NBSIR 80-2150

# Productivity in Residential Construction: An Annotated Bibliography

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, DC 20234

February 1981

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

uce E. Thompson
obert E. Chapman

NBSIR 80-2150

# PRODUCTIVITY IN RESIDENTIAL CONSTRUCTION: AN ANNOTATED BIBLIOGRAPHY

Bruce E. Thompson
Robert E. Chapman

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, DC 20234

February 1981

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

## PREFACE

This report was carried out under the sponsorship of the Rehabilitation Technology Group, Building Economics and Regulatory Technology Division, Center for Building Technology. It provides an annotated bibliography covering topics related to productivity in residential construction. Each bibliographic reference and abstract is listed under one or more of the categories covering various aspects of productivity in the construction industry. The references have been categorized so that articles and publications dealing with specific productivity and construction topics can be easily identified. The categories emphasized in this report are: general productivity/productivity measurement; construction productivity; residential rehabilitation/renovation; construction/housing costs; construction cost estimation and control; economics of construction; and building codes and regulations. Some of the references appear under more than one category. This indicates that the article, report or book contains substantial information related to more than one of the categories listed above. One should also note that the authors have been quite selective in both their choice of documents abstracted and the method of defining the primary and secondary technical areas. This approach was taken for two reasons. First, the technical areas abstracted were chosen to span the entire topic of productivity in the construction industry. This choice required the authors to perform an in-depth reorganization of the material turned up in the literature search; as a result the seven topic areas abstracted no longer fit the keywords used in the source documents searched. Second, to include all articles turned up in the search would significantly increase the size of the present document without providing the reader with much additional technically relevant information. In producing a survey such as this one, it is inevitable that some documents which are relevant will be overlooked. These omissions are regrettable and it is hoped that future research on the topic will add the needed emphasis to these documents.

Special appreciation is extended to Dr. John S. McConnaughey, formerly with the Applied Economics Group, whose stimulating discussions played an important role in developing the approach of this study. Appreciation is extended to Dr. Harold E. Marshall, Applied Economics Group, Mr. James H. Pielert, Rehabilitation Technology Group, and Dr. Belinda Collins, Building Safety and Security Group, of the Center for Building Technology, and Ms. Patsy B. Saunders, Operations Research Division, Center for Applied Mathematics, who provided many useful suggestions regarding the organization and treatment of specific topics within the paper. Special appreciation is extended to Ms. Elsie Cerutti, Library Division, for her thorough and efficient use of the numerous computerized information services. Without her assistance this survey of the literature would have been much more difficult and time consuming. Special appreciation is also extended to Mr. David Dresia, Director of Publications, American Society of Civil Engineering (ASCE) for permission to reprint the author's abstracts from the articles in The Journal of the Construction Division and Engineering Issues published by ASCE.

ABSTRACT

This report presents a state-of-the-art review of the technical literature related to one or more of the factors affecting productivity in residential construction. Particular emphasis is placed on identifying potential sources of variation between the level of productivity in new housing construction versus that in housing renovation. Although this report focuses on the residential sector, emphasis is also placed on topics such as construction management and cost control which perhaps more appropriately apply to the non-residential sector. The references have been categorized so that articles dealing with specific productivity and construction topics can be easily identified. The categories emphasized in this report are: general productivity/productivity measurement; construction productivity; residential rehabilitation/renovation; construction/housing costs; construction cost estimation and control; economics of construction; and building codes and regulations.

Key Words: Building codes; building economics; construction; cost; economics; housing; productivity; regulation; renovation.

TABLE OF CONTENTS

Most Common SI Units and their
Equivalent Values in Customary Units

| QUANTITY | INTERNATIONAL (SI) UNIT | U.S. CUSTOMARY UNIT | APPROXIMATE CONVERSION |
|---|---|---|---|
| LENGTH | meter (m) | foot (ft) | 1 m = 3.2808 ft |
| | millimeter (mm) | inch (in) | 1 mm = 0.0394 in |
| AREA | square meter ($m^2$) | square yard ($yd^2$) | 1 $m^2$ = 1.1960 $yd^2$ |
| | | square foot ($ft^2$) | 1 $m^2$ = 10.764 $ft^2$ |
| | square millimeter ($mm^2$) | square inch ($in^2$) | 1 $mm^2$ = 1.5500 x $10^{-3}$ $in^2$ |
| VOLUME | cubic meter ($m^2$) | cubic yard ($yd^3$) | 1 $m^3$ = 1.3080 $yd^3$ |
| | | cubic foot ($ft^3$) | 1 $m^3$ = 25.315 $ft^3$ |
| | cubic millimeter ($mm^3$) | cubic inch ($in^3$) | 1 $mm^3$ = 61.024 x $10^{-6}$ $in^3$ |
| CAPACITY | liter (L) | gallon (gal) | 1 L = 0.2642 gal |
| | milliliter (mL) | fluid ounce (ft oz) | 1 mL = 0.0338 fl oz |
| VELOCITY, SPEED | meter per second (m/s) | foot per second (ft/s or f.p.s.) | 1 m/s = 3.2808 ft/s |
| | kilometer per hour (km/h) | mile per hour (mile/h or m.p.h.) | 1 km/h = 0.6214 mile/h |
| ACCELERATION | meter per second squared ($m/s^2$) | foot per second squared ($ft/s^2$) | 1 $m/s^2$ = 3.2808 $ft/s^2$ |
| MASS | metric ton (t) [1000 kg] | short ton [2000 lb] | 1 t = 1.1023 ton |
| | kilogram (kg) | pound (lb) | 1 kg = 2.2046 lb |
| | gram (g) | ounce (oz) | 1 g = 0.0353 oz |
| DENSITY | metric ton per cubic meter ($t/m^3$) | ton per cubic yard ($ton/yd^3$) | 1 $t/m^3$ = 0.8428 $ton/yd^3$ |
| | kilogram per cubic meter ($kg/m^3$) | pound per cubic foot ($lb/ft^3$) | 1 $kg/m^3$ = 0.0624 $lb/ft^3$ |
| FORCE | kilonewton (kN) | ton-force (tonf) | 1 kN = 0.1124 tonf |
| | | kip [1000 lbf] | 1 kN = 0.2248 kip |
| | newton (N) | pound-force (lbf) | 1 N = 0.2248 lbf |
| MOMENT OF FORCE, TORQUE | kilonewton meter (kN•m) | ton-force foot (tonf•ft) | 1 kN•m = 0.3688 tonf•ft |
| | newton meter (N•m) | pound-force inch (lbf•in) | 1 N•m = 8.8508 lbf•in |
| PRESSURE, STRESS | megapascal (MPa) | ton-force per square inch ($tonf/in^2$) | 1 MPa = 0.0725 $tonf/in^2$ |
| | | ton-force per square foot ($tonf/ft^2$) | 1 MPa = 10.443 $tonf/ft^2$ |
| | kilopascal (kPa) | pound-force per square inch ($lbf/in^2$) | 1 kPa = 0.1450 $lbf/in^2$ |
| | | pound-force per square foot ($lbf/ft^2$) | 1 kPa = 20.885 $lbf/ft^2$ |
| WORK, ENERGY, QUANTITY OF HEAT | megajoule (MJ) | kilowatthour (kWh) | 1 MJ = 0.2778 kWh |
| | kilojoule (kJ) | British thermal unit (Btu) | 1 kJ = 0.9478 Btu |
| | joule (J) | foot pound-force (ft•lbf) | 1 J = 0.7376 ft•lbf |
| POWER, HEAT FLOW RATE | kilowatt (kW) | horsepower (hp) | 1 kW = 1.3410 hp |
| | watt (W) | British thermal unit per hour (Btu/h) | 1 W = 3.4121 Btu/h |
| | | foot pound-force per second (ft•lbf/s) | 1 W = 0.7376 ft•lbf/s |
| COEFFICIENT OF HEAT TRANSFER (U-value) | watt per square meter kelvin ($W/m^2•K$) [$=W/m^2•°C$)] | Btu per square foot hour degree Fahrenheit ($Btu/ft^2•h•°F$) | 1 $W/m^2•K$ = 0.1761 $Btu/ft^2•h•°F$ |
| THERMAL CONDUCTIVITY (k-value) | watt per meter kelvin (W/m•K) [=(W/m•°C)] | Btu per square foot degree Fahrenheit ($Btu/ft^2•°F$) | 1 W/m•K = 0.5778 $Btu/ft^2•°F$ |

# 1. INTRODUCTION

## 1.1 BACKGROUND

Over the past several years the median cost of a new single-family housing unit has increased at an annual rate in excess of 12 percent. Unfortunately, this upward spiral in housing costs has forced many prospective homeowners to look elsewhere in order to satisfy their housing demands. Since current forecasts indicate that between 22 and 30 million additional housing units will be needed in the current decade, this trend is likely to continue over the next five to ten years. A significant increase in the number of housing units being renovated is therefore likely if the Nation's housing needs are to be satisfied. The vital role that costs play in all investment decisions is a strong indicator that any significant change in current housing investment trends calls for a better understanding of how the recent decline in productivity on a national scale affects the relative cost of housing produced through renovation vis-a-vis new construction.

A comprehensive study of this problem cannot be separated from broader issues such as the implied productivity decline in the non-residential sector, the greater sophistication of modern construction management techniques, and the economic impact of building codes. A survey of the existing literature can, however, provide some basic guidelines for a limited approach which is more manageable and highlights major areas of interest within the broader topic. Due to the breadth of the issues mentioned above, as well as other problems which affect the structure of construction costs, the housing renovation industry has received relatively less research attention in the past than the other sectors of the construction industry. Its rapid growth over the last several years, however, has raised many pertinent research questions. One of the most important, at least from an economic viewpoint, concerns the determinants of productivity. This issue is important not only for its obvious impact on renovation costs but also for technical reasons tied to the basic production process of renovating buildings. More specifically, a better understanding of the determinants of productivity may free resources from a relatively inefficient endeavor to one which increases the returns to all factors in the construction process. It is with this latter objective in mind that this survey of the literature was conducted.

## 1.2 PURPOSE

The purpose of this report is to present a state-of-the-art review of the technical literature on one or more of the factors affecting productivity in residential construction. Particular emphasis has been placed on identifying potential sources of variation between the level of productivity in new housing construction versus that in housing renovation. Although this report focuses on the residential sector, emphasis is also placed on topics such as construction management and cost control which perhaps more appropriately apply to the non-residential sector. In all, seven distinct areas relating to the overall productivity issue are abstracted. These seven areas are:

general productivity/productivity measurement;
construction productivity;
residential rehabilitation/renovation;
construction/housing costs;
construction cost estimation and control;
economics of construction; and
building codes and regulations.

It is important to point out that the seven areas mentioned above were chosen in such a way that they span the entire topic of productivity in the construction industry. These areas are, in part, a reflection of the unique nature of the construction industry vis-a-vis the nation's other major industries. This uniqueness stems both from the fact that the construction industry does not produce a homogeneous product as well as the fragmented structure of the industry itself. The seven areas abstracted also reflect the physical process of construction which is perhaps unique among the nation's industries in its management, control and regulation. Finally, the choice of the topic areas was designed to reveal why the problem of productivity measurement in the construction industry is significantly more difficult than in other industries.

## 1.3 ORGANIZATION

The basic format of this study consists of a brief description of each of the seven major categories affecting productivity in residential construction. Specifically, the study is organized as follows:

Chapter 2 focuses on a general discussion of the concept of productivity and its measurement. Included are international comparisons of productivity growth, examinations of productivity trends, and methods of improving productivity through measurement and operations research techniques.

Chapter 3 includes studies dealing specifically with productivity in the construction industry.

Chapter 4 is concerned with various aspects of the renovation process. Issues treated include: scale economies, financial arrangements, and indicators of housing quality.

Chapter 5 concentrates on the factors affecting housing costs. Separate articles on cost and price indices, the comparative costs of new versus rehabilitation production of housing, and cyclical instabilities are presented.

Chapter 6 discusses the estimation and control of construction costs. Methods for estimating and controlling field labor construction costs which explicitly consider productivity factors are also presented.

Chapter 7 deals with economic analysis as it relates to the construction industry. Cost-benefit analysis and economies of scale with regard to residential construction are examined.

Chapter 8 examines building codes and regulations as they relate to the diffusion of technological innovations and overall construction costs.

Chapter 9 presents concluding remarks designed to summarize the major points addressed in the literature survey.

Several on-line computer searches were conducted in the preparation of this productivity bibliography. In cases where bibliographic information was obtained through computer sources, the name of the computer index utilized is indicated in parentheses following the abstract. Computer indexes cited in this report are: Data Courier's ABI/INFORM; Engineering Index's Compendex; and NTIS (National Technical Information Service).

## 2. GENERAL PRODUCTIVITY/PRODUCTIVITY MEASUREMENT

The studies abstracted in this section provide a general discussion of the concept of productivity, its measurement and those factors which affect its level and growth rate. Included are international comparisons of productivity growth and measurement, analyses of worker productivity, examinations of productivity trends, and methods of improving productivity through productivity measurement and operations research.

A study by Ruch and Hershauer identifies major factors which influence worker productivity. Denison discusses the effect on productivity of various changes in the institutional and human environment. The influence of technical change on gross output per manhour is described in an article by Solow, where six key industries are examined in terms of their ability to compete for world markets and employment opportunities. Various research needs are suggested in the Proceedings of an industrial workshop sponsored by the National Science Foundation. Leuthold indicates the profit potential for those investing in companies and industries instrumental in solving productivity problems.

Several studies provide an international perspective on the issue of productivity. The Saunders and Crum article presents information on the comparative productivity growth during the 1950's of several highly industrialized countries. Regarding the matter of inter-country economic comparison, Pilarski indicates that output per worker is a more meaningful measure of economic development than output per capita. Rostas' study uses three alternative methods to compare labor productivity in British and American manufacturing industries. British industries are also examined in an article by Tippett and in a book by the Anglo-American Council on Productivity. These works discuss the use of productivity measurement as a means of improving productivity in various industries.

