NATIONAL BUREAU OF STANDARDS REPORT

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FINAL REPORT
ON
BUILDING ECONOMICS STUDY PROGRAM
PHASE I--ANALYSIS & SUMMARY

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards [1] was established by an act of Congress March 3, 1901. Today, in addition to serving as the Nation's central measurement laboratory, the Bureau is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To this end the Bureau conducts research and provides central national services in four broad program areas. These are: (1) basic measurements and standards, (2) materials measurements and standards, (3) technological measurements and standards, and (4) transfer of technology.

The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

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THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System, and provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—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.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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PHASE I--ANALYSIS & SUMMARY

by
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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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BUILDING ECONOMICS STUDY PROGRAM
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McGraw-Hill Information Systems, Inc.
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Ralph M. Parsons Co.
1000 - 16th Street N. W.
Washington, D. C. 20036

Weinroth Associates Inc.
7235 Wisconsin Avenue N. W.
Washington, D. C. 20014

FOREWORD

This report is concerned with the economic analysis and costing process for the construction of Federal buildings and facilities. It is based upon personal interviews with knowledgeable individuals in both Government, and U. S. and foreign private industry as well as an extensive review of literature on the subject.

This study, as joint effort between the National Bureau of Standards and several agencies, was undertaken to provide back-ground material for future participation by Federal agencies in exchanging cost data,information and management in order to facilitate Government design,construction and maintenance operations.

This report will be reviewed and commented on by the participating Federal agencies.

The Building Research Division gratefully acknowledges the cooperation and assistance of the individuals who provided the information presented herein.

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INTRODUCTION

Purpose and Scope of Report

This is the final report on the analytical phase (Phase I) of the building economics study program.[1] This report is concerned first, with summarizing the current state of the art of building economics,[2] and with presenting the research efforts in building cost data,[3]

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[1] Several state of the art and progress reports have been furnished to the sponsors of the program during Phase I. A list of these reports is included in Appendix A herein.

[2] As used herein, building economics is the science concerned with how men and society choose to employ scarce productive resources to produce buildings over time and distribute them for use, now and in the future, among various people and groups in society. At the societal level, the science is concerned with the relationship between the total productive and consumptive capabilities of the Nation and those of the building industry -- a diversity of interest groups, business/industrial/financial enterprises, trades and professions, regulating bodies, and individual owners/operators/managers of buildings and structures. At the industrial level, the science is concerned with the relationship between the factors of production consumed in the building process -- programming, planning, design, construction, operation, maintenance, repair, improvement, and retirement of buildings -- and the utility of the output of the building process.

[3] As used herein, building cost data are facts which pertain to the economic resources invested in or expended on buildings.

building cost information, [1] and building cost management[2] to be undertaken in the next phases of the program. In the main, this report is focused upon building economics at the industrial level.

Background

The building economics study program had its genesis in the task to develop a performance specification for federal office buildings, a task undertaken by the Building Systems Section in April 1967 at the request of the Public Buildings Service. In the early stages

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[1] As used herein, building cost information is knowledge derived from building cost data, most particularly with respect to knowledge about how decisions made in some phase of the building process are reflected in the building cost data subsequently accumulated for a particular building or structure.

[2] As used herein, building cost management comprises, in sequential order:

- Planning - determination of economic resources needed and their necessary order of commitment in order to achieve the facility objective inherent in the organization's program objective.
- Allocation - determination of proper distribution of available economic resources among all the facility activities in order to achieve some measure of effectiveness in the organization's program objective.
- Scheduling - determination of proper timetable for committing economic resources to facility activities within the limits of internal and external constraints.
- Controlling - determination of actual deviations from the desired distribution of and timetable for committing economic resources, evaluation of the impact of the deviations on some measure of effectiveness in the organization's program objective, and iteration of the preceding steps to minimize or maximize the expected impact of the deviations on the organization's program objective.

Within an individual organization, building cost management is practiced at both strategic and operational levels. Building cost management at the strategic level is concerned with all facility projects undertaken as part of an over-all organization program; building cost management at the operational level is concerned with an individual facility project undertaken within the framework of all the facility projects of the organization.

of pursuing the task undertaken, the Section determined that full exploitation of the performance specification notion would be seriously constrained by the dearth of building cost data and information essential to making rational choices in the design phase of the building process between material and building costs and building performance. Consequently, the Section asked for, and received from, the Building Research Division, Institute for Applied Technology modest funds for exploring how building cost data are derived.

