level of understanding is needed for contractors working with you!

Why? Let us look very quickly at some of the great problems that will affect cities over the next few years. Perhaps the greatest problem that we will have to contend with is sheer urban growth!

Let me give you some idea of what is anticipated. At the very least, the population of the United States within the next 30 years will increase by 150 million people, even assuming that birth rates will decrease. Therefore, the population of the country is going to approximately double by the year 2005. Now, what does this imply for cities. At the very least, it means that we are going to have to build, in 30 years, some 500,000 miles of urban streets, sewers, water mains and light systems. We are going to have to supply 40 million or more dwelling units, and it may be as many as 60 or 80 million. We will need at least 100,000 primary schools, 30,000 high schools, 3,000 universities, colleges and community colleges, at least 7,000 major general hospitals, 10,000 to 20,000 municipal parks and playgrounds, and more than six billion square feet of office space. All of this adds up to a minimum public investment for the American people over 30 years of 2.5 trillion dollars, at current expenses. That is a lot of money, activity and effort demanding a lot of understanding.

In general, our review of contracting procedures across the country has revealed that there is some similarity in the approaches used, but that these represent a rather narrow range of the possible options. We have concluded that these approaches are inhabiting the growth of the industry and discouraging the entrance of larger contracting firms into the community development field.

What we find instead, due to a lack of sufficient scale in most areas and profit potential, is the smallest of local contractors and handymen who are short of management expertise, financial capability and even craftmanship.

The nature of rehabilitation, with its non-visible elements and its potential for self-help, makes it extremely difficult for them to accurately estimate the costs involved. The uncertainty is passed on by the contractor in the fees he charges. Uncertainty exists, as well, in the standards for accomplishing the work at hand. Specifications are normally cumbersome, work write-ups lacking in detail. Therefore, understanding is diminished, and costs rise, while quality falls below standards.

With the pending increase in neighborhood code rehabilitation projects, the key ingredients would appear to be the precise definition by the housing inspector of the work to be done; an increase in the supply of competent contractors interested and experienced in rehabilitation; and the ability to assure a steady flow of work into the bidding channels. Above all, we must educate those responsible for the actual work, with respect to quality, about code standards. Somehow, the big code books must be broken down into simple terms that clearly show how the work must be done.

Our firm has taken the approach of moving the time consuming work of preparing bid documents out of the office, and into a computerized form to effect standardization. This appears to short-circuit the slowness of imput to bid, as well as providing a method of presenting the task in writing with quality and detail understandable to all.

What happens when this is done, is that administration becomes less of a chore, and therefore, more productive. Contractor understanding has improved, more properties are being fed into the bidding circle, and more contractors, large and small, are vying for work in our areas of operation thus reducing even more the rehab cost.

While the computer may hold the answer for some, we know the majority of rehabilitation will be carried out in a straightforward manner devoid of much which could be labelled high technology.

The typical rehab contractor operates in much the same way as the small house builder making the normal trade-offs between labor and materials costs in deciding between alternate construction methods and products. The usual project is normally small in scale so that site organization in terms of men, equipment and materials is relatively simple. In fact, for a single house rehab contract it is unusual to find more than four to six men on the site at any one time.

The contruction methods used in the work vary, of course, with which items in the house are being rehabilitated and it is not possible to describe all the techniques in detail in an overview such as this. It is of interest to note, however, that there is a market for repair and rehab products and that this demand has spurred the development of some products used almost exclusively in this type of work. These include: aluminum siding, screw-on double windows and blow-in insulation, together with numerous patching and painting materials.

It is difficult to separate the rehab products market from that of new construction. The latter is by far the larger market so that most products are developed for it primarily and rehab contractors must adapt these products to the needs of their work. So must codes be adapted to recognize the legitimate differences of age, building type and market conditions that exist in different neighborhoods. That is what I meant earlier by the word "bend" and, of course, this is the very nature of rehab. Sometimes the product called for by code can not be used in the property, without jacking the cost beyond reality. By the same token, some standards must be downgraded for rehab, since they are out of line for the building's present use or occupancy.

A good example is what is sometimes required in the electrical code. Too often we see several hundred dollars or more dumped into a house occupied by one elderly woman who has a life expectancy of just a few more years. Her needs are not what the standards call for in number of outlets, etc., but because of the money we spend to meet these standards, we must overlook other repair items. We should bend here, and pick these items up when the house has a new owner or tenant. This can be done as some communities are doing with a certificate of occupancy inspection. Meanwhile, this lady's comfort in general living conditions such as first floor bedroom and bath, fresh paint, etc., will enhance a health code requirement and be money spent in a better interest. After all, how many super hi-fi- stereo's, C.B. radios, micro-wave ovens will she be plugging in?

This is where regulatory agencies must bend a little at times, in order to get many other defiencies cleared up. By the same token, we in rehabilitation, must begin to make the contractor's job easier, and outline the task ahead as clearly as possible, with standardization of words and methods. The work write-up is the method by which the violation is to be corrected. It should be precise, especially as to quantity and completeness. Without such quality, the contractor will be unable to make an intelligent bid.

For example, if we call for replacement of rotted siding, we should be specific about the quantity. Similarily, if we not only want the siding replaced, but also painted, we should say so and not assume that the contractor will figure it in his bid.

Also, we should avoid language like "check" roof for leaks. If the roof leaks, then we should call for its repair or replacement. How can the contractor otherwise make a bid without making his own judgement about the quality of the roof. If this approach is employed, then it is the contractor and not us who is performing the inspection.

The work write-up identifies which part of the property has to be worked on, what has to be done and the quantities involved. It does not cover things like the minimum standards to be observed in choosing materials and construction techniques. These items are essential, however, if the bids, cost estimates and owner expectations are to be comparable.

To illustrate: If the work write-up calls for painting, the contractor should have a set of standards which tells him the minimum quality of paint acceptable and the level of surface preparation required. Without this kind of direction, each contractor could conceivably base his bid on paint brands widely different in price and on surface preparation techniques with a similar price variance.

Regardless of the contractor selection techniques employed, the contractor's bid will have to be reviewed. Making this review will be easier if the contractor has to bid on an item-by-item basis as opposed to a lump sum method only. If it is lump sum, we really have no way of telling if the estimate and bid are comparable. The cost estimate total and lump sum bid could be exactly the same and yet there could be wide discrepencies in what we think will be done on the house as compared to what the contractor thinks he has to do.

For example, both the contractor and we may agree on the lump sum price of say $5,000.00. However, if the Contractor has seriously under-estimated the amount and therefore the cost of one item, while seriously over-estimating the scope and therefore the cost of another item, the result will be dissatisfaction on our part with the work done on the item which the contractor has underestimated.

We cannot accept a bid which is either too high or too low. If we accept a bid significantly below our estimate, there is the risk that the contractor will be unable or unwilling to complete the job. Further, he may try to make up for his error by skimping on various parts of the job. Even if neither of these things happen, he may be so seriously injured economically, that he cannot continue after finishing the job.

If this were to happen, the code enforcement rehabilitation program could be deprived of a contractor who is beginning to understand, one who is doing good work, and helping to clean out the code deficiencies in the neighborhood.

In summation, the contractor is the vital link to rehab in the intent of the code, and to meeting our housing goals. We must bend at times to make the program work, yet we must educate all concerned as to what codes are and what is expected by compliance. We must be prepared to make the contractor understand what is expected of him, make his job easier by being precise. If he can make money, he will stay within our guidelines, and perform as often as we will need him. The message is "CONTRACTOR UNDERSTANDING. . .IT IS RELATIVE TO REHAB COSTS."

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