Productivity trends are analyzed in separate books by Kendrick and Stigler. The Kendrick study estimates productivity in terms of all relevant inputs for 33 industry groups and the 20th century private American economy as a whole. Stigler analyzes output, employment, and output per worker in six industry groups over a period of forty years ending in 1939. A pamphlet by Steiner and Goldner discusses the concept of productivity and its measurement. Sears suggests that methods from operations research which seek to measure productivity for the system in its entirety, rather than simply for labor, are a more efficient means of improving productivity.

Anglo-American Council on Productivity. Productivity Measurement in British Industry. New York, 1950, 38 pp.

Abstract: This book is the result of a symposium of papers concerned with the use of productivity measurement in improving productivity and efficiency in the factory. The authors of the articles have direct experience in various industries including steel, light engineering, boots and shoes, and textiles. The use of productivity measurement for making comparisons between operatives

and shifts within a particular factory and between factories in the same industry is discussed, and methodologies for overcoming difficulties in making comparisons where products differ are described. Some papers indicate the improvements resulting from the application of productivity measurement to activities in a wide range of industries.

Denison, Edward F. "Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input," Survey of Current Business, Vol. 58, No. 1 (January 1978), pp. 21-44.

Abstract: The effect upon output per unit of input of three changes in the operating environment of business is estimated in this article. The study deals with the non-residential business sector, and with changes in the institutional and human environment within which business operates. The three changes are: (1) New requirements to protect against pollution of the physical environment; (2) Increased requirements to protect the safety and health of employed persons; and (3) A rise in dishonesty and crime. The common characteristic shared by these changes is that they have reduced the measured output (national income) produced by any given amount of input. The reductions were found to be small from 1968-70, but rose rapidly in the 1970's. In 1975, output per unit of input in the non-residential business sector of the economy was estimated to be 1.8 percent smaller than it would have been if business had operated under 1967 conditions. Most of this amount (1.0 percent) is ascribable to pollution abatement, while employee health and safety programs, and increased crime and dishonesty accounted for 0.4 percent each.

Kendrick, John W. Productivity Trends: Capital and Labor. New York: National Bureau of Economic Research, 1956, 23 pp.

Abstract: This paper summarizes productivity trends in the 20th century American economy by major segments and industries. It attempts to measure total factor productivity (i.e., productivity in terms of all relevant inputs) by relating output to all tangible inputs to determine the net saving in real costs per unit of output. Total factor productivity is estimated for 33 industry groups and the private domestic economy as a whole. In addition, the ratios of output to both labor and capital are estimated. Productivity in the private domestic economy rose at an average annual rate of 1 3/4 percent between 1899 and 1953, and accounted for more than half of the 33 percent average growth rate in real product.

Leuthold, Steven C. "U.S. Productivity Problem Means Big Profits for Insightful Investors." Pensions and Investments, Vol. 6, No. 22 (23 October 1978), pp. 31-32.

Abstract: Major problems like the decrease in U.S. productivity, create major investment opportunities for those investors able to identify the companies and industries potentially instrumental in the problem-solving process. This benefit could become a major stock market conception of investment theory. The best investment opportunities will be found among the problem solvers since it is better to invest with those who cure the problem rather than those who cause it. Watch the future, as some of the gains of the past might have reached their peak. Catch the turnarounds, the companies on the verge of a productivity breakthrough; catching them is a rare dramatic experience. The lagging U.S. economy is a real and complex problem, and the decline in productivity is one of the chief causes. It will not go away by itself; it must be treated. Improvement of services industries, the fastest growing part of the U.S. economy, is one way to cure some ills. These industries can be rescued the same as manufacturers. The potential for productivity improvement through systems and equipment is huge, but special research and counseling may be necessary. (ABI/INFORM)

Pilarski, Adam M. "Output Per Worker - A More Meaningful Measure of Economic Development," Economic Inquiry, Vol. XV (July 1977), pp. 435-440.

Abstract: Recent fluctuations in exchange rates have led to changes in the ranking of the richest countries in the world. A survey of the Union Bank of Switzerland, for example, places the United States only in fifth place for 1974 with respect to per capita income. This raises the question of inter-country economic comparison. A country's level of development is traditionally measured by income per capita. I want to argue here that output per worker ("worker" meaning economically active person) rather than output per capita is a measure which has more meaning. I also want to show that these two criteria produce significantly different rankings of countries. (Author)

Proceedings of Industrial Productivity Workshop Held at Washington, D.C. on October 29 and 30, 1975. Washington, D.C.: Research Applied to National Needs, National Science Foundation, January 1976, 53 pp.

Abstract: This Workshop was conducted to solicit from key labor leaders an assessment of research required to enhance industrial productivity. Productivity is defined here as the ability of American industry to compete for world markets and employment opportunities. Six key industries were selected for study in the workshop: automobile, steel, manufacturing and processing, transportation, food, and construction. A previous workshop has been conducted which included managerial executives in the six selected industries. Both labor and management agreed on the need for more productivity research. Major research needs suggested by the workshop participants are as follows: (1) Analysis and Measurement of Productivity; (2) International Productivity Comparisons; (3) Quality of Work Environment; (4) Government Regulation; (5) Construction; (6) Transportation; (7) Implementing Productivity Improvement; and (8) Socioeconomic Impacts. (Author)

Rostas, Laszlo. A Report on International Comparisons of Productivity in British and American Manufacturing Industry. Research Paper 13. London: National Institute of Economic and Social Research, 1947.

Abstract: This study concentrates on comparing the productivity of labor, as measured by physical output per head or per manhour, in British and American manufacturing industries. Three alternative methods of comparison are utilized: (1) The sample method, (2) the global method, and (3) the net output value method. Long-term changes in the labor productivity of British and American industry are analyzed. The degree of capital intensity on mechanization, organization factors, labor conditions, the degree of standardization and other factors are examined with regard to their effects on output per worker. Non-manufacturing sectors of the British and American economies such as agriculture, service industries, and building and construction are also compared in terms of labor productivity.

Ruch, William A. and James C. Hershauer. Factors Affecting Worker Productivity. Tempel, Arizona: Bureau of Business and Economic Research, Arizona State University, 1974, 133 pp.

Abstract: This study explores productivity with the purpose of identifying the major factors that influence output over time. The basic interactions between these factors are also examined. Three concurrent methodologies were utilized in this effort. First, conceptual schematic models were developed. Then expert opinion from individuals representing a broad range of organizations (small and large manufacturers, government agencies, consulting firms, labor unions, etc.) was gathered. Finally, specific company and employee data was gathered from seven Arizona firms. The study develops a variety of research tools, techniques and methodologies. The report also establishes the need and feasibility for studying productivity from both macro and micro economic perspectives.

Saunders, C. T. and R. E. Crum. "International Comparison of Productivity Growth in the 1950's." Journal of the Royal Statistical Society, Series A, Vol. 126, part 2 (1963), pp. 227-235.

Abstract: This paper explores some of the facts about comparative productivity growth in advanced industrial countries of the "Western world" during the 1950's. Our special interest is in the extent to which changes in productivity are associated with changes in total output, as between countries and between industries; and in what inferences (if any) can be drawn from this association (or lack of it), about the causes of changes in productivity. (Author)

Sears, G. W. "Productivity Improvement through Operational Research." Journal of the Royal Statistical Society, Series A, Vol. 126, Part 2 (1963), pp. 267-269.

Abstract: This paper expresses the view that a basic understanding of statistical philosophy and methodology is essential to success in the improvement of productivity. It is indicated that productivity improvement is the prime objective of industrial operational research. The operational research theorists attempts to develop a measure of productivity for the system as a whole, rather than simply measuring labor productivity. To accomplish this the organization (system) must have a clearly defined "master" objective, so that the whole range of resources can be allocated in a manner which most effectively reaches that objective. Brief examples of operational research approaches are provided, as is a simple mathematical model which illustrates the productivity improvement potential of the method.

Solow, Robert M. "Technical Change and the Aggregate Production Function." The Review of Economics and Statistics, Vol. 39 (August 1957), pp. 312-320.

Abstract: This study describes an elementary method for separating variations in output per head due to technical change from those due to changes in the availability of capital per head. The theoretical basis for this method is established both mathematically and diagrammatically. The method is applied to aggregate U.S. production for the years 1909-1949. Study conclusions indicate that during this period technical change was neutral (marginal rates of substitution remained unchanged while the output attainable from given inputs increased or decreased) on average. Apart from fluctuations, the upward shift in the production function was at a yearly rate of approximately one percent for the first half of the study period and two percent per year for the last half. The aggregate production function when corrected for technical change displayed diminishing returns. Gross output per manhour doubled between 1909 and 1949. Technical change was responsibile for 87.5 percent of the increase, while increased use of capital accounted for 12.5 percent of the gain.

Steiner, Peter O. and William Goldner. Productivity. Berkeley, California: Institute of Industrial Relations, University of California, 1952, 60 pp.

Abstract: The concept of productivity and how it is measured are examined in this pamphlet, as well as the effect of productivity on output, wages and the standard of living. The direct involvement of productivity measures in union agreements covering minimum production standards, piece rates and incentive wage systems and its effect on labor-management relations are also discussed.

Stigler, George J. Trends in Output and Employment. New York: National Bureau of Economic Research, 1947, 67 pp.

Abstract: This study analyzes output, employment, and output per worker from 1899 to 1939 in six groups of industries. These industry groups--manufacturing, agriculture, mining, gas and electric utilities, and steam railroad--displayed a tripling of physical output between 1899 and 1939.

Output per manhour of labor also tripled, while manhours of employment remained about the same time due to a 30 percent rise in employment countered by a decline in weekly hours of work. Rough estimates of changes in efficiency; that is, output per unit of all inputs, indicate that for the major manufacturing categories output per worker is an unreliable index of efficiency, especially when production is relatively capital intensive.

Tippett, L. H. C. "Productivity Measurement as an Aid to Productivity Improvement." Journal of the Royal Statistical Society, Series A, Vol. 126, Part 2 (1963), pp. 262-266.

Abstract: This paper aims at providing technical management with information which will help to improve productivity in the individual factory. Conclusions are drawn from a productivity survey of the British cotton spinning industry. Data were obtained on operative-hours per 100 pounds of yarn produced (OHP) and other factors from a sample of about 100 mills conducted between 1946 and 1948. For a given measure of yarn fineness the OHP for the least efficient mills was found to be two or three times that of more efficient mills, indicating the potential for substantial increases in labor productivity with existing mill equipment. The spinning mills were again surveyed in 1954-56, and although individual mills exhibited notable improvements in productivity, overall industry improvement was less than was earlier anticipated. The study concludes that productivity improvement comes from management action in individual factories. Relatively simple indexes of productivity are most likely to be utilized by management and the chief effect of productivity surveys is likely to be educative, rather than leading directly to improvements.

## 3. CONSTRUCTION PRODUCTIVITY

This section includes abstracts of studies dealing specifically with productivity in the construction industry. Some of the studies provide data based on measurements of construction productivity. Also examined are labor productivity and appropriate methods of increasing it. Productivity studies of specific skills (e.g., masons and carpenters) are included, as are several articles and reports which discuss the link between labor and management in improving productivity. Two articles examine the effect of equipment on construction productivity. Some of the studies abstracted develop models designed to measure and estimate productivity. Several other aspects of construction productivity are also discussed.

A report by the National Academy of Sciences focuses on the development of a national strategy for improving productivity in the construction industry. Included in this report are papers on labor-management relations, financial issues, innovation, and public sector activities aimed at promoting productivity growth in the construction industry. Finn's article indicates manhour requirements for public housing construction. A British Ministry of Works survey shows increased productivity resulting from incentives paid to workers and increased construction volume. Reiners and Broughton confirm the notion that cash incentives lead to higher productivity. In addition, their report indicates that productivity improved when the main contractor directly supervised work and was an experienced home builder.

Several articles and reports are concerned specifically with construction labor productivity. McNally and Havers consider various factors which have a substantial impact on labor productivity. Their study examines methods for determining the optimum crew size for various construction activities. Numerous in-depth interviews were used by Borcherding and Oglesby in determining that a well-planned, smooth work flow contributes to improved job satisfaction and productivity. The study of mason productivity (by Johnson, Worchel, Ferguson, and Geyer) indicates that labor is not solely responsible for productivity problems; other segments of the construction industry also bear responsibility. The Behman, et al. report derives physical labor productivity estimates for a number of building trades and examines the effect of several factors on the price of single-family housing.

Articles by Kupperman, Fox, and Borcherding, offer a variety of productivity improvement suggestions. Logcher and Collins examine the effect of management on labor productivity and suggests work specialization, work supervision, motivations and other methods as means of productivity improvement. Peltier, reporting on a construction industry productivity conference, indicates that mangement must develop innovative approaches in dealing with productivity problems. The study by Maloney presents the view that cooperation between labor and management is an important factor in achieving productivity gains.

Oriole discusses the productivity decrease resulting from government regulation. Howenstein indicates a higher European rate of productivity than has been achieved by the American construction industry. A National Association of Home Builders (NAHB) study comments that construction productivity gains have been obscured by rising land, labor, money and material prices, and other factors. Crandall's report indicates that there is a critical need for research on productivity issues and that an effective means of distributing research information within the construction industry is required. Two NAHB studies suggest subjects for productivity research, and detail methods for improving productivity. Reports by Dacy and Hahn provide information on the Construction Labor Demand System (CLDS). This model is used in forecasting at the local level labor hour requirements by construction type and building trade. The Adrian and Boyer article discusses another model, the Method Productivity Delay Model (MPDM). The focus of this model is on method productivity factors that the average construction firm can measure and control.

Adrian, James J. and LeRoy T. Boyer. "Modeling Method Productivity." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 102, No. 1 (March 1976), pp. 157-168.