During this initial effort, prevalent American building and construction cost indexes were examined, the affirmative and negative attributes of the British quantity survey method were investigated, and the operations of a national building cost system, the Swedish Building Data Central, were explored.

Based upon this initial work, the building economics study program was initiated in 1968, with increased funding by the Building Research Division as well as by funding from several other federal agencies having building program responsibilities. (The funding status of the program is shown in Table 1.)

Table 1. Fiscal Year Funding Obligations for the Building Economics Study Program

(In $1,000)

Agency	Fiscal Year 1968	1969	1970
U.S. DEPARTMENT OF COMMERCE (NBS)	$24.50	$52.00	$17.00
U.S. POST OFFICE DEPARTMENT		7.15	
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (NIH)		10.00	
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (OE)		5.00	
U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT		10.00	
VETERANS ADMINISTRATION	8.75	9.00	14.00
GENERAL SERVICES ADMINISTRATION (PBS)		32.00	
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION			10.00
TOTAL	$33.25	$125.15	$31.00

Objectives and Conduct of Study

The immediate objectives of the first phase of the program have been (a) to define the over-all objectives of the building economics study program, and (b) to determine what program tasks could and should be undertaken in succeeding phases which would be of benefit to federal agencies having responsibilities for building programs.

In pursuit of this immediate objective, the initial work, in 1968, comprised wide-ranging discussions between the program staff and cost consultants, data and system analysts, and

individuals having responsibilities for major building programs in private and non-federal governmental organizations. Subsequently, in April 1969, a contract was let to the joint venture of Smith,Hinchman and Grylls Associates, Inc. and McGraw-Hill Information Systems, Inc. to (a) study the building cost information needs of federal agencies and (b) determine whether private and non-federal governmental organizations had similar needs for building cost data and information.[1]

Concurrent with the efforts of the joint venture, the program staff initiated exploration of topics related to the task at hand, namely, definition of performance of materials, description of methods of building, definition of standards of housing acceptance, identification of building cost forecasting techniques, and identification of the decision-making sequence in the building process. At the same time, the staff took pains to establish or improve contact with other federal agencies or offices mounting substantial efforts to reduce the cost of federal construction.

Moreover, in early September 1969, as an outgrowth of the Office of Management and Budgeting, Bureau of the Budget, directing the National Bureau of Standards to be responsible for the transference of the latest technical building information among federal agencies, a series of federal workshops on building technology were convened. One of these workshops, moderated by the program staff, was concerned with two aspects of

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[1] State of the Art reports about individual agencies were previously furnished to the program sponsors as working papers. These reports are listed in Appendix A herein. The joint venture's summary of this activity as well as explanation of the survey conducted are being furnished to the program sponsors as working papers, designated, respectively, Annex A and B of this report.

building economics -- construction cost estimating and building cost management.[1]

Based upon the discussion had at this workshop, which discussion indicated that substantial interest existed within the federal agencies to improve drastically building cost management practices, a contract was let to Ralph M. Parsons Co. to (a) define the total building process and the points at which major cost decisions are made and (b) describe the economic advantages and disadvantages of various methods of building.[2]

Concurrent with this contract effort, the program staff, assisted by Weinroth Associates Inc., has been directing its efforts toward establishing the matrix within which a building economics study program responsive to the needs of federal agencies should advance.

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1 The report on this workshop was previously furnished to the program sponsors.

2 The report recently generated by the contractor is being furnished to the program sponsors as a working paper, designated Annex C of this report.
At this time, the Washington office of the Ralph M. Parsons Company is defining, by building type, cost standards for the total building process including the in-use phase, and is identifying the performance levels that contribute to cost.

II

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Findings

General

1. Building economics is of increasing interest to federal and non-federal governmental agencies and private organizations involved in the planning, design, construction, operation, maintenance, repair, improvement, and retirement of buildings.

2. In large measure, this interest is heightened by recent, rapid, largely unanticipated increases in the cost of construction, operation, and maintenance of buildings, and is evidenced by increasing conversations about such topics as implementation of life-cycle cost concepts, use of network analysis in construction administration, use of prefabricated or pre-engineered components (including relocatable structures), use of turnkey (one-step, two-step, and other) procurement methods, expanded use of contractor quality control specifications, greater use of standard designs and commercially available products, use of stronger warranty and guarantee clauses, use of total design-construction-maintenance bids, and reduction of seasonal variations in construction activity.