Abstract: A productivity model has been developed that provides the average construction firm with the means of measuring, predicting, and improving a given method's productivity. The model, referred to as the Method Productivity Delay Model (MPDM), focuses on method productivity parameters that are measurable and controllable by the average construction firm. Method productivity parameters are addressed by documenting productivity delay. The model recognizes the environment and constraints of the average construction firm, requires only simple mathematics, and is compatible with existing union work rules. The MPDM evolved from considering the positive attributes of existing models, from considerations of contractors' viewpoints, and from experience of observing construction methods and methods productivity. The model possesses all of the attributes necessary to provide the average construction firm with the means of measuring, predicting, and improving productivity. Its use can often provide dollar benefits exceeding its cost of implementation. (Author)

A National Strategy for Improving Productivity in Building and Construction: Proceedings of the Building Research Advisory Board's 1979 Building Futures Forum, November 7-8, 1979. Washington, D.C.: National Research Council, National Academy of Sciences, 1980, 209 pp.

Abstract: The Forum brought together representatives of all elements involved in or influencing construction. The primary objective of the Forum was to provide a foundation for improving productivity by: (1) delineating and developing a better understanding of the factors influencing productivity in the built environment; (2) determining how these factors affect productivity; (3) determining what must be done to improve industry efforts; and (4) making recommendations and identifying appropriate responsibility for necessary action. The Forum was organized into five major sessions:

(1) managing the building process for improved productivity; (2) financial planning for improved productivity; (3) government and public action for improving productivity; (4) human motivation and incentives for improving productivity; and (5) innovation for improved productivity. (Author)

A Pilot Study on Productivity in Residential Construction. Rockville, Maryland: National Association of Home Builders Research Foundation, July 1971, 49 pp.

Abstract: Rising prices of land, labor, money, and materials, along with the increasing size and increasing number of luxury, convenience, and comfort features in dwellings, have tended to obscure productivity gains by the industry. (NTIS)

Behman, Sara, Max DeGialluly, Erwin Dreessen and Clyde Johnson. Productivity Change for Carpenters and Other Occupations in the Building of Single-Family Dwellings and Related Policy Issues. Berkeley, California: Center for Labor Research and Education, University of California, April 1971, 221 pp.

Abstract: This study develops average physical labor productivity estimates for building trade occupations. Data on carpenters and other occupations involved in the on-site building of single-family dwellings in Alameda County, California in 1930 and 1965 are examined. The study seeks to determine (1) the extent to which new building techniques influenced carpenter employment over the 35 yaers; (2) the impact of productivity change on labor requirement forecasting in the selected building occupations; and (3) the inflationary bias, if any, of wage rate increases in these occupations. Findings indicate that average physical labor productivity for a crew of carpenters and related occupations working on the construction site grew at a rate of 3.2 percent per annum between 1930 and 1965. Despite a sixfold increase in total output (in terms of square feet of living area) between 1930 and 1965, the number of carpenters needed in 1965 was 55 percent of the number which would have been required in the absence of improved building methods and industry organization. Study findings suggest that manpower forecasts which do not consider rising productivity are likely to overestimate projected labor requirements.

Borcherding, John D. "Improving Productivity in Industrial Construction." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 102, No. 4 (December 1976), pp. 599-614.

Abstract: Electric utility executives ranked productivity, manual labor, union restrictions, and overtime at the top of the list of 10 problem areas where major improvements were needed. Previous research by manufacturing organizations that were faced with similar productivity problems indicate that 30 percent to 60 percent improvement is achievable by proper managment of human resources. In this paper, attitudes of workmen, supervisors and managers on $100,000,000 to $1,000,000,000 three-year to ten-year projects are compared to those of individuals on much smaller commercial building projects. Deep

hierarchical organizational structures which are familiar in government and manufacturing, but now appear on the larger construction projects are examined. Recommendations for improving motivation of workmen and supervisors on large projects plus alternative organizational structures will be given to improve overall productivity. (Author)

Borcherding, John D. and Clarkson H. Oglesby. "Construction Productivity and Job Satisfaction." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 100, No. 3 (September 1974), pp. 413-431.

Abstract: This article reports a portion of the findings of a study of the relationships between job satisfaction and construction productivity. Its objective was to clarify current thinking on personal work relationships, understanding, and communication as they affect home office management, field supervisors, and workmen. Data were collected from 65 in-depth interviews of one hour to five hours each with management and labor from companies employing carpenters, electricians, plumbers, pipe fitters, and sheet metal workers primarily from St. Louis, Missouri, with supplemental interviewing from Los Angeles and San Francisco. The research showed that in construction satisfactions are inherent in the work itself. It follows that efforts to improve job satisfaction and productivity lie in well-planned, smooth work flow rather than in job enrichment, as is advocated by organizational behaviorists for industrial or bureaucratic work situations. (Author)

Crandall, Keith C. Workshop for the Formulation of Specific Projects in Productivity Research for the Construction Industry. Technical Report No. 5. Berkeley, California: University of California, July 1978.

Abstract: This report is based on a workshop intended to provide a forum and a consensus for the advancement of specific research and development projects in construction productivity. The workshop utilized a broad definition of productivity -- it was considered to entail any problem that ultimately affects unit production. Panels composed of leaders from all sectors of the construction industry discussed proposals received from the research community. A panel was appointed to discuss each of seven areas related to the productivity question. The areas of emphasis were: Management, Labor, Capital Budgeting and Finance, Technology, Regulatory, Design/Construction Interface, and Productivity and Public Policy. The segment of the construction industry selected for review was larger projects valued at more than $1 million. The workshop concluded that there is a critical need for a national center which would review and establish research priorities for the construction industry, with special emphasis on research related to productivity. A means for effectively disseminating relevant research information within the industry is required. The workshop also indicated the need for increased research funding.

Dacy, Douglas C. An Evaluation of the Treatment of Labor Productivity in the Construction Labor Demand System. Institute for Defense Analyses Paper P-1351. Arlington, Virginia: Program Analysis Division, Institute for Defense Analyses, July 1978, 35 pp.

Abstract: The Construction Labor Demand System (CLDS) is a model for forecasting labor hour requirements by region, type of construction and building craft. The paper is concerned primarily with the appropriate adjustment for productivity growth. The CLDS method for adjusting labor requirements for productivity changes is described. Discussions are presented on the problem of productivity measurement, and on various construction costs and price indexes published by the Federal government. A critical evaluation of the CLDS method is included along with suggestions for generating slightly better estimates. There is also a discussion of productivity forecasting methods. The study indicates that the employment estimate in the CLDS model will be biased in an undetermined direction. This bias is due to the fact that the current system directly adjusts for labor efficiency changes over time, while it also implicitly adjusts via construction deflator indexes.

Finn, Joseph T. "Labor Requirements for Public Housing." Monthly Labor Review, Vol. 95, No. 4 (April 1972), pp. 40-42.

Abstract: This study was designed to measure the number of manhours per $1,000 of public housing construction contract. Forty-eight of the 354 projects sponsored by the Housing Assistance Administration of the Department of Housing and Urban Development, and scheduled to be completed between January 1967 and March 1968 were surveyed. The average apartment in a public housing project completed in 1968 was smaller in size and cost considerably more to build than the average apartment completed in 1960. The study indicates a decline in manhour requirements per unit of output over this period when measured in constant dollars. Each $1,000 of contract construction required a total of 177 manhours in 1968, as compared to 241 manhours required in 1960. Onsite manhours per $1,000 of contract cost declined from 114 to 80. The decline in onsite manhours between 1960 and 1968 to a large extent reflects the impact of rising construction costs. When square footage was used as a measure of output, onsite manhours per 100 square feet remained virtually unchanged. Public housing construction provided 32,990 full-time jobs in construction sites and 5,129 jobs for offsite contractor personnel in 1968. Another 30,249 full-time jobs were estimated to have been created through the production and distribution of materials used in public housing construction.

Fox, Arthur, J. "Productivity in the Construction Industry." Engineering Issues, Proceedings of the American Society of Civil Engineers, Vol. 104, No. 1 (January 1978), pp. 49-52.

Abstract: An interest in the problems of improving productivity in all the processes of construction led to an ASCE invitational conference on the subject in August 1976. The proceedings of that conference, preprinted for the participants, offered valuable suggestions for improving productivity, as reviewed herein. The conference itself created a momentum within ASCE, its newly established Engineering Management Division, and many of its members who continue to press for improved productivity as an engineering problem, and as a management problem. (Author)

Hahn, William F. "Construction Labor Demand System: An Overview." Research and Information in the Building Regulatory Process: Proceedings of the Third Annual NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 552 (edited by Patrick W. Cooke). Washington, D.C., July 1979, pp. 185-196.

Abstract: Currently under development by the Department of Labor is an extensive modeling effort designed to provide accurate forecasts at a local level of future construction levels and on-site labor requirements. The Construction Labor Demand System (CLDS) is a computerized management information system that provides continuously updated forecasts for local regions, for specific types of construction, and for precise construction trades. Actual construction project information is the nucleus of the CLDS system. Information on hundreds of thousands of current and planned projects are included in CLDS. Each project is time-phased to completion and estimates are generated of the associated craft requirements. Forecasts of construction initiations are accomplished through econometric modeling. Initiation forecasts are transformed into pseudo-projects within CLDS and pseudo-projects are combined with hard project data for the generation of forecasts of construction activity. A conversion subsystem translates construction activity into demand for labor. Over 200 conversion profiles translate activity levels into time-phased flows of requirements by occupation. (Author)

Howenstine, E. Jay. "Productivity Trends in the Construction Industry: A Comparative International Review." American Association of Cost Engineers Bulletin, Vol. 17, No. 6 (December 1975), pp. 189-194.

Abstract: A survey of European and American studies on productivity trends in the construction industry is presented. The survey focuses on (1) long-term productivity trends for the entire industry, (2) productivity trends in specific on-site studies, and (3) comparisons of productivity trends in construction vis-a-vis other industries. Empirical evidence uncovered in the survey indicates that post World War II productivity is significantly higher than the levels prevailing in the pre-war period and that the United States and a majority of the European counties had post-war growth rates in construction productivity below those in the manufacturing sector.

Johnson, Franklin D., Philip Worchel, Carl S. Ferguson, and John Geyer. Mason Productivity Study--Volume II: A Construction Industry Opinion Survey on Mason Productivity. Austin, Texas: Center for Building Research, Texas University, 12 July 1972, 228 pp.

Abstract: A survey of major U.S. masonry leaders and leaders from 23 foreign cities seeks to identify and evaluate the constraints to mason productivity as seen by the various segments of the industry. The general practice has been to blame construction unions for reducing productivity through local work rules, and strikes which impede the use of technological development. While there may be some justification for this criticism, all of the problems of productivity are not the responsibility of labor and must, as the survey shows, be shared with other segments of the industry. The macro problem of increasing productivity can be solved only by increasing the productivity of the individual crafts and better management techniques. (NTIS)

Kupperman, Melvin. "Improving Productivity: The Construction Phase." Consulting Engineer (Barrington, Illinois), Vol. 49, No. 6 (December 1977), pp. 52-55.

Abstract: This study focuses on the role played by construction management in containing the costs of increasingly more complicated building designs. The application of construction management to the problems of scheduling, budgeting, organizing, and coordinating, which have traditionally been carried out independently throughout the design and construction of the building, is the largest single step in the direction of completing the building within cost and on schedule. It is stressed that even on jobs where a construction manager is not utilized directly, the use of a group approach is required due to the complex interrelationships among the members of the building team and the construction problems they face.

Logcher, Robert D. and William W. Collins. "Management Impacts on Labor Productivity." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 104, No. 4 (December 1978), pp. 447-461.

Abstract: This paper uses a simplified model of specific building operations in order to recognize and determine basic influences of management on labor productivity. By making continuous on-site observations of many jobs of the same building operation with differing levels of management, the effect of management actions on labor productivity can be determined. By modeling the building operation around one of its major activities that has a quantifiable labor input and work input, a variety of jobs can be compared in spite of their lack of similarity. It is suggested that by applying the measurable work rate of the modeled activity to the percentage of productive work, a labor productivity index can be derived and used for comparison. The study indicated that labor productivity, even in a trade as simple as tile laying, can be improved 100 percent or better where work specialization, work supervision, on-site coordination, job security, motivations, and long-term pacing are employed and encouraged. (Author)

Maloney, William F. "Productivity Bargaining in Construction." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 104, No. 4 (December 1978), pp. 369-383.

Abstract: Labor and management in the unionized sector of the construction industry have, in several instances, reacted to the growth of the non-union sector by engaging in productivity bargaining. Collective bargaining in the industry has, historically, been characterized by union dominance. As employment in the union sector has decreased, management has begun to press for union concessions on work rules and practices in order to increase productivity and decrease unit labor costs. Productivity bargaining requires an explicit link between changes in work practices and changes in compensation. To date, the impact of productivity bargaining has not been great with regard to productivity and unit labor costs. The real impact has been on the parties' attitudes, which have become more cooperative. With the change in attitudes, the foundation has been laid for the beginning of true productivity bargaining. (Author)

McNally, Harold E. and John A. Havers. "Labor Productivity in the Construction Industry," Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 93, No. 3 (September 1967).

Abstract: Construction labor wage rates are increasing more rapidly than material and equipment costs. For this reason it is important to identify factors which significantly effect labor productivity. This study categorizes factors affecting labor productivity under the headings of Environmental, Labor Availability, Job, and Management Factors. Environmental Factors reflect the influences of climate and weather on various job locations. Labor Availability Factors refer to the adequacy of the available supply of trained labor in a given geographic area. Job Factors have to do with characteristics unique to a particular job. Management Factors cover project planning and scheduling decisions made by management. Possible methods for determining the optimum crew size for various construction activities are examined. These methods are: Time and Motion Studies, Random Observational Studies, Multiple Activity Charts, and Photographic Analysis. Also discussed are the effects of psychological factors and work area size on labor productivity. The study indicates that the various techniques could be applied to pilot studies of selected construction operations. The final research objective would be to improve the capability of predicting labor requirements for actual construction operations. (Author)

Ministry of Works, Productivity in House-Building: A Pilot Sample Survey in the South, East and West of England and in South Wales, August 1947-October 1948. National Building Studies Special Report No. 18. London, England: His Majesty's Stationery Office, 1950, 32 pp.