State of the Art

1. Building cost management is practiced at both strategic and operational levels, but emphasizes planning, allocation, and scheduling at the strategic level and controlling at the operational level.

2. Building cost management is constrained at both strategic and operational levels by the extreme lengths of time involved in the complete building process as well as in its individual phases, and by the changes in economic, sociological, and technological conditions that inevitably occur during the process.

3. Building cost management is handicapped at both strategic and operational levels by lack of realistic forecasts of economic resource requirements and by lack of definition of performance attainable.

4. Building cost information is sought at each phase of the building process, but the kind of information primarily sought at each phase tends to vary as follows:

Phase of the Building Process	Kind of Building Cost Information
Analysis of Needs	Initial and life cycle facility cost
Design	Facility and materials performance and cost
Construction	Construction manpower and material performance and cost
In-Use	Activity, facility, and material performance and cost

5. Building cost information is synthesized in highly individualistic fashions from accumulated and transformed building cost data, but most often without rigorous consideration of wider economic, sociological, and technological changes inherent in previously accumulated data and apt to influence data collected in a future period.

6. Building cost data are used at each phase of the building process, but the kind of data used at each phase tends to vary as follows:

Phase of the Building Process	Kind of Building Cost Data
Analysis of Needs	
Determination of facility requirements	Unit of capacity and space cost
Planning of facility	Space cost
Programming of facility construction	Space cost
Design	
Schematic design of facility	Space cost and/or system cost
Preliminary design of facility	Space cost, system cost and/or unit cost
Final design of facility	System cost and/or unit cost
Construction	
Analysis of facility construction bids	System cost and/or unit cost
Control of construction contract payments	Unit cost
In-Use	
Operation/maintenance/repair/improvement	Space cost, system cost and/or unit cost
Activity operation	Activity cost

7. Building cost data are generated only in the construction and in-use phases of the building process, and only with respect to a particular facility in a particular place at a particular time.

8. Building cost data are accumulated by disparate means in different places by different organizations, but most often in the form of price (expressed in current dollars) per unit of measurement of materials furnished or installed, amalgamating within the price the cost to the contractor of labor and material specifically devoted to the particular facility, the ancillary cost to the contractor of conducting a business, and the minimum acceptable rate of return of the contractor.

9. Building cost data are transformed from the kind of data accumulated to the kind of data used in other phases of the building process by disparate means by different organizations, but most often by utilizing some area, capacity, or volume parameter of the facility as a common denominator and adjusting the result by historical constants and indexes to reflect geographic and time displacements.

Research

1. Building economics research is not a separately identifiable research activity in either private or governmental research endeavors; what little building economics research is being pursued is, for the most part, incorporated in market studies for individual industrial products, management analyses of either a governmental or private real property development organization, and general or specific studies of low-and moderate-income housing.

2. Research efforts directed toward developing either inter-federal agency or national building cost data and information systems are, at best, seedling efforts looking to accumulate and transmit (a) construction price data and (b) facility, system and component description data.

3. Research efforts directed toward advancing building cost management are primarily concerned with improving control at the operational level.

Conclusions

1. Building cost management decisions made in the analysis of needs phase of the building process are a major determinant of the initial and life cycle cost[1] of buildings and structures.

2. Building cost management decisions made in one phase of the building process limit appreciably the technical and operational decisions which can be made in a subsequent phase, and constrain significantly a manager's opportunity to capitalize on beneficial occurrences or to reduce the impact of detrimental events in the subsequent phase.

3. Building cost management decisions made in all phases of the building process are now made on the basis of building cost information individually synthesized from incomplete building cost data, imperfect definition of facility performance attainable, and unrealistic mid-and long-range economic, sociological, and technological forecasts of the environment in which the building and structure will be planned, designed, constructed, operated, and maintained.

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[1] As used herein, initial cost is the value of the economic resources originally invested in buildings, including investment in land and in the programming, planning, and design of buildings. Life-cycle cost is the value of all investments (including investment in land and in programming, planning, and design) made in buildings from the time of their creation until the time of their retirement, including the capitalization of all operation, maintenance, repair, and improvement expenses and investments.

4. Building cost information is now individually synthesized because building cost data are largely individually accumulated and are not readily usable by others.

5. Building cost data accumulated by one organization are not readily usable by another organization because of (a) differences in definition of units of measurement and in methods of cost accounting, (b) absence of description of performance and other criteria specified and attained, (c) lack of methods for rationally comparing the value of economic resources expended on diverse construction-related items in different times and places.

Recommendations

1. The National Bureau of Standards and federal agencies having responsibility for the planning, design, construction, operation, maintenance, repair, improvement, and retirement of buildings should sponsor collectively the building economics study program recommended herein.

2. The objectives of the over-all program should be:
   a. Advancement of the science of building economics
   b. Improvement of the practice of building cost management
   c. Progress in the state of the art of building cost data and information systems.

3. The principal ingredients of the over-all program should be:
   a. Studies and seminars designed to determine and measure
      (1) dynamic equilibrium between the supply and demand capabilities of the Nation and those of the building industry

(2) cost and utility (to whomsoever it accrues) of the building process.

b. Studies, seminars, and workshops designed to develop and promote the use of scientific methods, techniques, and tools of building cost management.

c. Research, development, test, and evaluation of building cost data and information systems to be used collectively by federal agencies having responsibility for the planning, design, construction, operation, maintenance, repair, improvement, and retirement of buildings.

4. With respect to 3a above, the major components of the next, three-year phase of the program should be:

a. Conduct of a study to evaluate building construction and maintenance activities (as well as related service activities such as architect-engineer design, mortgage finance, and real estate brokerage) as a factor of production in the Nation's economy.

b. Conduct of a study to evaluate the building process as a factor of production in the following federal activities and programs: general agency administration, higher education and school facilities construction, health facilities construction, and housing programs.

c. Conduct of a study to evaluate building and related code specifications as a determinant of the initial cost of construction of administrative, educational, and health facilities as well as of single- and multi-family dwellings.

d. Conduct of a study to evaluate design and construction methodology as a determinant of the initial cost of construction of administrative, educational, and health facilities as well as of single- and multi-family dwellings.

e. Conduct of a study to evaluate the cost and utility of different levels of maintenance of roofing, flooring, exterior and interior finishes, heating, ventilating, and air conditioning systems, and lighting and plumbing fixtures.

5. With respect to 3b above, the major components of the next, three-year phase of the program should be:

a. Organization of a discipline of scientific value engineering methods, techniques, and tools applicable to administrative, educational, and health facilities as well as to single- and multi-family dwellings.

b. Development of scientific methods, techniques, and tools applicable to analyzing the process of replacing components (such as those enumerated in 4e above) and complete facilities which deteriorate or become obsolete.

c. Development of scientific methods, techniques, and tools applicable to analyzing bidding strategy for construction of federally-owned or - sponsored administrative, educational, and health facilities.

d. Development of scientific methods, techniques, and tools applicable to analyzing space allocation within federally-owned or - sponsored administrative, educational, and health facilities.

6. With respect to 3c above, the major components of the next three-year phase of the program should be:

a. Development of a uniform chart of accounts, including definition of cost parameters contained therein, for federally-owned or - sponsored administrative, educational, and health facilities.

b. Development of a construction and in-use cost data accumulation, processing, and transmission system for use by federal agencies in regard to federally-owned or - sponsored administrative facilities.

c. Conduct of a study to define in detail the building cost information flows in the building process of federally-owned or - sponsored administrative facilities.

7. The funding in any fiscal year of the over-all program outlined in 3a,b, and c above should be proportioned 20, 40, and 40 percent respectively; the budget for the next, three-year phase of the programs should be $500,000 in the first fiscal year, $550,000 in the second fiscal year, and $605,000 in the third fiscal year.

III

DISCUSSION

State of the Art

Organizations with building program responsibilities have traditionally performed economic analyses of proposed ventures in building investments. Additionally, these organizations have generally applied customary industrial practices to building cost management. Indeed, in the years since World War II, they have either developed or adapted from other sources many concepts and techniques to aid in making investment decisions and in managing the building process.[1] However, in times of great economic/sociological/technological change, such as that which marked the past decade and is apt to be endemic in future decades, these organizations have not been able to apply these concepts with any high degree of certainty. Thus, frequently in the past decade, these organizations have either been unable to make a timely investment in buildings or, having made the investment, been unable to realize the intended investment goal.

The shortage of dwellings, the overcrowding of schools, the deferral of public office building construction -- all bear mute testimony to this predicament of public agencies seeking to discharge their program responsibilites. The increasing frequency with which building cost data, information, and management seminars are attended by representatives of such agencies bears silent testimony to the conundrum of these agenaies about mitigating the predicament. The

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[1] To cite but one example, the critical path method (CPM) now frequently used to manage the construction phase was spawned in 1956 by the E.I. duPont de Nemours Company in its search for possible application of operations research techniques to the company's planning and scheduling of construction projects.

concentration of focus of these seminars on matters merely related to one phase of the building process -- the construction phase -- bears quiet testimony to the lack of perception by all involved to the totality of the science of building economics.