Abstract: The focus of this study is on discovering changes in house building productivity during a particular period and the factors affecting these changes. A sample survey based on approximately 160 contracts covering more than 3,000 homes built in areas of England and South Wales in 1947 and 1948 was conducted. The houses in the sample had an average size of 935 square feet (plus 85 square feet for an outhouse). An average incentive of 15 pounds per house was paid. The average number of houses on a site was 20. Although survey results varied widely, it was found, on average, that the payment of a five pound bonus reduced manhours by 60. Furthermore, for every five pounds spent on incentives there was a net average saving of five pounds over and above the bonus paid. Productivity increased during the study period as manhours were reduced by 2 1/2 percent (or about 75) on a standard house design. Increases in material prices, however, offset the effect of the productivity rise on total costs. Findings also indicate that for each additional ten houses built on a site, manhours were reduced by 2 1/2 percent, as were labor costs.

Oriole, Kenneth A. Productivity in the Construction Industry--Influence of Regulatory Law. Unpublished Master of Science Thesis, Department of Civil Engineering, Worcester Polytechnic Institute, 1979, 261 pp.

Abstract: Government regulation of the construction industry results in increased construction cost and decreased productivity. This thesis reports the effect of regulation on the productivity of contractors and business operating in various construction sectors. Results from a questionnaire survey of the construction industry are presented to illustrate the effect of regulation on construction productivity. Most of the data used in this study comes from a comparative analysis of various areas of regulation with different aspects of the construction industry. Output per manhour of work, total amount of construction put in place and comparative costs for units of construction are among the methods used to measure regulatory effects on productivity. Recommendations for improved productivity through regulatory enforcement are provided.

Peltier, Eugene J. "Productivity in the Construction Industry Management Processes." Engineering Issues, Proceedings of the American Society of Civil Engineers, Vol. 104, No. 1 (January 1978), pp. 53-56.

Abstract: A conference on construction industry productivity at Lincolnshire, Illinois in August 1976 is reported. Improving productivity in designing, constructing and operating facilities is central to the health of the construction industry. Suggestions are made for improvements in these areas. Top management support for the philosophy and the requirements of the control system, along with timely data collection and analysis produce tangible results. The main responsibility in design and construction rests with management, and management should take fresh approaches to solving productivity problems. The ASCE Committee on Engineering Management should work in this area and seek generalized and specialized definitions and methods of measuring productivity. It should collect, analyze, and disseminate productivity data in design and construction, and foster development of positive productivity improvement approaches. (Author)

Productivity in Residential Construction. Rockville, Maryland: National Association of Home Builders Research Foundation, March 1974.

Abstract: Overall good supervision, detailed work planning and scheduling plus the application of industrial engineering concepts and techniques to a home building operation are of significant value to productivity gains. Of prime importance is the ability of management to design the structure for optimum material use and for maintaining a high quality of construction so that excessive material and the proportionate amount of labor is eliminated. Report includes charts, analysis and evaluation sheets for 49 case studies and a summary of builder comments and recommendations dealing with methods to improve productivity. Productivity potential gain assessment, evaluation, dollar savings and principles are discussed. An example is given of the potential productivity gain for a floor system. Potential subjects for long-range productivity research are included. (Author)

Productivity in the Residential Building Trades. Washington, D.C.: National Association of Homebuilders, 1976.

Abstract: This study seeks to determine the productivity of several building trades involved in the construction of typical single-family homes and low-rise apartments. Two methods, the Group Timing Technique (GTT) and Work Sampling Technique, are used in classifying work as productive-direct (work applicable to a particular construction operation), productive-support (necessary work not specifically applicable to a particular construction operation), and nonproductive (personal breaks, unfavorable delays, idleness, and rework). The GTT records the amount of work done by a crew every 30 seconds throughout the workday. The Work Sampling Technique permits work classification by detailing the type of work performed by a crew at stratified random times throughout the workday. The productivity of carpenters, bricklayers, electricians, plumbers, and painters is examined. Findings of 13 case studies indicate that on average, 65.4 percent of work time is productive, 19.6 percent is support, and the remaining 15 percent is nonproductive. The study also indicates that productivity may be significantly improved in the areas of material handling and productive time.

Reiners, W. J. and H. F. Broughton. Productivity in House-Building: Second Report. National Building Studies Special Report No. 21. London, England: Her Majesty's Stationery Office, 1953, 41 pp.

Abstract: This study applies the direct method (a detailed study of a relatively small number of individual firms) to a sample of 177 completed housing contracts for from two to 80 homes built in England and Wales between October 1947 and March 1951. The average contract called for the construction of 26 houses with an average floor area of 938 square feet. Data were collected on the manhours of operatives directly engaged in production. This information was obtained for each trade and for labor employed by both main and sub-contractors. About 25 percent of the work on an average house was sub-contracted, and the labor expenditure in manhours per house for

sub-contractors averaged between 17 and 26 percent less than that of main contractors for work in the same trades. Results also indicate that productivity was higher than average when cash incentive schemes were used, when the main contractor was an experienced home builder, and when the main contractor directly supervised work. Regional differences in manhours per house were found to exist, and manhours per house was determined to be inversely related to the number of units specified in the contract.

U.S. Bureau of Labor Statistics. Labor and Material Requirements for Private Multi-family Housing Construction.

For complete citation see Chapter 5, Construction/Housing Costs.

U.S. Bureau of Labor Statistics. Labor and Material Requirements for Private One-Family House Construction.

For complete citation see Chapter 5, Construction/Housing Costs.

## 4. RESIDENTIAL REHABILITATION/RENOVATION

This section is concerned with various aspects of the rehabilitation and renovation of existing residential structures. Residential rehabilitation is an increasingly important facet of the construction industry. Studies abstracted in this section detail the level of expenditures on residential renovation, and indicate the extent of such renovation activities in urban areas. Other reports discuss ways of financing residential rehabilitation efforts.

In the Sternlieb and Listokin study, cost-benefit analysis, an economic evaluation technique, is used to compare the relative value of rehabilitation versus new construction. A separate study by Bagby also estimates rehabilitation costs and compared them to the costs of new housing and urban renewal. It also discusses societal costs and policy implications arising from rehabilitation activities.

Separate articles by Downs and Ingersoll indicate that small builders may be particularly suited for rehabilitation work. This belief contradicts the view expressed in the Rogg article; that is, the rehabilitation industry should be characterized by sizeable firms. Ingersoll's article details various costs related to remodeling and new construction and gives pointers to builders on the estimation of remodeling costs. The Downs study and more comprehensive ones by Colwell and Valenza are also concerned with the motives by which investors alter the flow of housing services through rehabilitation activities. Goedert and Goodman provide an evaluation of the quality of the U.S. housing stock.

Urban Land Institute studies by Black, and by Black, Borut and Dubinski provide information on the trend toward private-market renovation activities in central cities. The latter report presents case studies of five neighborhoods where residential rehabilitation has occurred, while the former report has as its focus a survey of central cities conducted to determine the extent of private-market renovation activity throughout the nation. Rubinstein's article is based on a U.S. Census survey and gives a broad overview of the extent of alterations and repairs to residential properties. Two reports sponsored by the U.S. Department of Housing and Urban Development (one of them in conjunction with the Department of Interior) provide guidelines covering the planning and execution of residential rehabilitation efforts.

Approaches to financing housing rehabilitation activities are provided in reports by Gressel and by Phillips and Teitz. The Gressel report details several techniques which communities can use in financing rehabilitation efforts, while the Phillips and Teitz study concentrates on the mortgage refinancing authority provided under the 1974 Housing and Community Development Act as a means of obtaining reahbilitation financing.

Bagby, D. Gordon. Housing Rehabilitation Costs. Lexington, Massachusetts: Lexington Books, 1973, 98 pp.

Abstract: This study examines the belief that decent housing provided through the rehabilitation of substandard dwelling units offers an alternative to new construction at a lower cost. The data utilized pertains to single-family brick row houses located in the North-Central section of Philadelphia. Eighty-nine row houses wrecked out and restored to a common standard served as a basis for cost information. The nature of rehabilitation, its cost and long-term prospects, as well as the societal costs and policy implications arising from rehabilitation efforts are discussed. Multi-variable regression of data on several structural characteristics is used to derive rehabilitation costs and revenue estimates. When these estimates were compared with the costs of new construction, rehabilitation was found to be 12 to 15 percent cheaper than new housing and 22 to 24 percent cheaper than urban renewal.

Black, J. Thomas. "Private Market Housing Renovation in Central Cities: A ULI Survey." Urban Land, November 1975.

Abstract: A number of cities have recently been experiencing increased private-market, non-publicly-assisted housing construction and renovation activity. This report includes case studies of three cities--St. Louis, Dayton, and Philadelphia--where older, deteriorated neighborhoods were experiencing renovation activity. A mail and telephone survey of the 260 central cities with populations of 50,000 or more was conducted to determine the extent of renovation activity nationally. Survey results indicated that 124 of the 260 central cities (48 percent) are experiencing some degree of private-market, non-subsidized housing renovation. The incidence of renovation activity varies considerably by city size and location. Cities with populations over 500,000 have the greatest likelihood of reporting renovation activity (73 percent). Central city housing renovation is most extensive in the South and least extensive in the Western region of the U.S. An estimated total of 54,600 units (441 units per city experiencing private market renovation activity) have been renovated since 1968.

Black, J. Thomas, Allan Borut and Robert Dubinsky. Private-Market Housing Renovation in Older Urban Areas. Washington, D.C.: The Urban Land Institute, 1977, 47 pp.

Abstract: In recent years there has been a definite trend toward property renovation in many older, inner-city neighborhoods. This report discusses general trends in renovation and the factors which appear to influence these trends. Case studies of five neighborhoods where private-market renovation has occurred are presented. The areas studied are: The South End in Boston, Inman Park in Atlanta, Munger Place in Dallas, the Hill District of Saint Paul, and the Victorian areas of San Francisco. Each case study includes a description of the nature of the particular renovation activity, and analysis of factors which have affected renovation, and a presentation of the economic characteristics of renovation in the area.

Chapman, Robert E. Cost Estimation and Cost Variability in Residential Rehabilitation.

For complete citation see Chapter 6, Construction Cost Estimation and Control.

Colwell, Peter F. An Economic Analysis of Residential Abandonment and Rehabilitation. National Bureau of Standards Interagency Report 76-1043. Washington, D.C., May 1976.

Abstract: This paper is an analysis of market and governmental factors which lead to socially inefficient rehabilitation and abandonment decisions. Its purpose is to abstract from complex problems related to the rehabilitation and abandonment of residential buildings by identifying the essential characteristics of the problems and the role some past and existing social programs have had on aggravating or mitigating these problems. Alternative programs are analyzed for their potential effects on these problems, however policy recommendations are not made. (Author)

Downs, Anthony. "Investing in Housing Rehabilitation Can be Successful." Real Estate Review, Vol. 6, No. 2 (Summer 1976), pp. 66-73.

Abstract: This article is concerned with the principles governing the rehabilitation of older urban housing primarily for investment purposes. It suggests that rehabilitation must shift each structure from a lower-rent, lower-value status to a higher-rent, higher-value status, and that each structure should be located in a neighborhood characterized by this transition. High crime areas should be avoided by investors; they should seek areas in which at least some rehabilitation efforts have begun and where local property values have stabilized or are rising. Some desirable design features should be present in the structure to be rehabilitated which are not found in more modern housing units. Since residential rehabilitation is generally unsuited to large-scale rehabilitation and the economies of mass production, it should be conceived of and carried out on a relatively small scale. Furthermore, the economic feasibility of urban housing rehabilitation often depends on the intense personal involvement of the investor in the renovation process.

Goedert, Jeanne E. and John L. Goodman, Jr. Indicators of the Quality of U.S. Housing. Washington, D.C.: The Urban Institute, September 1977, 69 pp.

Abstract: This study develops a set of housing quality indicators and applies them to the nation's housing stock. It is part of an attempt by the Experimental Housing Allowance Program (EHAP) of the Department of Housing and Urban Development to analyze and develop U.S. housing policy. Meaningful quality indicators are defined as housing deficiencies that tend to be present in the dwellings of households with low long-run expected income. The analysis indicates higher incidences of deficiencies in rural housing relative to

urban housing and in rental units as compared to owner-occupied units. Housing deficiencies were found to be widely distributed over the majority of all units, and not limited to a relatively small number of seriously dilapidated units. The study concludes that no simple measure adequately assesses the many dimensions of housing quality. The housing deficiencies listed in the set of basic indicators are, however, more likely to be present in the dwelling units of households with low incomes than in those of high income households.

Gressel, David. Financing Techniques for Local Rehabilitation Programs. Washington, D.C.: National Association of Housing and Redevelopment Officials, 1976, 98 pp.

Abstract: This guidebook examines alternative techniques that a community can use to make affordable rehabilitation financing available to owners of properties in need of rehabilitation. It is noted that no single housing rehabilitation financing technique is appropriate for all communities. Rehabilitation programs that rely on public resources alone are discussed, as are those programs that take advantage of both public and private capital. A discussion of local direct loan and grant programs is included in the guidebook. It is indicated that community development block grant funds have been used to provide financing directly to property owners. Basic techniques for leveraging public funds such as subsidizing or guaranteeing loans made by local lending institutions are examined. Another technique covered in the guidebook is tax-exempt revenue financing; that is, channeling the flow of private capital to the property owner so that the Federal government, in effect, subsidizes the interest rate on each rehabilitation loan. There is also a discussion of a housing assistance payments program (Section 8, The Housing and Community Development Act of 1974) which can aid lower-income tenants of rehabilitated properties.

Gross, James G., James H. Pielert and Patrick W. Cooke. Impact of Building Regulations on Rehabilitation -- Status and Technical Needs.