The Science of Building Economics

Reminiscent of Samuelson, building economics can be defined as the science concerned with how men and society choose to employ scarce productive resources to produce buildings over time and to distribute them for use now and in the future, among various people and groups in society[1]. Thus, the science seeks to deal with such questions as:

1. What is the organization of the Nation's building industry?
   a. What buildings, building components, and building materials can the industry produce and in what qualitites?
   b. How -- by whom, with what resources, and in what technological manner -- can the industry produce buildings, components, and materials?
   c. How is the total output of buildings, components, and materials distributed among different productive and consumptive sectors of the Nation?
2. What is the operation of the Nation's building industry?
   a. How does technological knowledge together with finite amounts of capital and labor define the potential output of buildings, components, and materials of the industry?
   b. How is the potential output of the industry controlled by changing costs, the law of diminishing returns, and economies of scale?

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[1] Paul A. Samuelson, Economics (New York: McGraw-Hill Book Company, Inc., 1961), p.6.

As with the general science of economics, building economics comprises both "macroeconomics" and "microeconomic" hemispheres.

In the macroeconomic hemisphere, the science treats of the aggregates of income, employment, and price levels in the building industry, and the relationship between these industry aggregates and those of the national economy. In this hemisphere -- which might better be called the societal level of building economics -- the science is concerned with the relationship between the total productive and consumptive capabilities of the Nation and those of the building industry, a diversity of interest groups, business/industrial/financial enterprises, trades and professions, regulating bodies, and owners/operators/managers of buildings and structures. At this level, the science seeks to deal with such questions as:

1. What is the "net industry product" (measured both by the flow-of-product and earnings-cost approaches) of the building industry?
2. What is the price index by which the "net industry product" of any year or region can be compared to the "product" of any other year or region?
3. How does the Nation's (or a region's or a municipality's)propensity-to-consume and its marginal propensity-to-consume affect the amount of investment likely to be made by the building industry?
4. What is the business cycle of the building industry and how is it related to the cycles of other industries and to the National economy?
5. To what extent can the various outputs of the industry be classified as complementary, substitute, or independent goods as compared to all the outputs of the building industry as well as to the outputs of other sectors of the Nation?

6. What are the momentary, short-run, and long-run demand and supply functions for the factors of production used by the building industry?
7. How can the potential level of output of the building industry be continuously increased, year by year, decade by decade?

In the microeconomic hemisphere, the science treats of the production, cost, and supply functions of the building industry as well as of the demand functions of the consumer for the industry's output of goods and services. In this hemisphere -- which might better be called the industrial level of building economics -- the science is concerned with the relationship between the factors of production (capital, labor, and materials) consumed in the building process -- programming, planning, design, construction, operation, maintenance, repair, improvement, and retirement of buildings -- and the utility of the output of the process. At this level, the science seeks to deal with such questions as:

1. What are the momentary, short-run, and long-run demand and supply functions for various types of buildings, components, and materials?
2. What are the cost and production functions for the various outputs of the building industry?
3. What are the life-cycle cost functions for the various outputs of the building industry and how do standards of design, construction, and repair affect these functions?

One need only note that no one of the dozen or so preceding questions can be rigorously answered to conclude that the science of building economics is a largely undeveloped science deserving appreciable attention.

Building Cost Management

Though the science of building economics is not now well developed, the art of building cost management is far from primitive.[1] This state of affairs is a logical consequence of the facts that

1. Almost from the dawn of history, man has engaged in construction and, for three or four thousand years, has engaged in the building process much as we know it today
2. Even though throughout almost all that time, management of the building process (like all other industrial activity) was largely "rule with a big stick", nonetheless, since the days of the industrial revolution (and certainly for the past half century), management of the process widely employs practices which evolved from the reasoned study of management begun by F. W. Taylor, L.L. Gantt, F.B. and L.B. Gilbreth and others in the early 1900's
3. As division of management functions increased, management of the building process -- like management of other industrial activity -- began to develop and apply scientific industrial engineering, engineering economy, and operations research methods and techniques in the management functions.

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[1] This seeming paradox is quite analagous to the disparity that commonly exists between the businessman's knowledge of economics and his knowledge of day-to-day commerce and finance. In the short-run, one might better go straight to the firing line to learn how to profit in the day-to-day world rather than to study economics. But in times of stress and in the long-run, the businessman with the deeper understanding of the great external forces that constrain his activities is apt to fair better than the one who rushed into an apprentice position.

Managers of the building process function at both strategic and operational levels. At the strategic level, managers are concerned with the total building program which must be accomplished by an organization in order to achieve the over-all program objectives of the organization. At the operational level, managers are concerned with the economic and efficient acquisition and operation of a single building project within the framework of the total building program of the organization. At both the strategic and operational levels, managers are concerned with, in sequential order,

1. Planning - determination of economic resources needed and their necessary order of commitment in order to achieve the end desired.
2. Allocation - determination of proper distribution of available economic resources among all the tasks involved in order to achieve some measure of effectiveness.
3. Scheduling - determination of proper timetable for committing economic resources to the tasks involved within the limits of internal and external constraints.
4. Controlling - determination of actual deviations from the planned allocation and schedule of resource commitment, evaluation of the impact of these deviations on some measure of effectiveness, and the iteration of the preceding steps to minimize or maximize the impact of the deviations.

All four steps do not appear to be accorded equal rigorousness of application throughout the building process. For example, at the strategic level, building cost management appears to emphasize planning, allocation, and scheduling, whereas at the operational level, it emphasizes controlling. And even at any one of the levels, (strategic or operational), the steps are not

accorded uniform concern throughout the building process. For example, at the operational level, particular emphasis is placed upon controlling the construction phase, primarily in an effort to minimize the impact of deviations.

This lack of uniformity in the rigorousness with which building cost management functions are exercised throughout the building process at both strategic and operational levels can have untoward effects on the building program of an organization. It can lead, for example, to the predicament wherein a federal agency cannot have a suitable building designed and constructed within the funds which the agency programmed for the purpose and for which it gained Congressional authorization and approval.

To some degree, this lack of uniformity is a function of the enigmatic decision-making process in the building industry. For example, although the decisions made within one federal agency in order to acquire a proposed facility are easily definable, neither the significance of these decisions relative to the over-all program of the agency nor the costs associated with the possible means and sequences in which such decisions can be made are definable.

To some degree, this lack of uniformity is a function of the absence of methods and techniques suitable for rigorously addressing particular management functions. For example, although there are many methods available for dealing with the controlling function at the operational level, there are few methods readily available for dealing with the controlling function at a strategic level. Similarly, while there are methods available for more or less rigorously dealing with the allocation function at a strategic level, there are no methods available for readily dealing with the second-degree and higher polynomial, step, and other discontinuous relationships that characterize the allocation function at an operational level.

To some degree, this lack of uniformity is a function of the amount of data available at the time particular decisions must be made. For example, although a relatively large amount of cost/performance data about new building products and techniques may be available at the time design decisions are made (say, one or two years in advance of actual construction), little of such data is apt to be available at the time programming decisions are made (say, three or four years in advance of actual construction) which may define the function, location, size, configuration, and cost of the particular facility.

In sum, the feeling cannot be denied that building cost management, though it is far from crude, it still has a higher content of fortune associated with it than precision. If the expression, "one peek is worth a thousand finesses," is valid, then building cost management needs a broader base of building economics science, better methods and techniques, and more complete building cost data.

Building Cost Data and Information

Sir Arthur Conan Doyle, or rather his alter ego, Sherlock Holmes, once admonished: It is a capital mistake to theorize before one has data. Yet, in building cost management, such is the common practice.

The state of the art reports previously generated as part of this study[1] illustrate well the kinds of building cost data and information sought at each phase of the building process at both

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[1] A list of these reports is given in Appendix A herein.

strategic and operational levels of management. Nothing more on this score need be played here.

If one adopts the notions that building cost data are facts (expressed in numbers, words, or pictures) which pertain to the economic resources invested in or expended on buildings and building cost information is knowledge derived from such data, then several salient observations can be made about the data which exist. First, building cost data now comprises primarily initial cost data generated in the construction phase of a particular building in a particular phase at a particular time, and secondarily annual operating and maintenance expense data generated in the in-use phase of a particular building. Second, except with respect to the mechanical and electrical systems of the building or some major components of these systems, the discrete annual operating and maintenance expense data accumulated for a particular building are not readily relatable to the discrete initial cost data accumulated for the same building. Third, neither the initial cost data nor the annual operating and maintenance expense data are accumulated with reference either to the program functions to be served or to the building performance to be provided and maintained. Fourth, initial cost data are accumulated by individual organizations but without reference to either the construction technology employed or the socio-economic environment in which construction contracts are awarded and executed. Fifth, although both initial cost and annual operating and maintenance expense data accumulated by different organizations frequently use the same units of measurement (e.g., dollars per sq.ft.), the units of measurement are often not identical because of differences in definitions adopted. Sixth, other kinds of building cost data (e.g., facts pertaining to the questions raised herein in the discussion of building science and facts relating to the economic life and risk consideration