For complete citation see Chapter 8, Building Codes and Regulations.

Guidelines for Rehabilitating Old Buildings: Principles to Consider When Planning Rehabilitation and New Construction Projects in Older Neighborhoods. Washington, D.C.: U.S. Department of Housing and Urban Development and U.S. Department of the Interior, January 1979.

Abstract: This report lists several principles to be considered in the planning of new construction or rehabilitation projects. Specific actions to be considered or avoided to insure that new work does not damage the distinguishing qualities of buildings or neighborhood environments are provided. The guidelines were designed to assist property owners and local officials in the formulation of plans for the rehabilitation, preservation and continued use of old buildings, neighborhoods and commercial areas. They

were primarily developed to aid persons eligible to receive Historic Preservation Loans and for local officials responsible for the community development block grant program of the Housing and Community Development Act of 1974. The report provides as appendices lists of HUD offices, State Historic Preservation Officers, and other helpful offices and organizations.

Ingersoll, John H. "Remodeling: A Natural for Builders--But with Key Differences." Housing, Vol. 55, No. 2 (February 1979), pp. 76-81.

Abstract: Estimating remodeling costs is far more difficult than estimating the cost of building a new home. The costs per square foot of a new house are generally lower than those for remodeling. In Minneapolis, additions and alterations average $70 per square foot while new houses go for about $30 to $40 per square foot. Small builders are particularly advantaged when tackling remodeling jobs because of their experience in custom building and in dealing with customers on a personal basis. Special care should be taken in estimating labor costs and time utilized by unproductive labor, as well as in figuring set-up and clean up time. Overhead (salaries, insurance, rent, etc.) and profit margin should be considered in remodeling job estimates, since the small size of these jobs (generally ranging from $5,000 to $15,000) relative to new house construction can undermine profits by greatly magnifying a small dollar mistake in estimating.

Kapsch, Robert J. "Building Codes: Preservation and Rehabilitation."

For complete citation see Chapter 8, Building Codes and Regulations.

Phillips, Kenneth F. and Michael B. Teitz. Housing Conservation in Older Urban Areas: A Mortgage Insurance Approach. Institute of Governmental Studies Report 78-2. Berkeley, California: University of California, February 1978, 42 pp.

Abstract: This report examines the feasibility of utilizing the mortgage refinancing authority provided for under Section 223(f) of the Housing and Community Development Act of 1974 to rehabilitate older declining urban areas (ODA's). The study suggests administrative mechanisms and program supports which would promote rehabilitation activities in ODA's. It is noted that the unavailability of rehabilitation financing, the mixed record of past inner city rehabilitation efforts, and the lack of managerial and technological rehabilitation know-how are impediments to the revitalization of ODA's. Conversely, the high cost of new construction and the neighborhood preservation movement emerging at state and local levels tend to favor the expansion of rehabilitation activities. The report suggests that the skillful use of Section 223(f) to gain ODA's mortgage insurance, in conjunction with housing and non-housing program aids could provide significant resources for moderate rehabilitation without requiring major subsidies or forcing rent increases.

Rehabilitation Guide for Residential Properties. Washington, D.C.: U.S. Department of Housing and Urban Development, January 1968.

Abstract: This report provides physical guidelines for the rehabilitation of existing residential properties. The provisions are intended to provide minimum design and construction criteria on a national basis. The rehabilitation of a broad range of residential structures is covered--from the single family detached house to the large multi-story apartment building. The Guide is intended to be used (1) in the development of local "Property Rehabilitation Standards" for urban renewal rehabilitation, (2) for property rehabilitation under FHA mortgage insurance programs, and (3) as a guide for judging the adequacy of local codes in concentrated code enforcement areas.

Rogg, Nathaniel H. Urban Housing Rehabilitation in the United States. Chicago: United States League of Savings Associations, 1977.

Abstract: Several major American cities are reversing the trend of decline through efforts aimed at rehabilitating and revitalizing their neighborhoods. The study indicates the need for a housing rehabilitation industry characterized by sizeable firms with adequate capitalization. The constraints inhibiting the expansion of rehabilitation efforts are noted. They include land use, construction standards, building codes, income and real property taxes, lack of agreement on what segments of society should benefit, lack of adequate resources on the part of many city residents to undertake rehabilitation, problems of credit access and availability, absentee ownership of inner-city property, and construction industry preference for new housing, among others. A series of recommendations desined to encourage urban rehabilitation are listed. These recommendations present policies and strategies which could be utilized by financial institutions, the building and real estate industries, local and Federal governments, and neighborhoods to revitalize housing and other facets of urban areas. Details on visits to elevent cities located throughout the United States provide background for the study's conclusions and highlight specific urban rehabilitation activities in various cities.

Rubinstein, Nathan. "Residential Alterations and Repairs." Construction Review, Vol. 23, No. 3 (April/May 1977), pp. 4-14.

Abstract: This Bureau of Census survey of alterations and repairs to residential properties covered structures with at least half of their enclosed space devoted to nontransient residential use. In 1976, household interviews were used to sample 4,900 owner-occupied housing units out of a universe of 44,800,000, and a mail survey sampled approximately 1,500 residential and non-residential owners of rental or vacant properties out of a universe of 11,500,000 rented properties. Expenditures incurred by residential property owners are broadly classified as either maintenance and repairs (current costs arising from the upkeep of property) or construction improvements (additional investment in property). Total expenditures increased from $25.2 billion in 1975 to $29.0 billion in 1976, with maintenance repairs accounting for $11.4 billion (39 percent) and construction improvements costing $17.6 billion or 61 percent of the 1976 total.

Smith, Baird. "Information Structure of Building Codes and Standards for the Needs of Existing Buildings."

For complete citation see Chapter 8, Building Codes and Regulations.

Sternlieb, George and David Listokin. Rehabilitation Versus Redevelopment: Cost-Benefit Analyses. New Brunswick, New Jersey: Center for Urban Policy Research, Rutgers University, June 1973, 202 pp.

Abstract: This study evaluates and compares costs and benefits of rehabilitation and redevelopment (new construction) efforts in considering the optimal housing strategy. Findings indicate that the initial costs of rehabilitation are generally at least 20 percent cheaper than those incurred in new construction. Long term cost-benefit analysis indicates that redevelopment is usually cheaper than rehabilitation, but the extent of redevelopment's cost advantage varies by neighborhood and the level of rehabilitation effected. Rehabilitation was slightly cheaper than new construction according to mid-range cost-benefit analysis results. It is significant to note that the alleged social benefits of rehabilitation were disregarded in this study due to the difficulty in assigning dollar values to some of these benefits and the belief of many that such factors are ancillary to rehabilitation's cost advantage in producing housing.

Valenza, Joseph J. Residential Rehabilitation. Unpublished Ph.D. Dissertation, Department of Economics, George Washington University, 1978, 181 pp.

Abstract: This study examines the issue of residential rehabilitation from the viewpoint of a profit maximizing landlord. Based on the profit motive, the landlord makes adjustments to the dwelling unit, one of which is residential rehabilitation. Several decision alternatives are open to the landlord in an attempt to maximize the present value of the annual profit flow from the dwelling unit by altering the flow of housing services. These decisions relate to variations in the level of maintenance, operating inputs, or investment. At the beginning of each time period the landlord assesses the current situation and modifies the flow of housing services accordingly. The direction and amount of change in the level of services is based on the landlord's perception of existing conditions. The landlord then selects the least-cost combination of inputs for the desired level of housing services.

## 5. CONSTRUCTION/HOUSING COSTS

The studies abstracted in this section deal with construction and other costs related to residential housing. Clearly, cost information is essential to any discussion of construction productivity. Several articles and reports provide data on various types of construction costs. Reports of the U.S. Bureau of Labor Statistics provide construction cost information. Two of these reports present data on construction wage rates paid to workers throughout the U.S. Two other studies provide survey results on labor and material requirements for residential construction. The Levy article provides construction cost indexes which permit the measurement of real cost changes between any two years (from 1915-76). Musgrave discusses research efforts toward the development of construction price indexes for single-family homes.

The Eaves study indicates the major factors contributing to increased housing costs and suggests means of cost reduction. The Burns and Mittelbach article touches on many of the issues addressed by Eaves but focuses more on productive (and distributional) efficiency and impediments to the diffusion of innovation which affect both productivity and costs. The Mills book discusses the bases of inflationary pressures in the construction industry and includes an examination of public policy problems with regard to housing. A wide-ranging report of the U.S. Department of Housing and Urban Development pinpoints several national policy problems related to housing. In addition, it gives recommendations to reduce or stabilize new housing costs and to make rehabilitation more affordable.

Mastey discusses the role of the open shop contractor in reducing construction costs. Social costs arising from instability in the construction industry are considered in a U.S. Labor Department report. This study presents dollar values representing the potential savings which would result from a reduction in the magnitude of construction fluctuations.

Bergman, Edward M. External Validity of Policy Related Research on Development Controls and Housing Costs -- Final Report.

For complete citation see Chapter 8, Building Codes and Regulations.

Burns, Leland S. and Frank G. Mittelbach. "Efficiency in the Housing Industry." Housing and Economics: The American Dilemma, (edited by Michael A. Stegman). Cambridge, Massachusetts: The MIT Press, 1970, pp. 119-185.

Abstract: This study focuses on three interrelated areas: (1) the productive and distributional efficiency of the housing industry; (2) the effects of various factors which may impede the diffusion of innovation; and (3) the effect of such factors on the cost of housing. These areas are addressed by first analyzing the historical performance of the housing industry, including the concept of housing as an operating subsystem within other systems. The factors which affect the price and value of housing are discussed next. The study concludes with a discussion of the level and incidence of housing costs.

Eaves, Elsie. How the Many Costs of Housing Fit Together. Research Report No. 16. Washington, D.C.: National Commission on Urban Problems, 1969, 111 pp.

Abstract: The challenge of providing sufficient decent housing for low income families has produced the need to determine the costs of housing and their effect on total cost. This study attempts to devise a cost reduction strategy through the use of data from a broad range of public and private sources. It was found that specific housing cost components (site acquisition and improvement, structure, overhead, financing, etc.) varied significantly in different parts of the country, among different types of housing, and from one builder to another. The greatest recent increase in housing cost has been in land prices; labor costs, mortgage prices and interest rates have also increased markedly. It is indicated that lengthy delays in the building of public housing have resulted in high overhead and carrying charges. Conversely, large cooperative projects displayed the lowest cost figures. This fact implies that the cooperative method and economies of scale both yield significant housing cost savings.

Final Report of the Task Force on Housing Costs, Washington, D.C.: U.S. Department of Housing and Urban Development, May 1978.

Abstract: Throughout the nation, the costs of acquiring and occupying decent housing have increased dramatically in recent years. This study examines reasons other than general inflation for the rise in the costs of housing. Specific measures to reduce or stabilize new housing costs and ways to make rehabilitation more affordable are presented, as well as recommendations to reduce operating costs. The HUD sponsored Task Force identifies several national policy problems. Some of the solutions proposed to remedy these problems are: (1) setting national monetary policy with stabilization of the housing sector as one of its goals; (2) examining the use of tax incentives and indirect subsidies as part of a national tax policy which takes into account the needs of the housing sector; (3) attacking poorly conceived and cost-increasing regulation; (4) establishing mechanisms for creating new building technology and financing techniques; (5) using modified design and financing schemes to support housing development or renovation as part of a concerted effort to meet the needs of those for whom housing costs are an especially intractable problem; and (6) reducing high operating costs through analysis of potential energy conservation benefits, studies of local property tax and hazard insurance cost impacts, and exploration of innovative utility tax and insurance practices.

Ingersoll, John H. "Remodeling: A Natural for Builders -- But With Key Differences."

For complete citation see Chapter 4, Residential Rehabilitation/Renovation.

Levy, Elliot. "Construction Cost Indexes, 1915-76." Construction Review, Vol. 23, No. 4 (June/July 1977), pp. 4-17.

Abstract: The article provides data based on 19 construction cost indexes updated and revised from a mid-sixties Construction Review supplement. The data allows for the measurement of real changes in cost between any two years (up to 1976). A description of each index is provided, in addition to a discussion of its use as a deflator for construction activity. The 19 construction cost indexes are presented on a 1972 = 100 basis, with changes in common index values obtained by expressing the index at various points of time as a percent of a selected base. Changes in construction costs are important to real estate investors, insurance companies, mortgage lenders and local government bodies in estimating current property replacement values, and to homeowners and insurers concerned with accurately determining adequate insurance coverage.

Mastey, Anthony. "New Competition Lowers Construction Costs." Industry Week, Vol. 193, No. 5 (June 1977), pp. 66-70.

Abstract: This article focuses on the cost saving potential of the increasing trend toward the use of open shop contractors. Over the past five years the number of open shop contractors, as measured by membership in the Associated Builders and Contractors Inc., has more than tripled. Problem areas such as jurisdictional disputes, restrictive work practices, construction supervision and labor classification associated with reliance on the building trades unions has prompted many large clients to switch to open shop contractors. Representatives from large industrial firms and utilities are interviewed and report savings in terms of the difference in project bids, of between 15 and 45 percent on the cost of the project. The rapid increase in the volume of open shop construction has resulted in several major concessions concerning overtime wage rates, scheduling and the appropriate scale for small projects. In several instances however, the reaction to the inroads made by open shop contractors was marked by violence and property damage. The effect of the failure of the trades unions' bid to pass the common situs picketing bill, which would permit a single building trades union to picket the general contractor and in essence shut down the entire project, is unclear at the present time. Some contractors claim that if it is ever passed its effect would be to drive contractors toward the use of nonunion labor exclusively.

Mills, Daniel Q. Industrial Relations and Manpower in Construction. Cambridge, Massachusetts: The Massachusetts Institute of Technology Press, 1972, 307 pp.

Abstract: This work explores the sources of inflationary pressure in construction and means of reducing them, attempting also to accurately reflect the enormous variety in the industry and in the relationships between contractors and their employees. The book is divided into four sections: Collective Bargaining--which describes the inflation that developed in the late 1960's; Manpower Utilization--including seasonality, manpower planning, and problems of racial imbalance; Formal Training--particularly apprenticeship;

and Problems of Public Policy--especially in regard to housing. The study ends early in 1971, at the time of the imposition of wage controls in construction. (Author)

Musgrave, John C. "The Measurement of Price Changes in Construction." American Statistical Association Journal, Vol. 64 (September 1969).

Abstract: The development of a statistically adequate set of construction price indexes is the goal of a research effort recently instituted at the Bureau of the Census. This paper describes research done to date on price indexes for single-family houses and indicates plans for future research. Using data from the Bureau's Housing Sales Survey, indexes of the price of new one-family houses sold (including value of site), have been computed by determining the most important characteristics of these houses and estimating, by regression analysis, the price change in houses with a constant "mix" of these characteristics. (Author)

Office of Construction Industry Services, Labor-Management Services Administration. Social Costs of Instability in Construction: A Preliminary Report. Washington, D.C.: U.S. Department of Labor, April 1979.

Abstract: The magnitude of cyclical and seasonal fluctuations in employment and output in the construction industry exacerbate inflation and unemployment in the national economy. This study assigns dollar values to the potential savings that would accrue to society from a modest reduction in the amplitude of construction fluctuations. Savings would be realized through lower unemployment benefits, since there would be a heavier reliance on year-round workers, and through lower depreciation charges on invested capital. Stability in the construction industry would also yield lower inventory carrying costs by supplier firms, and savings through lower wage rates (due to a reduction in the number of construction workers) and higher annual incomes. Fewer accidents would occur because of the smaller number of inexperienced workers. Shorter apprenticeships and fewer dropouts due to steadier employment during the early months of training would also produce substantial savings. These factors represented a potential annual total savings of nearly $5.7 billion in 1977, while social costs for that year were estimated at $7.1 billion.

Paulus, Virginia. Housing: A Bibliography 1960-1972. New York: Ams Press, Inc., 1974, 351 pp.

Abstract: This book focuses on the years 1960 through 1972 which represented an era of growing concern with the nation's housing problem as well as a time of vigorous experimentation and research in the housing field. It is a selective listing of materials of research value issued during that time period and is intended as a reference source for those studying various aspects of housing. Included in the bibliography are also a number of major works published before 1960. The bibliography is largely limited to items

published in the United States and dealing with housng concerns of that country.

U.S. Bureau of Labor Statistics. Industry Wage Survey. Bulletin 1911. Washington, D.C.: U.S. Department of Labor, 1976.

Abstract: The results of a September 1973 survey of wages and related benefits in the construction industry in 17 areas are summarized in this bulletin. Based on a representative sample of construction firms in selected metropolitan areas, this survey of both union and non-union contractors measures pay levels and pay relationships by occupation at a particular time. Findings of the study indicate that average straight-time hourly earnings of union and non-union construction carpenters ranged from $6.19 an hour in Dallas to $9.56 an hour in Cleveland, while the wage for construction laborers ranged from $3.41 in Dallas to $7.39 in Cleveland. Construction workers whose rates were set by labor-management agreements were generally found to enjoy substantial, although widely varying, wage advantages over their non-union counterparts.

U.S. Bureau of Labor Statistics. Labor and Material Requirements for Private Multi-family Housing Construction. Bulletin 1982. Washington, D.C.: U.S. Department of Labor, 1976.

Abstract: This study provides detailed information on employee-hour requirements by occupation and contractor, and data on the amount and type of materials and supplies used in the construction of private multi-family housing. A sample of 89 projects of five or more dwelling units each in 22 Standard Metroplitan Statistical Areas located throughout the continental United States was used to measure the employee-hours and value of materials required for each $1,000 of and each 100 square feet of new private multi-family housing construction in 1971. Findings indicate that this type of construction required 50 employee-hours of on-site labor for each $1,000 and 65 on-site employee-hours for each 100 square feet of space. A total of 126 employee-hours per $1,000 of multi-family housing construction (or 164 employee-hours per 100 square feet), was generated in all sectors of the economy, and materials and supplies constituted over two-fifths of construction costs.

U.S. Bureau of Labor Statistics. Labor and Material Requirements for Private One-Family House Construction. Bulletin 1404. Washington, D.C.: U.S. Department of Labor, June 1964, 41 pp.

Abstract: This study analyzes the labor and material requirements for private, nonfarm, new, one-family house construction. Expenditures in 1962 on this type of construction amounted to about $14 billion, while accounting for approximately 75 percent of private nonfarm new housing construction and 23 percent of all construction. Data were collected on 101 houses located throughout the continental United States. These homes had an average floor

space of 1,240 square feet and an average construction price (construction cost to purchaser) of $14,585. Survey findings indicate that for every $1,000 of construction price utilized in building private one-family homes in 1962, 204 manhours of employment--72 for on-site construction and 132 for off-site activities--were created. Material costs made up 48.2 percent of the total construction price of all the houses surveyed.

U.S. Bureau of Labor Statistics. Union Wages and Hours. Bulletin 1907. Washington, D.C.: U.S. Department of Labor, 1976.

Abstract: This bulletin provides a study of construction wage rates paid to union workers primarily engaged in the construction of commercial and residential buildings. Thirty-three building trades are covered by this study. Average union wage rates for building trades workers increased by 8.6 percent between July 1, 1974 and July 1, 1975, in cities of at least 100,000 inhabitants. Average wage rates were found to be highest in the Middle Atlantic and Pacific regions of the U.S. and lowest in Southeast and Southwest.

## 6. CONSTRUCTION COST ESTIMATION AND CONTROL

The studies abstracted in this section discuss methods, techniques, and systems useful in the estimation and control of construction costs. The Schmidt article is concerned with various factors related to estimating international construction costs. Several articles are concerned with the estimation of labor requirements and/or the control of labor costs of construction projects. Guthrie uses graphical techniques as a means of analyzing field-labor requirements. Paulson's study considers labor costs in terms of financial and productivity factors. The article outlines principles for estimating and controlling field labor costs. The Teicholz article delineates the characteristics of a labor cost control system, while Ulrich's study examines project cost control techniques and suggests a specific cost control system. Likewise, the Shaw article provides information on an effective construction cost control program. Gates' paper reviews techniques and strategies utilized in construction cost estimating and contract bidding. The study by Chapman presents a critique of the four major types of cost estimation procedures which may be used for rehabilitation projects. Implications of the cost saving potential associated with the use of performance concept are also discussed.

Chapman, Robert E. Cost Estimation and Cost Variability in Residential Rehabilitation. National Bureau of Standards Building Science Series 129. Washington, D.C.: U.S. Government Printing Office, December 1980.

Abstract: This study analyzes four methods of estimating the costs of residential rehabilitation. Each method is critiqued with regard to its treatment of changes in the size of the renovation project, the productivity of labor, and the contractor's markup for overhead and profit. Cost comparisons and a discussion of the way in which the inherent riskiness of renovation activities may be assessed are also presented. A theoretical approach for dealing with cost variability which integrates the performance concept with established engineering economics techniques is also developed. (Author)

Gates, Marvin. "Review of Existing and Advanced Construction Estimating Techniques." Advanced Construction Estimation and Cost Control Methods. Proceedings of a Conference Held at the University of Houston, 1976, 31 pp.

Abstract: This paper provides a non-technical discussion of a wide variety of techniques and strategies currently used in construction cost estimation and contract bidding. Preliminary estimating methods discussed include the treatment of capacity, unit pricing considerations, key systems and parameters, and component ratios. Pricing schemes for line items of work are then discussed. Nomographs are also used to illustrate how one would apply an elementary form of break-even analysis. Probabilistic concepts are then introduced which show how to compute the likelihood of at least breaking even. Other topics discussed include: index numbers; the efficiency of labor; economies of scale; and bidding strategy.

Guthrie, K. M., "Field-Labor Predictions for Conceptual Projects." Chemical Engineer, Vol. 76, No. 7 (7 April 1969), pp. 170-172.

Abstract: This study presents techniques which can be used to anlayze field-labor requirements for capital projects. The graphical techniques also permit the visualization in early phases of development of the construction schedule for capital projects. This study provides data helpful in testing and appraising the realism of labor manhours in relation to material cost, manpower, density, craft availability, and other limitations. This data also serves as a basis for predictions of approximate manpower requirements and field durations. An example illustrating field-labor analysis is provided.

Paulson, Boyd C. Jr. "Estimation and Control of Construction Labor Costs." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 101, No. 3 (September 1975), pp. 623-633.

Abstract: This paper outlines basic principles for estimating and controlling field labor costs on construction projects. It divides labor costs into two main categories. The first deals with the strictly financial aspects. These include basic wages, fringe benefits, insurance, taxes, and wage premiums. Most of these are readily quantifiable. The second category introduces factors related to productivity. These include regional variation in skill and work rules; environmental effects ranging from weather and topography to the immediate working conditions of individual craftsmen; learning curve relationships; project work schedule; and interrelationships of labor and management. Productivity factors are difficult to quantify and require much experience and judgment to do so. However, they also offer the contractor the greatest opportunity for control. In both the financial and productivity categories, several of the more subtle cost implications of the various factors are explained. Brief precautionary reference is also made to the many published sources of labor cost data. (Author)

Schmidt, Hubert O. "Construction Cost Estimating International." Transactions of the American Association of Cost Engineers 21st Annual Meeting. Morgantown, West Virginia: 1977, pp. 60-63.

Abstract: Construction cost estimating for architects, engineers and builders in the international area requires careful studies of the local market and the many components which make up the construction estimate. Architects and engineers often obtain cost data by talking with various local or foreign contractors who worked in that area. A prepared survey check list containing questions on major material and labor components is an excellent guide. Relating these questions to construction costs in the United States will result in a sound understanding of the local costs and any special conditions which may exist there. The following list highlights some of the major components of an estimate which have to be studied carefully: Material and equipment, Labor, Contracting, Shipping, Taxes and Duties, Currency fluctuations, Escalation, Schedules, and Profit. (Author)

Shaw, Robert J. "Bringing the Project in With a Profit." Management Focus, Vol. 25, No. 2 (March-April 1978), pp. 18-27.

Abstract: This article describes the characteristics of a project control system. It is specifically targeted to the small contractor. The system seeks to provide for the accurate and timely reporting of actual construction costs and commitments, to compare these costs with the project estimate or budget, and to predict final direct construction costs on the basis of work performance as the project is completed. The article provides an example of a project control system which involves significant use of construction labor in the field. Information on subcontractors and labor, in addition to data on office and field purchases are used to develop a summary of the entire project status.

Teicholz, Paul. "Labor Cost Control." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 100, No. 4 (December 1974), pp. 561-570.

Abstract: The complexity of a labor control system increases in direct proportion to the size of a project and the variables that must be monitored. A comprehensive system must delineate variances resulting from differences in budgeted and actual productivity, labor rates, overtime, and quantity of work performed. The system should produce a weekly report that highlights significant variances. In addition, internal controls are necessary to ensure the accuracy of the reports and to permit the tracing of a given cost figure back to its source. On projects involving significant equipment resources, it is desirable to monitor the combined cost of labor and equipment, since these may be combined in a variety of ways to accomplish a given operation. Finally, it is important to emphasize that a labor control system is effective only when it is utilized as a decision-making tool. This often requires teaching project managers how to make the best use of control reports, and to employ this knowledge in taking effective corrective action. (Author)

Ulrich, Walter E. Jr. "Construction Labor Cost Measurement and Control." Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 103, No. 3 (September 1977), pp. 329-341.

Abstract: This paper examines project cost control techniques. Problems particularly relevant to the construction industry are specially and separately examined. A specific cost control system is suggested including detailed report descriptions. Briefs. (Author)

Zelechoski, Joseph R. "Compatible Units -- A Multi-project System Synthesizing Cost Estimating, Engineering, Productivity and Accounting." Transactions of the American Association of Cost Engineers, July 1979, C5.1-C5.10.

Abstract: Compatible units (CU) is a computer system utilized at the Pennsylvania Power and Light Company to generate cost estimates, standards for productivity measurement, accounting data, etc., for the entire transmission and construction effort. Unique to this system, relative to normal construction practice, is its application of the Methods-Time Measurement (time standards system of work measurement) as the method for the measurement of crew efficiency. The CU system is outlined, and the details are reviewed of an American Association of Cost Engineers Sample Job. Also addressed is how the engineer becomes and then handles the role of cost engineer and standards setter for productivity for each project which he designs. The time standards approach is discussed as it applies to these latter responsibilities. Diagrams. (ABI/INFORM)

## 7. ECONOMICS OF CONSTRUCTION

Studies in this category relate economic analysis to the construction industry. The effect of volume on the cost of residential construction is examined in a report of the National Association of Home Builders Research Foundation. The Ph.D. Dissertation of McConnaughey and to a lesser extent the Cassimatis book take a more comprehensive approach in examining the interrelationship of contract construction, total construction activity, and the national economy. Econometric techniques are used by both authors to derive production functions for the contract construction industry. McConnaughey also presents empirical evidence which supports the claim that substitution of materials for labor and capital may be an important source of productivity growth in the contract construction industry. Similarly, Hillebrandt's study discusses economics as it applies to the construction industry, the market, and contracting firms. The book describes the supply and demand situation relative to the construction industry in detail.

A Pilot Study of the Economies of Scale Related to Residential Construction. Rockville, Maryland: National Association of Home Builders Research Foundation, April 1968, 96 pp.

Abstract: The principal objectives of this study are to determine the effect of volume on the cost of residential construction and the market potential required to induce manufacturers to invest in the development of new products for use in low-cost housing. Personal and telephone interviews, as well as letter requests for information, were utilized to obtain data from builders and manufacturers on: (1) Price-quantity breakpoints for major materials and products used in low- and middle-income housing; (2) The effect of volume on builders' site operations and management; and (3) Methods and criteria used by major building product manufacturers to determine whether to invest in new product development. The builders studied varied widely in terms of their volume, geographic location and type of operation. The study expresses the belief of many builders that maximum or near maximum overall efficencies can be achieved at a volume of about 70 to 100 dwellings per year. In judging whether to invest in new product development, it was found that manufacturers stress the importance of yield and likelihood of success over potential market volume.

Cassimatis, Peter J. Economics of the Construction Industry. Studies in Business Economics No. 111. New York: National Industrial Conference Board, 1969, 168 pp.

Abstract: This study seeks to advance economic knowledge of the contract construction industry and examines the relationship of contract construction to total construction activity and the national economy. Factors governing the economic efficiency of the construction industry are assessed. The study utilizes econometric techniques to derive production and cost functions. The analysis indicates that productivity is lagging in construction partly due to failure to achieve economies of scale. The lack of continuous working

relationships between general contractors and subcontractors which leads to inefficiency or limits the effective span of managerial control is the primary source of diseconomies of scale. Productivity in construction in terms of output per manhour increased an average of about three percent annually between 1947 and 1965. This figure is well below that of other industries and that of the national economy. Furthermore, gains in labor productivity were more than offset by rising wage rates.

Hillebrandt, Patricia M. Economic Theory and the Constuction Industry. London: Macmillan Press Ltd., 1974, 245 pp.

Abstract: The book deals with the economics of the construction industry, the market and the contracting firms. In the introductory chapters the subject is defined and set against the background of the way in which the industry is connected the whole economy. The demands on this industry are examined from a theoretical standpoint including an examination of the intricacies of the market for housing, the importance of the accelerator in derived demand, and the peculiarities of social type demand, e.g., hospitals and schools. The theory is related to the practice of forecasting demand for construction in all major sectors. The demand section ends with a description of the way demand is put to the industry, as this has implications for later chapters. The nature of the supply situation is then analyzed, keeping always in sight the problem of the relationship of the underlying cost and revenue functions to the requirement in the industry to determine cost and price separately for each individual project. The cost curves of the firm are examined and the market supply curves derived from them. The market and industry demand and supply curves are combined in a discussion of market equilibrium, after which it is possible to determine the characteristics of the demand curves facing the individual firm. There follows a section on the mechanism for price determination of a single project and finally a synthesis of the whole analysis. (Author)

McConnaughey, John S. Production Functions in Contract Construction for the United States, 1972. Unpublished Ph.D. Dissertation, Department of Economics, Michigan State University, 1976, 133 pp.

Abstract: This study estimates single equation Cobb-Douglas and Constant Elasticity of Substitution (CES) production functions[1] for twenty-four 4 digit contract construction industries using data from the 1972 Census of Construction Industries. This census, the second since World War II, is the first to contain data on capital inputs. No previous production function study of this type has been undertaken for the contract construction industries because of the lack of appropriate statistical data. The models

[1] The production function expresses the maximum possible output which can be produced with any specified quantities of the various necessary inputs.

developed are similar to those used in production function studies of manufacturing. Traditional production function models generally use value added as output, and ignore the possibility of substitution between materials and other inputs. This study provides evidence that substitution of materials for labor and capital occurs in construction, and that this substitution may be an important source of productivity growth in the sector. Models are developed which facilitate an analysis of substitution between materials and other inputs, especially onsite labor.

## 8. BUILDING CODES AND REGULATIONS

This section examines the nature of building codes and regulations, and their impact on technical innovation and building costs. Such regulations can significantly affect construction productivity. The book by Field and Rivkin and the articles by Falk and by Oster and Quigley indicate that the nature and effectiveness of local building codes varies among different communities. They contend that outmoded local regulations make it difficult to introduce technical improvements. The McConnaughey report provides an economic analysis of the cost to society of saving a life through the code provision requiring the use of Ground Fault Circuit Interrupters in residences. Trellis' National Association of Home Builders study is concerned with the rapidly escalating cost of housing and the role of regulations by all levels of government in increasing housing costs. The cost effects of controls on development on the supply of new housing are examined in a report by Bergman.

Several articles discuss the nature of the building code process and its effect on technical innovation. Winter indicates that despite constant innovation in the building industry, the language of the major U.S. codes often does not allow for items not specifically identified. Kornsand notes that in recent years there has been a trend toward greater complication of the building code process. His study indicates areas in which the process of building code promulgation can be refined and made more efficient. Owen's paper suggests a lessening of producer influence on building codes and increased input by users as a means of speeding evaluation and implementation procedures necessary to introduce innovations in standards and codes.

A brief introduction to the growing literature on the performance concept in building is provided by the Wright article. In this article the prescriptive and performance approaches to code compliance are compared and a framework for introducing the performance concept in building is outlined. An application of the performance concept is given in the report by Nelson and Shibe which develops the Fire Safety Evaluation System for health care facilities. The Nelson-Shibe methodology is a hybrid system because it draws on some attributes which are prescriptive in nature to define a level of performance for each of four categories of fire safety. The economic aspects of the Nelson-Shibe methodology is pursued in the study by Chapman, Chen and Hall. This study shows that the Fire Safety Evaluation System can readily be adopted to mathematical optimization techniques which permit the least-cost means of achieving compliance to the Life Safety Code to be identified. This study also demonstrates the greater flexibility of the performance-based approach by permitting on-the-scene decision makers to superimpose their objectives on a set of retrofit alternatives which are known to be equivalent to the code.

Three studies deal with the effect of building codes on rehabilitative construction. The Gross, Pielert and Cooke report discusses the development of technical bases for regulation, new technology and evaluation tools, and cost effective decision methods with regard to the rehabilitation of existing structures. Kapsch's paper summarizes a number of studies concerned with

the impact of building codes on rehabilitation and preservation projects. Masterson indicates that the development of computer-based systems for building regulation can lead to a more efficient, performance-oriented regulatory process.

Bergman, Edward M. External Validity of Policy Related Research on Development Controls and Housing Costs -- Final Report. Chapel Hill, North Carolina: Center for Urban and Regional Studies, University of North Carolina, August 1974, 226 pp.

Abstract: The three papers which compose this study are each concerned with a particular perspective on development controls and their probable or potential cost effects on the supply of new housing. The papers are: (A) - A Guidance System Perspective on Development Controls and Housing Costs; (B) - A Residential Investment Perspective on Development Controls and Housing Costs, and (C) - A Reasonable Level of Protection Perspective on Development Controls and Housing Costs. The perspectives dealt with in each of these papers represent major objectives underlying the adoption and use of development controls. The "guidance system" paper (A) covers a wide array of development controls, while the "residential investment" (B) and "level of protection" (C) papers deal exclusively with zoning ordinances, subdivision regulations and building controls.

Chapman, Robert E., Phillip T. Chen and William G. Hall. Economic Aspects of Fire Safety in Health Care Facilities: Guidelines for Cost-Effective Retrofits. National Bureau of Standards Interagency Report 79-1902. Washington, D.C., November 1979, 117 pp.

Abstract: This study focuses upon one aspect of the fire safety problem in health care facilities; the use of the Fire Safety Evaluation System developed by the Center for Fire Research at the National Bureau of Standards for determining equivalence to the Life Safety Code. The Life Safety Code, a voluntary code developed by the National Fire Protection Association, is currently the most widely used guide for identifying the minimum level of fire safety in buildings. Using the Fire Safety Evaluation System as a basis, this study developes a computerized procedure which permits the least-cost means of achieving compliance to the Life Safety Code in health care facilities to be identified. Since each of the parameters used in the Fire Safety Evaluation System has a unique value which corresponds to strict compliance, it is possible to quantify the cost savings attributable to the use of the Fire Safety Evaluation System over strict compliance to the Life Safety Code. Preliminary studies conducted by the National Bureau of Standards of a prototypical hospital have concluded that the use of this computerized procedure can result in cost savings of 50 percent or more over those associated with strict compliance to the Life Safety Code. (Author)

Falk, David. "Building Codes in a Nutshell." Real Estate Review, Vol. 5, No. 3 (Fall 1975), pp. 82-91.

Abstract: Model code associations and allied groups are largely responsible for the drafting of basic building codes in the U.S. The technical core of the model codes is provided by three types of national standards: (1) Engineering practice standards, which define methods of design, fabrication or construction; (2) Material standards, which establish quality requirements, physical properties, and sampling and testing methods; and (3) Test standards, which indicate quality and performance testing methods under conditions of use. States normally delegate their building code authority to local governments. Consequently, the nature of these codes as well as the effectiveness in enforcing them often varies greatly among localities. Due to the fact that building codes are generally written in terms of specifications, it is difficult to introduce new materials and techniques which are acceptable under local code provisions. The establishment of a National Institute of Building Sciences under the Housing and Community Development Act of 1974 may facilitate the development and maintenance of nationally recognized performance criteria and standards, and the evaluation of new and existing building technologies.

Field, Charles G. and Steven R. Rivkin. The Building Code Burden. Lexington, Massachusetts: D.C. Heath and Company, 1975, 215 pp.

Abstract: This book asserts that the present system of locally based building codes is overly restrictive and restrains the diffusion of industrialization and innovation in the industry. The authors recommend a move from the custom manufacture approach forced on the industry by the nature of the building regulatory process to a system analagous to assembly-line mass production. Such an approach would better serve the goals of the home building industry to provide quality housing at lower costs and increased efficiency by creating a market large enough to justify investment in innovation and industrialization and to set professional standards for developing and testing new products. To remedy the problems caused by the local nature of building codes, the authors recommend a regulatory system oriented to the local community and its particular problems but operating through a nationwide framework.

Gross, James G., James H. Pielert and Patrick W. Cooke. Impacts of Building Regulation on Rehabilitation: Status and Technical Needs. National Bureau of Standards Technical Note 998. Washington, D.C.: U.S. Government Printing Office, May 1979, 50 pp.

Abstract: This report presents the results of a study of the impact of regulations on building rehabilitation and includes a discussion of the activities of the Building Rehabilitation Technology Group of the Center for Building Technology. Particular activities discussed relative to existing buildings include: (a) development of the technical bases for regulations and an improved regulatory process, (b) development of new technology and evaluation tools, and (c) development of responsive and cost-effective decision tools. A new code concept is outlined which could be a replacement for the "25-50 percent" rule presently in codes for new construction. This rule often controls the amount of work that may be required in the

rehabilitation of existing buildings. The status of existing code documents for building rehabilitation is provided along with an overview of other publications which discuss the impact of building regulations on rehabilitation. (Author)

Kapsch, Robert J. "Building Codes: Preservation and Rehabilitation." Research and Innovation in the Building Regulatory Process: Proceedings of the First NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 473 (edited by Patrick W. Cooke). Washington, D.C., June 1977, pp. 437-452.

Abstract: 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 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. (Author)

Kornsand, Norman J. "A Consulting Engineer's View of Building Code Process from Conception to Adoption." Research and Innovation in the Building Regulatory Process: Proceedings of the Joint Conference, National Bureau of Standards Special Publication 518 (edited by Patrick W. Cooke). Washington, D.C., August 1978, pp. 67-76.

Abstract: The author has been attending the meetings of the model code groups for the past several years. During that time period, he has observed the process, noted the changes that are taking place in the process, identified forces responsible for the changes, analyzed the problems and has formulated possible areas to refine, streamline and be more efficient in

the building code promulgation process. The paper presents the building code process from the standpoint of the designers and engineers who must work with its provisions. The paper shows a significant trend in the past few years that is complicating the process. This includes more code changes, more complex code changes, expansion of the codes into more areas of control, and attempts to keep pace with the plethora of new products, devices and designs flooding the building materials market. (Author)

Masterson, Charles. "The Development of Computer Based Systems for Building Codes." Research and Innovation in the Building Regulatory Process: Proceedings of the First NBS/NCSBCS Joint Conference National Bureau of Standards Special Publication 473 (edited by Patrick W. Cooke). Washington, D.C., June 1977, pp. 369-375.

Abstract: 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. (Author)

McConnaughey, John S. An Economic Analysis of Building Code Impacts: A Suggested Approach. National Bureau of Standards Interagency Report 78-1528. Washington, D.C., October 1978, 65 pp.

Abstract: This report suggests an evaluation approach which can be used by building officials and legislative bodies faced with making building code decisions. A method to evaluate many of the potential benefit and cost impacts of specific building code provisions is developed. The report also defines and categorizes the economic impacts of building codes. While no approach to classifying building code impacts will be fully appropriate for all uses, the definitions and categories proposed may help to clarify or reconcile some of the differing opinions concerning the impact of building codes. Finally, the report illustrates the suggested approach by evaluating the 1975 National Electrical Code requirement for the use of Ground Fault Circuit Interrupters (GFCIs) in residences. Based on sensitivity analysis, estimates are made of how much it costs society in order to save one life through the GFCI code provision. This case study concludes that the estimated cost to save a life is nearly $4 million. A lower bound estimate of the cost to save a life is about $2.5 to $3.5 million. (Author)

Nelson, Harold E. and A. J. Shibe. A System for Fire Safety Evaluation of Health Care Facilities. National Bureau of Standards Interagency Report 78-1555-1. Washington, D.C., May 1980.

Abstract: A quantitative evaluation system for grading health care facilities in terms of fire safety is described. The system can be used to determine how combinations of widely accepted fire safety equipment and building construction features may provide a level of safety equivalent to that required by the widely accepted Life Safety Code of the National Fire Protection Association. The system will provide flexibility to both the designer of new facilities and to the renovator of existing health care facilities. Three major concepts form the basis for code equivalency: a. Occupancy Risk - the number of people affected by a given fire, the level of fire they are likely to encounter and their ability to protect themselves; b. Building Safety Features - the ability of the building and its fire protection systems to provide measures of safety commensurate with the risk; c. Safety Redundancy - in-depth protection, through the simultaneous use of alternative safety methodologies such as containment, extinguishment, and people movement methodologies. The design of the complete fire safety system is intended to ensure that the failure of a single protection device or method will not result in a major failure of the entire system. In this system, equivalency is judged to exist when the total impact of the occupancy risk factors and the compensating building safety features produce a level of safety equal to or greater than that achieved by rigid conformance to the explicit requirements of the NFPA Life Safety Code. In this evaluation, safety performance is gauged both in terms of overall safety impact and depth of redundance. (Author)

Oriole, Kenneth A. Productivity in the Construction Industry -- Influence of Regulatory Laws.

For complete citation see Chapter 3, Construction Productivity.

Oster, Sharon M. and John M. Quigley. "Regulatory Barriers to the Diffusion of Innovation: Some Evidence from Building Codes." The Bell Journal of Economics, Vol. 8, No. 2 (Autumn 1977), pp. 361-377.

Abstract: Previous studies, including the reports of the Douglas and Kaiser Commission, 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 these regulations. The permissibility of four particular innovations in a cross section of jurisdictions in 1970 and the timing of these innovations are explained by attributes of local firms, labor unions, building officials, and housing demand. Our results suggest that the educational level of the chief building official, the extent of unionization, and the relative size of house-building firms in an area affect the diffusion of innovations in residential construction. (Author)

Richard, Owen. "Performance vs. Producer-Controlled Codes." Research and Innovation in the Building Regulatory Process: Proceedings of the First NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 473 (edited by Patrick W. Cooke). Washington, D.C., June 1977, pp. 279-284.

Abstract: 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 versus potential in thermal insulation and nondestructive in-place strength testing by the pullout method. (Author)

Smith, Baird. "Information Structure of Building Codes and Standards for the Needs of Existing Buildings." Research and Innovation in the Building Regulatory Process: Proceedings of the First NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 473 (edited by Patrick W. Cooke). Washington, D.C., June 1977, pp. 453-489.

Abstract: 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. (Author)

Trellis, Alan. "Regulation and the Housing Industry." Research and Innovation in the Building Regulatory Proceedings of the First NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 473 (edited by Patrick W. Cooke). Washington, D.C., June 1977, pp. 391-396.

Abstract: 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 spiraling 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. (Author)

Winter, Steven. "Response to Building Innovation by Building Codes and Regulations." Research and Innovation in the Building Regulatory Process: Proceedings of the Second NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 518 (edited by Patrick W. Cooke). Washington, D.C., August 1978, pp. 49-66.

Abstract: The major U.S. building codes are updated intermittently (e.g., MPS[1] issues updates as they are processed, BOCA[2] issues supplements annually, etc.). The States and other regulatory bodies which adopt these codes do so sometime after the updates are issued. The result is that there is a considerable time span for the process of: recognition of the need for a code change; adoption of the code change; revision of the code; adoption of the revision by regulatory bodies; and implementation of the revision. Innovations in the building industry, however, are constantly occurring, and there is frequently no allowance in the language of codes or in their interpretation for items not specifically identified. The position of the author is that building codes and regulatory agencies must be more responsive to innovative materials and methods in order to foster, rather than hinder, improvements and efficiencies in the building process. (Author)

Wright, James R. "Performance Criteria in Building." Scientific American, Vol. 224, No. 3 (March 1971), pp. 17-25.

Abstract: This article compares the prescriptive and performance-based approaches as they relate to both building specifications and building regulations; a framework for introducing the performance concept in building is also outlined. (A prescriptive approach specifies the dimensions, composition and nature of materials, components and systems. A performance approach sets forth the results expected rather than the means of achievement.) In its most basic form, the performance approach identifies human requirements and the attributes necessary to satisfy them. Second, it undertakes to convert the attributes to criteria that a builder or manufacturer can follow. Third, it establishes procedures for evaluating against the criteria a material, a component, a system or an entire building. In addition, the greater flexibility associated with the performance concept should promote innovations which will result in lower costs to purchasers of construction services.

---

[1] Minimum Property Standards.

[2] Building Officials and Code Administrators.

## 9. CONCLUDING REMARKS

This report has presented a state-of-the-art review of the technical literature concerned with the various factors affecting construction productivity. Particular emphasis was placed on identifying potential sources of variation in the level of productivity in residential construction. Although the emphasis of this report is on the residential sector and rehabilitation activities in particular, it is also focused on topics such as construction management and cost control which perhaps more appropriately apply to large non-residential contractors. During the course of this literature survey a number of recurrent issues were uncovered.

The single topic of greatest interest was concerned with how one can identify the factors affecting productivity and measure their differential impact. Such issues as building regulations, management expertise, job size, training, crew composition, the method of financing, and the quality of materials, equipment and the work environment all exert some influence on the productivity of the factor inputs.

One theme which recurred throughout the documents abstracted was the effect of building codes on construction costs and productivity. Although many authors agree that some form of building code is necessary to ensure compliance with health and safety regulations, the set of codes actually in place goes far beyond these minimal levels in its regulation of the construction process.[1,2,3] The building regulatory process including codes and their enforcement affect productivity in two distinct ways. First, they place physical constraints on the construction process by creating a series of critical check points which may cause work stoppage. The proliferation of on site inspections by code officials was cited frequently as a cause of unnecessary delays by both residential and non-residential contractors.[4] Second, and perhaps more fundamental, building codes slow or prevent the introduction and diffusion of innovations in building technology.[5,6] In the opinion of several authors studied, the nation's set of building codes is poorly organized.[7,8] Furthermore, they conclude that coordination among local jurisdictions is inadequate. This lack of coordination is perhaps the single largest setback to the introduction of new building technologies because the innovator is faced with a task of introducing the technique into many areas, some of which may have conflicting requirements for the same product or process.[9,10] Therefore the costs of introduction and the time before any major economies of scale are realized may be such that the innovator's initial investments in the technique could never be recouped. Approaches recommended by the surveyed literature to the solution of this problem include either the use of the performance concept[11] or the establishment of a uniform set of code provisions (or both).[12]

At a finer level of detail, labor productivity is affected by the size and composition of the crew carrying out the work;[13] the construction practices which govern how these workers carry out their tasks;[14] an the relative skill levels of the labor force engaged in[15] and managers of[16] the construction activity. Another factor affecting labor productivity will be reflected in differences in the availablility of mechanical equipment and specialized

tools which would promote a smooth work flow.[17,18] Since residential contractors tend to be small relative to non-residential contractors and sub-contractors, it seems reasonable to assume that less "capital" equipment will be available to their workers.

Another question of crucial importance is whether the production function for all types of construction is the same. Since the technical options open to certain types of contractors are much more constrained than for others, it is likely that the physical process will exhibit systematic differences in the utilization of labor and materials. The levels of productivity are therefore likely to differ significantly. Empirical studies cited in this report[19,20] have shown that production functions for different classes of construction activities may differ significantly. This would imply that marked differences in the marginal physical product of the factors of production (labor, materials and equipment) would quite likely exist. Their measurement is by no means a "simple" problem, however.[21]

Another issue which affects productivity is the cyclical nature of the construction industry. Construction is very sensitive to cyclical changes of both an economic and a seasonal nature.[22,23] The impact of cyclicality on the productivity of the industry is uncertain, however, since it has been hypothesized that the productivity of employed factors would be higher during times of substantial unemployment in the industry. This hypothesis is based on the assumption that as unemployment rises contractors lay off their least productive (unexperienced) workers and idle inefficient equipment. Thus greater production efficiency is achieved through the use of better "qualified" labor and equipment. In addition, during a recessionary period there will be more competition for the limited projects available which will also tend to increase productivity.[24] On the other hand, due to cyclical instabilities during recovery it will be necessary to hire back less efficient labor and equipment to meet the increased demand for the industry's product. The bid price for contracts may also rise due to lower levels of competition. Another issue related to cyclicality concerns industrialization, a process which seeks to increase productivity by mass producing certain products which are traditionally fabricated at the job site.[25,26] Industrialization will also reduce the seasonal effects on the construction industry to a certain extent. As pointed out by a number of authors, however, the regulatory process may prevent innovation and industrialization from taking place.[27,28]

The issues discussed previously were often mentioned in the studies cited. Unfortunately, agreement on the issues does not imply agreement on the approach for resolution. In particular, some of these issues pose problems in measurement almost as difficult as the measurement of productivity itself. How does one quantify managerial expertise, the amount of human capital the worker brings onto the job, the relative safety or danger of the task, or the quality of the materials and equipment? These issues must be understood, if changes in the level of productivity for certain factors of production are to be carried out in a systematic and efficient manner.

CITATIONS FOR THE CONCLUDING REMARKS SECTION


[1] Charles G. Field and Steven R. Rivkin, The Building Code Burden, Lexington, Massachusetts: D.C. Heath and Company, 1975.

[2] John S. McConnaughey, An Economic Analysis of Building Code Impacts: A Suggested Approach, National Bureau of Standards Interagency Report 78-1528, Washington, D.C., October 1978.

[3] Norman J. Kornsand, "A Consulting Engineer's View of Building Code Process from Conception to Adoption," Research and Innovation in the Building Regulatory Process: Proceedings of the Second NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 518 (edited by Patrick W. Cooke), Washington, D.C., August 1978, pp. 67-76.

[4] A National Strategy for Improving Productivity in Building and Construction: Proceedings of the Building Research Advisory Board's 1979 Building Futures Forum, November 7-8, 1979, Washington, D.C.: National Research Council, National Academy of Sciences, 1980.

[5] Charles G. Field and Steven R. Rivkin, op. cit.

[6] Sharon M. Oster and John M. Quigley, "Regulatory Barriers to the Diffusion of Innovation: Some Evidence from Building Codes," The Bell Journal of Economics, Vol. 8, No. 2 (Autumn 1977), pp. 361-377.

[7] Charles G. Field and Steven R. Rivkin, op. cit.

[8] Sharon M. Oster and M. Quigley, op. cit.

[9] Charles G. Field and Steven R. Rivkin, op. cit.

[10] Sharon M. Oster and M. Quigley, op. cit.

[11] James R. Wright, "Performance Criteria in Building," Scientific American, Vol. 224, No. 3 (March 1971), pp. 17-25.

[12] David Falk, "Building Codes in a Nutshell," Real Estate Review, Vol. 5, No. 3 (Fall 1875), pp. 82-91.

[13] Harold E. McNally and John A. Havers, "Labor Productivity in the Construction Industry," Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 93, No. 3 (September 1967).

[14] Melvin Kupperman, "Improving Productivity: The Construction Phase," Consulting Engineer, Vol. 49, No. 6 (December 1977), pp. 52-55.

[15] John D. Borcherding and Clarkson H. Oglesby, "Construction Productivity and Job Satisfaction," Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 100, No. 3 (September 1974), pp. 413-431.

[16] Robert D. Logcher and William W. Collins, "Management Impacts on Labor Productivity," Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 104, No. 4 (December 1978), pp. 447-461.

[17] John D. Borcherding, "Improving Productivity in Industrial Construction," Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 102, No. 4 (December 1976), pp. 599-614.

[18] Melvin Kupperman, op. cit.

[19] Peter J. Cassimatis, Economics of the Construction Industry, Studies in Business Economics No. 111, New York: National Industrial Conference Board, 1969.

[20] John S. McConnaughey, Production Functions in Contract Construction for the United States, 1972, Unpublished Ph.D. Dissertation, Department of Economics, Michigan State University, 1976.

[21] Ibid.

[22] Office of Construction Industry Services, Labor-Management Services Administration, Social Costs of Instability in Construction: A Preliminary Report, Washington, D.C.: U.S. Department of Labor, April 1976.

[23] Daniel Q. Mills, Industrial Relations and Manpower in Construction, Cambridge, Massachusetts: The Massachusetts Institute of Technology Press, 1972.

[24] Anthoney Mastey, "New Competition Lowers Construction Costs," Industry Week, Vol. 193, No. 5 (June 1977), pp. 66-70.

[25] Office of Construction Industry Services, op. cit.

[26] Charles G. Field and Steven R. Rivkin, op. cit.

[27] Ibid.

[28] Sharon M. Oster and John M. Quigley, op. cit.

NBS-114A (REV. 9-78)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET | 1. PUBLICATION OR REPORT NO. NBS 80-2150 | 2. Gov't. Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|

**4. TITLE AND SUBTITLE**
Productivity in Residential Construction: An Annotated Bibliography

**5. Publication Date**
Febuary 1981

**6. Performing Organization Code**

**7. AUTHOR(S)**
Bruce E. Thompson and Robert E. Chapman

**8. Performing Organ. Report No.**

**9. PERFORMING ORGANIZATION NAME AND ADDRESS**

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, DC 20234

**10. Project/Task/Work Unit No.**

**11. Contract/Grant No.**

**12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS** *(Street, City, State, ZIP)*

Same as item 9

**13. Type of Report & Period Covered**
Final

**14. Sponsoring Agency Code**

**15. SUPPLEMENTARY NOTES**

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

**16. ABSTRACT** *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report presents a state-of-the-art review of the technical literature related to one or more of the factors affecting productivity in residential construction. Particular emphasis is placed on identifying potential sources of variation between the level of productivity in new housing construction versus that in housing renovation. Although this report focuses on the residential sector, emphasis is also placed on topics such as contruction management and cost control which perhaps more appropriately apply to the non-residential sector. The references have been categorized so that articles dealing with specific productivity and construction topics can be easily identified. The categories emphasized in this report are: general productivity/ productivity measurement; construction productivity; residential rehabilitation/ renovation; construction/housing costs; construction cost estimation and control; economics of construction; and building codes and regulations.

**17. KEY WORDS** *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Building codes; building economics; construction; cost; economics; housing; productivity; regulation; renovation.

**18. AVAILABILITY** ☒ Unlimited

☐ For Official Distribution. Do Not Release to NTIS

☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003-

☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

**19. SECURITY CLASS (THIS REPORT)**
UNCLASSIFIED

**21. NO. OF PRINTED PAGES**
58

**20. SECURITY CLASS (THIS PAGE)**
UNCLASSIFIED

**22. Price**
$8.00

USCOMM-DC