attending the use of various elements and combinations of elements of buildings) are generally not now accumulated in any form readily usable in the building process. Seventh, the most widely used form of building cost data is the building cost index.[1]

As a consequence of this state of affairs with respect to the availability and content of existing building cost data, building cost information tends to be synthesized by each organization individually and to result in positive feedback in the decision making process rather than the preferable negative feedback.[2] Further, not only is the information within any one organization incomplete but it is not readily relatable to the information synthesized in another organization.

Research Program

Although the tenor of the immediately preceding pages may suggest that the state of affairs with respect to the economic organization and operation of the building industry is nothing but confusion and disorder, such is not the case at all. Without a central intelligence, the industry solves one of the most complex problems imaginable, involving almost an infinite number of unknown variables and relationships. Moreover, though it merely evolved and continues to change as a result of some unknown forces, the industry meets the very first test of any socio-economic organization -- it is able to survive.

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[1] A description of the more prevalent building cost indexes will be included in future work.

[2] In order for an organization to determine if a discrepancy exists between what it is doing and what it intended to do to meet its goals, it must monitor its own activities: it must feed back data about its output for comparison with its input or standard. If the feedback tends to reduce error, rather than aggravate it, the feedback is negative feedback because it tends to appose what the organization is doing.

Accordingly, the primary goal of the research program is not to create a replacement for this industry or, indeed, even to change the industry, but rather to understand it, to appreciate the internal and external forces which govern it, and to determine how its output can best serve the other functions of society. To achieve these ends, tripartite improvements are needed: improvements in knowledge about the science of building economics, improvements in methods and techniques for building cost management, and improvements in building cost data and information.

The Science of Building Economics

One of the major difficulties currently attending the management of a federal agency's building program is the lack of reliability with which the agency can make forecasts of construction and operation and maintenance costs for proposed building. This difficulty is particularly acute in the analysis of needs phase of the building process. In relatively static times, this difficulty is lessened appreciably because rather simple extrapolations can be made from agency - accumulated building cost data and from the prevalent building cost indexes. In relatively dynamic times, this difficulty is not softened by such mechanical exercises of statistical theory, but by realistic appraisal of the answers to the questions raised herein in the discussion of the state of the art of the science at both the societal and the industrial level.

To be responsive to this concern, the research program should include a modest attempt both to bring the current state of knowledge about the economic organization and operation of the industry to the attention of federal agencies having building programs as well as to extend

this current state of knowledge. A useful, and accomplishable initial effort in this direction could be made by conducting a study to evaluate building construction and maintenance activities as a factor of production in the Nation's economy.

Another of the major difficulties is the inability of a federal agency to appraise the utility of potential changes in building technology and in design and construction methodology to their over-all program goals. This difficulty is directly traceable to a combination of existing deficiencies: the lack of suitable theories and methods for describing the building process as a productive factor in the over-all program, for describing design decisions and standards as an initial cost determinant, and for describing maintenance decisions and standards as an operating cost determinant. Furthermore, this difficulty has an interesting and significant ramification -- it precludes rigorous determination by an agency of its priority order of interest in building research.

To be responsive to this concern, the research program should include four study areas:

1. The conduct of a study to evaluate the building process as a factor of production in several federal activities and programs, such as general agency administration, educational facilities construction, health facilities construction, housing
2. The conduct of a study to evaluate building and related code specification as a determinant of the initial cost of construction of facilities for the above activities and programs
3. The conduct of a study to evaluate design and construction methodology as a determinant of the initial cost of construction of facilities for the above activities and programs
4. The conduct of a study to evaluate the cost and utility of different levels of maintenance of components used in facilities for the above activities and programs, such as roofing,

flooring, exterior and interior finishes, heating, ventilating, and air conditioning systems, and lighting and plumbing fixtures.

A start in these areas has been made in the preliminary work on evolving a life-cycle concept for buildings (a working paper on this subject is included herein as Annex C) which seeks, at least initially, to identify properly the decision points and functions of the building process.

Building Cost Management

Even though, as discussed earlier, there is not even an approximation of something like a fund of useful building cost data and information available, nonetheless, the availability of more and better methods and techniques for managing the building process would assist the federal agencies in getting more effective use of their program funds. To this end, each of the four main phases of the building process -- analysis of need, design, construction, operation and maintenance -- merit attention. For example, the development of scientific methods, techniques, and tools for analyzing space allocations -- not just for existing program goals depending on currently available technology but for predictable future changes in goals and technologies -- would not only tend to improve the efficiency of program operations but would also tend to mitigate the effect of future changes. The development of a discipline of value engineering, in lieu of the current ad hoc practice with its more or less fortuitous results, could accomplish a great deal in terms of exposing better design alternatives for program needs. The development of game and bidding theories, methods, and the like could greatly improve the government estimate - bid award process. The development of rigorous methods for deciding when to replace items that deteriorate or become obsolete or when to replace and according to

what schedule items that fail could replace the arbitrary rules of thumb that often pervade maintenance operations (paint every three years) and thereby might either reduce the cost of the current standard of maintenance or improve the standard of maintenance without an increase in cost.

Inasmuch as the foregoing kinds of development can be prosecuted without waiting for an increase in either the science of building economics or in the availability of additional data and because the results of such efforts can be applied quickly, this portion of the research program should receive significant attention, say on the order of 40 per cent of the total program effort.

Building Cost Data and Information Systems

Even though it is axiomatic that a manager will never have all the data and information which he desires when he must make a decision, nonetheless it is equally self-evident that the effectiveness of the building process depends on the economical transmission of relevant, timely, and accurate data and information to meet the needs of each decision-maker involved in the process.

Several aspects of the problem of getting economical transmission of such data and information can and should be undertaken now. First, there is a need to develop a uniform chart of accounts so that one building can be compared to another. Quite clearly, this need encompasses development of a "cost language" which does not suffer from a tyranny of ambiguous and miltiple meanings and which conveys not only financial but also performance aspects of the buildings. It further encompasses identification of sources of building cost data and

information. Second, there is need to identify means for accumulating, processing, and transmitting building cost data and information. Obviously, this need encompasses both "hardware" and "software" aspects attending data/information systems. Third, and closely related to the preceding, there is need to define in detail the building cost information flows, within and outside a federal agency, which are involved in the building process of agency-owned or - sponsored buildings.

USCOMM-NBS-DC

APPENDIX A

PREVIOUSLY ISSUED PROGRAM REPORTS

This appendix lists reports previously furnished to the program sponsors as working papers.

State of the Art Reports

Smith, Hinchman & Grylls Associates, Inc. and McGraw-Hill Information Systems Co. reports on the following organizations:

1. Public Buildings Service; October 20, 1969
2. American Telephone and Telegraph Company; October 20, 1969
3. Veterans Administration; October 22, 1969
4. Levitt & Sons; October 26, 1969
5. International Business Machines Corporation; October 26, 1969
6. Post Office Department; October 31, 1969
7. District of Columbia; November 5, 1969
8. State University of New York; November 10, 1969
9. Century City, Inc.; November 20, 1969
10. Department of Health, Education, and Welfare -
    a. Office of Education; November 24, 1969
    b. Health Services and Mental Health Administration; November 25, 1969
    c. Consumer Protection and Environmental Health Service; November 25, 1969
    d. National Institutes of Health; November 25, 1969
    e. National Institutes of Health; November 26, 1969

Building Research Division, IAT, Building Economics Workshop - A Collection of Papers; February 1970

Progress Reports

Periodic progress reports have been issued to the program sponsors since the program's inception.

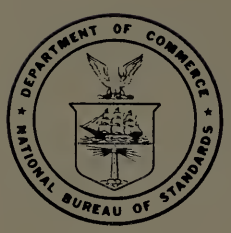
Annexes to this Report

Program sponsors are now being furnished the following contractor reports as working papers:

Annex A - Smith, Hinchman & Grylls Associates, Inc. and McGraw-Hill Information Systems Co., Final Report & Summary - Cost Analysis/Synthesis System for Construction Control, December 3, 1969.

Annex B - McGraw-Hill Research, Construction Cost Information Survey, January, 1970.

Annex C - The Ralph M. Parsons Company, A Life Cycle Concept for Buildings and Facilities, April 23, 1970.


DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS