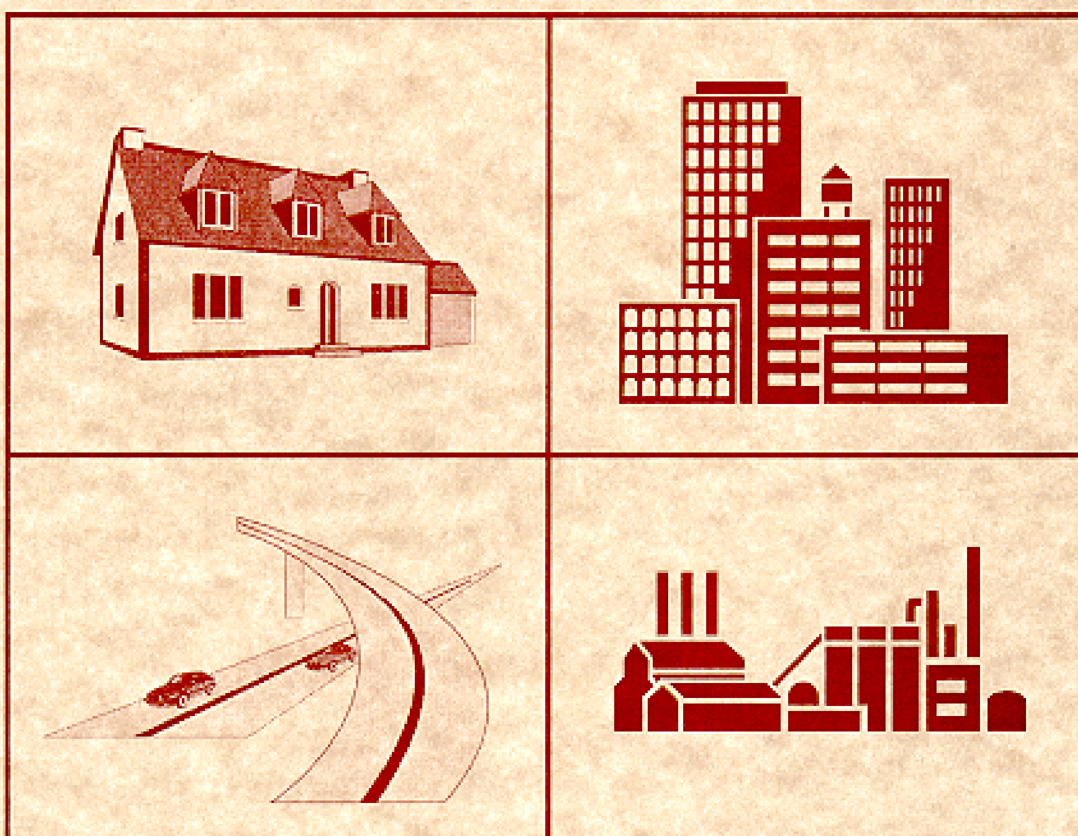
NISTIR 6189

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards and Technology

Office of Applied Economics
Building and Fire Research Laboratory
Gaithersburg, Maryland 20899

An Approach for Measuring Reductions in Delivery Time: Baseline Measures of Construction Industry Practices for the National Construction Goals

Robert E. Chapman and Roderick Rennison



Residential • Commercial/Institutional • Industrial • Public Works

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National Institute of Standards and Technology
Building and Fire Research Laboratory
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U.S. DEPARTMENT OF COMMERCE
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Abstract

The Construction and Building Subcommittee of the National Science and Technology Council is developing baseline measures of current construction industry practices and measures of progress with respect to each of the seven National Construction Goals. The seven National Construction Goals are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. Baseline measures and measures of progress are being produced for each of the four key construction industry sectors. The four sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works. This document provides a detailed set of baseline measures for National Construction Goal 1 (reductions in delivery time). As such, it describes data sources, data classifications and hierarchies, and the metrics used to develop the baseline measures. Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed.

Keywords

building economics; buildings; construction; construction costs; construction time; costs; cycle time reduction; delivery time; economic analysis; metrics; schedule compression

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Preface

This study was conducted by the Office of Applied Economics in the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST). The study was sponsored by the Construction and Building Subcommittee of the National Science and Technology Council. The BFRL project, of which this study is a part, seeks to develop baseline measures and measures of progress with respect to each of the seven National Construction Goals. These measures are to be disseminated both through publications and, ultimately, electronically via the World Wide Web. The intended audience for this document is the Construction and Building Subcommittee member organizations as well as construction industry representatives and other interested parties.

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The authors wish to thank all those who contributed so many excellent ideas and suggestions which they have attempted to incorporate into this document. The authors wish to thank Drs. Richard N. Wright and Arthur H. Rosenfeld, Co-Chairs of the Construction and Building Subcommittee, and Dr. Andrew J. Fowell, Secretariat of the Construction and Building Subcommittee, for their guidance, suggestions, and support. The authors also wish to thank the British Government, the Royal Academy of Engineering, and WS Atkins PLC, who provided both financial and technical support throughout the preparation of this document. Special thanks are extended to Ms Alison Bowen, Projects Manager at the Royal Academy of Engineering, and Dr. Tim Broyd, Technology Development Director at WS Atkins. The authors also wish to thank the Construction Industry Institute (CII) for providing an aggregated, project-level data set covering the commercial/institutional, industrial, and public works sectors. Special thanks are extended to Dr. Richard Tucker, Director, CII and to Dr. Kirk Morrow, formerly with CII, for their stimulating discussions on the uses of these data. Special appreciation is extended to Drs. Harold E. Marshall and Sieglinde K. Fuller of the Office of Applied Economics at NIST's Building and Fire Research Laboratory (BFRL) for the thoroughness of their reviews and for their many insights and Ms. Sandy Kelley for her assistance in preparing the manuscript for review and publication. Special appreciation is also extended to Ms. Julia D. Rhoten of Virginia Polytechnic Institute and State University, formerly with BFRL's Office of Applied Economics, who helped immensely with the data collection and analysis effort during her summer and winter internships. Thanks are due to Mr. Noel J. Raufaste of BFRL's Office of Technology Transfer and Cooperative Research for his comments and helpful suggestions.

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Executive Summary

The Construction and Building Subcommittee of the National Science and Technology Council has established seven National Construction Goals in collaboration with a broad cross section of the construction industry.[i] Data describing current practices of the US construction industry are needed to establish baselines against which the industry can measure its progress towards achieving the seven National Construction Goals. The Goals are: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. Baseline measures and measures of progress will be produced for each National Construction Goal in each of the four key construction industry sectors. The four sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works.

This document is the second in a series of studies prepared by NIST's Building and Fire Research Laboratory.[ii] It provides a detailed set of baseline measures for National Construction Goal 1, reductions in the delivery time of constructed facilities. The baseline measures characterize current industry performance for Goal 1. Industry performance in 1994 is used as the reference point from which the values of the baseline measures are calculated. Goal 1 was identified as one of the highest priority National Construction Goals by the construction industry.

Delivery time is defined as the elapsed time from the decision to construct a new facility until its readiness for service. Delivery time issues affect both industrial competitiveness and project costs. Owners, users, designers, and constructors are calling for technologies and practices to reduce delivery time.

The intended audience for this document is the Construction and Building Subcommittee member organizations, the four sector council member organizations,[iii] construction industry representatives, and other interested parties. In addition, because this document includes both detailed information on the baseline measures for National Construction Goal 1 and a compilation of statistics on the four sectors and the construction industry as

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i Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1995. *Construction and Building: Federal Research and Development in Support of the US Construction Industry*. Washington, DC: National Science and Technology Council.

ii An earlier companion document focuses on National Construction Goal 2. For information on reductions in operations, maintenance, and energy costs, see Chapman, Robert E., and Roderick Rennison. 1998. *An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs: Baseline Measures of Construction Industry Practices for the National Construction Goals*. NISTIR 6185. Gaithersburg, MD: National Institute of Standards and Technology.

iii The four sector council member organizations are: (1) National Association of Home Builders Research Center (residential); (2) National Institute of Building Sciences (commercial/institutional); (3) Construction Industry Institute (industrial); and (4) American Public Works Association (public works).

a whole, it is anticipated that this document will serve as a resource reference for readers with a wide variety of interests in the construction industry.

This document has seven chapters and seven appendices. Chapter 1 explains the purpose, scope, and general approach. Chapter 2 introduces the National Construction Goals, describes how a well-defined set of metrics is used to develop the baseline measures and measures of progress, and outlines the project approach. Chapter 3 provides an overview of the construction industry. The overview provides the context within which the baseline measures are developed. Chapter 4 presents two data classification schemes. These data classification schemes are used to construct data hierarchies from which key metrics are derived and used to develop the baseline measures. Chapter 5 presents the baseline measures for the residential sector. These measures are based on data published by the US Bureau of the Census, supplemented by information from the National Association of Home Builders. Chapter 6 presents the baseline measures for the three non-residential sectors—commercial/institutional, industrial, and public works. These measures are based primarily on aggregated, project-level data made available by the Construction Industry Institute. A discontinued data series published by the US Bureau of the Census is included as a reference point and for purposes of comparison. Chapter 7 concludes the document with a summary and suggestions for further research. The individual data hierarchies for each construction industry sector are presented in Appendices A through D. Each sector occupies an appendix: Appendix A covers the residential sector; Appendix B covers the commercial/institutional sector; Appendix C covers the industrial sector; and Appendix D covers the public works sector. Three additional appendices are also included as an aid to cross referencing terms, statistical information, and other material contained in this document. Appendix E lists the assignment of each state to one of the four census regions: (1) Northeast; (2) Midwest; (3) South; or (4) West. Appendix F lists the two-digit Standard Industrial Classification (SIC) Codes. Appendix G provides a list of acronyms and their definitions.

Chapter 2 provides perspective on the overall effort to develop baseline measures and measures of progress for each of the seven National Construction Goals. First, each National Construction Goal is introduced and described. Next, the process for developing baseline measures for each Goal is described. This process involves: (1) specifying a data-oriented hierarchy; (2) collecting and compiling the key data and supporting information for the base year, 1994; (3) defining metrics for each goal/sector combination; and (4) producing the metrics in a summary form (i.e., figures and tables to depict the metrics). The methods for measuring progress use the baselines as their reference point. Because the National Construction Goals may be specified as targets measured against baseline values, "gap analysis" is the preferred method for defining the measures of progress. The advantage of this measure of performance is that it employs the same values for each measure as used in computing the baselines. The gap analysis method measures how much of the initial gap (i.e., between the baseline value and the goal value) has been closed by some future date. Criteria are then presented which ensure that the data selected for *analysis* are well-defined, consistent, and replicable. The chapter also outlines a strategy for collecting and disseminating information on each National Construction Goal.

Chapter 3 provides a snapshot of the US construction industry. As such, it provides the context within which the baseline measures are developed. An extensive set of statistics has been compiled on each sector; many of these statistics are included in Chapter 3. These statistics are useful not only as a tool for defining the baseline measures but also as a resource reference for readers with a wide variety of interests in the construction industry.

Chapter 3 contains four sections. Each section deals with a particular topic. The topics progress from general in nature to very specific. First, information on the value of construction put in place is provided to show the size of the construction industry and each of its four sectors—residential, commercial/institutional, industrial, and public works. Second, information on the nature of construction activity for each sector of the industry is presented. The SIC Codes for the construction industry are introduced and described as a means for organizing construction activity. Information on the nature of construction activity includes breakouts between new construction activities, maintenance and repair activities, and additions and alterations. The challenge of developing annual estimates for each sector by nature of construction activity is described. Examples are given which demonstrate how different data sources result in major differences in a particular year's estimates. Third, information on employment in the construction industry is summarized and a series of employment-related statistics are presented. The SIC Codes for the construction industry are used as a means for organizing key employment-related information. Comparisons between employment and output in the construction industry and employment and output in the overall US economy are also included. Fourth, information on cost trends and on other, special considerations, is presented.

The construction industry is a key component of the US economy. Total construction investment represents about 11 percent of Gross Domestic Product. A key indicator of construction activity is the value of new construction put in place. Data published by the US Bureau of the Census are used to establish the composition of construction expenditures by type of construction. These expenditures are then assigned to one of the four key construction industry sectors.

Table ES-1 summarizes both the annual sector totals and the sum total. Since 1992, the value of new construction put in place has risen slightly from $393.8 billion in 1992 to $435.5 billion in 1996 in constant 1992 dollars. The largest component of new construction over this period was in the residential sector (about 32 percent of the total), with the smallest component in the industrial sector (about 6 percent).

Table ES-1. Value of New Construction Put in Place in Millions of 1992 Dollars: Sector Totals and Sum Total

Sector	Value of Construction Put in Place ($ Millions)				
	1992	**1993**	**1994**	**1995**	**1996**
Residential	133,658	141,076	156,576	146,167	157,846
Commercial/Institutional	122,960	125,770	128,116	137,006	149,445
Industrial	30,902	27,212	28,161	30,391	29,219
Public Works	106,311	103,762	103,360	101,593	98,973
Total – All Sectors	393,831	397,820	416,213	415,157	435,483

Source: US Bureau of the Census

Chapter 4 covers the data classification schemes, how the sectors were defined, how data sources were identified, and how key delivery time data were collected. Data classification hierarchies were developed for each of the four industry sectors. These hierarchies were essential in order to be able to sort data into relevant sectors, to prioritize the data, and to establish data linkages. Initially, an "idealized" hierarchy was developed for each sector. *Idealized hierarchies* were developed with a view to defining for the four industry sectors the extent and key components considered relevant to Goal 1. Within each sector hierarchy, the key components likely to have an impact upon the Goal are examined. The *data oriented hierarchies* represent the modification of the idealized hierarchies to reflect data availability and constraints. This is an important step in ensuring that the baseline measures remain succinct (see Appendices A through D where the data oriented hierarchies are presented). The two primary types of data collected were electronic data and published data. As data were collected, the data oriented hierarchies for each industry sector were refined to reflect data availability constraints. Section 4.2 summarizes the extensive data searches of publicly accessible Federal Agency databases carried out by the authors. A further set of data searches focused upon research, trade, professional, private sector, and academic organizations. In addition, a number of useful data sources have been identified where organizations are systematically collecting and publishing data. The key sources of data and information, including those that are accessible electronically, are listed in Section 4.2 and in the References section.

Chapter 5 describes the residential sector and traces the development of the baseline measures for the residential sector. The baseline measures for the residential sector are based on data published by the US Bureau of the Census, supplemented by information from the National Association of Home Builders (NAHB).

The Census data cover two key parts of the residential construction process: (1) from the issuance of the building permit until the start of construction; and (2) from the start of construction until the completion of construction. The Census data do not include any estimates of the amount of time required for the permitting process. In the context of this document, the permitting process is the first part of the three part residential construction process.

The key baseline measures for the residential sector are summarized in Table ES-2. It is important to note that the data recorded in Table ES-2 are for the reference year 1994. Table ES-2 shows that once authorization is received, construction commences within two months on average. For example, construction of single-family dwellings commences within 0.7 months of authorization. Table ES-2 shows that construction duration—from start of construction to completion—ranges from 5.6 months for single-family dwellings to 9.3 months for residential structures with 5 units or more.

Table ES-2. Selected Baseline Measures for New Housing Units by Type of Structure: 1994

Baseline Measure	Average Number of Months by Type of Structure		
	1 unit	2 to 4 units	5 units or more
From Authorization to Start of Construction	0.7	1.1	1.8
From Start of Construction to Completion	5.6	7.3	9.3

Source: US Bureau of the Census

The information from the NAHB is drawn from a single research report which focused on the Atlanta regional market. Although the NAHB estimates may not be indicative of national averages, they are well documented and are based on data provided by practitioners in the field. Furthermore, the NAHB report identifies opportunities for reducing cycle time which translate into significant reductions in delivery time.

Chapter 6 describes the non-residential sectors and traces the development of the baseline measures for the non-residential sectors. The baseline measures for the three non-residential sectors are based on a discontinued data series published by the US Bureau of the Census and aggregated, project-level data made available by the Construction Industry Institute (CII). The Census data cover the elapsed time from the start of construction until the completion of construction. The Census data do not include any estimates of the amount of time required for the permitting process. Although CII data are used as the primary source for non-residential delivery time statistics, the Census data are used as a reference point and for purposes of comparison. It is important to note that the CII data include estimates of both total project duration and construction phase duration. Thus, the CII data capture a more complete meaning of delivery time, than provided by the Census data. However, to facilitate comparisons with the Census data, estimates of the construction phase duration based on the CII data are included.

CII divides its data into four industry groups: (1) buildings; (2) heavy industrial; (3) light industrial; and (4) infrastructure. CII's four industry groups are easily assigned to the three non-residential sectors. Industry group 1 maps into the commercial/institutional sector. Industry groups 2 and 3 map into the industrial sector. Industry group 4 maps into the public works sector. The CII data set also contains information on metrics related to schedule growth and the relationship between the use of best practices and key delivery time metrics. Both sets of information are discussed in this document.

The key baseline measures for the non-residential sectors are summarized in Table ES-3. It is important to note that the data recorded in Table ES-3 are not for the reference year 1994; they are for 1996 and 1997. This is because the Census data series was discontinued in 1992 and the CII data series was begun in 1996. Table ES-3 shows that construction duration for industrial projects is shorter than for commercial/institutional projects and public works projects. Typically, industrial projects are process-related and hence are driven by schedule considerations.

Table ES-3. Selected Baseline Measures for the Non-Residential Sectors: 1996-1997

Baseline Measure	Average Number of Months by Industrial Group			
	Commercial/ Industrial	Heavy Industrial	Light Industrial	Public Works
Construction Duration	23.7	13.5	14.2	21.0

Source: Construction Industry Institute

Chapter 7 discusses additional areas of research that might be of value to government agencies and private bodies who are concerned about reducing the delivery time of constructed facilities. These areas of research are concerned with: (1) the duration of the permitting process for all four sectors; (2) the collection of additional delivery time data for the commercial/institutional sector and the public works sector; (3) the collection of additional project-level data to analyze the relationships between best practice use and reductions in delivery time; and (4) the measurement and evaluation of progress toward achievement of National Construction Goal 1.

1. Introduction

1.1. Background

Data describing current practices of the US construction industry are needed to establish baselines against which industry can measure its progress towards achieving the seven National Construction Goals. The seven National Construction Goals are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries.

Although information having relevance to the seven goals is available, for the most part, this information has such a narrow focus that a consistent set of baseline measures and associated measures of progress cannot be produced without first conducting a significant research effort. Specifically, information from a wide variety of data sets needs to be collected, reviewed, analyzed, and critiqued to ensure that the baseline measures and measures of progress which result are:

(1) adequate (i.e., they not only capture the complexities of the US construction industry but also represent a consensus among experts in the field); and

(2) suitable for dissemination to the public.

It is essential to have baseline data and associated measures of progress to determine the success of actions taken to improve the competitiveness of the US construction industry. In addition, baselines and measures of progress will make it possible to demonstrate the benefits of advanced technologies and practices, and to guide decision makers in prioritizing potential programs.

The goal of this project is to develop a suite of products which support the measurement and attainment of the National Construction Goals by the four key construction industry sectors. The four industry sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works. Three basic sets of products are envisioned:

(1) *Baseline Measures*: Develop baseline measures which characterize current industry performance with respect to each of the seven goals. The averages of current practice (defined in this document as industry performance in 1994) will become the baselines for measuring progress towards achieving each of the goals.

(2) *Measures of Progress*: Develop methods for measuring progress. These "results" measures are envisioned as a composite of performance measures

offering a means not only for monitoring actual performance but also for marshaling support for improving results.

(3) *Periodic Reports*: Provide information on each of the seven goals. This information will be made available to interested parties both through publications and, ultimately, electronically via the World Wide Web. Potential outlets for the baselines and measures of progress include the Construction and Building Subcommittee member organizations and the four sector council member organizations.[1]

1.2. Purpose

The purpose of this document is twofold. First and foremost, this document provides a detailed set of baseline measures for National Construction Goal 1 (reductions in delivery time). As such, it describes data sources, data classifications and hierarchies, and the metrics used to develop the baseline measures. Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed. This document is the second in a series of studies prepared by NIST's Building and Fire Research Laboratory (BFRL). An earlier companion document[2] focuses on National Construction Goal 2, reductions in operations, maintenance, and energy costs.

The second purpose of this document is to outline BFRL's strategy for collecting information on each National Construction Goal, for gaining consensus on what information should be included in the baseline measures and measures of progress, and for disseminating information to interested parties. Specifically, a two-phase, four-step process for developing and disseminating the baseline measures and measures of progress is described.

1.3. Scope and Approach

This document has six chapters and seven appendices in addition to the Introduction. Chapter 2 introduces the National Construction Goals, describes how a well-defined set of metrics is used to develop the baseline measures and measures of progress, and outlines the project approach. Chapter 3 provides an overview of the construction industry. The overview provides the context within which the baseline measures are developed. Chapter 4 presents two data classification schemes; one which is idealized

[1] The four sector council member organizations are: (1) National Association of Home Builders Research Center (Residential); (2) National Institute of Building Sciences (Commercial/Institutional); (3) Construction Industry Institute (Industrial); and (4) American Public Works Association (Public Works).
[2] Chapman, Robert E., and Roderick Rennison. 1998. *An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs: Baseline Measures of Construction Industry Practice for the National Construction Goals.* NISTIR 6185. Gaithersburg, MD: National Institute of Standards and Technology.

and one which is data driven. These data classification schemes are used to construct data hierarchies from which key metrics are derived and used to develop the baseline measures. Chapter 5 presents the baseline measures for the residential sector. These measures are based on data published by the US Bureau of the Census, supplemented by information from the National Association of Home Builders. Chapter 6 presents the baseline measures for the three non-residential sectors—commercial/institutional, industrial, and public works. These measures are based on a discontinued data series published by the US Bureau of the Census and aggregated, project-level data made available by the Construction Industry Institute. Chapter 7 concludes the document with a summary and suggestions for further research.

The individual data hierarchies for each construction industry sector are presented in Appendices A through D. Each sector occupies an appendix: Appendix A covers the residential sector; Appendix B covers the commercial/institutional sector; Appendix C covers the industrial sector; and Appendix D covers the public works sector. Three additional appendices are also included as an aid to cross referencing terms, statistical information, and other material contained in this document. Appendix E lists the assignment of each state to one of the four census regions: (1) Northeast; (2) Midwest; (3) South; or (4) West. Appendix F lists the two-digit Standard Industrial Classification (SIC) Codes. Appendix G provides a list of acronyms and their definitions.

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2. The National Construction Goals: A Tool for Promoting Competitiveness Within the Construction Industry

2.1. Description of the National Construction Goals

The Construction and Building (C&B) Subcommittee has studied research priorities expressed by the construction industry. These priorities translate into the following seven National Construction Goals:

1. 50% Reduction in Delivery Time
2. 50% Reduction in Operation, Maintenance, and Energy Costs
3. 30% Increase in Productivity and Comfort
4. 50% Fewer Occupant-Related Illnesses and Injuries
5. 50% Less Waste and Pollution
6. 50% More Durability and Flexibility
7. 50% Reduction in Construction Worker Illnesses and Injuries

To make the National Construction Goals operational, their values are based on the values of a well-defined set of baseline measures. As noted in the Introduction, the values of the baseline measures for each goal are averages of industry performance in 1994. The year 1994 was established as the basis for computing the values of the baseline measures because it was the year when the National Construction Goals were first formulated.[3]

Two priority thrusts, better constructed facilities and health and safety of the construction work force, were defined as the focus of C&B-related research, development, and deployment (RD&D) activities. The objective of the C&B-related RD&D activities is to make technologies and practices capable of achieving the goals under the two priority thrusts available for general use in the construction industry by 2003.

Achievement of the National Construction Goals will: (1) reduce the first costs and life-cycle costs of constructed facilities in the four key construction industry sectors (i.e., residential, commercial/institutional, industrial, and public works); (2) result in better constructed facilities; and (3) result in improved health and safety for both construction workers and occupants of constructed facilities. Achievement of the goals will convey benefits to each of the four construction industry sectors (e.g., housing will become more affordable through reductions in first costs and life-cycle costs). However, depending on the goal and the construction industry sector, the beneficial impacts are expected to vary. To gain a better appreciation of the importance of the National Construction Goals, both

[3] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1994. *Rationale and Preliminary Plan for Federal Research for Construction and Building*. NISTIR 5536. Washington, DC: National Science and Technology Council.

individually, and taken together, and of their relationship to the four key construction industry sectors, a brief description of each goal follows. The descriptions are patterned after those given in the report by Wright, Rosenfeld, and Fowell.[4]

Goal 1: 50% Reduction in Delivery Time

Delivery time is defined as the elapsed time from the decision to construct a new facility until its readiness for service. Delivery time issues affect both industrial competitiveness and project costs. During the initial planning, design, procurement, construction, and start-up process, the needs of the client are not being met. Furthermore, the client's needs evolve over time, so a facility long in delivery may be uncompetitive or unsuitable when it is finished. Delays almost always translate into increased project costs due to inflationary effects, higher financial holding costs, and reduced productivity. Furthermore, the investments in producing the facility cannot be recouped until the facility is operational. Owners, users, designers, and constructors are among the groups calling for technologies and practices to reduce delivery time.

Goal 2: 50% Reduction in Operation, Maintenance, and Energy Costs

Operations, maintenance, and energy (OM&E) costs are a major factor in the life-cycle costs of a constructed facility. In some cases, OM&E costs over the life of a facility exceed its first cost. However, because reductions in OM&E costs are often associated with increased first costs, facility owners and managers may under invest in cost saving technologies. Furthermore, undue attention on minimizing first costs may result in a facility which is expensive to operate and maintain, wastes energy resources, is inflexible, and rapidly becomes obsolete. Finally, because OM&E costs tend to increase more rapidly than the general rate of inflation, facility owners and operators are often forced to reallocate funds to cover OM&E costs. Reductions in OM&E costs will produce two types of benefits. First, constructed facilities will become more affordable because facility owners and operators are making more cost-effective choices among investments (e.g., design configurations) which affect life-cycle costs. Second, these same facilities will better conserve scarce energy resources.

Goal 3: 30% Increase in Productivity and Comfort

Industry and government studies have shown that the annual salary costs of the occupants of a commercial or institutional building are of the same order of magnitude as the capital cost of the building.[5] Occupant comfort depends largely on the nature of buildings, building furnishings, and indoor environments. The quality of indoor environments also has a large impact on occupant health and productivity. Improvement of the productivity

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[4] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1995. *Construction and Building: Federal Research and Development in Support of the US Construction Industry*. Washington, DC: National Science and Technology Council.

[5] Building Owners and Managers Association. 1994. *Experience Exchange Report, National Cross-Tabulations, 1994*. Washington, DC: Building Owners and Managers Association.

of the occupants (or for an industrial facility, improvement of the productivity of the process housed by the facility) is an important performance characteristic for most constructed facilities.

Goal 4: 50% Fewer Occupant-Related Illnesses and Injuries

Buildings are intended to shelter and support human activities, yet the environment and performance of buildings can contribute to illnesses and injuries for building users. Examples are avoidable injuries caused by fire or natural hazards, slips and falls, disease from airborne microbes, often associated with a workplace environment, and building damage or collapse from fire, earthquakes, or extreme winds. Reductions in illnesses and injuries will increase building users' productivity as well as reduce the costs of medical care and litigation.

Goal 5: 50% Less Waste and Pollution

Improvement of the performance of constructed facilities provides major opportunities to reduce waste and pollution at every step of the delivery process, from raw material extraction to final demolition and recycling of the facility and its contents. Additional reductions come from reduced energy use, reduced water consumption, and reductions in waste water production, which are considered in part by Goal 2.

Goal 6: 50% More Durability and Flexibility

Durability denotes the capability of the constructed facility to continue (given appropriate maintenance) its initial performance over the intended service life. Flexibility denotes the capability to adapt the constructed facility to changes in use or users' needs. Increased durability and flexibility of constructed facilities reduces life-cycle costs and prolongs the economic life of the facility (i.e., the period of time over which an investment in the original facility is considered to be the least-cost alternative for meeting a particular objective).

Goal 7: 50% Reduction in Construction Worker Illnesses and Injuries

Health and safety issues exert a major effect on the competitiveness of the US construction industry. Construction workers die as a result of work-related trauma at a rate which is higher than all other industries except mining and agriculture. Construction workers also experience a higher incidence of nonfatal injuries than workers in other industries do. Although the construction workforce represents less than 5 percent of the nation's workforce, it is estimated that the construction industry pays about 15 percent of the nation's workers' compensation.[6]

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[6] The Center to Protect Workers' Rights. 1997. *The Construction Chart Book: The US Construction Industry and Its Workers*. Report D1-97. Washington, DC: The Center to Protect Workers' Rights.

2.2. Baseline Measures

As noted earlier, the baseline measures for each goal are averages of industry performance in 1994. Thus, with regard to the baseline measures, 1994 is the "base year." Consequently, data from 1994 drive the data collection effort culminating with the development of the baseline measures for each National Construction Goal.

The process for developing baseline measures used in this project involves: (1) specifying a data-oriented hierarchy; (2) collecting and compiling the key data and supporting information for the base year, 1994;[7] (3) defining metrics for each goal/sector combination; and (4) producing the metrics in a tabular summary form and, where appropriate, producing charts and graphs to depict the metrics. If the goal/sector combination has components and subcomponents, then metrics are defined for each. This process is employed because the metrics represent not only a statement of current construction industry performance but tools for measuring an individual organization's performance as well. By providing a small set of well-defined metrics, individual organizations can construct their own performance baselines. For example, individual organizations can see how a collection of their projects performs vis-à-vis the "national" data. To summarize, the basic philosophy behind the baseline measures is that they are not a static tool whose sole purpose is quantifying the value of the goal but a means for driving performance improvement within individual organizations.

2.3. Measures of Progress

The methods for measuring progress use the baselines as their reference point. The measures of progress employ a method which makes use of both key outputs (i.e., summary measures) and interlinking metrics (i.e., a composite of performance measures including constituent parts and functional relationships). Because the National Construction Goals may be specified as targets measured against baseline values, "gap analysis" is an appropriate method for defining the measures of progress.

To gain a better understanding of how gap analysis may be applied, consider the following case illustration. One component of Goal 7, Construction Worker Illnesses and Injuries, is recordable injuries. If Goal 7 targets a 50% reduction in construction worker illness and injuries, we may adopt an across-the-board reduction of 50% for all components of that goal. Therefore, for this component, the goal is to reduce recordable injuries by 50%. Denote the industry average in 1994 by BR_{94} (i.e., the <u>B</u>aseline value for <u>R</u>ecordable injuries). Denote the goal for recordable injuries for 2002 by GR_{02}; it is equal to $0.5*BR_{94}$. Denote the difference between the baseline and the goal (i.e., $BR_{94} - GR_{02}$) by dR_{94}. This difference may be thought of as a gap (i.e., the difference between the

[7] If data are available for years in addition to 1994 (e.g., 1992 through 1996), then these data are collected at the same time as the base year data and used to illustrate trends; these data are also used to compute the associated measures of performance.

actual level and the desired level). Similarly, for some future year, say 1997, whose actual value is R_{97}, the gap becomes dR_{97} (i.e., R_{97} - GR_{02}).

This method also enables us to measure how much of the initial gap has been closed. One measure of performance is the percent of the initial gap which has been closed by some future date, say 1997. Denote this amount as $P(dR_{97})$, where:

$$P(dR_{97}) \quad = \quad (1 - (dR_{97} / dR_{94})) * 100$$

The advantage of this measure of performance is that it employs the same values for each measure used in computing the baselines. Although the gap analysis method is simple and straightforward, it offers considerable flexibility. Consequently, it is the recommended method for generating measures of progress.[8]

2.4. Interactions Between the National Construction Goals, the Baseline Measures, and the Measures of Progress

As noted earlier, the objective of the C&B-related RD&D activities is to have *technologies and practices* capable of meeting the goals available in 2003. This objective raises an important issue, namely, the relationships between the baseline measures, the measures of progress, and the goals. Several relationships which warrant consideration are the following. First, it is important to recognize that the goal can always be represented as a function of the baseline measure. Thus, given a baseline "value," a target or goal "value" can be specified. Second, for baseline measures to be most beneficial, they need to be tied to specific "metrics" which are well-defined and able to be used by interested parties (e.g., a specific government agency could substitute its own data into the metric and use it to establish its own "baseline" values). Finally, the measures of progress need to make explicit the relationship between the baseline, the goal, and the current level of improvement.

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[8]The gap analysis method has another advantage in that priorities can be easily incorporated. For example, during the consensus building step, the focus group might feel strongly that one component of an National Construction Goal (NCG) is of greater importance than another. Consequently, progress towards closing the gap on this component would be viewed as more important than progress on another component for that NCG. Multiattribute decision analysis (MADA) provides a well-established tool for assigning priorities to components. (See, American Society for Testing and Materials. 1995. *Standard Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems*. E 1765. Philadelphia, PA: American Society for Testing and Materials.) MADA may also be used to develop a hierarchical relationship among components (i.e., a composite of performance measures including constituent parts and functional relationships). Such an approach would help to analyze how changes in individual metrics (i.e., components at a lower level within the hierarchical relationship) affect the level and rate of change of key outputs (i.e., the highest level metric in the hierarchical relationship).

The previous discussion implies that the form of the baseline measure is important as a "facilitator" of performance (i.e., a linkage to performance-improving technologies and practices). Two forms of baseline measures which may serve as facilitators are point estimates (i.e., an average value) and a distribution of values. Although an *average value* is a good baseline measure, it collapses a great deal of information into a single reference point. An alternative way to think about a baseline measure is as *the distribution of values* of industry performance in 1994. This approach, while more data intensive, is a great deal more flexible. Over the long term, the key stakeholders (e.g., researchers, innovators, owners, and contractors) can focus on pushing the entire distribution towards a more competitive position (e.g., faster delivery time) rather than just focusing on improving the average value of some "unknown" distribution. It is important to recognize that *the distribution of values* contains not only the mean or average value of the metric which defines the baseline measure, but the highest and lowest values as well. For example, if the percentiles of the distribution are available, an individual organization (e.g., government agency, construction firm, etc.) could calculate a representative set of values and, hence, determine their location within the distribution. This information could then be used for goal setting and for developing measures of progress within a particular organization.

2.5. Project Approach

Developing baseline measures and measures of progress--whether they are based on average values or a distribution--for each National Construction Goal and each construction industry sector is a complex process. Fortunately, some goals are relatively more important to the construction industry, which suggests setting priorities for data collection. The report by Wright, Rosenfeld, and Fowell[9] provides information reflecting the construction industry's priorities. The construction industry's four highest priority goals are Goal 1, Goal 2, Goal 6, and Goal 7. The three lowest priority goals are Goal 3, Goal 4, and Goal 5.

The availability of data and level of sector-specific information are other key considerations. For some goals, there is a well-defined linkage to data (e.g., national/regional statistics or sector-specific information). For other goals, little quantitative information is available. Consequently, a two-phase approach is being employed. The order (i.e., phase) in which the baseline measures and measures of progress are developed is based on three characteristics: (1) the priority of the goal; (2) the availability of data; and (3) the level of sector-specific information. Phase I covers the four highest priority goals. Phase II covers the three lowest priority goals.

This two-phase approach was designed to produce a set of baseline measures and measures of progress in the most timely manner. This approach is summarized in Table 2-1; it combines information on priorities from the construction industry with constraints

[9]Wright, Rosenfeld, and Fowell. 1995. *Op. Cit.*, p. 10.

on data availability and the level of sector-specific information. This approach provides the basis for focusing project resources on those goals where baseline measures and measures of progress: (1) are most needed by the construction industry; (2) can be defined and agreed upon by key construction industry stakeholders; and (3) can be developed in a timely manner. Consequently, these data sets, once developed and disseminated, offer the greatest potential for acceptance and use by the construction industry.

Table 2-1. Phases in the Development of Baseline Measures

Phase	National Construction Goals		Data Characteristics	
	Goals Covered	**Priority**	**Data Availability**	**Sector Definition**
I	7	High	Readily Available Well Documented Authoritative Sources	Good Sector Definition
	1,2,6	High	"Pockets" of Good Data	Some Sectors Not Clearly Defined
II	3,4,5	Low	"Composite" Data Types: Either Few Pockets of Good Data Or Total Lack of Data	Some Sectors Not Clearly Defined

For each of the phases shown in Table 2-1, a four-step process is envisioned. The four steps are:

1. Establish Criteria for Data Selection;

2. Identify and Collect Data;

3. Develop Consensus on Key Measures and Supporting Data; and

4. Produce and Disseminate Baseline Measures and Measures of Progress.

In the sections which follow, each step is described briefly and, where appropriate, related to each phase.

2.5.1. Criteria for Data Selection

Criteria are needed to ensure that the data selected for *analysis* are well defined, consistent, and replicable. Because data are so important to the baseline measures for each goal, BFRL reviewed many potential sources (e.g., journals, technical publications, electronic media) of baseline-related data/information. This review suggested three criteria which must be met by any data in order to be accepted for analysis. These criteria are:

(1) Published by a reliable, nationally recognized organization and available to the public;

(2) Updated on a regular basis; and

(3) Able to be normalized to account for changes in the building stock and the level of construction activity.

These three criteria are appropriate for establishing the baseline measures for each goal for each of the two phases shown in Table 2-1. These criteria are also appropriate for any data associated with measures of progress for each goal.

2.5.2. Identify and Collect Data

Matching data to goals employs the two phases shown in Table 2-1, beginning with Phase I. The objective of this step is to begin with those goals where data is both well defined and readily available. This strategy enables us to gain experience from the outset, learn from these experiences, and modify the data collection effort accordingly.

The Phase I effort is divided into three stages. The first stage focused on Goal 7 (i.e., Construction Worker Illnesses and Injuries). In this stage, two hierarchies for classifying data were established prior to initiating the data collection effort. The first hierarchy produced an overlay of the construction industry Standard Industrial Classification (SIC) Codes and the four construction industry sectors used in this study. The second hierarchy was purely data oriented. Both hierarchies produced “workable” baseline measures. The purpose of the first stage was to evaluate if, or how, the data collection effort was to be refined. No refinements were identified.

The second stage focused on the two “highest priority” goals, Goal 1 and Goal 2. Wherever “pockets” of good data existed (e.g., selected information on delivery time for the residential and industrial sectors), they were collected and analyzed. This stage, like the first, began with the establishment of two data classification hierarchies. A key difference between the first and second stages was the second stage’s use of a comprehensive “idealized” sector-specific hierarchy as a starting point. The idealized hierarchy was then modified to reflect data constraints. The resultant data-oriented hierarchy was similar to the purely data-oriented hierarchy produced for Goal 7 but with slightly better sector definition. Completion of the second stage revealed no refinements to the data collection effort. However, several caveats associated with the interpretation of the baseline measures were noted (see Section 2.5.5).

The third stage will focus on Goal 6 (i.e., Durability and Flexibility). It is anticipated that upon completion of the third stage, refinements to the data collection effort will be identified. In particular, whether to establish linkages between durability and flexibility, or to treat the two major components of Goal 6 as separate entities.

The Phase II effort is not planned for initiation until the Phase I effort is nearly completed. This strategy is based on the assumption that experience gained in the Phase I data collection efforts, particularly the second and third stages, will suggest sources and ways in which data on Phase II's goals can be collected and analyzed.

2.5.3. Consensus on Key Measures and Supporting Data

Gaining consensus is essential if the data are to be useful to the construction industry and hence used to measure improvement towards goal attainment. This "consensus building" step is composed of five parts. The five parts are:

(1) Conduct analytical studies of the "Phase" data and other data recommended by the C&B Subcommittee;

(2) Produce a "Set" of proposed data and derived measures (e.g., baseline measures and measures of progress);

(3) Form a "Focus Group" from the C&B Subcommittee member organizations, industry representatives, and other interested parties to discuss the proposed data and derived measures;

(4) Brief the C&B Subcommittee on progress and solicit feedback; and

(5) Revise the data and derived measures and present findings to the C&B Subcommittee

Data collected on baselines and measures of progress for each phase will go through this step. For the Phase I goals, a single iteration should be sufficient. For the Phase II goals, multiple iterations may be required.

2.5.4. Production and Dissemination of Baseline Measures and Measures of Progress

Based on the focus group discussions and feedback from the C&B Subcommittee, the data sets and derived measures are finalized for each goal. The data are delivered initially in the form of tables and reports. No data are disseminated on individual companies. Potential outlets for the baselines and measures of progress include the C&B Subcommittee member organizations and the four sector council member organizations. In order to reach an even larger audience, data will be incorporated into a computerized delivery system and made available on the World Wide Web.

2.5.5. Limitations of the Project Approach

The project approach described in Sections 2.5.1 through 2.5.4 has two basic limitations. It is important for readers to understand what these limitations are and how they affect the values of the baseline measures presented in this document or other documents focused on the National Construction Goals. The two basic limitations of the project approach are concerned with the availability of data ***and*** the selection of data, information, and metrics for inclusion with (or exclusion from) the baseline measures.

The first limitation to the project approach is concerned with the availability of data. Data availability problems manifest themselves in three ways: (1) unspecified functional relationships between metrics within a given goal (e.g., linkages among components at a lower level in the goal's hierarchy): (2) no data for a specific goal/sector combination; and (3) incommensurate base-year data (e.g., no information is available prior to 1996).

The first two problems are being addressed through research. Extensive research has been done and continues on sources of data. This research has uncovered several research reports that address ways in which components associated with a goal can be modeled. Several research reports that represent "point" estimates for a goal/sector component have also been uncovered. Unfortunately, while these reports provide valuable insights, they lack specificity. In the first case, although the research reports imply functional relationships (i.e., a linkage mechanism), the functional form is unspecified. For example, both Goal 3--Productivity and Comfort--and Goal 6--Durability and Flexibility--have two major components. Ideally, these components would be linked via a functional relationship. The alternative is to treat each component as a separate and distinct entity. In the second case, one of a kind "estimates" or "information" are tantamount to no data. There is no opportunity to replicate the results without repeating the research that produced the "estimates" or "information" in the first place.

The third problem, incommensurate base-year data, is being addressed through a set of carefully stated caveats. If data are being collected now that satisfy the criteria for data selection but were not available in 1994 (i.e., the year specified for the baseline measures), then they still represent meaningful metrics. ***The caveats come in regarding how to interpret the values of these metrics.*** In cases where such caveats are made (e.g., delivery time metrics for the three non-residential sectors), they are stated clearly. In addition, guidance is given on how to interpret the values of these metrics vis-à-vis the goal.

The second limitation stems from decisions the project team made regarding what was to be included in or excluded from the baseline measures. Although our objective is to produce baseline measures for each goal/sector combination, it became necessary to include some types of information only at a higher level of aggregation (e.g., at the construction industry level rather than the individual sector level). Similarly, decisions were made to exclude some types of information for which data were available but their inclusion would provide no new insights. In both cases--whether data were included at a higher level of aggregation or excluded from the document--the authors have clearly stated their reasons and given guidance to help readers interpret the results.

2.6. How This Document Helps

This document is part of a series. As such, it provides perspective on the overall effort to develop baseline measures and measures of progress for each of the seven National Construction Goals. It also serves to highlight how these measures and their associated metrics can be used to drive performance improvement.

On a deeper level, this document provides step-by-step descriptions of how to construct a well-defined set of baseline measures, their components, and associated metrics for a specific goal for each of the four construction industry sectors. Information on data classification, data sources, and data collection and analysis provide the underpinnings for the results presented in this document. It is anticipated that once users of this document have understood the vital role of metrics as a process improvement tool, they will see how the National Construction Goals will benefit both their organization and the US construction industry.

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3. Overview of the Construction Industry

The construction industry is a key component of the US economy and is vital to the continued growth of the US economy. Investment in plant and facilities, in the form of construction activity, provides the basis for the production of products and the delivery of services. Investment in infrastructure promotes the smooth flow of goods and services and the movement of individuals. Investment in housing accommodates new households and allows existing households to expand or improve their housing. It is clear that construction activities affect nearly every aspect of the US economy. However, construction activities are also strongly affected by the health of the economy and the associated business cycle.[10]

This chapter provides a snapshot of the US construction industry. As such, it provides the context within which baseline measures are developed, a subject which occupies the remainder of this document. The chapter contains four sections. Each section deals with a particular topic. The topics progress from general in nature to very specific. This progression is described below.

First, information on the value of construction put in place is provided to show the size of the construction industry and each of its four sectors--residential, commercial/ institutional, industrial, and public works. Second, information on the nature of construction activity for each sector of the industry is presented. The Standard Industrial Classification (SIC) Codes for the construction industry are introduced and described as a means for organizing construction activity. Information on the nature of construction activity includes breakouts between new construction activities, maintenance and repair activities, and additions and alterations. The challenge of developing annual estimates for each sector by nature of construction activity is described. Examples are given which demonstrate how different data sources result in major differences in a particular year's estimates. Third, information on employment in the construction industry is summarized and a series of employment-related statistics are presented. The SIC Codes for the construction industry are used as a means for organizing key employment-related information. Comparisons between employment and output in the construction industry and employment and output in the overall US economy are also included. Fourth, information on cost trends (e.g., average cost per square foot for residential and non-residential buildings) and on other, special considerations, is presented.

3.1. Value of Construction Put in Place

This section provides information on a key indicator of construction activity, the value of construction put in place. Data published by the US Bureau of the Census are used to

[10] Readers interested in learning more about construction statistics, their sources and interpretation, are referred to an excellent source document by Rogers (Rogers, R. Mark. 1994. *Handbook of Key Economic Indicators*. Burr Ridge, IL: Irwin Professional Publishing).

establish the composition of construction expenditures by type of construction/function (e.g., non-residential/office building). These expenditures are then assigned to the four key construction industry sectors. The reference document used throughout this section is the **Current Construction Reports** series C30 publication *Value of Construction Put in Place*.[11] A brief description of the "C30 report" follows. Special attention is given to the organization of the data in the C30 report and how these data map into the four key construction industry sectors. The section concludes with tabular and graphical summaries of the value of construction put in place.

Current Construction Reports *Series C30*

Construction expenditures data are published monthly in the **Current Construction Reports** series C30 publication *Value of Construction Put in Place*. Construction expenditures refer to actual construction rather than planned or just initiated activity. It is noteworthy that the C30 report covers both private residential and non-residential construction activities and public sector construction activities.

The value of construction put in place is a measure of the value of construction installed or erected at a site during a given period. For an individual project, this includes: (1) cost of materials installed or erected; (2) cost of labor (both by contractors and force account (i.e., construction done for own use)) and a proportionate share of construction equipment rental; (3) contractor's profit; (4) cost of architectural and engineering work; (5) miscellaneous overhead and office costs chargeable to the project on the owner's books; and (6) interest and taxes paid during construction. Expenses do not include the cost of land nor do they include maintenance and repairs to existing structures or service facilities.

The C30 data are compiled via survey and through indirect estimation. In the context of the C30 survey, construction includes the following: (1) new buildings and structures; (2) additions, alterations, conversions, expansions, reconstruction, renovations, rehabilitations, and major replacements (e.g., the complete replacement of a roof or a heating system); (3) mechanical and electrical installations (e.g., plumbing, heating, electrical work, and other similar building services); (4) site preparation and outside construction of fixed structures or facilities (e.g., sidewalks, highways and streets, water supply lines, sewers, and similar facilities which are built into or fixed to the land); (5) installation of boilers, overhead hoists and cranes, and blast furnaces; (6) fixed, largely site-fabricated equipment not housed in a building (e.g., petroleum refineries and chemical plants); and (7) cost and installation of construction materials placed inside a building and used to support production machinery (e.g., concrete platforms, overhead steel girders and pipes, etc.). ***It is important to note that the C30 survey produces information not only on the value of new construction put in place but also contains an unquantified component for additions and alterations for the non-residential sectors.***

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[11] Throughout this chapter, reference is made to the **Current Construction Reports** series C30 publication. These references include both how it is used as the basis for other sets of calculations presented in this chapter and as a vehicle for comparing calculations based on other Census publications.

The data presented in the C30 report are divided into two parts: (1) private construction; and (2) public construction. These data are summarized in Table 3-1. The table records annual values (in millions of constant 1992 dollars) for the years 1992 through 1996. Separate column headings showing the type of construction/function and the assigned sector--R for residential, C for commercial/institutional, I for industrial, and P for public works--are also included. The sector assignment was made by the authors.

Private construction contains two major components--residential buildings and non-residential buildings--plus a number or subcomponents. Both the two major components and the various subcomponents are shown as headings in the first column of Table 3-1.

The residential buildings component includes new private housing and improvements. New private housing includes new houses, apartments, condominiums, and town houses. New private housing units are classified as “1 unit” or “2 or more units.” The value of improvements put in place are a direct measure of the value of *residential additions and alterations* activities. Consequently, improvements are not included in the “new construction” residential sector totals recorded at the bottom of Table 3-1.

The non-residential buildings component includes industrial, office buildings, hotels and motels, and “other commercial” (e.g., shopping centers, banks, service stations, warehouses, and other categories). Also falling under the non-residential buildings component are religious, educational, hospital and institutional, and “miscellaneous” non-residential buildings.

Rounding out the private construction component are farm non-residential, public utilities, and “all other private.” These are generally of a non-residential nature but are not part of non-residential buildings. Farm non-residential construction includes structures such as barns, storage houses, and fences. Land improvements such as leveling, terracing, ponds, and roads are also a part of this subcomponent. Privately owned public utilities construction is categorized by industry rather than function of the building or structure. This subcomponent includes expenditures made by utilities for telecommunications, railroads, petroleum pipelines, electric light and power, and natural gas. “All other private” includes privately owned streets and bridges, sewer and water facilities, airfields, and similar construction.

For public construction, there are two major components--building and non-building. Both the two major components and the various subcomponents are shown as headings in the first column of Table 3-1. The building component contains subcomponents similar to those for private construction, with educational buildings being the largest subcomponent. Expenditures for the non-building component overwhelmingly consist of outlays for highways and streets, with sewer systems being a distant second subcomponent.

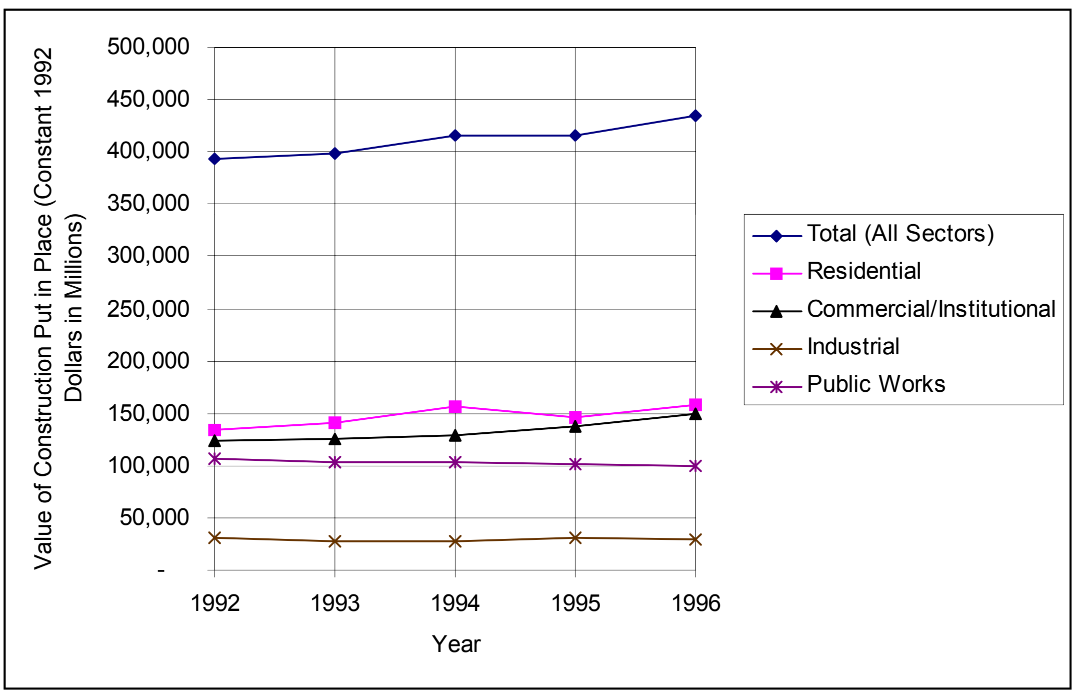
To get the “new construction” sector totals, which appear in the bottom portion of Table 3-1, each subcomponent was assigned to a sector and summed. The sector assignments are recorded in the second column of Table 3-1. Reference to the bottom portion of the table reveals that sector totals vary considerably, with residential being the largest and industrial the smallest.

Table 3-1. Value of New Construction Put in Place

		VALUE OF CONSTRUCTION PUT IN PLACE (SERIES C30)				
Type of Construction	**Assigned Sector**	Constant 1992 Dollars in Millions				
		1992	1993	1994	1995	1996
Total construction		*451,998*	*461,078*	*480,965*	*474,426*	*493,587*
Private construction		336,126	347,851	367,265	359,411	378,150
Residential buildings		187,687	200,502	218,005	201,682	212,069
New housing units		129,522	137,243	153,250	142,413	153,965
1 unit	R	116,419	126,960	140,416	126,773	136,516
2 or more units	R	13,103	10,283	12,833	15,640	17,449
Improvements		58,165	63,259	64,755	59,268	58,104
Nonresidential buildings		105,615	106,729	111,416	120,627	130,394
Industrial	I	29,027	25,554	26,803	29,043	28,003
Office	C	20,271	20,197	20,553	22,891	24,099
Hotels, motels	C	3,690	4,405	4,308	6,351	10,263
Other commercial	C	29,172	31,292	34,756	38,098	41,301
Religious	C	3,483	3,748	3,584	3,864	3,961
Educational	C	4,475	4,484	4,471	4,908	5,790
Hospital and institutional	C	11,485	12,050	11,377	10,051	10,460
Miscellaneous	C	4,011	5,000	5,565	5,421	6,516
Farm nonresidential	C	2,396	3,271	3,008	2,693	2,736
Public utilities	P	36,859	34,120	32,074	31,767	30,842
Telecommunications	P	9,005	9,468	9,785	10,071	10,420
Other public utilities	P	27,854	24,652	22,289	21,696	20,422
Railroads	P	2,926	3,056	3,186	3,202	4,030
Electric light and power	P	17,184	15,096	13,877	12,656	11,191
Gas	P	6,895	5,536	4,308	5,004	4,291
Petroleum pipelines	P	849	965	918	834	910
All other private	P	3,569	3,229	2,763	2,644	2,109
Public construction		115,872	113,227	113,700	115,014	115,437
Buildings		49,988	46,813	45,177	47,832	49,415
Housing and development	R	4,136	3,833	3,326	3,754	3,881
Industrial	I	1,875	1,658	1,358	1,348	1,216
Educational	C	20,645	18,465	17,593	19,237	20,131
Hospital	C	3,383	3,579	3,787	3,854	3,981
Other	C	19,949	19,279	19,114	19,638	20,207
Highways and streets	P	33,132	34,164	36,151	33,500	33,297
Military facilities	P	2,502	2,405	2,196	2,729	2,225
Conservation and development	P	5,946	5,771	6,091	5,773	5,244
Sewer systems	P	9,658	8,622	8,592	8,975	9,060
Water supply facilities	P	5,170	4,868	4,443	4,923	5,121
Miscellaneous public	P	9,475	10,583	11,050	11,282	11,075
New Construction						
SECTOR TOTALS and SUMMARY						
Residential (R)		133,658	141,076	156,576	146,167	157,846
Commercial/Institutional (C)		122,960	125,770	128,116	137,006	149,445
Industrial (I)		30,902	27,212	28,161	30,391	29,219
Public Works (P)		106,311	103,762	103,360	101,593	98,973
Total for all Sectors		393,831	397,820	416,213	415,157	435,483

Table 3-1 highlights an important distinction between the residential sector and the three non-residential sectors. Reference to the "Residential Buildings" component of the table (i.e., the entry immediately below the heading **Private Construction**) for the year 1992 produces a value of $187,687 million. This value differs from the value for the residential sector, $133,658 million, given immediately below the heading of **SECTOR TOTALS and SUMMARY** in the bottom portion of the table. The reason for the difference is due to the *exclusion* of the value of private residential improvements (i.e., additions and alterations) and the *inclusion* of the value of public housing and development. Because the values given in the bottom portion of Table 3-1 are estimates of the values of *new construction put in place*, it is necessary to net out the value of residential improvements. While this is a straightforward process for the private residential sector, no specific information on additions and alterations is published in the C30 report for either the three non-residential sectors or for public housing and development. Consequently, we have assumed that the values for additions and alterations for the three non-residential sectors and for public housing and development are zero. This implies that the sector totals for commercial/institutional, industrial, and public works are the values of *new construction put in place* for each of the years 1992 through 1996. A rationale for this assumption is given in the next section, which covers the nature of construction activities.

Figure 3-1. Value of New Construction Put in Place



The Table 3-1 sector totals and the overall construction industry totals for the value of *new construction put in place* are shown graphically in Figure 3-1. The horizontal axis of the figure records the year, from 1992 through 1996. The vertical axis records the value of new construction put in place, in millions of constant 1992 dollars. Each trace is keyed to designate either the sector or the overall total.

3.2. Nature of Construction Activity

The nature of construction activity may be conveniently classified as either new construction, additions and alterations, or maintenance and repair. Definitions of each are as follows.

> *New construction* activities include the complete original building of structures and essential service facilities and the initial installation of integral equipment such as elevators and plumbing, heating, and air-conditioning supplies and equipment.
>
> *Additions and alterations* include construction work which adds to the value or useful life of an existing building or structure, or which adapts a building or structure to a new or different use. Included are major replacements of building systems such as the installation of a new roof or heating system and the resurfacing of streets or highways. This contrasts to the repair of a hole in a roof or the routine patching of highways and streets, which would be classified as maintenance and repair.
>
> *Maintenance and repair* activities include incidental construction work which keeps a property in ordinary working condition. Excluded are trash and snow removal, lawn maintenance and landscaping, cleaning and janitorial services.

This section presents information from three different data sources: (1) the **1992 Census of the Construction Industry**; (2) **Current Construction Reports** series C30, *Value of Construction Put in Place*; and (3) **Current Construction Reports** series C50, *Expenditures for Residential Improvements and Repairs*. Although each data source provides insights into the nature of construction activity, they differ in degree of detail, frequency of publication, and sector coverage. Brief descriptions of the **1992 Census of the Construction Industry** and the “C50 report” are given in the text that follows. Readers seeking information on the C30 report are referred to Section 3.1 of this report. Statistics from each source are also presented and, where appropriate, comparisons are made.

1992 Census of the Construction Industry

The Census of the Construction Industry is conducted every five years. The construction industry is one of seven industries tabulated as part of the Economic Census. The Economic Census is highly detailed. However, because the Economic Census is performed only in years ending with 2 or 7, 1992 is the latest year for which such highly detailed construction industry data is available.

The census of the construction industry enumerates establishments with paid employees engaged primarily in one of the following three areas: (1) ***constructing new homes and other buildings***; (2) ***heavy construction***, such as highways; and (3) ***special trades***, such as plumbing and electrical work. Most construction establishments are described as contractors (e.g., general contractors and special trades contractors), but the census also includes operative builders who construct buildings or other structures on their own account to be sold when completed.

A "construction establishment" is defined as a relatively permanent office or other place of business where the usual business activities related to construction are conducted. With some exceptions, a relatively permanent office is one that has been established for the management of more than one project or job and which is expected to be maintained on a continuing basis. Such "establishment" activities include, but are not limited to estimating, bidding, purchasing, supervising, and operation of the actual construction work being conducted at one or more construction sites. The census did not require separate construction reports for each project or construction site. However, companies with more than one construction establishment were required to submit a separate report for each such establishment operated during all or any part of 1992.

For purposes of the census, construction establishments are classified by kind of business according to the principal work performed. There are three major Standard Industrial Classification (SIC) groups--two-digit SIC codes--in the construction industry:

15 Building construction--general contractors and operative builders

16 Heavy construction other than building construction--contractors

17 Special trade contractors

These major SIC groups are sub-divided into 13 three-digit SIC codes which in turn are sub-divided into 26 four-digit SIC codes. Table 3-2 provides a description of each of the 26 four-digit SIC codes. Part A of the table covers the two-digit SIC codes 15 (building construction--general contractors and operative builders) and 16 (heavy construction other than building construction--contractors); Part B of the table covers the two-digit SIC code 17 (special trade contractors).

Data tabulated in the 1992 Census of the Construction Industry provide information grouped by the types of buildings, structures, or other facilities being constructed or worked on by construction establishments in 1992. Respondents were instructed to classify each building, structure, or other facility in terms of its function. For example, a restaurant building was to be classified in the restaurant category whether it was designed as a commercial restaurant building or an auxiliary unit of an educational institution. If respondents worked on more than one type of building or structure in a multi-building complex, they were instructed to report separately for each building or type of structure. If they worked on a building that had more than one purpose (e.g., office and residential), they were asked to classify the building by major purpose. In addition, all respondents were requested to report the percentage of the value of construction work done for new construction, additions and alterations, and maintenance and repair activities for each type of building, structure, or facility.

The detailed breakout for new construction, additions and alterations, and maintenance and repair activities provided by the 1992 census is noteworthy because prior to 1987, construction receipts only were collected. In 1987 and 1992, the value of construction work was collected to better measure actual construction activity done during the year. This conceptual change was made because receipts during a calendar year may include advance payments or payments for work done in a prior year, and thus not accurately reflect construction work done during the census year. For certain key industries, such as operative builders and developers, receipts and work done may also differ because receipts do not include work contractors perform for their own account and use, which can be substantial.

At the time of the 1992 census, there were about 1.4 million construction establishments, and about one third of them had paid employees. Establishments without payroll, typically one-person operations or partnerships, were not surveyed by the US Bureau of the Census. The Bureau of the Census did, however, obtain a limited amount of data on self-employed construction workers from the administrative records of other Federal agencies.

Current Construction Reports *Series C50,*
Expenditures for Residential Improvements and Repairs

The C50 report is published quarterly; it presents improvement and repair expenditures by property owners for residential properties. Data presented in the C50 report are based on personal interviews obtained from household members as part of the Consumer Expenditure Surveys conducted by the Bureau of the Census for the Bureau of Labor Statistics. These data cover single and multi-unit structures, publicly- and privately-owned structures, non-farm and farm properties, and residential properties which are occupied by owners or renters or are vacant.[12]

The expenditures covered in the C50 report are those connected with construction activity intended to maintain or improve the property. These expenditures involve expenses for maintenance and repair, additions, alterations, and major replacements which are made to the property by the owners. Included are all costs, for both the inside and outside of the house, whether on the main dwelling, on other structures on the property incidental to the residential use of the main dwellings, or for the grounds on which the structures are erected.

[12] Expenditures made by renters are not included in the C50 report. A study of renters' expenditures conducted in 1989 showed that they accounted for less than one percent of all expenditures for improvements and repairs.

Table 3-2. Four-Digit SIC Codes for the Construction Industry

Part A: Two-Digit SIC Codes 15 (Building Construction - General Contractors and Operative Builders) and 16 (Heavy Construction Other than Building Construction - Contractors)

SIC code	Label	Description
1521	General contractor - single-family houses	Includes townhouses, repair of mobile homes on site, and assembly of premanufactured and modular units
1522	General contractors - residential buildings other than single-family	Includes hotels, motels, and dormitories
1531	Operative builders	Condominiums, cooperative apartments, and singe-family houses built by developers to sell, instead of as contractors working for other companies
1541	General contractors - industrial buildings and warehouses	Includes grain elevators and automobile assembly, pharmaceutical manufacturing, and aluminum plants
1542	General contractors - nonresidential buildings, other than industrial buildings and warehouses	Commercial, institutional, religious, and amusement and recreational buildings
1611	Highway and street construction, except elevated highways	Roads, streets, alleys, public sidewalks, guardrails, parkways, and airports (general and special-trade contractors)
1622	Bridge, tunnel, and elevated highway construction	Bridges, viaducts, elevated highways, and highway, pedestrian, and railway tunnels (general construction)
1623	Water, sewer, pipeline, and communications and power-line construction	Includes transmission towers (general and special-trade contractors)
1629	Heavy construction, not elsewhere classified	For instance, athletic fields, blasting (except building demolition), canals, dams, hydroelectric plants, land clearing, nuclear reactor containment, petroleum refineries, piers (general and special-trade contractors)

Part B: Two-Digit SIC Code 17 (Special Trade Contractors)

SIC code	Label	Description
1711	Plumbing, heating, and air conditioning	Includes drainage system installation, cesspool, and septic tank; lawn sprinkler system; sewer hookups for buildings; solar heating; and related sheet metal work
1721	Painting and paper hanging	Excludes roof painting
1731	Electrical work	Covers work on site, including installation of telephones and alarms
1741	Masonry, stone setting, and other stone work	Excludes foundation digging and concrete work
1742	Plastering, drywall, acoustical, and insulation work	Includes installation of lathing and other accessories to receive plaster
1743	Terrazzo, tile, marble, and mosaic work	Excludes manufacture of precast terrazzo steps, benches, and other terrazzo articles
1751	Carpentry work	Includes on-site installation of cabinets, folding doors, framing, ship joinery, store fixtures, trim and finish, and prefab windows and doors
1752	Floor laying, and other floor work, not elsewhere classified	Includes laying and removal of carpet, finishing of parquet flooring, installation of asphalt tile. Excludes ceramic floor tile, concrete floors
1761	Roofing, siding, and sheet metal work	Includes metal ceilings skylight, gutter, and downspout installation; roof painting and spraying
1771	Concrete work	Includes private driveways and walks of all materials. Excludes concrete foundations, excavations, public sidewalks, and highways
1781	Water well drilling	Excludes oil- or gas-field water intake wells
1791	Structural steel erection (ironwork)	Includes similar products of prestressed or precast concrete and placing of concrete reinforcement
1793	Glass and glazing work	Excludes automotive
1794	Excavation work	Includes grading (except for highways, streets and airport runways) and incidental concrete work
1795	Wrecking and demolition	Includes concrete breaking for streets and dismantling of steel oil tanks. Excludes marine wrecking and demolition
1796	Installation or erection of building equipment, not elsewhere classified	Includes elevators, pneumatic tube systems, small incinerators, dust-collecting equipment, and revolving doors. Also includes dismantling and maintenance
1799	Special trade contractors, not elsewhere classified	Includes construction of swimming pools and fences, house moving, shoring work, fireproofing, and sandblasting and steamcleaning of building exteriors

As a general principle, expenses connected with items not permanently attached or affixed to some part of the house or property are outside the scope of the C50 report. Thus, expenses connected with the repair or replacement of household appliances (e.g., stoves, refrigerators, etc.) are excluded, as are costs connected with house furnishings. While the costs of appliances are excluded, the construction costs of building-in such appliances (e.g., the cost of building-in a wall oven) are included in the scope of the C50 report. Expenditures for grading, draining, fencing, and paving are included, but the costs of landscaping are not included in the C50 report.

The kinds of expenditures included cover work done under contract or with hired labor, and the costs of purchasing or renting tools and equipment for purposes of carrying out jobs which fall within the scope of the C50 report. However, no attempt is made to estimate or include the value of labor in do-it-yourself jobs.

The types of expenditures are classified broadly as either maintenance and repair or construction improvements. Maintenance and repair expenditures represent current costs for incidental maintenance and repair activities which keep a property in ordinary working condition, rather than additional investment in the property. Expenditures for construction improvements are capital expenditures which add to the value or useful life of a property. Improvements are further classified as additions to residential structures (e.g., enlargement of the structure by adding a room), alterations within residential structures (e.g., changes or improvements made within or on the structure), additions and alterations on property outside residential structures (e.g., laying or improving walks or driveways), and major replacements (e.g., a roof replacement).

Summary of Key Data Sets and Selected Comparisons

At this point, it is useful to compare the three data sets and examine the differing values for new construction, maintenance and repair, and additions and alterations which result for a single year (1992) or across years for a single sector (residential). The first set of comparisons and data summaries are for the 1992 census of the construction industry (CCI) and the estimates for new construction, maintenance and repair, and additions and alterations "derived" from the C30--value of construction put in place--report (VIP). The second set of comparisons and data summaries trace annual expenditure estimates for residential maintenance and repair and additions and alterations "derived" from the C30 report data along side data published in the C50 report.

The Bureau of the Census recognizes that only about two-thirds of the construction as defined in VIP is actually done by the construction industry as defined by the CCI.[13] Examples of construction work included within the VIP estimates but excluded from the CCI are architectural and engineering design and force-account construction. Also outside the scope of the CCI is work done by non-employers (i.e., self-employed

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[13] US Department of Commerce. 1997. *Overview of Construction Statistics Programs*. Draft Mimeo. Washington, DC: US Bureau of the Census.

construction workers). Thus, in developing comparisons between VIP and CCI data, estimates and assumptions have to be made for these differences.[14]

The VIP, C30 report data, were used as the basis for deriving estimates for new construction, maintenance and repair, and additions and alterations expenditures for each sector for each year between 1992 and 1996. Information from the CCI was used to construct a series of multipliers; one set for each sector. One component of each sector's set of multipliers recorded the ratio of maintenance and repair expenditures to new construction expenditures. The other component of each sector's set of multipliers recorded the ratio of expenditures for additions and alterations to new construction expenditures. To develop a framework for deriving these estimates, it was necessary to make eight assumptions. These assumptions are as follows; they are enumerated from A.1 to A.8.

A.1 Expenditures for new residential construction for each year, derived from the C30 report data, equal expenditures for private residential buildings *plus* expenditures for public housing and development *less* expenditures for residential improvements (see Table 3-1).

A.2 Expenditures for new non-residential construction for each year, derived from the C30 report data, equal the unadjusted sector expenditure totals (see Table 3-1).[15]

A.3 Multipliers for maintenance and repair activities for each sector for each year are a fixed proportion equal to the ratio of that sector's CCI expenditures for maintenance and repair activities to that sector's CCI expenditures for new construction.

A.4 Multipliers for additions and alterations for each sector for each year are a fixed proportion equal to the ratio of that sector's CCI expenditures for additions and alterations to that sector's CCI expenditures for new construction.

A.5 Expenditures for residential maintenance and repair activities in a given year equal that year's new construction value as defined in A.1 times the fixed proportion multiplier for the residential sector defined in A.3.

A.6 Expenditures for non-residential maintenance and repair activities for a given sector in a given year equal that year's new construction value as defined in A.2 times the fixed proportion multiplier for the appropriate non-residential sector as defined in A.3.

[14] *Ibid.*, p.26.
[15] Note that the C30 report data contain an unquantified component for additions and alterations.

A.7 Expenditures for residential additions and alterations in a given year equal that year's new construction value as defined in A.1 times the fixed proportion multiplier for the residential sector defined in A.4.

A.8 Expenditures for non-residential additions and alterations for a given sector in a given year equal that year's new construction value as defined in A.2 times the fixed proportion multiplier for the appropriate non-residential sector as defined in A.4.

Figure 3-2 shows the results of applying these assumptions to the C30 report (VIP) data for 1992 and plotting them side-by-side with the CCI data. Notice that each component--new construction, maintenance and repair, and additions and alterations--is higher for the "derived" VIP data than for the CCI data. The underlying assumptions, however, are plausible because the CCI contains only about two-thirds of the construction activity covered in the VIP (e.g., CCI only includes establishments with payroll and excludes items such as architectural and engineering services which in 1992 amounted to approximately $50 billion).

The "derived" total for all construction expenditures shown in Figure 3-2 may be broken down into its constituent parts. This break down is shown in Figure 3-3 for the year 1992. Reference to Figure 3-3 reveals that 61 percent, or $393.8 billion, of all construction expenditures are associated with the value of new construction put in place. Expenditures for additions and alterations amounted to $156.5 billion, or 24 percent of the total. Expenditures for maintenance and repair activities amounted to $93.3 billion, or 15 percent of the total.

When assumptions A.5 and A.6 are applied, annual estimates for the value of maintenance and repair expenditures for each sector result. These sector estimates are plotted, as multi-year traces keyed to each sector, in Figure 3-4. These "derived" estimates exhibit a slight upward trend. Maintenance and repair expenditures in the commercial/institutional sector are the highest in each year while maintenance and repair expenditures in the industrial sector are the lowest in each year.

When assumptions A.7 and A.8 are applied, annual estimates for the value of expenditures for additions and alterations for each sector result. These sector estimates are plotted, as multi-year traces keyed to each sector, in Figure 3-5. As was the case for maintenance and repair expenditures, expenditures for additions and alterations exhibit a slight upward trend. Reference to Figure 3-5 reveals that the dollar value of expenditures for additions and alterations in the commercial/institutional sector are about two to three times the amount for the other sectors.

Figure 3-2. Total Value of Construction Work: Comparison of Value Put in Place and 1992 Census of the Construction Industry

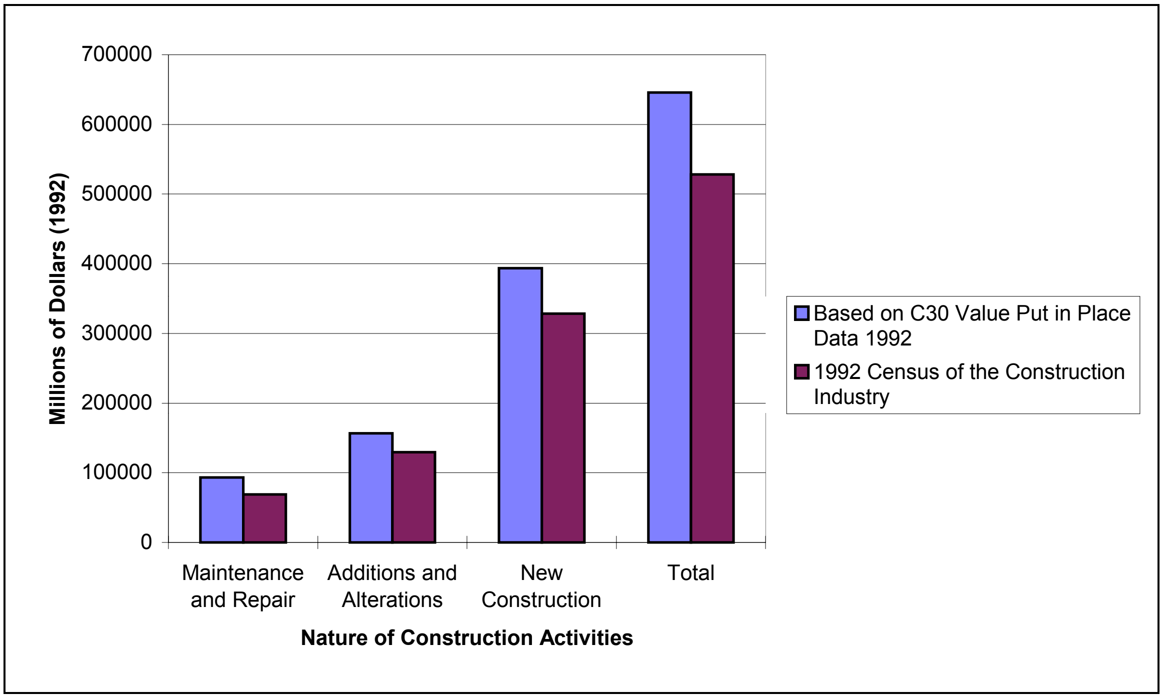


Figure 3-3. Distribution of Total Construction Expenditures in 1992 by Nature of Construction Activity

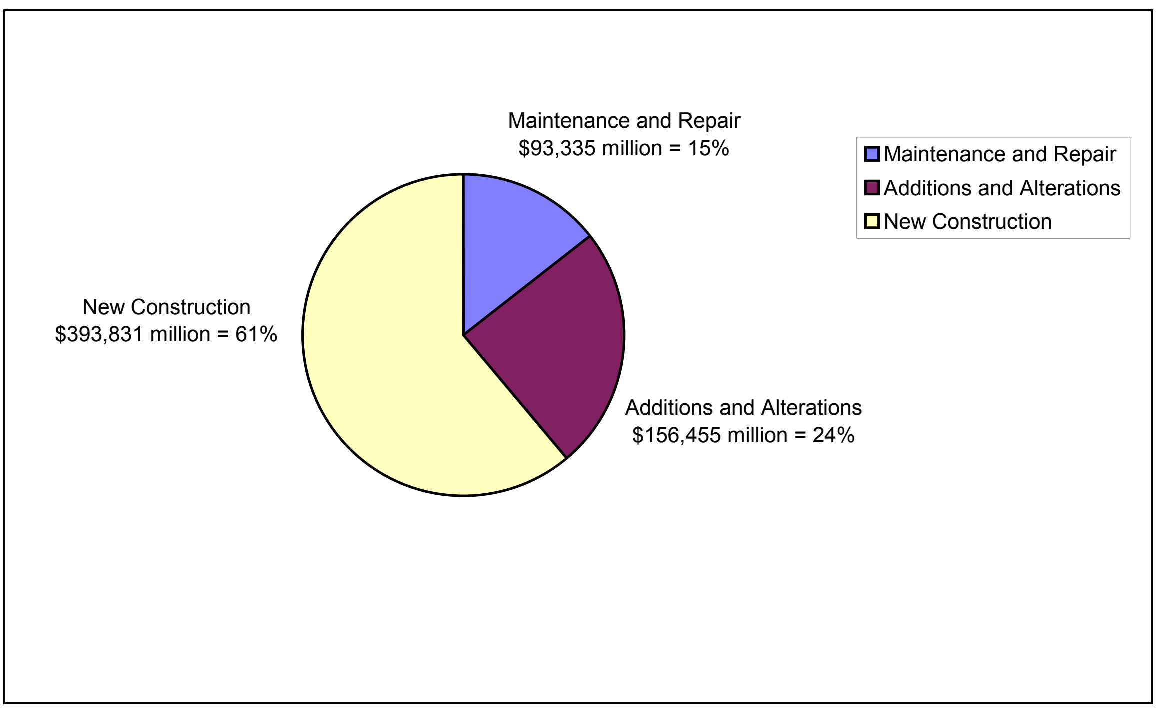


Figure 3-4. Annual Expenditures for Maintenance and Repair Activities by Sector

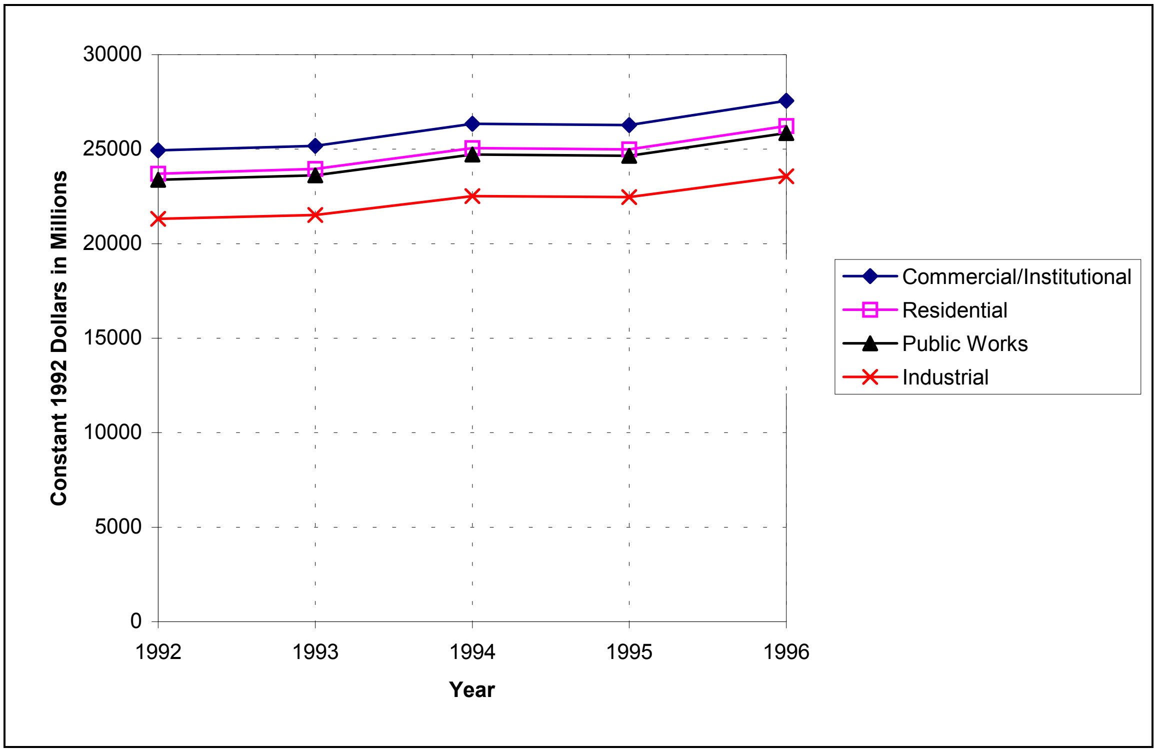
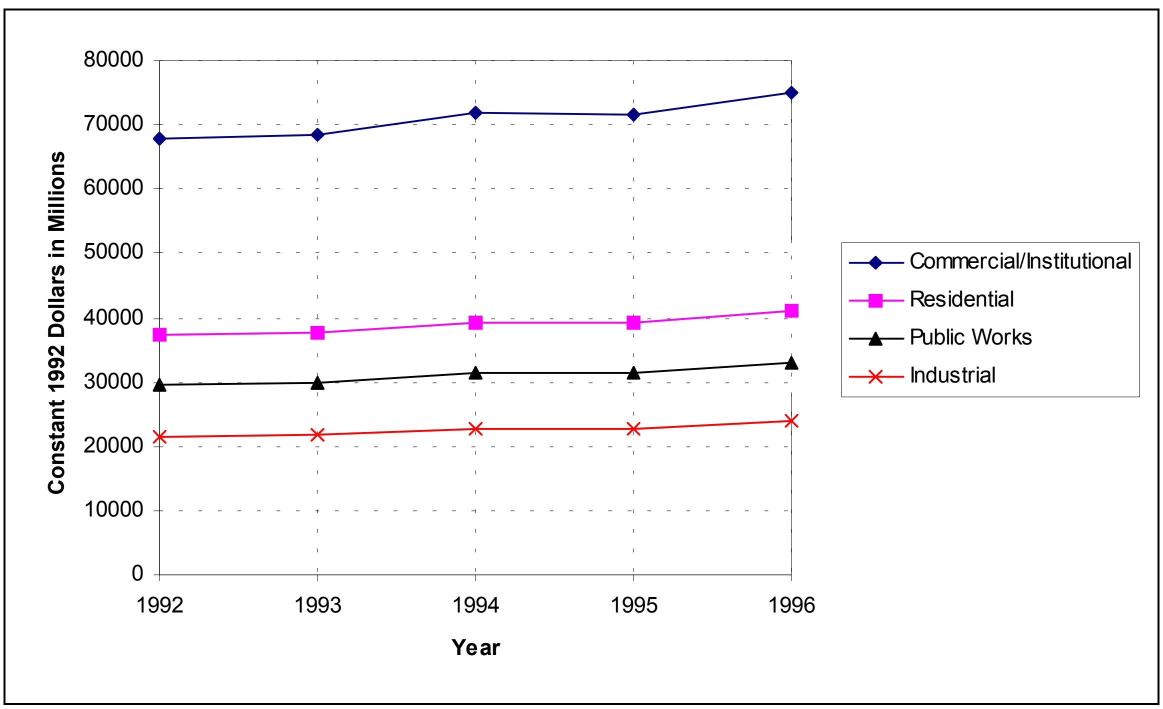


Figure 3-5. Annual Expenditures for Additions and Alterations by Sector



Although information on expenditures for maintenance and repairs and additions and alterations are not available for all four construction industry sectors, such information is available for the residential sector via the C50 report. Figure 3-6 shows these data side-by-side with the derived C30 data. Figure 3-6 consists of a series of bar charts; four bars for each year. For each year, maintenance and repair expenditures are the two leftmost bars and expenditures for additions and alterations are the two rightmost bars. For each two-bar set (i.e., maintenance and repair ***or*** additions and alterations), the left-hand bar records the annual combined total for estimates derived from the C30 report data and the CCI multipliers (i.e., based on assumptions A.1, A.3, A.4, A.5, and A.7). Similarly, for each two-bar set, the right-hand bar records the annual combined total for data published in the C50 report. The values underlying each year's set of bars are given in Table 3-3. Reference to Figure 3-6 and Table 3-3 shows that the estimated values for the C30/CCI derived data are about two-thirds of the expenditures resulting from the C50 report data. There are two plausible explanations for these differences. First, the CCI does not capture information on construction establishments without employees. Although such establishments are not expected to be major players in the non-residential sector, they are often very active in the residential maintenance and repair and additions and alterations markets. These activities are captured through the C50 survey process. Second, the CCI does not capture information on materials and equipment purchases by residential property owners for use in maintenance and repair and additions and alterations activities. Because the C50 survey is aimed at residential property owners, it captures information on purchases of materials and equipment.

Table 3-3. Comparison of Derived Data and Household Survey Data for Total Expenditures on Improvements and Maintenance and Repairs in the Residential Sector

RESIDENTIAL SECTOR	Value (Millions of Current 1992 Dollars) By Year				
	1992	1993	1994	1995	1996
Maintenance and Repair (Derived Data)	23,709	23,949	25,057	24,993	26,217
Improvements (Derived Data)	37,204	37,581	39,319	39,219	41,139
Total (Derived Data)	60,913	61,530	64,376	64,212	67,356
Maintenance and Repair (C50 Data)	45,121	40,198	39,731	37,338	32,113
Improvements (C50 Data)	58,580	64,208	66,671	61,837	67,636
Total (C50 Data)	103,734	104,405	106,402	99,733	99,749

For the non-residential sectors, it is unclear whether the estimates derived from the C30/CCI data can be expected to exhibit a similar trend (i.e., are about two-thirds of the value resulting from a survey of the respective sector) or not. Consequently, we have adopted a conservative approach and opted to use the estimates derived from the C30/CCI data for each of the four construction industry sectors. These data are plotted as multi-year traces in Figure 3-7. Detailed estimates by year, by sector, and by nature of construction activity are recorded in Table 3-4.

Figure 3-6. Comparison of Derived Data and Household Survey Data for Total Expenditures on Improvements and Maintenance and Repairs in the Residential Sector

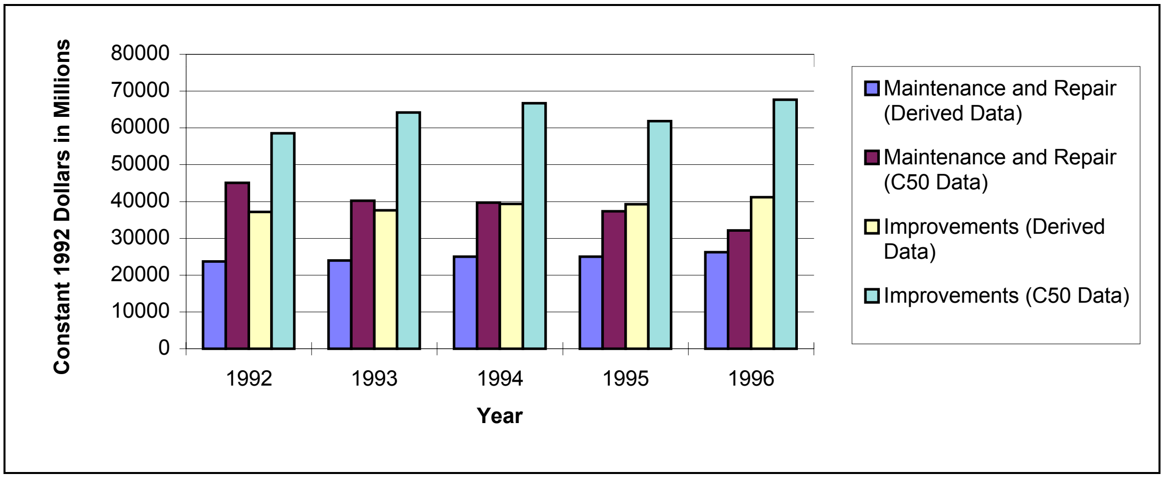


Figure 3-7. Total Value of Construction Work

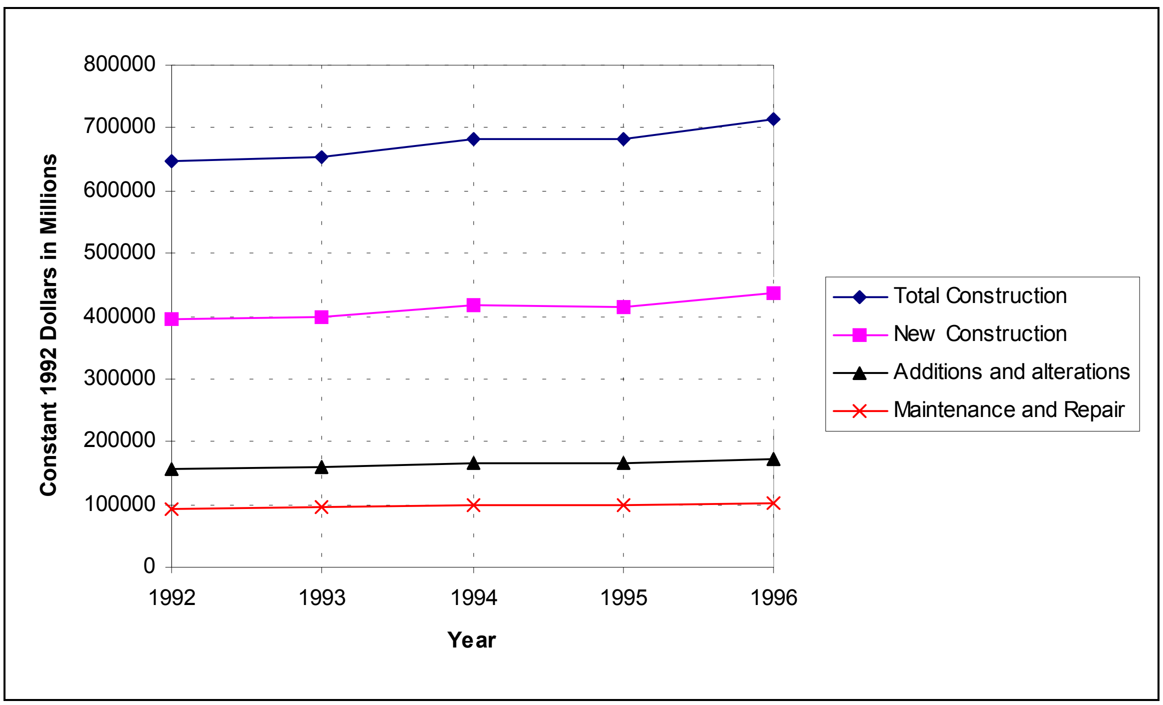


Table 3-4. Value of Construction Work: 1992 - 1996

Part A: Total Value of Construction Work: 1992 - 1996

DERIVED DATA - ALL SECTORS	Total Construction	New Construction	Additions and alterations	Maintenance and Repair
1992	645,769	393,831	156,455	93,335
1993	652,310	397,820	158,040	94,280
1994	682,469	416,213	165,347	98,639
1995	680,738	415,157	164,928	98,389
1996	714,067	435,483	173,002	103,206

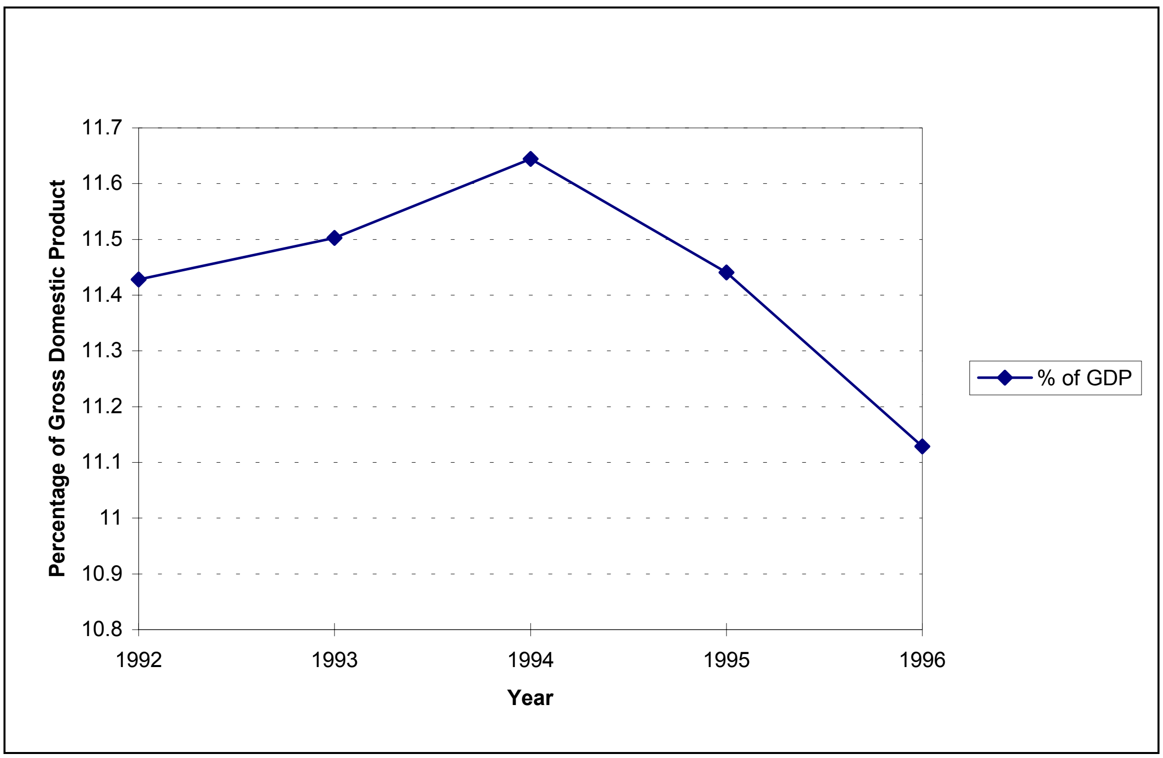
Part B: Value of Construction Work by Sector and by Nature of Construction Activity: 1992-1996

NEW CONSTRUCTION	All Sectors	Residential	Commercial/ Institutional	Industrial	Public Works
1992	393,831	133,658	122,960	30,902	106,311
1993	397,820	141,076	125,770	27,212	103,762
1994	416,213	156,576	128,116	28,161	103,360
1995	415,157	146,167	137,006	30,391	101,593
1996	435,483	157,846	149,445	29,219	98,973
DERIVED DATA - MAINTENANCE/ REPAIR					
1992	93,335	23,709	24,931	21,310	23,385
1993	94,280	23,949	25,183	21,526	23,622
1994	98,639	25,057	26,348	22,521	24,714
1995	98,389	24,993	26,281	22,464	24,651
1996	103,206	26,217	27,568	23,564	25,858
DERIVED DATA - ADDITIONS/ ALTERATIONS					
1992	156,455	37,204	67,904	21,632	29,715
1993	158,040	37,581	68,592	21,851	30,016
1994	165,347	39,319	71,764	22,861	31,404
1995	164,928	39,219	71,581	22,803	31,324
1996	173,002	41,139	75,086	23,919	32,858

Importance of the Construction Industry to the US Economy

The relative importance of the construction industry to the overall US economy is shown in Figure 3-8. Figure 3-8 uses the estimated annual values of all construction activities--new construction, maintenance and repair, and additions and alterations--based on the C30/CCI data and the published figures for the US gross domestic product (GDP) to create a measure of the construction industry's relative importance. The metric which is plotted in Figure 3-8 is the percent of GDP accounted for by all expenditures for construction activities. It is worth noting that while expenditures for all construction activities have been increasing in each year (in constant 1992 dollar terms), the construction industry's relative importance peaked in 1994 and has been declining since then. Reference to Figure 3-1 shows that 1994 was a year in which the value of new residential construction put in place was particularly strong. To gain a better understanding of how the construction industry interacts with the rest of the US economy, it is useful to turn to the labor market.

Figure 3-8. Relative Importance of the Construction Industry to the US Economy

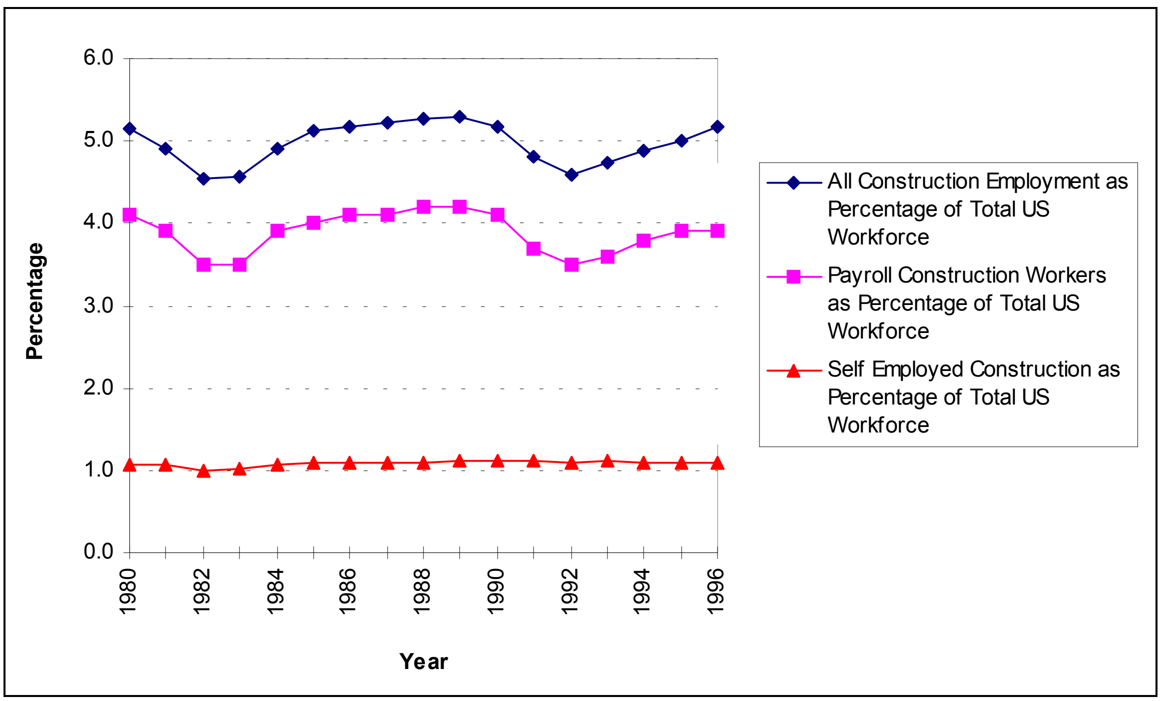


3.3. Employment in Construction

Construction tends to be a cyclical activity that can have a significant impact on the national economy and even more so on various local economies. Construction activity has a significant impact on local employment due to secondary effects on construction supply and service industries.

Figure 3-9 illustrates the cyclical nature of construction activity. Figure 3-9 records employment in construction as a percent of overall employment in the US civilian workforce for the years 1980 through 1995. Because the construction workforce consists of a large number of self-employed workers, Figure 3-9 also includes multi-year traces which divide the construction workforce into its two constituent parts. The first part records the percentage of the US civilian workforce associated with construction establishments with employees. The second part records the percentage of the US civilian workforce associated with self-employed construction workers.

Figure 3-9. Construction Employment as a Proportion of the Total US Civilian Workforce



Source: Bureau of Labor Statistics, National Employment Data, and US Industrial Outlook

Figure 3-9 shows the impact of recessions very clearly, as these are years when sharp declines in the construction workforce relative to the rest of the US civilian workforce occur. Notice that most of the declines and increases shown in Figure 3-9 are due to construction establishments with employees. The percentage of self-employed workers hovers around one percent throughout the 15 year period. The relative increase in employment in the construction industry between 1992 and 1996 shown in Figure 3-9 and its interaction with the rest of the economy can better be understood through reference to and comparison with Figures 3-8 and 3-1. In Figure 3-8, the relative importance of the construction industry vis-à-vis the rest of the economy reached a peak in 1994. Thus, one would expect a positive influence of the overall economy on the construction industry labor market leading up to that peak. Reference to Figure 3-1 shows strong increases in the value of new commercial/institutional construction put in place from 1994 through 1996. This upward trend was reinforced by a strong performance in 1996 for the residential sector.

Table 3-5 provides detailed information for a single year, 1992. The data presented in Table 3-5 are from the 1992 census of the construction industry. Table 3-5 is organized around the three two-digit SIC codes and 26 four-digit SIC codes described earlier (see Table 3-2). The table lists a specific segment or subsegment of the construction industry in the leftmost column. Immediately to the right is the corresponding two-digit or four-digit SIC code for the segment or subsegment of the construction industry. The four remaining columns record information on the number of establishments with payroll, the total number of employees in thousands, the value of construction work in millions of 1992 dollars, and value added in millions of 1992 dollars. It is important to recognize that only construction establishments with employees are included in these figures. Consequently, the values shown in Table 3-5 differ from those given in Section 3.2 where data from the C30 report were used to compute the total value of construction work (see Figure 3-2 for a comparison of the two sets of totals).

Data from the 1992 census of the construction industry are used here because they provide the necessary level of detail to link employment and output information. For example, a key measure of productivity within the construction industry is value added per employee. The information in Table 3-5 is very useful in characterizing employment and output in the construction industry. One such characterization is illustrated through a series of four pie charts and one bar chart.

Figure 3-10 summarizes information on the number of establishments and the percentage of all construction establishments within each of the three two-digit SIC codes. Note that SIC code 17, special trade contractors, account for nearly two-thirds of all construction establishments. By contrast, heavy construction contractors, SIC code 16, are only six percent of the total number of construction establishments.

Figure 3-11 summarizes information on the number of employees and the percentage of all construction employment within each of the three two-digit SIC codes. Note that the percentage of employment in SIC code 16, heavy construction contractors, amounts to 17 percent of the total, implying that establishments in this segment of the construction industry tend to be larger than for SIC codes 15 and 17.

Figure 3-12 summarizes information on the value of construction work and the percentage of the total value (i.e., $528.1 billion) within each of the three two-digit SIC codes. Note that general building contractors, SIC code 15, and special trade contractors, SIC code 17, each account for 41 percent of the total.

Table 3-5. Employment and Output Figures for the Construction Industry: 1992

Industry	SIC Code	Establishments with Payroll (1000's)	Total Employees (1000's)	Value of Construction Work (Million Dollars)	Value Added (Million dollars)
All industries, total	(X)	572.9	4,668	528,106	234,618
General building contractors	**15**	**168.4**	**1,097**	**215,629**	**63,117**
Single-family houses	1521	107.5	404	48,633	17,183
Other residential buildings	1522	6.5	49	7,835	2,454
Operative builders	1531	17.0	114	44,588	15,289
Industrial buildings and warehouses	1541	7.7	123	20,586	6,438
Nonresidential buildings, n.e.c.	1542	29.7	407	93,987	21,754
Heavy construction contractors	**16**	**37.2**	**799**	**95,571**	**49,165**
Highway and street construction	1611	10.1	257	35,332	15,711
Bridge, tunnel, and elevated highway	1622	1.0	44	7,198	3,078
Water, sewer, and utility lines	1623	10.2	194	20,205	11,734
Heavy construction, n.e.c.	1629	15.8	304	32,837	18,642
Special trade contractors	**17**	**367.3**	**2,772**	**216,905**	**122,336**
Plumbing, heating, air-conditioning	1711	75.4	613	56,902	29,432
Painting and paperhanging	1721	32.0	163	8,690	5,855
Electrical work	1731	54.0	487	40,259	23,548
Masonry and other stonework	1741	22.6	148	8,458	5,146
Plastering, drywall, insulation	1742	18.6	207	14,056	8,143
Terrazzo, tile, marble, and mosaic work	1743	6.5	34	2,439	1,358
Carpentry	1751	38.2	178	12,852	6,760
Floorlaying and other floor work	1752	10.2	49	4,428	2,166
Roofing, siding, and sheet metal work	1761	27.6	216	16,788	8,906
Concrete work	1771	26.1	193	14,423	7,703
Water well drilling	1781	3.6	19	1,727	995
Structural steel erection	1791	3.8	58	4,952	3,021
Glass and glazing work	1793	4.6	32	2,724	1,424
Excavation work	1794	13.9	77	6,870	4,340
Wrecking and demolition work	1795	1.0	13	1,059	775
Installing building equipment, n.e.c.	1796	3.9	83	6,611	4,494
Special trade contractors, n.e.c.	1799	25.3	204	13,667	8,270

Figure 3-10. Number of Establishments with Payroll by Two-Digit SIC Code: 1992

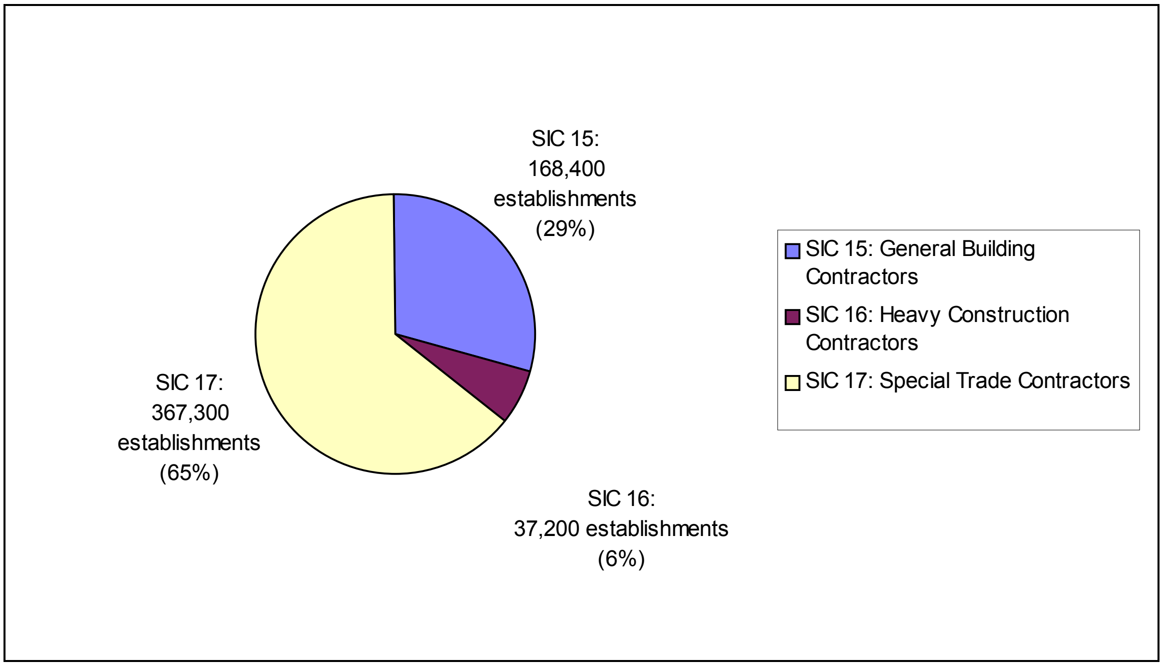


Figure 3-11. Number of Employees for Establishments with Payroll by Two-Digit SIC Code: 1992

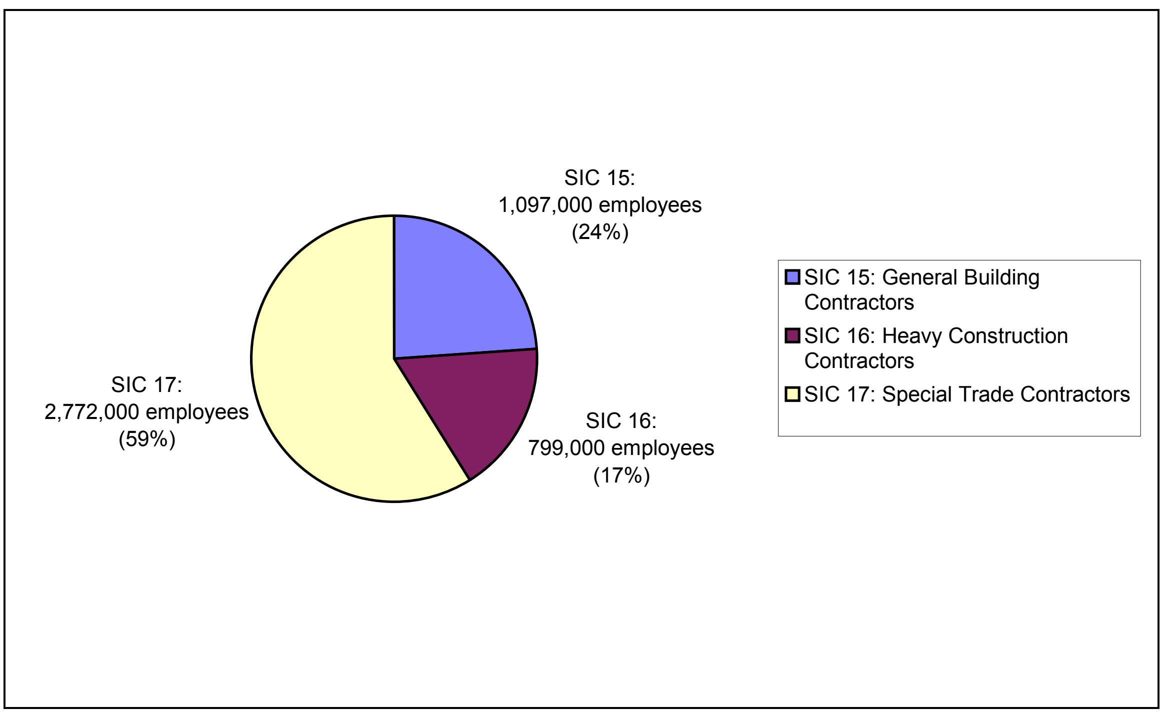


Figure 3-12. Value of Construction Work for Establishments with Payroll by Two-Digit SIC Code: 1992

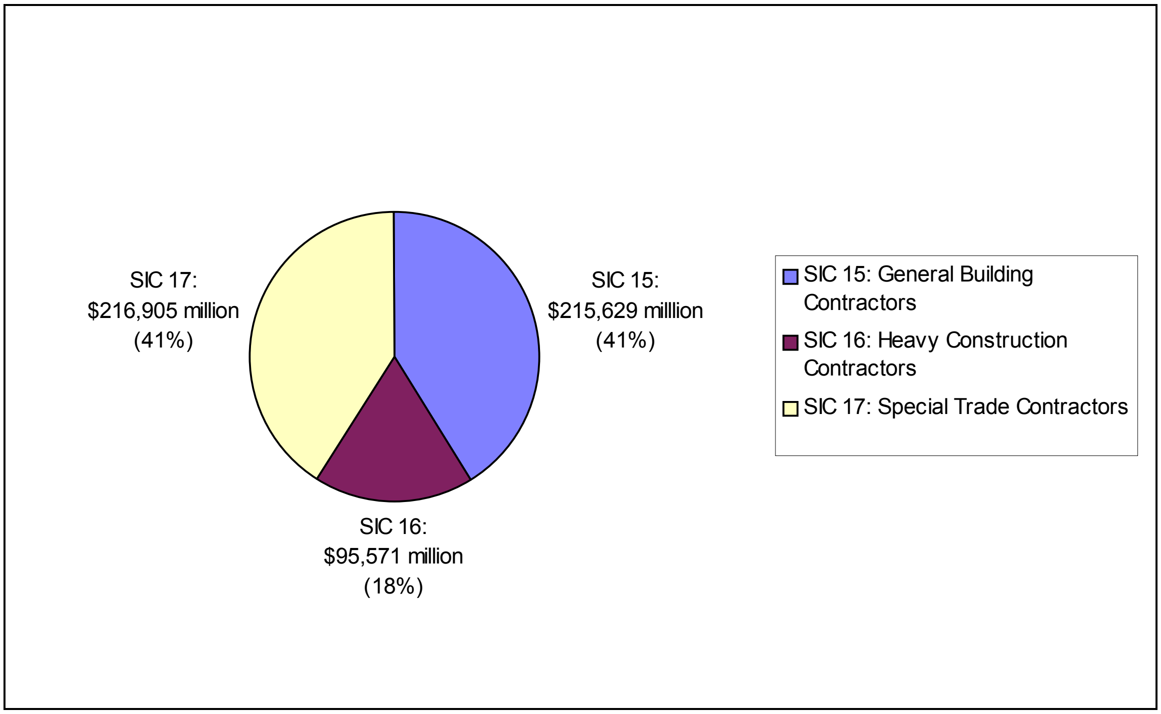


Figure 3-13 summarizes information on value added and the percentage of the total value added (i.e., $234.6 billion) within each of the three two-digit SIC codes. Figure 3-14 factors employment into the calculation; it records value added per employee in thousands of 1992 dollars.

Reference to Figure 3-14 reveals that SIC code 16, heavy construction contractors, has the highest average value added per employee, $61.5 thousand, and SIC code 17, special trade contractors, has the lowest value added per employee, $44.1 thousand. That SIC code 16 is the highest should come as no surprise. Establishments within SIC code 16 tend to be larger on the average than for SIC codes 15 and 17 and accounted for a "relatively" larger percentage share of overall value added. For example, for SIC code 16, the percentage share of overall value added exceeded the percentage share of overall employment. While for SIC codes 15 and 17, their percentage shares of value added were either approximately equal or less than the percentage shares of overall employment.

Figure 3-13. Value Added for Establishments with Payroll by Two Digit SIC Code: 1992

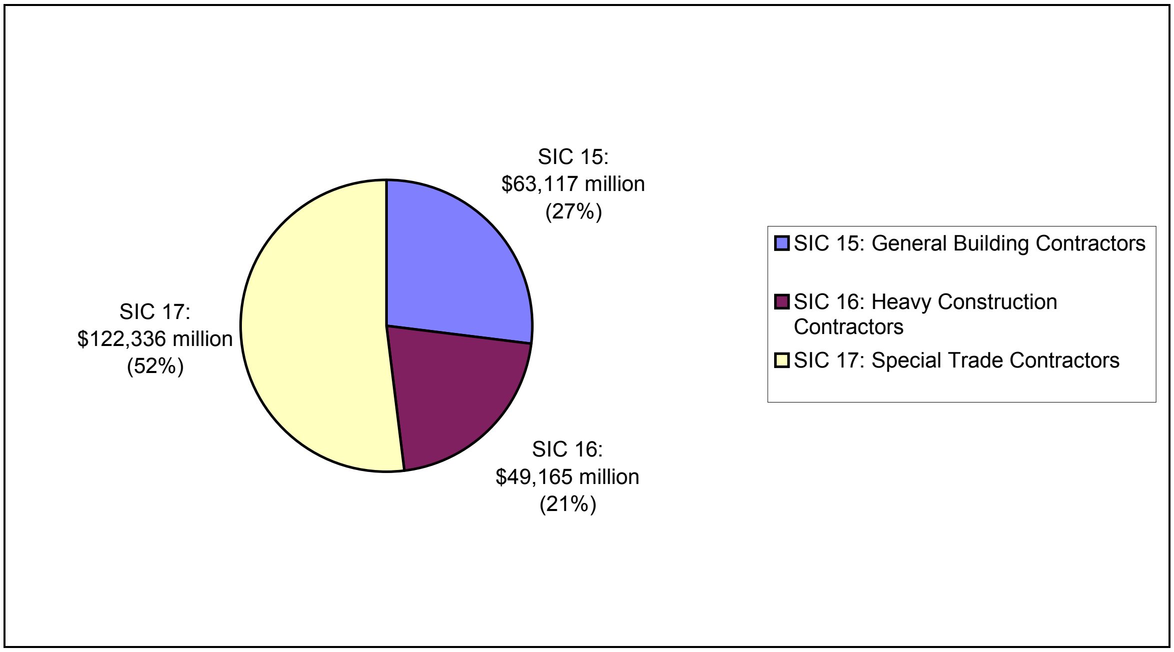
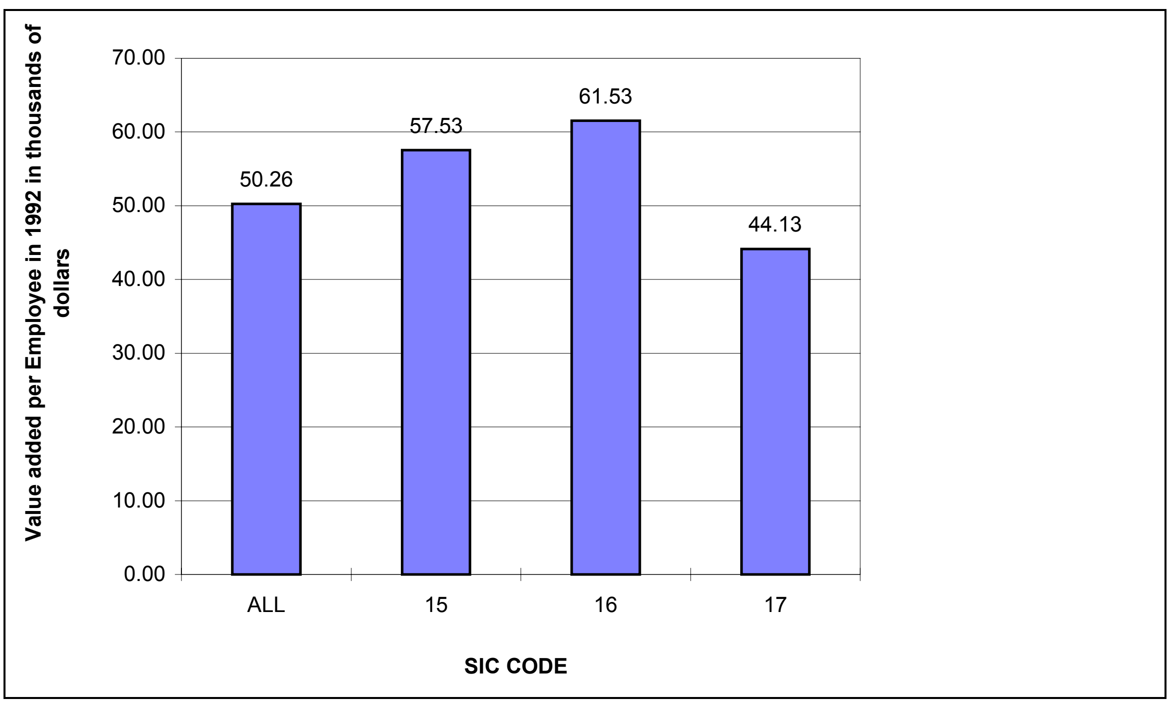


Figure 3-14. Value Added per Employee for Establishments with Payroll: 1992



3.4. Special Considerations

The purpose of this section is twofold. First, it provides information on cost trends. This information builds on the material presented in the earlier sections. As such, it promotes a better understanding of interactions between the construction industry and the rest of the US economy. Second, this section introduces information that has relevance to the National Construction Goal of reducing delivery time but is general in nature.

Trends in Residential and Non-Residential Construction Costs

In Sections 3.2 and 3.3, information was presented and discussed on the relative importance of the construction industry and on interactions between employment and output in the construction industry and the overall US economy. Both sets of information included trends which showed the cyclical nature of construction activity. Figure 3-15 provides a different perspective on the same issue; namely, trends in per unit construction costs (i.e., costs per square foot and costs per square meter). Figure 3-15 consists of three multi-year traces: (1) all buildings; (2) residential buildings; and (3) non-residential buildings. The cost trend data cover the 15 year period 1980 through 1995. Reference to Figure 3-15 shows an upward trend for residential buildings modulated by the business cycle. For non-residential buildings, the upward trend is more heavily modulated by the business cycle (see Figures 3-8 and 3-9 for purposes of comparison).

Table 3-6 records the data used to produce each multi-year trace. The table is divided into three parts: Part A covers all buildings; Part B covers residential buildings; and Part C covers non-residential buildings. The leftmost column in each part of Table 3-6 records the year. The remainder of the table records the construction contract value in billions of constant 1992 dollars, the floor space in millions of square feet, the construction cost in dollars per square foot, the floor space in millions of square meters, and the construction cost in dollars per square meter.

Delivery Time Statistics Published by the US Bureau of the Census

The US Bureau of the Census publishes a wide variety of construction statistics as part of its ***Current Construction Report*** series. Statistics related to delivery time have historically been published under two different ***Current Construction Report*** series: (1) C20, *Housing Starts*; and (2) C30, *Value of Construction Put in Place*. Because the Census statistics published in the C20 and C30 reports are considered to be both authoritative and representative of national averages, every effort is made to incorporate them into the baseline measures for each sector.

Figure 3-15. Average Cost per Square Foot and per Square Meter of New Construction and Major Additions to Buildings

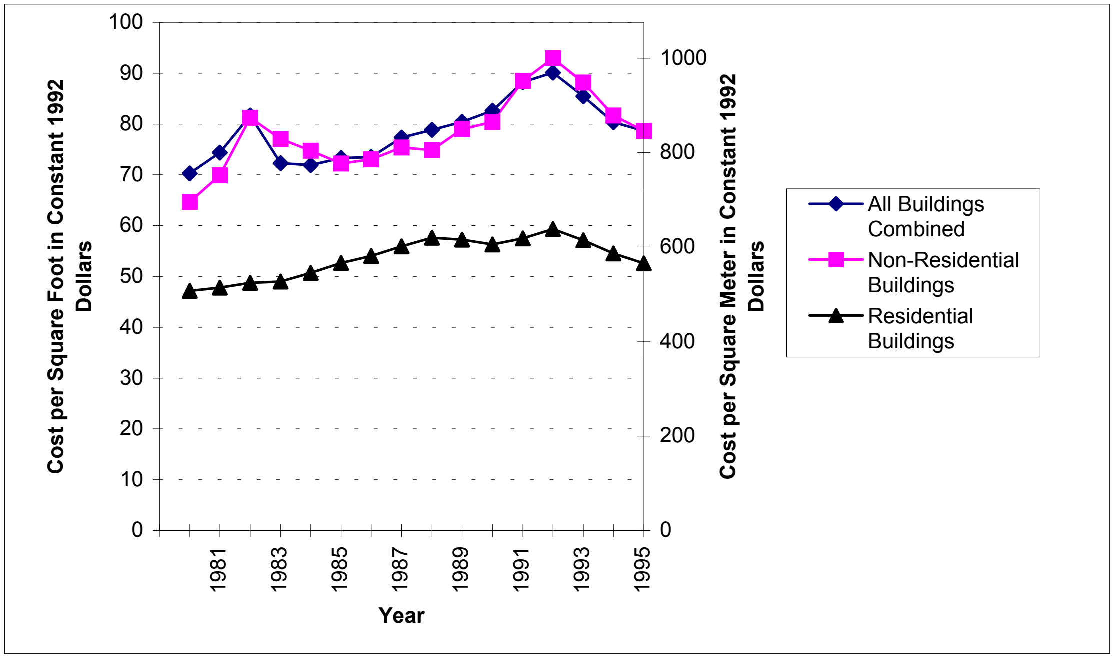


Table 3-6. Background Information Used to Compute Average Cost per Square Foot and Average Cost per Square Meter Figures

Part A: All Buildings

YEAR	ALL BUILDINGS				
	Construction Contract Value (Billion Constant 1992 Dollars)	Floorspace (Million Square Feet)	Floorspace (Million Square Meters)	Construction Cost (Dollars/Square Foot)	Construction Cost (Dollars/Square Meter)
1980	218.0	3,102	288.2	70.27	756.13
1981	208.6	2,805	260.6	74.36	800.11
1982	200.5	2,455	228.1	81.65	878.59
1983	244.8	3,387	314.7	72.26	777.57
1984	263.4	3,661	340.1	71.94	774.08
1985	282.5	3,853	357.9	73.32	788.87
1986	289.2	3,935	365.6	73.49	790.77
1987	290.3	3,756	348.9	77.30	831.75
1988	283.4	3,594	333.9	78.86	848.58
1989	282.7	3,516	326.6	80.40	865.13
1990	249.4	3,020	280.6	82.60	888.75
1991	232.4	2,634	244.7	88.24	949.43
1992	252.2	2,799	260.0	90.10	969.51
1993	261.7	3,062	284.5	85.48	919.72
1994	274.0	3,410	316.8	80.35	864.54
1995	271.3	3,448	320.3	78.68	846.61

Part B: Residential Buildings

YEAR	RESIDENTIAL BUILDINGS				
	Construction Contract Value (Billion Constant 1992 Dollars)	Floorspace (Million Square Feet)	Floorspace (Million Square Meters)	Construction Cost (Dollars/Square Foot)	Construction Cost (Dollars/Square Meters)
1980	86.7	1,839	170.8	47.16	507.48
1981	74.7	1,562	145.1	47.79	514.26
1982	70.2	1,440	133.8	48.74	524.40
1983	111.5	2,276	211.4	48.98	527.00
1984	117.1	2,311	214.7	50.68	545.33
1985	122.4	2,324	215.9	52.68	566.79
1986	134.1	2,481	230.5	54.05	581.57
1987	127.9	2,288	212.6	55.90	601.52
1988	125.6	2,181	202.6	57.59	619.71
1989	121.1	2,115	196.5	57.25	615.99
1990	102.3	1,817	168.8	56.31	605.88
1991	95.1	1,653	153.6	57.51	618.79
1992	110.6	1,864	173.2	59.33	638.44
1993	119.4	2,091	194.3	57.12	614.62
1994	123.6	2,266	210.5	54.54	586.81
1995	114.2	2,172	201.8	52.59	565.81

Part C: Non-Residential Buildings

YEAR	NON-RESIDENTIAL BUILDINGS				
	Construction Contract Value (Billion Constant 1992 Dollars)	Floorspace (Million Square Feet)	Floorspace (Million Square Meters)	Construction Cost (Dollars/Square Foot)	Construction Cost (Dollars/Square Meter)
1980	81.7	1,263	117.3	64.69	696.11
1981	86.9	1,243	115.5	69.87	751.84
1982	82.4	1,015	94.3	81.21	873.83
1983	85.6	1,111	103.2	77.07	829.25
1984	100.9	1,350	125.4	74.74	804.22
1985	110.4	1,529	142.0	72.22	777.11
1986	106.3	1,454	135.1	73.08	786.32
1987	110.8	1,469	136.5	75.39	811.25
1988	105.8	1,413	131.3	74.90	805.90
1989	110.6	1,400	130.1	78.97	849.70
1990	96.7	1,203	111.8	80.41	865.23
1991	86.8	981	91.1	88.48	952.09
1992	87.0	936	87.0	92.95	1000.13
1993	85.6	971	90.2	88.16	948.60
1994	93.4	1,144	106.3	81.67	878.72
1995	100.4	1,276	118.5	78.66	846.41

Residential delivery time statistics are published annually as a supplement in the March edition of the C20 report. These statistics provide information on the average length of time in months from authorization of construction (i.e., issuance of the building permit) to the start of construction (i.e., excavation begins) ***and*** from the start of construction to completion (i.e., floor finishes are installed). No complementary information on the length of time required to obtain authorization (i.e., from application for until issuance of the building permit) is published in the C20 supplement. Because the C20 supplement provides an unbroken time series of statistics on the duration of the construction process, it is used as the primary source for delivery time estimates for the residential sector.

Prior to 1993, non-residential delivery time statistics were published as an annual supplement in the October edition of the C30 report. These statistics provide information on the average length of time in months from start of construction until completion. No complementary information on the length of time required to obtain authorization was published in the C30 supplement. However, since October 1992, no non-residential delivery time statistics have been published by the US Bureau of the Census. Consequently, in order to generate delivery time statistics for the three non-residential sectors, it was necessary to locate additional data sources. Although additional data sources are used as the primary source for non-residential delivery time statistics, data from the October 1992 C30 supplement are used as a reference point and for purposes of comparison (see Chapter 6).

Delivery Time Statistics Provided by the Construction Industry Institute

Data from the Construction Industry Institute (CII) are used to produce estimates for delivery time statistics for the three non-residential sectors. CII is an internationally-recognized research consortium focused on advancing the capital projects industry. The CII data are used in this document because CII has committed itself to an annual cycle of surveying its member companies, collecting data on an individual project basis, analyzing these data, and publishing its findings.

Research by the authors indicates that CII is one of the few organizations in the US that is systematically collecting construction project data in a manner conducive to the formulation of baseline measures for all three non-residential sectors. CII has agreed to provide NIST with aggregated data from its database, which will enable NIST to develop broad-based, industry-wide baseline measures for reductions in delivery time.[16] At the same time, NIST's analyses of the data provided by CII will provide CII with valuable insights into the schedule performance of its member companies, which will be of direct benefit to its membership.

Several private companies also collect some construction project data for one or more of the three non-residential sectors. However, these data are often specific to a particular segment of the construction industry (e.g., petrochemicals) and thus cannot be used to develop the broad-based, industry-wide baseline measures associated with the National Construction Goals. Furthermore, there may be no fixed reporting intervals or broad-based data collection effort that would provide confidence that these data are authoritative. In addition, it is likely that such data could only be obtained on a fee-for-service basis.

[16] All data provided to NIST by CII have been aggregated in a manner that precludes identification of an individual company's or project's performance.

In the search for sources of information on delivery time, a wide range of public bodies were also consulted. Our findings indicate that there is little data available from public associations relating to cycle times for non-residential construction projects.

Therefore, it is considered to be appropriate to make use of data from CII. The frequency for publishing these data and the methods of data collection meet the criteria established in Chapter 2. For purposes of this document, the only limitation of the CII data is that they may not be representative of construction industry "averages" for the three non-residential sectors. This caveat is based on the assumption that CII member companies *may be more aggressively pursuing* performance improvement measures than companies that are not members of CII. Thus the baseline measures derived from these data *may be skewed towards the "best practice" end* of the non-residential construction project spectrum. However, in the absence of other data, the CII data are considered to be both appropriate and of value for establishing the baseline measures presented in this document.

CII membership is nearly equally split between owner members and contractor members. CII draws its membership primarily from companies involved in the operation or construction of chemical manufacturing, oil refining, pulp and paper, or similar industrial facilities. Because these facilities also include infrastructure and commercial/office type operations, CII member companies span all three non-residential sectors. In addition, CII contractor members often perform substantial amounts of work in the commercial/ institutional and public works sectors as well as in the industrial sector.

CII's role as a catalyst within the capital projects industry promotes a belief that these project-oriented data are likely to become widely recognized throughout the non-residential sectors of the construction industry as benchmarks by which to measure the improvement of the industry. In addition, CII's mission to improve the safety, quality, schedule, and cost effectiveness of the capital investment process--not only through research but also through a systematic implementation process--should ensure the broad dissemination of findings from the annual data collection cycle. Finally, CII's *Goal 2000* initiative closely parallels the aims of National Construction Goals 1 and 7. To achieve *Goal 2000*, CII will perform research that will help reduce total project costs by 20 percent, reduce total project duration by 20 percent, and improve project safety by 25 percent by the year 2000.

A key resource in CII's effort to achieve *Goal 2000* is the Benchmarking and Metrics Program. The purposes of the Benchmarking and Metrics Program are: (1) to provide information to member companies on the net impact in overall project performance associated with using CII-endorsed best practices; and (2) to assist member companies in statistical measurements that can improve their own capital project effectiveness. The vehicle through which the purposes of the Benchmarking and Metrics Program are implemented is CII's Benchmarking and Metrics Committee. The Benchmarking and Metrics Committee was chartered by CII's Board of Advisors in November 1993. The

Benchmarking and Metrics Committee is composed of representatives from both owner and contractor companies; it met for the first time in February 1994.

To provide quantitative measures of project performance, the CII Benchmarking and Metrics Committee established a benchmarking database in 1996. The benchmarking database is based on survey data collected from CII member companies. The Benchmarking and Metrics Committee is responsible for the design of the survey instrument, the training of data liaison officers from member companies, and the compilation and analysis of respondent data.

The survey instrument focuses on information on project size, cost, schedule, overall performance, as well as on details of project execution. The survey instrument is designed to collect information both on performance metrics--cost, schedule, and safety--and on the use of CII-endorsed best practices. Perhaps most importantly, CII's analysis of respondent data seeks to quantify the impacts of best practice usage on the values of performance metrics (e.g., how the use of best practices translates into reductions in delivery time). Detailed information is collected on 8 of the 34 CII-endorsed best practices, including the following: (1) safety;[17] (2) pre-project planning;[18] (3) team building;[19] and (4) constructability.[20] These data are used to construct a series of indices for measuring the degree of usage both for individual best practices (e.g., team building) and for the overall set. Having data which links best practice use to reductions in delivery time is a valuable tool for identifying performance opportunities. Thus, the inclusion of these data provide a valuable additional dimension to our effort to develop baseline measures for delivery time in the three non-residential sectors.

To date, information from 393 projects totaling $20.6 billion (installed cost) has been collected, compiled, and analyzed. Figure 3-16 summarizes the project data received from 30 owners and 29 contractors. Note that the number of projects is almost equally split between owners and contractors.

While an owner is ultimately responsible for an entire project, a contractor will normally have responsibility only for a subset of the total functions required to develop a project. Contractor respondent projects in the database represent only those functions for which the contractor respondent has responsibility. Figure 3-17 reports the responsibility for the

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[17] Safety practices include the site-specific program and efforts to create a project environment and state of consciousness embracing the concept that all accidents are preventable and that zero accidents is an obtainable goal.

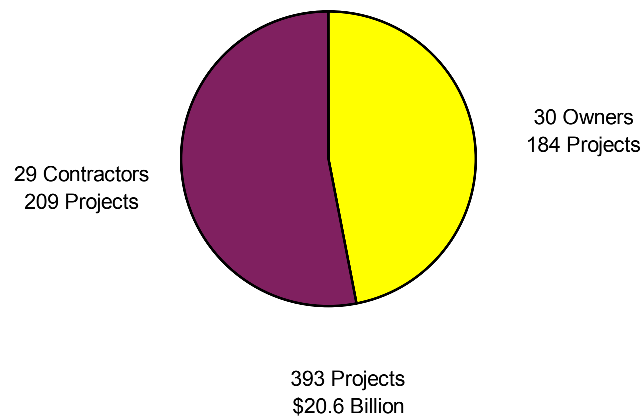
[18] Pre-project planning involves the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project.

[19] Team building is a process that brings together a diverse group of project participants and seeks to resolve differences, remove roadblocks, and proactively build and develop the group into an aligned, focused, and motivated work team that strives for a common mission for shared goals, objectives, and priorities.

[20] Constructability practices seek to achieve overall project objectives through the optimum use of construction knowledge and experience in planning, design, procurement, and field operations. Constructability is achieved through the effective and timely integration of construction input into planning and design as well as field operations.

209 projects submitted by contractors. Of the projects submitted by contractors, 40 contractor respondents had responsibility only for design, 64 had responsibility only for construction, and 105 had responsibility for both design and construction.

Figure 3-16. Database by Respondent Type



The Benchmarking and Metrics Committee uses four construction industry groups and allows for categorization of the database by these groups. The four industry groups are: (1) buildings; (2) heavy industrial; (3) infrastructure; and (4) light industrial. Figure 3-18 reports the distribution of projects in the database by industry group. Data on both owner respondent projects and contractor respondent projects are shown in Figure 3-18. The heavy industrial group comprises approximately 60 percent of the database. The remainder of the projects are fairly equally distributed among the other three industry groups. Throughout this document buildings are classified under the commercial/institutional sector, both heavy industrial projects and light industrial projects are classified under the industrial sector, and infrastructure projects are classified under the public works sector.

The CII database currently represents a broad range of project size as measured by cost. As shown in Figure 3-19, approximately one-third of the projects have a cost of less than $15 million, one-third have a cost between $15 and $50 million, and one-third have a cost in excess of $50 million. The individual project costs range from slightly below $5 million to in excess of $500 million, with an average cost of approximately $50 million. Data on both owner and contractor respondent projects are shown in Figure 3-19.

Figure 3-17. Database by Contractor Function

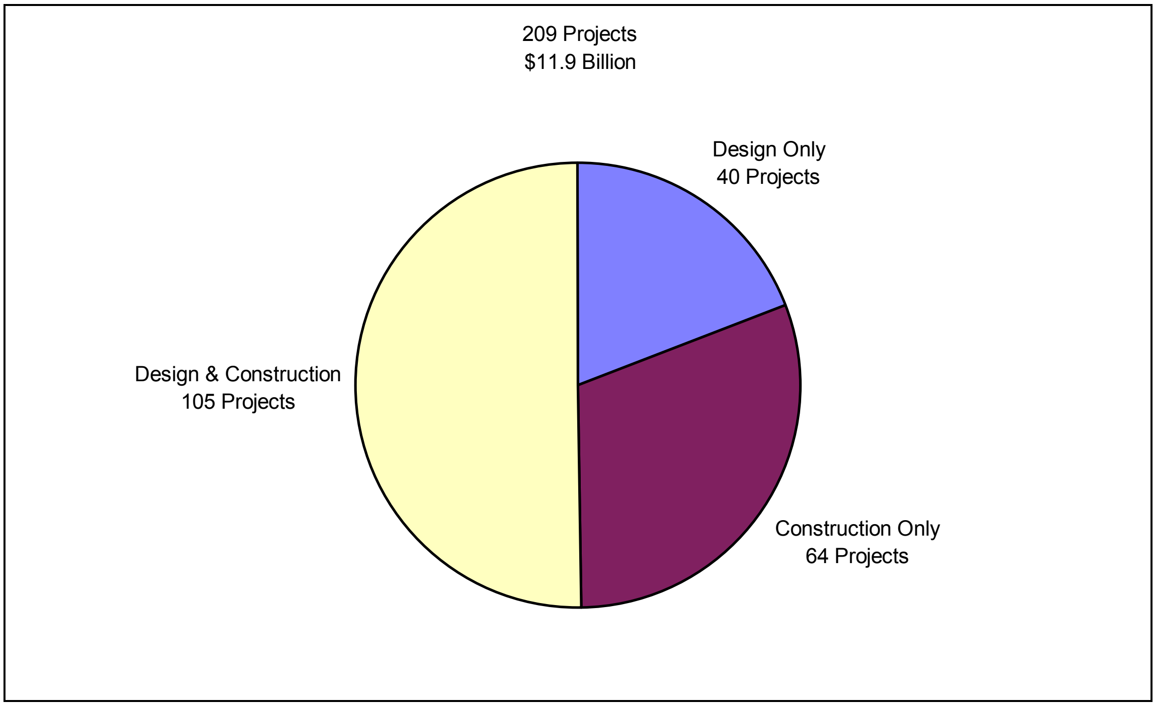


Figure 3-18. Database by Industry Type

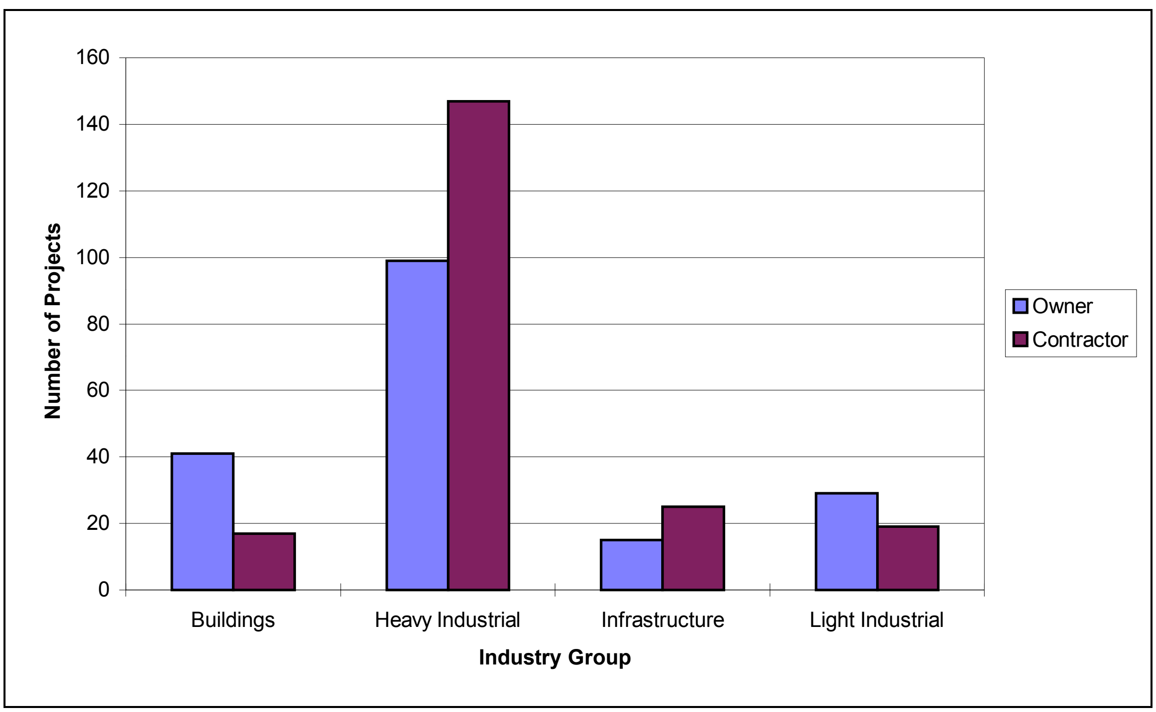
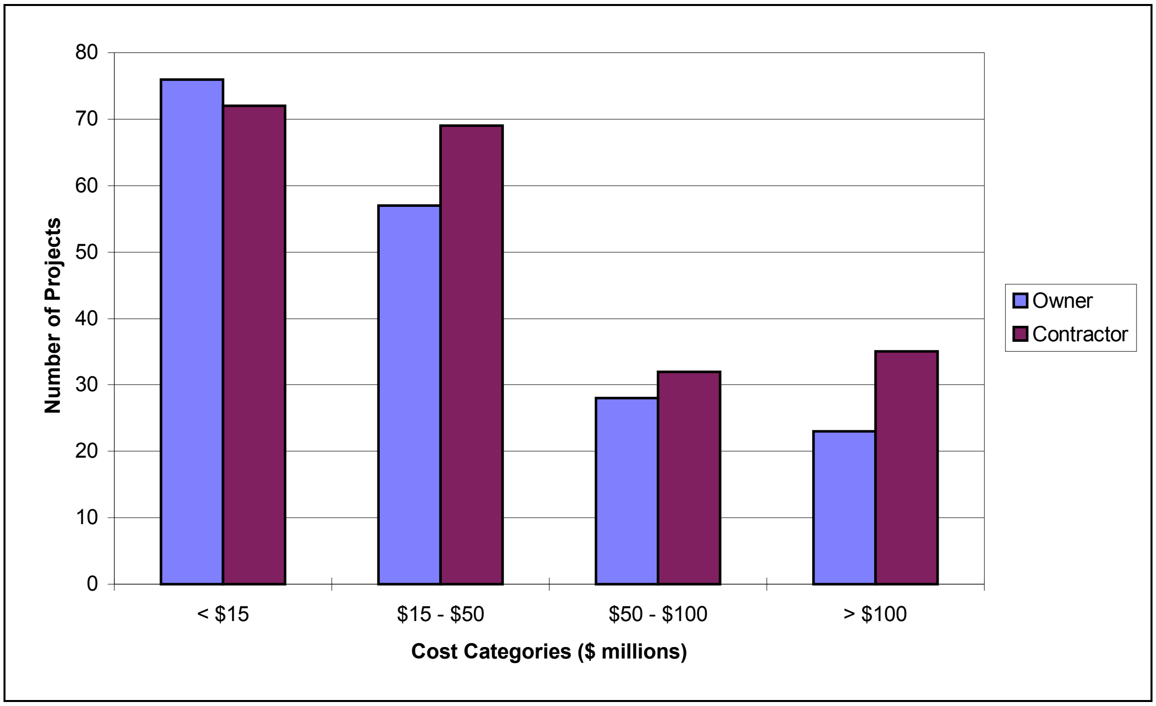


Figure 3-19. Database by Cost of Project



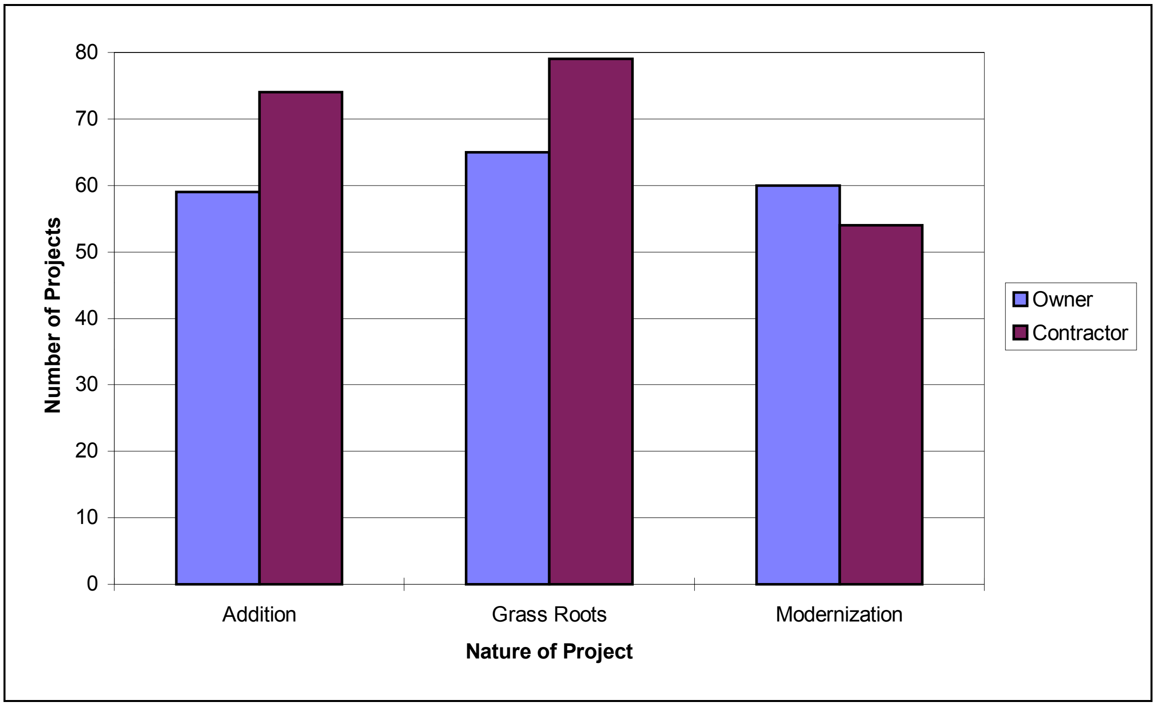
Projects in the CII database can be identified and categorized by the nature of the project. Project nature indicates to which of the three categories a project belongs: (1) grassroots; (2) addition; and (3) modernization. The survey instrument defined grass roots as a new facility. An addition was defined as a new facility component that ties in to an existing facility, often intended to expand capacity. Modernization was defined as a facility for which a substantial amount of the equipment or structure is replaced or modified, and which may expand capacity. For purposes of this document, grassroots projects are classified under the heading of new construction, and addition and modernization projects are classified under the heading of additions and alterations. Figure 3-20 shows how the projects in the database are distributed among the three categories of project nature. The projects are approximately equally distributed among all three categories. Data on both owner respondent projects and contractor respondent projects are shown in Figure 3-20.

CII has adopted a system for classifying project activities into five phases. The five phases are: (1) pre-project planning; (2) detail design; (3) procurement; (4) construction; and (5) start-up. This system for classifying project activities provides the basis for nearly all of the CII-defined metrics and associated data collected via the survey instrument. The five CII project phases are summarized in Table 3-7.[21] Table 3-7 is included as a means of linking information presented in Chapter 4, where the authors' data classification schemes are presented, with the baseline measures presented in

[21] Construction Industry Institute. 1998. *Benchmarking and Metrics Data Report for 1997*. Austin, TX: Construction Industry Institute.

Chapter 6. The table includes for each phase such useful information as the typical participants, the start and stop points, typical activities and products, and typical cost elements.

Figure 3-20. Database by Nature of Project



Key CII-defined metrics, which are used to produce the baseline measures presented in Chapter 6, are summarized in Table 3-8. Table 3-8 includes both formulas, which represent each metric mathematically, and definitions of all terms used in each formula.[22] The definitions of all key terms are shown in the bottom portion of Table 3-8. In some cases, the formula for a metric differs between owner respondents and contractor respondents. Such cases are identified clearly within the relevant section of Table 3-8.

[22] *Ibid*.

Table 3-7. Definitions and Descriptions of CII Project Phases

Project Phase	Start/Stop	Typical Activities & Products	Typical Cost Elements
Pre-Project Planning Typical Participants: Owner personnel Planning Consultants Constructability Consultants	Start: Defined Business Need that requires facilities Stop: Initial Funding Authorized	Options Analysis Life-cycle Cost Analysis Project Execution Plan Appropriation Submittal Package P & IDs and Site Layout Project Scoping Procurement Plan Arch. Rendering	Owner Planning team personnel expenses Consultant fees & expenses Environmental Permit fees Project Manager/ Construction Manager fees
Detail Design Typical Participants: Owner personnel Design Contractor Constructability Consultants	Start: Design Basis Stop: Release of all (last package for fast-track) approved drawings and specs for construction	Drawing & spec prep. Bill of material prep. Procurement Status Sequence of operations Technical Review Field Cost Estimate	Owner project management personnel Designer fees Project Manager/ Construction Manager fees
Procurement Typical Participants: Owner personnel Design Contractor	Start: Procurement Plan for Engineered Equipment Stop: All engineered equipment has been delivered to site	Vendor Qualifications Vendor Inquiries Bid Analysis Purchasing Expediting Engineered Equipment	Owner project management personnel Project Manager/ Construction Manager fees Procurement & Expediting personnel Engineered Equipment
Construction Typical Participants: Owner personnel Design Contractor (Inspection) Construction Contractor and its subcontractors	Start: Mobilization for construction Stop: Mechanical Completion	Set up trailers Site preparation Procurement of bulks Issue Subcontracts Construction plan for Methods/Sequencing Build Facility & Install Engineered Equipment Complete Punchlist Demobilize construction equipment Warranties	Owner project management personnel Project Manager/ Construction Manager fees Building permits Inspection fees Construction labor, equipment & supplies Bulk materials Construction equipment Contractor management personnel
Start-up *Note: Does not usually apply to infrastructure or building type projects* Typical Participants: Owner personnel Design Contractor Construction Contractor Training Consultant Equipment Vendors	Start: Mechanical completion Stop: Custody transfer to user/operator	Testing Systems Training operators Documenting Results Introduce feedstocks and obtain first Product Hand-off to user/operator Operating System Functional Facility	Owner project management personnel Project Manager/ Construction Manager fees Consultant fees & expenses Operator training expenses Wasted feedstocks Vendor fees

Table 3-8. Definitions of Key CII Schedule-Related Metrics

Metric	Formula
Schedule Growth	$\frac{\text{Total Project Duration - Initial Predicted Project Duration}}{\text{Initial Predicted Project Duration}}$
Phase Duration Factor *(Owner data only)*	$\frac{\text{Actual Phase Duration}}{\text{Actual Overall Duration}}$

Definition of Terms

Total Project Duration**:**

- Owners - Duration from beginning of detail design to turnover to user.
- Contractors - Total duration for the final scope of work from mobilization to completion.

Overall Project Duration:

- Unlike Total Project Duration, Overall Project Duration also includes time consumed for the Pre-Project Planning Phase.

Actual Phase Duration:

- Actual total duration of the project phase in question. See Table 3-7 for phase definitions.

Initial Predicted Project Duration:

- Owners - Duration prediction upon which the authorization to proceed with detail design is based.
- Contractors - The contractor's duration estimate at the time of contract award.

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4. Developing Baseline Measures and Measures of Progress for Reductions in Delivery Time

4.1. Data Classification Schemes

The first stage in developing baseline measures and measures of progress for Goal 1 (i.e., reduction in delivery time) involved establishing data classification hierarchies for each of the four industry sectors. These hierarchies were essential in order to be able to sort data into relevant sectors, to prioritize the data, and to establish data linkages. Initially, an "idealized" hierarchy was developed for each sector, on the premise that there would be no limitations upon data availability. However, as the data collection effort progressed, these "idealized" hierarchies were modified to reflect data availability and format constraints.

4.1.1. Industry Oriented

The industry oriented, or "idealized" hierarchies were developed with a view to defining the extent and key components for the four industry sectors considered relevant to Goal 1. The hierarchies for each sector divided the project delivery sequence into a series of 'phases' and then listed the key components within each of these phases. A brief description of each hierarchy, outlining the extent and key components of each sector, as defined in this document, is given below.

Residential Sector

The residential sector, was taken to comprise all permanent single and multi-unit structures, as well as mobile homes or trailers in the United States. These can be grouped according to whether the buildings are site (or 'stick') built, or modular/manufactured units. Housing can be further categorized by geographic location, type, size, and age.

Site or 'Stick-Built' Housing

For site or 'stick-built' residential housing, which, for the purposes of this document will be defined as housing where the building shell is substantially constructed on site, seven construction phases are defined in the hierarchy. These are:

(1) pre-start
(2) foundation, first floor, and groundworks
(3) framing, decking, and sheathing
(4) wall and roof coverings
(5) rough mechanical, electrical, plumbing and insulation
(6) finishes and service connections
(7) external works

The pre-start phase includes all actions leading up to permit acquisition and start of construction on site. As with modular housing, the time required for permit acquisition is influenced by factors such as site location and type, design, aesthetic, and environmental requirements.

The duration of phases two through seven (the 'construction' phases) is affected by inventory procedures and stock handling activities carried out in parallel with permit acquisition procedures in phase one.

The foundation, first floor, and ground-works phase duration is affected by factors such as the type and size of house, geographic location, ground conditions, and type of first floor construction. Factors which are likely to affect the duration of this phase are unforeseen ground conditions or adverse weather conditions.

The framing, decking, and sheathing phase duration is affected by factors such as the degree of pre-fabrication of components (e.g., wall paneling and trussed rafters for roofing), and the type of tools used on site (e.g., use of pneumatic tools). The duration of this phase may also be affected by adverse weather conditions.

The wall and roof coverings phase duration is affected by factors similar to those for the framing stage.

The rough mechanical, electrical, plumbing, and insulation phase duration is affected by factors such as the type of housing unit, degree of coordination between the different work disciplines, the types of systems used, and the tools and work methods employed.

The finishes and service connections phase duration is dependent upon the level of customization of the unit, and the extent of pre-fabrication off-site. In addition, coordination with external agencies to provide utilities connections or diversions may impact phase duration.

Finally, the external works phase, which includes all works outside the house such as landscaping, fencing and so forth, is affected by factors such as type and sequencing of work and adverse weather conditions.

All of the construction phases identified above are influenced in particular by the methods used to schedule work activities and to identify and solve problems on site. Factors which will influence the duration of the construction phases are:

- centralized or de-centralized system for construction management
- type of site/office communications system (phone/fax/modem)
- concurrent or sequential sequencing of activities using Critical Path Method or similar system for controlling Change Orders
- use of Just-in-Time or similar such system

- bonus/incentive package rewarding time/quality achievement
- method for reviewing and monitoring systems
- quality assurance/quality control systems in place
- staff training provided
- good safety record emphasized

Modular/Manufactured Housing

For modular/manufactured residential housing, which, for the purposes of this document will be defined as housing where the building shell is substantially complete prior to arrival on site[23], four construction phases are defined in the hierarchy. These are:

(1) pre-start
(2) housing manufacture
(3) transport to site
(4) site works

The pre-start phase includes all actions leading up to permit acquisition and start of manufacture of the housing, and any subsequent site works which might be carried out prior to or during manufacture. Site works during this phase might include placing the foundations for the modular housing. The time required for permit acquisition is influenced by factors such as site location and type, design, aesthetic, and environmental requirements.

The housing manufacture phase considers all activities carried out off-site prior to the transport of the house to the site. Many factors will influence the duration of the manufacturing process. The type and size of the house will clearly affect the manufacturing duration. In addition, the size of manufacturing establishment/number of production lines, production line efficiency, quality assurance/quality control procedures, degree of automation, extent of standardization, work sequencing, extent of outsourcing for subassemblies, and organizational structure of the establishment will all impact the manufacturing duration. The investment in research and development of new technologies, materials, and products, and the investment in staff training will also affect delivery time to some extent. The duration of phase two (the housing manufacture phase) is affected by inventory procedures and stock handling activities carried out in parallel with permit acquisition procedures in phase one.

The transport to site phase duration is influenced by factors such as distance of the site from the factory, geographic area, size of unit, and the type of equipment used to transport the unit.

[23] For more detailed definitions of the different types of manufactured housing, refer to the Manufactured Housing Institute's Internet site (URL: http://www.mfghome.org).

The site works stage encompasses all activities carried out on site after manufacture of the unit, up to the point at which the house is handed over to the customer in a completed condition. Site works can be conveniently categorized as follows:

(1) foundations (to receive the manufactured/modular unit)
(2) service connections (electricity, gas, water etc.)
(3) finishes
(4) external works (hard landscaping (e.g., paved areas), and soft landscaping (e.g., tree planting, etc.))

The duration of the site works phase is affected by the type of unit being placed, the extent of prefabrication/off-site fitting-out, and level of quality and customization of the unit. In addition, the scheduling of these activities (concurrent or sequential site activities) will also be of critical importance. Some of these site activities are particularly vulnerable to delay resulting from factors such as adverse weather conditions or safety-related incidents on site.

Commercial/Institutional Sector

The commercial/institutional sector, was taken to comprise the following generic types of building/facility, as defined by the Energy Information Administration (EIA):

- Farm Buildings
- Food Sales
- Food Service
- Health Care
- Laboratories
- Lodging
- Mercantile and Service
- Office
- Public Assembly
- Public Order and Safety
- Religious Worship
- Skilled Nursing
- Warehouse
- Other

Certain facilities, such as utilities, communications and transportation, are included under ‘services’ by organizations such as the International Facilities Management Association (IFMA). However, for the purposes of this document, they are considered as being part of the public works sector. Similarly, buildings within the manufacturing sector (e.g., computing, electronics, consumer products) are considered as being part of the industrial sector in this document.

The EIA categorization is similar to that used by the Construction Industry Institute, which groups commercial facilities under the industry title ‘buildings’. This encompasses low and high-rise office, warehouse, hospital, school, prison, retail, hotel, parking garage, dormitory, maintenance, and laboratory facilities.

Commercial/institutional facilities can also be categorized primarily by geographic location, type and size of facility, age, number of employees, and hours of operation. In addition, new projects can be categorized by the nature of the project (i.e. whether it is new build, addition, or modernization) and the installed cost.

For the purposes of this document, the delivery cycle for a “typical” commercial/institutional project has been broken down into a number of distinct phases. Given that there does not appear to be any industry-wide consensus regarding the definition of these project phases, this document will make use of phase definitions similar to those used by the Construction Industry Institute (CII) for recording data from actual, recently-completed construction projects. The five phases used by CII are as follows:

- Pre-Project Planning
- Detail Design
- Procurement
- Construction
- Start-up

The five phases which are identified in the idealized hierarchy are very similar to these phases, and are as follows:

- Pre-project Planning
- Design
- Tender
- Construction
- Commissioning

Each of these phases and the associated factors affecting phase duration are addressed below.

Pre-Project Planning

The start of the pre-project planning phase is defined as being the point at which a business need is defined. The termination of the phase is the point at which initial funding is authorized. Typical activities and products during this phase include options analysis, life-cycle cost analysis, production of a project execution plan and appropriation submittal package, project scoping, procurement planning, and architectural rendering.

Important factors affecting pre-project planning phase duration are likely to be the adequacy and timeliness of desktop/literature, site/topographic, geotechnical, and statutory authority searches. In addition, planning, environmental, and legislative requirements must be addressed in a timely manner. Failure to adequately address these issues may seriously impact the duration of subsequent project phases.

The need for adequate assessment of the financial, contractual, health and safety, and environmental risks, and production of suitable feasibility reports and preliminary cost plans will also impact pre-project planning phase duration, as well as possibly influencing the duration of subsequent project phases.

The hierarchy also identifies some generic 'best practices', which if developed during the pre-project planning phase and carried on throughout the project, will impact project duration. These include:

- clear brief and program of implementation for the project
- good team communications and cooperation
- sufficient business, technical, and construction expertise in project team
- low project team turnover
- commitment of all parties to best practice
- sufficient funding provided by owner
- flexible fee arrangements
- use of advanced information technology
- early contractor involvement in project (i.e., prior to construction phase)
- quality assurance systems in place

Design

The description of this phase has been slightly modified from 'detail design' (used by CII) to 'design'. The reason for this is that the 'design' phase description is unambiguous in that it encompasses conceptual, preliminary and detailed design. The start of this phase is defined as being the point at which the basis for design is defined. The termination of the phase is the point at which all approved drawings and specifications are completed. Typical activities and products during this phase include preparation of drawings, specifications, bills of quantities/materials, sequence of operations statements, carrying out project technical reviews, and field cost estimates.

Important factors affecting design phase duration, as well as the duration of subsequent phases, are likely to be the adequacy and timeliness of detailed risk assessments for the construction, maintenance, modification and decommissioning of the project, the use of value engineering, and consideration of planning, environmental, and legislative requirements. The level of owner involvement in the design process, control of project changes, and the flexibility that the design affords the construction process will also influence phase duration. Failure to adequately address these issues may seriously impact the duration of subsequent project phases.

The hierarchy also identifies some generic ‘best practices’, which if used during the design phase, and carried on throughout the project, will shorten project duration. These include:

- consideration of buildability, with early involvement of contractor
- standardization wherever possible
- modularization and prefabrication wherever possible
- minimize on-site welding
- innovation and use of high technology where appropriate
- consideration of construction in adverse weather conditions
- design “fit for purpose”

Tender

This phase is not identified by CII as a separate phase. This phase is difficult to locate within the typical CII project cycle, as it is dependent upon the type of construction contract that is used (e.g., design-build, design-bid-build, etc.), and the nature of the project. However, ideally, it would be useful to be able to separate this part of the project cycle, as it may be programmed as a separate activity where more traditional contracting approaches are used.

The start of this phase is defined as being the point at which the decision to select the project for competitive tender is made, whether for construction only, or for design and construction. The termination of this phase is the point at which the contract is awarded to the successful bidder. Typical activities and products during this phase include preparation of tender documents, tender submission, evaluation, and award.

Factors affecting the phase duration, as well as the duration of subsequent phases, are the clarity and brevity of the tender documents, number of tenders invited, provision for contractor-designed elements, and consideration of any special site considerations (e.g., diversion of statutory services, treatment of contaminated ground, etc.) which might favor early letting of part of the work. Failure to adequately address these issues may also seriously impact the duration of subsequent project phases.

The hierarchy also identifies some generic ‘best practices’, which if developed during the tender phase, and carried on throughout the project, will impact project duration. These include:

- selection of non-adversarial contract
- clear allocation of risk
- method for early notification of claims
- incentive clauses
- flexibility

Construction

The start of this phase is defined as being the point at which mobilization for construction begins. The termination of the phase, as defined by CII, is the point at which all components have been checked. In practice, a ‘defects correction period’ may exist in the contract, but this is not included as part of the construction phase. The end of construction can therefore be defined as the point of ‘substantial completion.’ Typical activities and products during this phase include setting up site offices, site preparation, procurement of materials, issue of sub-contracts, production of method statements and safety plans, construction of the project, removing defects prior to substantial completion/certification, and site demobilization.

Important factors affecting construction phase duration are likely to be the methods of working used on site and their impact upon site productivity, site access, drainage and temporary works provision, and level of re-work. These factors may be influenced by unforeseen ground conditions or adverse weather.

Special health and safety, or environmental risks will also impact phase duration.

The hierarchy also identifies some generic ‘best practices’, which if developed during the pre-project planning phase, and carried on throughout the project, will impact project duration. These include:

- tender is financially sufficient and meets requirements
- concurrent sequencing of site activities
- efficient materials handling procedures
- standardization wherever possible (e.g., concrete formwork)
- modularization and off-site fabrication wherever possible
- adequate and sufficiently experienced site staff
- good relationship with owner and designer
- early notification of claims and speedy resolution
- effective Change Order management
- clear communications and accountability between main contractor and subcontractor

Commissioning

This phase differs from the start-up phase defined by CII, in that CII's definition of the start-up phase is relevant to process facilities, but does not usually apply to building-type projects. The start of this phase is defined as being the point at which the work is substantially completed, and certified as such. The termination of the phase is the point at which the custody is transferred to the user/operator, with all defects having been corrected. In some contracts this period is referred to as the 'maintenance period' or 'defects correction period'. Typical activities and products during this phase include independent inspection and testing, defects correction, and certification.

The principle factors affecting the commissioning phase duration will be the quality of the work carried out during the construction phase, and its fitness for purpose.

Industrial Sector

The industrial sector was taken to comprise all manufacturing industries with Standard Industrial Classification Codes (SIC) between 20 and 39 inclusive. These SIC Codes are as follows:

- SIC 20 - Food and Kindred Products
- SIC 21 - Tobacco Products
- SIC 22 - Textile Mill Products
- SIC 23 - Apparel and Other Textile Products
- SIC 24 - Lumber and Wood Products
- SIC 25 - Furniture and Fixtures
- SIC 26 - Paper and Allied Products
- SIC 27 - Printing and Publishing
- SIC 28 - Chemicals and Allied Products
- SIC 29 - Petroleum and Coal Products
- SIC 30 - Rubber and Miscellaneous Plastic Products
- SIC 31 - Leather and Leather Products
- SIC 32 - Stone Clay and Glass Products
- SIC 33 - Primary Metal Products
- SIC 34 - Fabricated Metal Products
- SIC 35 - Industrial Machinery and Equipment
- SIC 36 - Electronic and Other Equipment
- SIC 37 - Transportation Equipment
- SIC 38 - Instruments and Related Products
- SIC 39 - Miscellaneous Manufacturing Industries

Note that all mining industries (which includes off-shore exploration and extraction activities) are excluded from this document. All transportation, communications, electric power generation/distribution, and sanitary services are included in the public works sector for this document. Industrial facilities can be characterized primarily by geographic location, size of facility (e.g., by capacity as a function of installed cost), and type/function. In addition, new projects can be categorized by the nature of the project (i.e., whether it is new build, addition, or modernization) and the installed cost.

This categorization is similar to that used by the CII, which groups industrial facilities according to whether they are ‘heavy industrial’, or ‘light industrial’. The heavy industrial category includes oil refining, chemical manufacturing, electrical generation, oil exploration, oil production, natural gas processing, pulp and paper, and metals refining and processing. The light industrial category includes pharmaceutical manufacturing, electronics manufacturing, automotive manufacturing, consumer products, and general manufacturing. However, it will be noted that there is some overlap between the public works sector (called the ‘infrastructure’ sector by CII) and the industrial sector if the CII definitions are compared with the SIC Code definitions.

As with the commercial/institutional sector, the delivery cycle for a “typical” industrial project has been broken down into a number of distinct phases. This document will make use of phase definitions similar to those used by the CII for recording data from ‘live’ construction projects. The five phases used by CII are as follows:

- Pre-Project Planning
- Detail Design
- Procurement
- Construction
- Start-up

The five phases which are identified in the idealized hierarchy are the same as these phases, with the exception of the detail design phase, which has been renamed ‘design’. In addition, a sixth phase called ‘tender’ has been identified in the idealized hierarchy, in a similar way to the commercial/institutional sector.

Each of these phases, and the associated factors affecting phase duration are addressed below.

Pre-Project Planning

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Design

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Tender

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Procurement

For industrial facilities, and in particular process-oriented projects, the procurement of engineered equipment is identified by CII as a separate construction phase. The start of this phase is defined as being the point at which a procurement plan for engineered equipment is produced. The termination of this phase is the point at which all engineered equipment is delivered to the site. Typical activities and products during this phase include vendor qualification, bid analysis, equipment purchasing, and engineering activities.

Important factors affecting the phase duration, as well as the duration of subsequent phases are likely to be the clarity and brevity of the tender documents, number of bidders, provision for contractor designed elements, and consideration of an enabling works program/work activity phasing. Failure to adequately address these issues may seriously impact the duration of subsequent project phases.

The hierarchy also identifies some generic 'best practices', which if developed during the tender phase and carried on throughout the project, will impact project duration. These include:

- clear procurement plan specified
- special requirements and specialist contractors identified
- team member responsibilities communicated clearly
- materials availability, lead-in times, and price confirmed
- trade skills required on site are assessed
- potential storage/access/lay-down problems addressed
- testing/inspection requirements clearly documented
- design completed in time for early purchase contracts
- regulatory approvals coordinated
- sub-contractors pre-qualified
- incentive schemes and non-adversarial contracts encouraged

Construction

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Start-up

This phase is particularly relevant to the heavy process industries, where a highly complex series of systems may need to be tested prior to custody transfer to the plant user/operator. The start of this phase is defined as being the point at which all components are in place and functioning. The termination of the phase is the point at which the custody is transferred to the user/operator, with all defects having been corrected. Typical activities and products during this phase include independent inspection and testing of systems, defects correction, certification, operator training, introduction of feed-stocks, and obtaining first product/output.

The principle factors affecting the start-up phase duration will be the quality of the work carried out during the construction phase, and its fitness for purpose.

Public Works Sector

For this document, the public works sector has been divided into a number of sub-sectors, which are broadly aligned with the SIC Codes, as follows:

- **Transportation** (SIC 40, 41, 42, 44, 45). This sub-sector includes transportation by road, rail, water, and air.
- **Communications** (SIC 48). This sub-sector includes communication masts and other structures, and associated cabling and related services.
- **Power Utilities** (SIC 49). This sub-sector includes the generation and distribution of electricity, gas, and steam (electric, gas, coal, nuclear, and other types of power station). It includes the distribution of natural gas.
- **Water** (SIC 44, 49). This sub-sector includes the storage, supply, and treatment of water, plus flood and storm water control.
- **Solid Waste** (SIC 42, 44). This sub-sector includes the collection and disposal of solid waste materials (domestic and industrial).
- **Pipelines** (SIC 46). This sub-sector includes pipelines for the transport of petroleum and other commodities except natural gas.

The extent of the industry oriented hierarchy for each of these sub-sectors is considered in more detail below

Transportation Sub-Sector

This sub-sector was taken to comprise the US highway and bridge network (including highway tunnels), rail network, airports and associated infrastructure, and navigable rivers, canals, related structures and ports. Highways and bridges can be relatively easily categorized by type of operating authority, functional type, and geographic location. Railroads can be categorized by geographic location and by class of railroad. Categorization of airports, waterways, and ports is more difficult, given that many do not share common characteristics and cannot be easily compared.

Communications Sub-Sector

This sub-sector was taken to comprise telephone, TV and broadcast, and cable and pay TV services. While there is a certain amount of construction effort involved in this sector, it has been decided to omit this sub-sector from the document, given that much of the work in this sector is either not directly construction related, or is considered elsewhere in this document (e.g., manufacture of components and pre-fabricated structures, cabling and other specialized electrical installation work).

Power Utilities Sub-Sector

This sub-sector is defined as encompassing electricity, gas, or steam generation and distribution for the primary fuel sources (electric, gas, coal, nuclear, and other). Power generation plants can be categorized by generating capacity, size (as a function of installed cost), and geographic location. It is more difficult to categorize power distribution systems, other than by type of system used (buried or catenary) and geographic location.

Water Sub-Sector

This sub-sector was taken to comprise water storage (dams, reservoirs, and associated hydro-electric power (HEP) projects), supply (domestic, commercial, industrial, and power generation), treatment (sewage etc.), and flood control/storm water management. Water storage systems are considered only where there is an associated end-use in the form of HEP generation. Categorization is then in terms of installed generation capacity. Water supply and treatment systems can be categorized by end-user and geographic location. Flood control/storm water management can be categorized to some extent by nature of work and geographic area.

Solid Waste Sub-Sector

This sub-sector was taken to comprise the collection and disposal of solid domestic, commercial, and industrial waste at processing facilities and landfill sites. Although there is some construction related activity within this sub-sector (particularly in terms of earthworks for landfill sites/repositories), this will be covered in a future document relating to National Construction Goal 5 (Reduction in Waste and Pollution).

Pipelines Sub-Sector

This sub-sector is defined as comprising all pipelines for the transportation of petroleum and other commodities except natural gas (considered as part of the power utilities sub-sector). Pipelines can be characterized by type, size, and geographic location.

Description of Project Phases - All Sub-Sectors

The categorization of the sub-sectors that has been described is similar to that used by the CII, which groups public works projects under the title ‘infrastructure’. This encompasses electrical distribution, highway, bridge, river navigation, flood control, rail, water/wastewater, airport, tunneling, marine, and environmental facilities.

New projects can be categorized by the nature of the project (i.e., whether it is new build, addition, or modernization) and the installed cost.

As with the commercial/institutional and industrial sectors, the delivery cycle for a “typical” public works project has been broken down into a number of distinct phases. This document will make use of phase definitions similar to those used by CII for recording data from actual, recently-completed construction projects. The five phases used by CII are as follows:

- Pre-Project Planning
- Detail Design
- Procurement
- Construction
- Start-up

As with the industrial sector, six phases, as opposed to five, are identified in the idealized hierarchy. These are as follows:

- Pre-project Planning
- Design
- Tender
- Procurement
- Construction
- Commissioning/Start-up

Each of these phases and the associated factors affecting phase duration are addressed below.

Pre-Project Planning

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Design

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Tender

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Procurement

For some public works facilities, such as power stations, the procurement of engineered equipment represents a significant construction phase, therefore procurement is included in the idealized hierarchy. However, for many projects, such as highways, this phase does not really exist.

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the industrial section of this document.

Construction

The definition of this phase, factors affecting phase duration, and generic best practices have already been described in the commercial/institutional section of this document.

Commissioning/Start-up

This phase is slightly different in definition to the start-up phase defined by CII, in that the latter is usually only relevant to process industries and does not usually apply to infrastructure type projects, with the exception of projects such as power stations or large scale wastewater treatment facilities. As with previous definitions, the start of the commissioning phase is defined as being the point at which the work is substantially completed, and certified as such. The termination of the phase is the point at which the custody is transferred to the user/operator, with all defects having been corrected. In some contracts this period is referred to as the 'maintenance period' or 'defects correction period'. Typical activities and products during this phase include independent inspection and testing, defects correction, and certification.

Where a highly complex series of systems may need to be tested prior to custody transfer to the plant user/operator, it is more appropriate to refer to the phase as a 'start-up' phase. As previously mentioned, the start of this phase is defined as being the point at which all components are in place and functioning. The termination of the phase is the point at which custody of the facility is transferred to the user/operator, with all defects having been corrected. Typical activities and products during this phase include independent inspection and testing of systems, defects correction, certification, operator training, introduction of feed-stocks, and obtaining first product/output.

As with the industrial sector, the principle factors affecting the commissioning/start-up phase duration will be the quality of the work carried out during the construction phase, and its fitness for purpose.

4.1.2. Data Oriented

The data oriented hierarchies represent the modification of the idealized hierarchies to reflect data availability and constraints. Furthermore, the hierarchies reflect the relative importance attributed to data, in that certain elements of the idealized hierarchy may not be covered by the data oriented hierarchy even though data may be available. This is an important step in ensuring the baseline measures remain succinct. The hierarchies are provided in Appendices A through D[24]. A brief description of the differences between the data oriented and idealized hierarchies for each sector is given below.

Residential Sector

The residential sector for the data oriented hierarchy is identical to that shown on the idealized hierarchy. It is considered to be important to differentiate between site-built and modular housing where possible, as indicated in the idealized hierarchy.

Within the "site-built" section of the data oriented hierarchy, data provided by the U.S Bureau of the Census describing industry performance maps on to some of the components in the idealized hierarchy. The data examine the duration from permit acquisition to start of works on site for various types of residential housing, as well as the duration from the start on site until completion of the work. However, the data do not break down the construction sequence into phases as indicated in the idealized hierarchy. Furthermore, no information has been located that examines the duration of the permitting process.

Within the "modular" section of the data oriented hierarchy, very few data have been found that describe industry averages for manufactured housing plant performance, nor for site works activities.

Commercial/Institutional Sector

The commercial/institutional sector for the data oriented hierarchy is very similar to that shown on the idealized hierarchy. However, in practice, it has been found that different organizations tend to group facilities very differently, thus it is often difficult to compare data from different sources. Where comparisons are made between data from different sources in this document, the assumptions which have been made are clearly stated.

The data oriented hierarchy differs from the idealized hierarchy in that the phases defined by CII, as opposed to the slightly different phases shown in the idealized hierarchy have been used. This is because CII is the primary source of delivery time data for commercial/institutional projects, hence its phase definitions have been adopted.

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[24] The four appendices are organized as follows: Appendix A covers the residential sector; Appendix B covers the commercial/institutional sector; Appendix C covers the industrial sector; and Appendix D covers the public works sector.

Industrial Sector

The industrial sector data oriented hierarchy is very similar to that shown on the idealized hierarchy. There is some scope for categorizing industrial facilities by size, number of employees, and dollar value of business carried out, but it is generally not possible to categorize facilities by installed cost, except where data for new facilities have been collected.

The data oriented hierarchy differs from the idealized hierarchy in that the phases defined by CII, as opposed to the slightly different phases shown in the idealized hierarchy have been used. This is because CII is the primary source of delivery time data for industrial projects, hence its phase definitions have been adopted.

Public Works Sector

The transportation sub-sector for the data oriented hierarchy is very similar to that shown on the idealized hierarchy. The components described in the industry oriented hierarchy are also applicable. However, in the case of airports and ports, it is not considered to be meaningful to provide aggregated data relating to project delivery time as there are likely to be large variations between different facilities.

For the reasons previously described, the communications sub-sector will not be considered in this document.

The power utilities sub-sector for the data oriented hierarchy is identical to that shown on the idealized hierarchy. However, this document will focus primarily upon aggregated data for all utilities.

The water sub-sector data oriented hierarchy is very similar to that shown on the idealized hierarchy.

For the reasons already described, the solid waste sub-sector will not be considered in this document.

The pipelines sub-sector for the data oriented hierarchy is identical to that shown on the idealized hierarchy. However, pipelines are not categorized by size.

For all sub-sectors, the data oriented hierarchy differs from the idealized hierarchy in that the phases defined by CII, as opposed to the slightly different phases shown in the idealized hierarchy have been used. This is because CII is the primary source of delivery time data for public works projects, hence its phase definitions have been adopted.

4.2. Data Collection and Analysis

The two primary types of data collected were electronic data and published data. Electronic data was collected from the World Wide Web and from various CD-ROM's. Published data was collected from NIST libraries and from publicly accessible libraries and data warehouses on the World Wide Web. Information gleaned from telephone conversations, meetings, and workshops/seminars was often the catalyst in successfully locating relevant published or electronic information. As data were collected, the data oriented hierarchies for each industry sector were refined to reflect data availability constraints.

The authors carried out extensive data searches of publicly accessible federal agency databases for information relevant to Goal 1. These searches frequently involved browsing lists of current and historic research activities/reports which have been, or are presently being carried out, and included the following Executive Agencies:

- Department of Agriculture (Water Management Research Laboratory)
- Department of Commerce (Economics and Statistics Administration, Economic Development Administration, National Oceanic and Atmospheric Administration, National Telecommunications and Information Administration, Technology Administration)
- Department of Defense (Advanced Research Projects Agency, Defense Logistics Agency, Defense Technical Information Center, US Air Force, US Army Corps of Engineers, Office of Naval Research)
- Department of Energy (Energy Efficiency and Renewable Energy Network, Energy Information Administration, Fissile Materials Disposition, Fossil Energy, Human Resource and Administration, Oak Ridge National Laboratory)
- Department of Housing and Urban Development
- Department of the Interior (US Geological Survey)
- Department of Labor (Bureau of Labor Statistics)
- Department of Transportation (Bureau of Transportation Statistics, Federal Aviation Administration, Federal Highway Administration, Federal Railroad Administration, Federal Transit Administration)

Searches of Independent Agency databases such as the Environmental Protection Agency, Federal Emergency Management Agency, General Services Administration, National Performance Review, and the Nuclear Regulatory Commission were also performed.

A second set of data searches focused upon research, trade, and professional organizations, some of which are listed below:

- American Association of Cost Engineers
- American Public Works Association
- American Society for Heating, Refrigeration and Air-Conditioning Engineers

- American Society of Civil Engineers
- Associated Builders and Contractors
- Associated General Contractors of America
- Association of Energy Engineers
- Building Research Establishment (UK)
- Civil Engineering Research Foundation
- Construction Industry Institute
- Construction Industry Research and Information Association (UK)
- Council for Continuous Improvement
- Design Build Institute of America
- European Construction Institute (UK)
- Institute of Real Estate Management
- Industrial Technology Institute
- Infrastructure Technology Institute
- Institution of Civil Engineers (UK)
- Inter Agency Benchmarking and Best Practices Council
- International Facilities Management Association
- Manufactured Housing Institute
- National Association of Manufacturers
- National Association of Homebuilders
- National Center for Manufacturing Sciences
- National Housing Institute
- National Institute of Building Sciences
- Strategic Planning Institute

A third set of data searches examined private sector organizations, some of which are listed below:

- The Benchmarking Exchange
- Logistics Management Institute
- Independent Project Analysis
- RS Means
- DuPont
- McGraw Hill
- Journal of Management in Engineering
- American Productivity and Quality Center
- The Strategic Planning Institute

The final search focused upon academic institutions such as:

- Massachusetts Institute of Technology
- University of Texas at Austin
- University of Illinois at Urbana
- Center for Integrated Facility Engineering at Stanford University
- Loughborough University of Technology (UK)

The results of this extensive information search suggest that there is only a limited amount of information available relating to Goal 1. Where data does exist, it is often not useful for establishing baseline measures or measures of progress. This is because the methods used for data collection, the size of the survey sample, or the frequency of reporting is highly variable. In particular, there is frequently no clear definition of project phases, or data are not recorded in a manner that allows meaningful interpretation of project phase duration. The exception comes where data collection is being done by a federal agency as part of its mission. For example, the US Bureau of the Census has a responsibility to collect and disseminate information relating to the construction industry and the built environment. However, the Bureau of the Census only collects a limited amount of information relating to project delivery times in the construction sector. Although the Bureau of the Census publishes several key statistics on delivery times for the residential sector, similar statistics for the non-residential sectors are no longer published. One of the few data sources which has been identified, where an organization is systematically collecting data from new construction projects that are at least in part representative of the whole of the US, is the Construction Industry Institute (CII). For this reason, the data collected by CII have been used in this document. It is also possible that a number of federal agencies have more detailed databases which could prove useful for Goal 1, but if these exist, they have not been located by the authors. A similar comment applies to private organizations, some of which are thought to have extensive databases relating to the construction sector, though it is not known how much of this information relates to project delivery times, nor whether it is representative of national averages for establishing baselines. This information is likely to be available only on a commercial fee for service basis.

A detailed description of the data sources used in establishing baselines and measures of progress for each sector is given in Chapters 5 and 6 of this document.

Prior to any data analysis being performed, all relevant electronic and published information was imported into spreadsheet files so that it could be easily manipulated. This approach also enabled charts and tables to be generated relatively rapidly. Initially, a large number of charts were produced from the raw data, which assisted in identifying trends in the data. These charts also helped in prioritizing the data prior to developing the baseline measures.

5. Delivery Time Measures for the Residential Sector

5.1. Key Considerations for the Residential Sector

This section of the document addresses the issue of data sources, availability, and constraints in the residential sector, and summarizes the key data sources which are used for developing the baseline measures. The section also provides an overview of the residential sector.

5.1.1. Data Considerations: Sources, Availability, and Constraints

Preliminary data searches for the residential sector focused upon organizations such as the Department of Housing and Urban Development (HUD), the National Association of Home Builders (NAHB), and the Manufactured Housing Institute (MHI). These searches indicated that while some of these organizations are carrying out their own research about the US housing industry, the majority of them are making use of information collected by the US Bureau of the Census when considering housing at a national level. It therefore seemed appropriate to examine the source data provided by the US Bureau of the Census in detail for the development of the baseline measures.

Data from the US Bureau of the Census

The US Bureau of the Census (USBC) carries out a number of surveys of the US housing sector, and reports periodically upon a wide variety of related issues. Surveys/reports which are of particular interest for this document are the **American Housing Survey**, the **Census of Housing**, and the **Current Construction Reports**.

The **American Housing Survey** collects data on the nation's housing, including apartments, single-family homes, mobile homes, and vacant housing units. It provides data on housing characteristics, such as income, housing and neighborhood quality, housing costs, equipment and fuels, and size of the housing unit. National data is collected every other year, and data for selected Metropolitan Areas (MA's) is collected about every four years. The sample covers approximately fifty-five thousand homes. Data are available for years up to and including 1995.

The **Census of Housing** provides detailed information on housing characteristics. The survey is carried out every ten years; data from the 1990 survey are available at present. Housing characteristics such as number of units, plumbing facilities, tenure, value, rent, fuels, heating equipment, and so forth are examined. Every home in the US is asked the basic questions in the survey, while approximately one sixth of all houses in the US are asked more detailed survey questions relating to issues such as income and housing expenses.

The **Current Construction Reports** comprise a series of periodic surveys, which include the following monthly surveys:

- Series C20 - *Housing Starts* - provides data on the number of new privately owned housing units started in the US, by number of units in the structure, and census region, and data on the number of mobile homes shipped.
- Series C22 - *Housing Completions* - provides data on the number of new privately owned housing units completed in the US, by number of units in the structure, and census region.
- Series C25 - *New Home Sales* - provides data on the sales of new single-family homes in the US
- Series C30 - *Value of Construction Put in Place* - provides data on new private and public housing construction, as well as residential improvements in the US (refer to Chapter 3 for further details)
- Series C40 - *Building Permits* - provides data on the number of privately owned housing units started in the US, as well as the number of houses where building permit authorization was given, by number of units in structure, and census region. There is some commonality with the C20 data.

Selected data from USBC are available through its Internet site (URL: http://www.census.gov), or via electronic or paper publications. Inquiries by the authors indicate that customized data searches conducted by USBC can be carried out on a fee for service basis, provided that confidentiality criterion for the source data are not breached.

In this document, data from the USBC have been used to characterize the size and nature of the residential sector, and to provide information on delivery times for housing. Where specific data constraints have been found, these have been identified in the text.

One publication which makes extensive use of data from the USBC, but which, on occasion provides data in a slightly different form to that used by USBC in its own publications, is the *Statistical Abstract of the United States*, which is published annually. Where appropriate, this document makes use of data provided in the 1996 and 1997 versions of the *Statistical Abstract* (the 1997 version has very recently become available, and can be viewed at the USBC web site). The *Statistical Abstract* also uses a variety of other sources when compiling its statistics. Details of the sources used are presented in Appendix I of the *Statistical Abstract*. Data from the *Statistical Abstract* have been used to characterize the size of the residential sector. The *Statistical Abstract* has also been used where price deflators/indices were needed to adjust statistics for this document.

Data from the National Association of Home Builders

The National Association of Home Builders (NAHB) Research Center has examined the issue of cycle-time reduction in the home-building process. Of particular interest in the establishment of delivery time baselines is a report prepared by NAHB entitled *Cycle Time Reduction in the Residential Construction Process,* which examines the time taken to construct housing in Atlanta. In this document, data from the NAHB report have been reproduced, principally because the information is relatively detailed in comparison with that available from the US Bureau of the Census, is well documented, and also provides some comparison between manufactured and site-built housing.

Data from Other Sources

A wide variety of other data sources were examined. However, few were located that provided any data relevant to delivery times in the residential sector. One source which is used in this document is the Manufactured Housing Institute (MHI), which provides comparative cost data for site-built and manufactured housing. This information is based upon data from USBC, as well as other sources. These data can be found on the MHI Internet site (URL: http://www.mfghome.org). The MHI also provides some useful definitions of the different types of manufactured housing (see http://www/mfghome.org/media/definemh.html), which have been used in this document. Selected data from MHI has been used in this document to compare the size of the manufactured and site built markets, and to compare installed costs.

5.1.2. Overview of the Residential Sector

The overview of the residential sector presented in this section of the document expands upon that which is presented in Chapter 3 of this document. This section examines the total size of the US residential sector, and how the housing stock is divided between the different types of structure, such as single-family housing, apartments, and mobile homes. It also examines a number of key characteristics of the housing sector, such as the age, size, and geographic distribution of housing. A number of figures are then presented which indicate how the residential sector is changing over time. Finally, some comparisons between site-built and manufactured housing are made.

Data from the *1995 American Housing Survey Current Housing Reports H150/95RV* have been used to generate Figure 5-1. Figure 5-1 shows that the total number of housing units in the US in 1995 numbered approximately 110 million, of which approximately sixty-six percent are single-family (one unit) houses. Of the 72.4 million single-family homes, approximately ninety percent are detached units. Mobile homes and trailers represent approximately seven percent of the total housing stock. A more detailed breakdown of homes in the US, by number of units in the structure, is shown in Figure 5-2. Reference to the figure indicates that there are significantly more multi-unit structures containing only two to four units compared with structures containing either five to nine units, 10 to 19 units, 20 to 49 units, or 50 or more units.

Figure 5-1. Size of US Housing Sector by Type of Structure: 1995

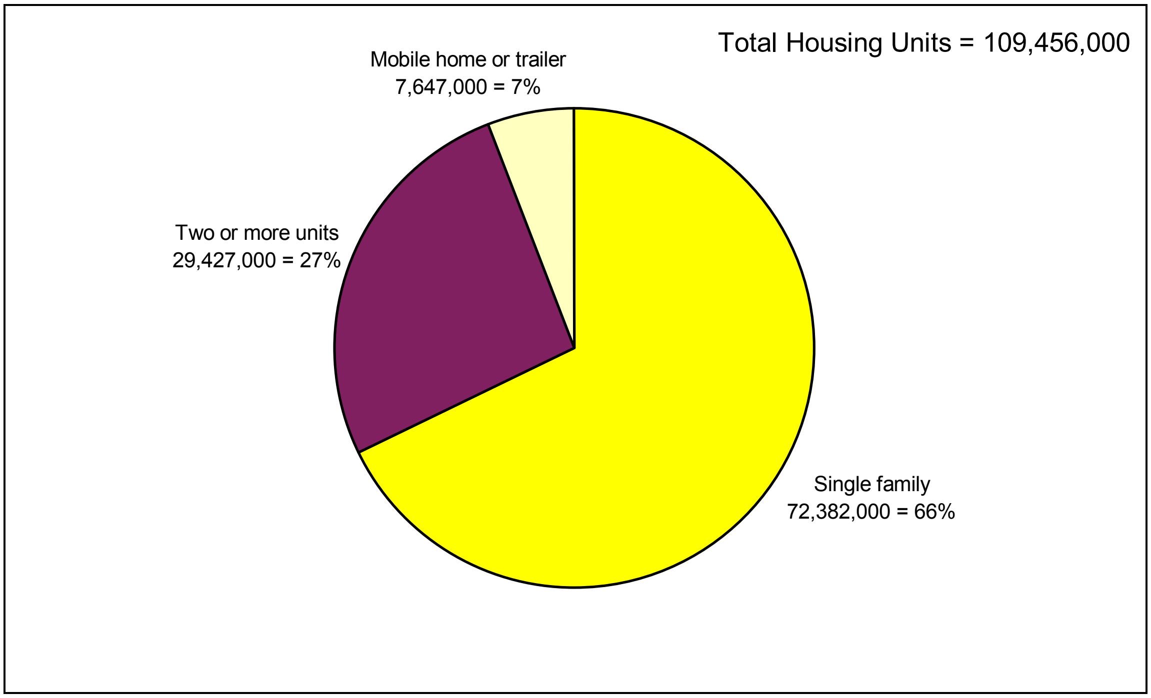


Figure 5-2. Total US Housing - Detailed Description of Types of Structure : 1995

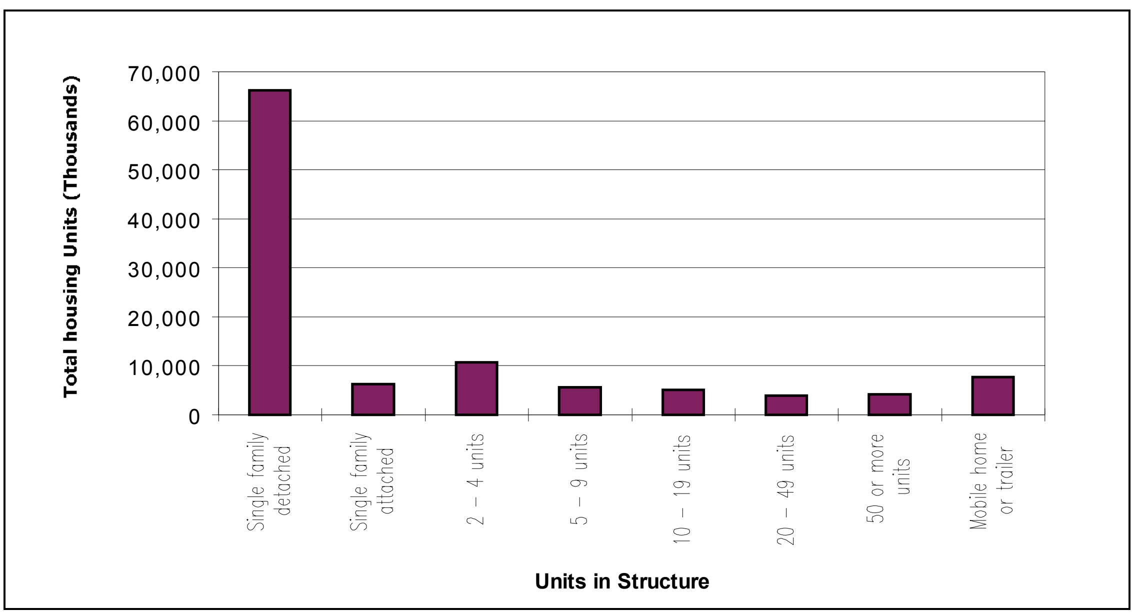


Figure 5-3 indicates the geographic distribution of occupied housing by type/number of units and census region in 1995. Reference to the figure shows that while there is a significantly larger number of single-family homes in the south and mid-west census regions, compared with in the north and west, multi-unit housing is more evenly distributed across all four census regions. Approximately half of all mobile homes or trailers are located in the south census region. A description of the census regions, as defined by the US Bureau of the Census, is provided in Appendix E of this document. Data from the *American Housing Survey* also indicates that approximately half of all homes in the US are in city locations, with the remaining half relatively evenly distributed between town, suburban and rural/open country locations.

Figure 5-4 and Figure 5-5 are based upon data from the *1995 American Housing Survey*, and show some of the key characteristics of homes in the US. Reference to Figure 5-4, which shows the age structure of the housing stock, indicates that approximately seven percent of houses are less than five years old, and approximately nine percent are greater than 75 years old. The highest number of houses were built between the years 1960-1969, with the median age between these years. Figure 5-5 shows the size characteristics of occupied detached single-family homes and mobile homes in 1995. The figure indicates that the median size was 161 square meters (1,732 square feet). Comparison with 1993 data indicates that the median size has remained relatively stable (160 square meters (1,725 square feet) in 1993). A comparison of median unit size across the four census regions indicates that in 1995, the median unit area is higher in the northeast and mid-west compared with the south and west.

Figure 5-6 is based upon data from the EIA report *Housing Characteristics 1993* and shows the number of households with various types of external wall construction. Reference to the figure shows that brick, wood and siding predominate, except in the west census region, where wood and stucco dominate. There is comparatively little use of other wall materials such as concrete or block across all census regions. Similar data for type of foundation construction (not presented graphically in this document), indicates that approximately 33 percent of all occupied detached single-family homes have full basements, 12 percent have partial basements, 26 percent have crawl spaces, 27 percent have concrete slabs/rafts, and the remainder have other types of foundation.

Figure 5-7, Figure 5-8, and Figure 5-9 are based upon data from the *Statistical Abstract of the United States 1997*, and show how the residential sector has been changing since 1980. All three figures indicate that the rate of change in the size of the housing sector, measured as a function of privately-owned housing units started, is modulated by the business cycle, which has been discussed in Chapter 3 of this document.

Figure 5-3. Occupied Housing Units by Census Region: 1995

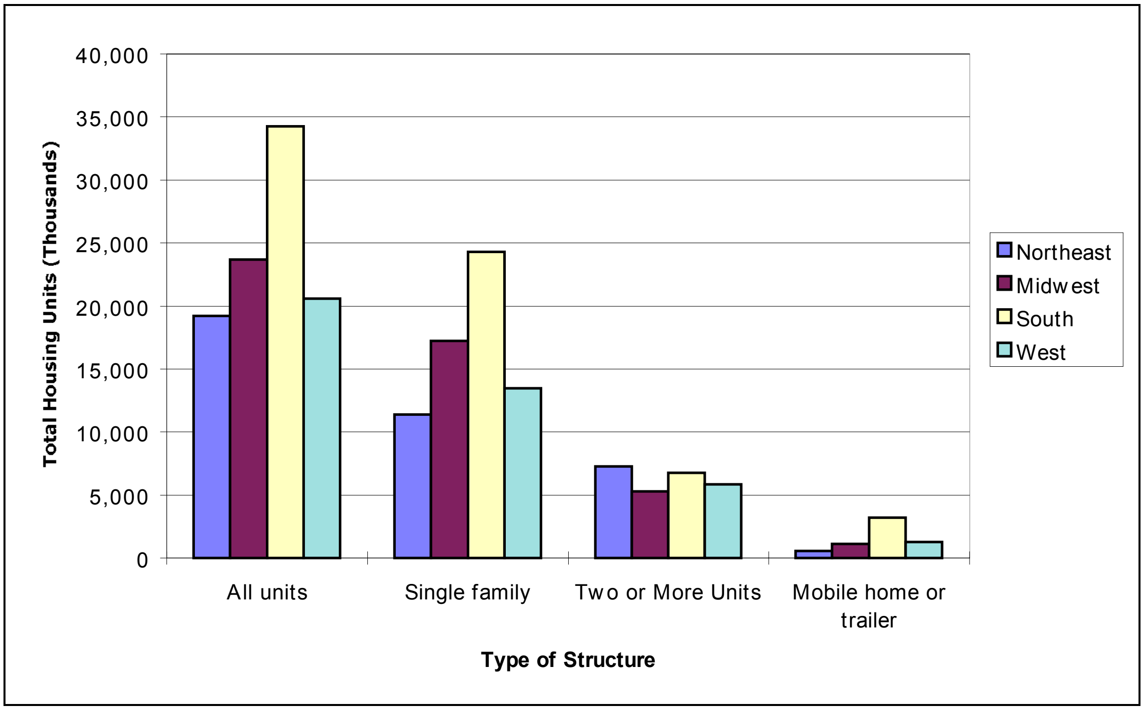


Figure 5-4. Total Housing Units by Age of Structure: 1995

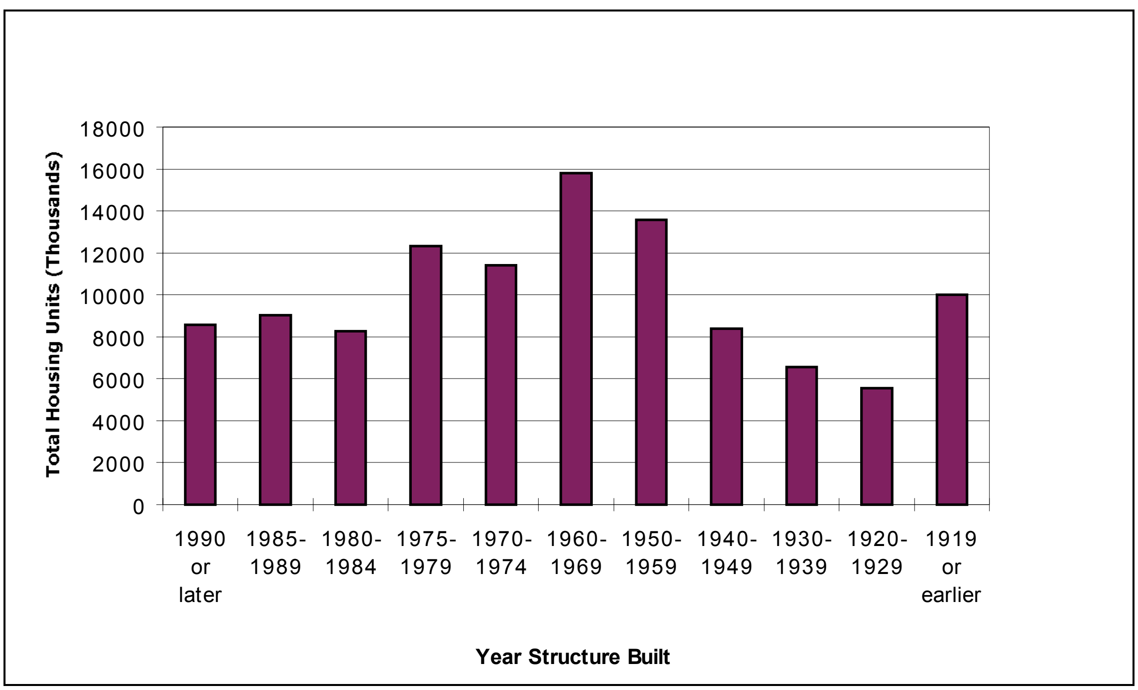


Figure 5-5. Size of Occupied Detached Single Family Homes and Mobile Homes: 1995

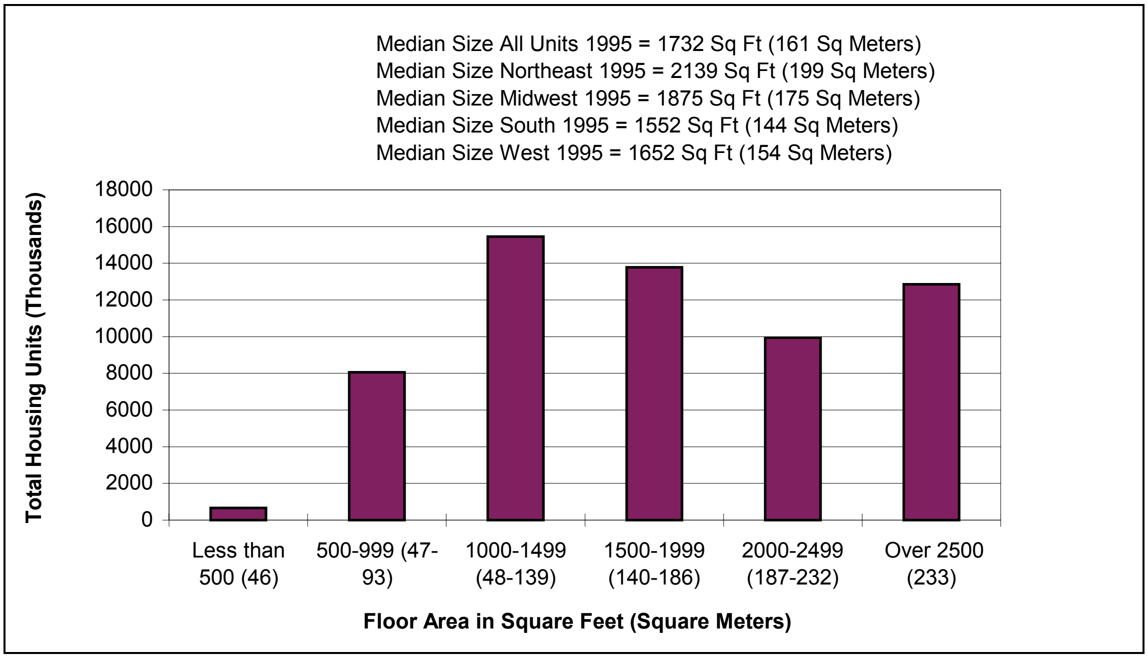
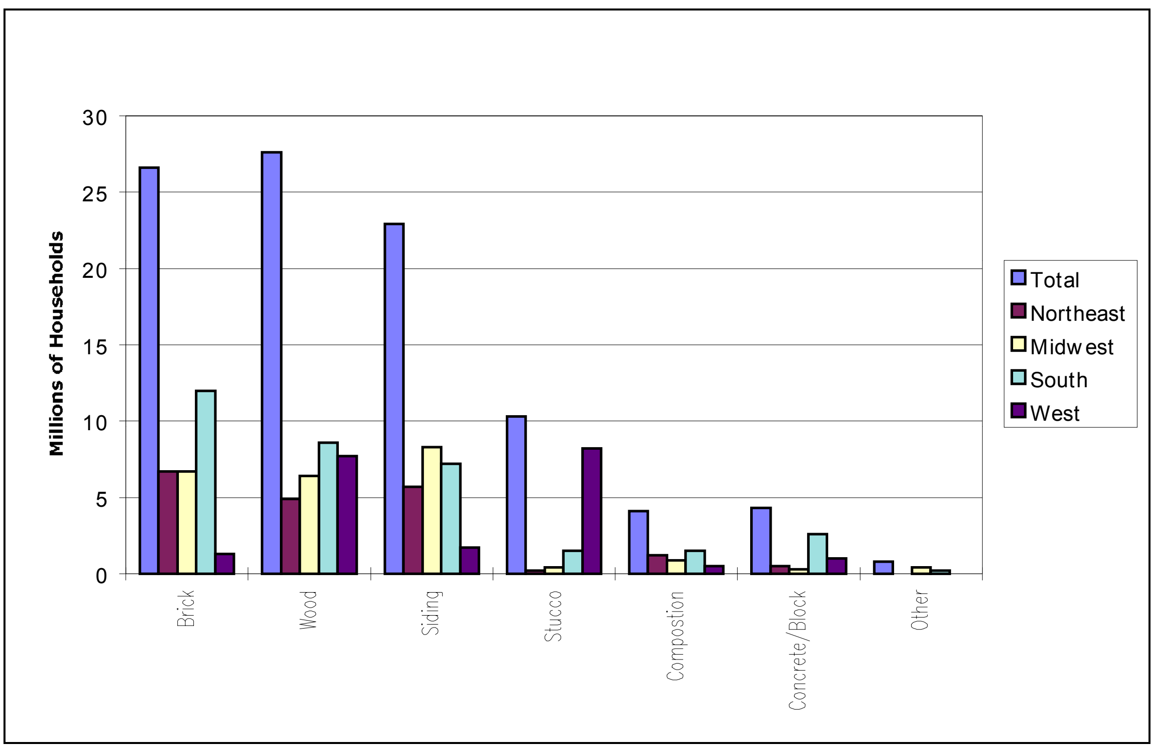


Figure 5-6. External Wall Construction (All Households): 1993



Reference to Figure 5-7, which shows the number of new privately-owned housing units started, indicates that a peak rate of approximately 1.8 million new units per year was reached in the mid 1980's, but that this output level declined in the early 1990's to approximately 1.0 million units per year, before starting to recover more recently. This trend is reflected both in the single-family and multi-unit housing markets. However, the recovery in the multi-unit market since the early 1990's has been significantly slower than that in the single-family-housing market.

This trend is also reflected in Figure 5-8, which shows the number of new privately financed, non-furnished rental apartments with greater than five units completed as a percentage of total privately owned units started in the US, for the US as a whole, and how this percentage is broken down by census region. However, it appears that apartment construction in the south and east is more heavily influenced by the business cycle than that in the northeast and mid-west, despite the similarity in total number of apartments in each census region (refer to Figure 5-3). In all regions, there has been a significant decline in the percentage of new apartments placed as a function of total new private housing in the US. Therefore, it would appear that the relative importance of apartment building in the residential sector has declined since the mid-1980's. For single-family housing, data showing how the total number of new units placed varies between the different census regions has not been located. However, this information may be available from USBC for a fee.

Figure 5-9 shows the number of mobile homes placed for residential use as a percentage of total new privately owned units started in the US, and how this percentage is distributed within the four census regions. Reference to the figure indicates that the mobile home market has recovered its share of the private housing market which was lost during the mid 1980's, but that mobile homes placed still only represent approximately 20 percent of all private housing constructed. In addition, any changes in the market appear to be occurring principally in the south census region, where approximately half of all mobile homes are located, as opposed to the other three census regions, where the market appears to be relatively stable.

Finally, Figure 5-10, which is based upon data from the Manufactured Housing Institute, shows the number of manufactured housing units shipped and number of new mobile homes placed in the US as a proportion of new privately owned housing units started. Reference to the figure indicates that manufactured housing has increased its market share since 1986, and in 1996 represented approximately 24 percent of all new units placed. The figure also shows that the majority of manufactured homes are mobile homes. Manufactured housing is clearly a significant element of the US housing market.

Figure 5-7. New Privately-Owned Housing Units Started

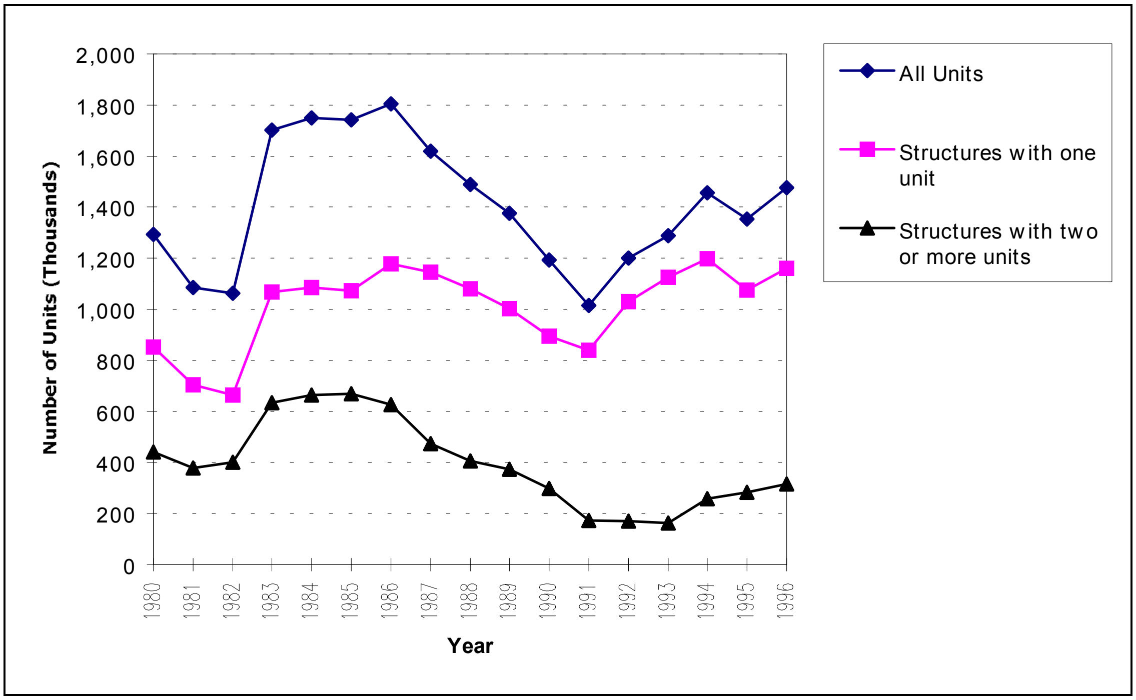


Figure 5-8. New Apartments Completed as a Percentage of Total New Privately-Owned Housing Units Started

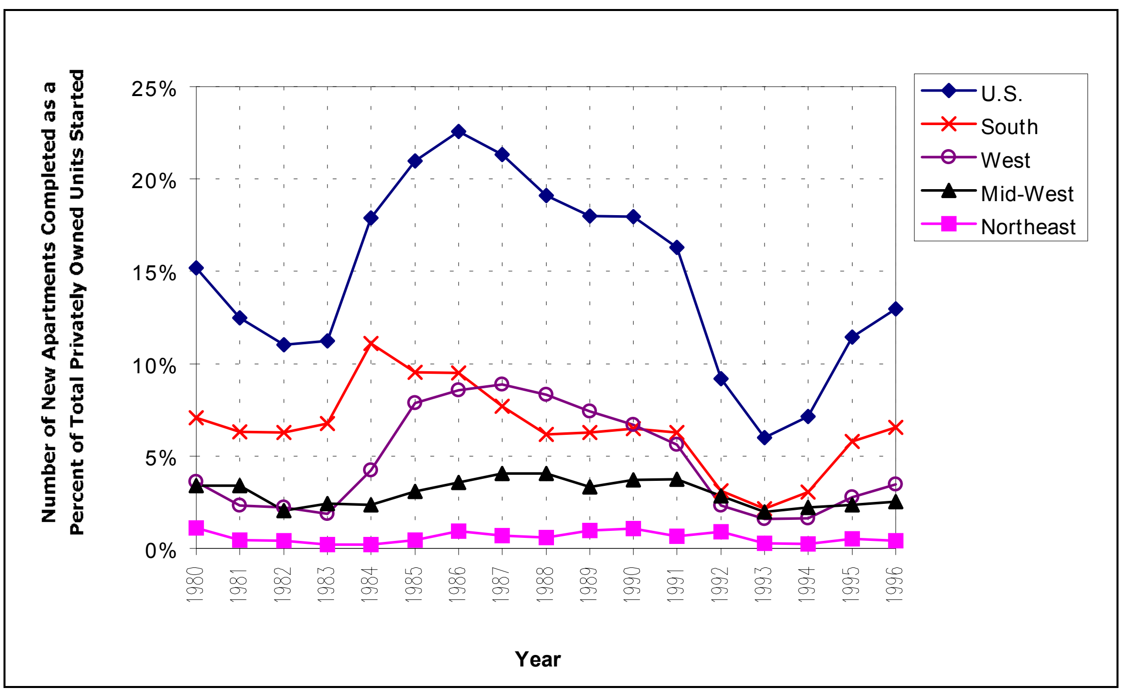


Figure 5-9. New Mobile Homes Placed as a Percentage of Total New Privately-Owned Housing Units Started

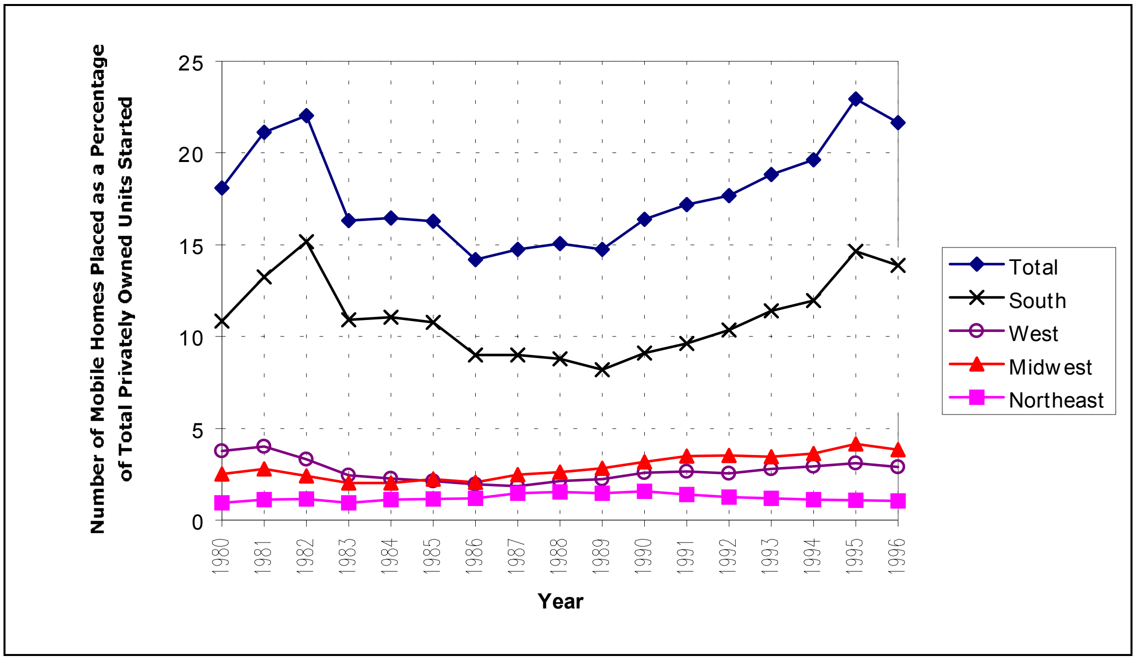
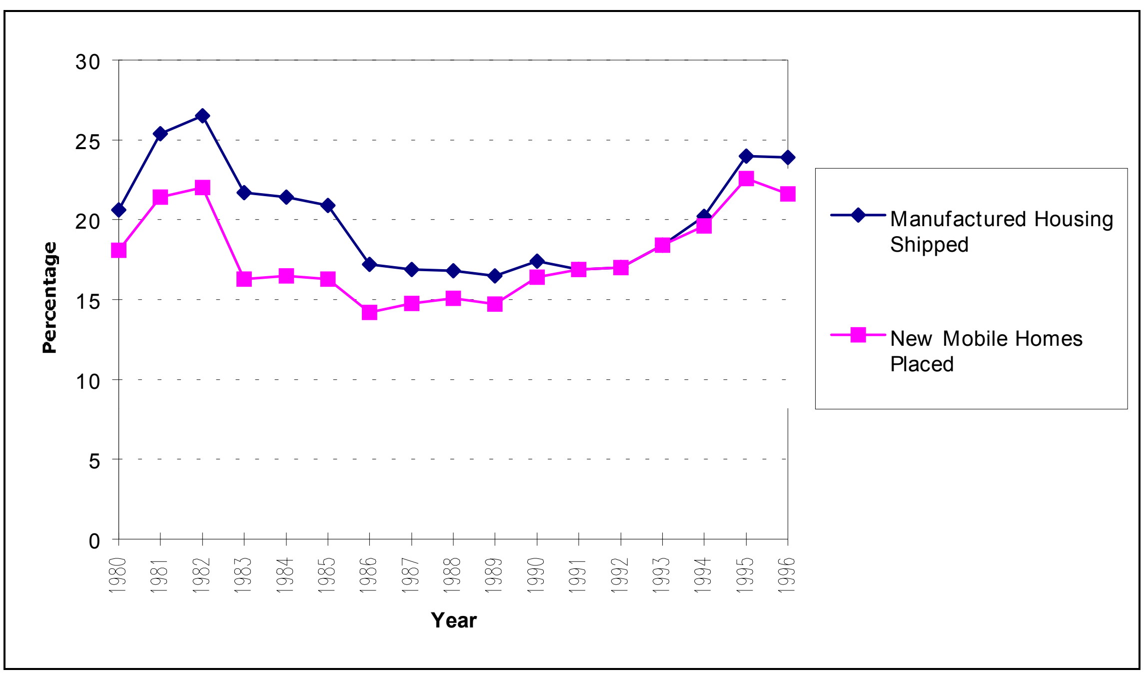
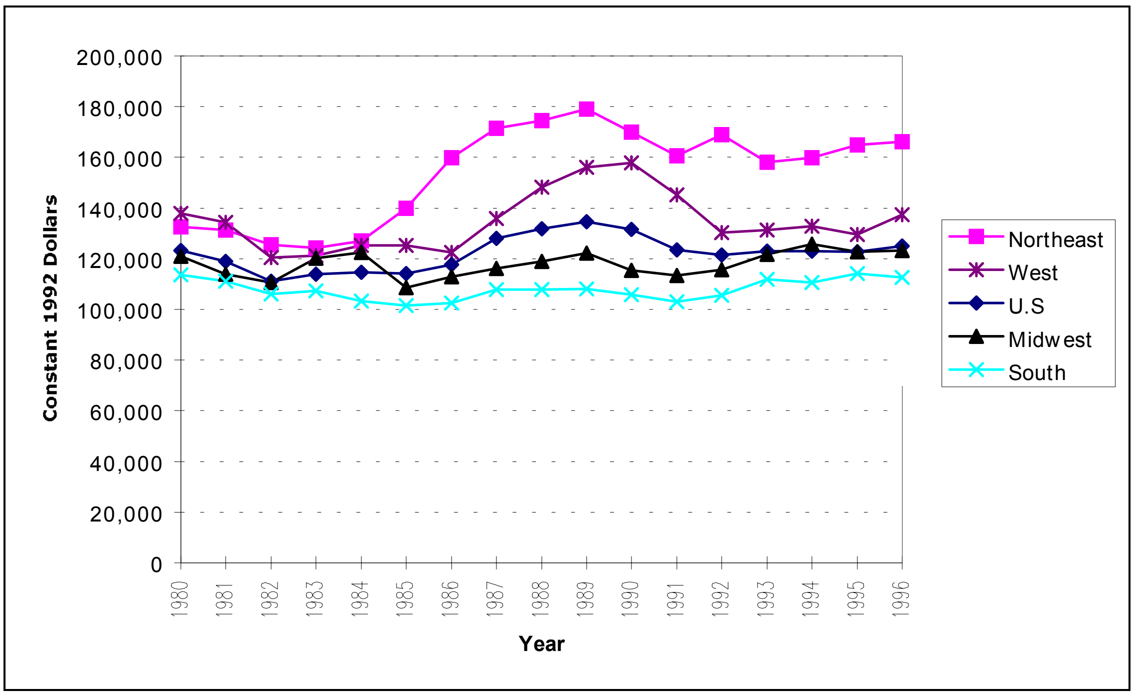


Figure 5-10. Manufactured Housing Shipped and New Mobile Homes Placed as a Percentage of New Privately-Owned Housing Started



The figures presented in this section show that single-family housing represents approximately two-thirds of total US homes, and accounts for approximately three-quarters of all new privately owned housing starts in the US. In Chapter 3, Figure 3-15 showed that there is an upward trend in constant dollar construction costs for residential buildings. We would also expect this trend to be reflected in the median sales price of single-family homes in the US. Figure 5-11, which is based upon data from the *Statistical Abstract of the United States 1997*, shows the median sales price of new single-family homes in the US. Sales prices have been adjusted to a 1992 base year, using a price index for personal consumption expenditures from the *Statistical Abstract*. Reference to the figure indicates that sales prices, like construction costs, tend to be rising in the residential sector. The most significant fluctuations in single-family sales prices have occurred in the northeast and west census regions, while in the south and mid-west, prices have been more stable.

Figure 5-11. Median Sales Price of New Privately-Owned Single Family Housing



Part A and Part B of Table 5-1 are based on data from the Manufactured Housing Institute. They show the comparative costs of site built versus manufactured housing (based on the price of the structure) between 1990 and 1996. Although the data have not been adjusted to a common base year, they indicate that there are similarities in cost growth between the site built and manufactured housing industries. These data suggest that the cost per square meter (foot) of manufactured homes is significantly lower than that of site built homes. However, these figures should be viewed with caution, as it is difficult to assess whether a like-for-like comparison is necessarily being made.

Table 5-1. Comparative Costs of Site-Built and Manufactured Housing

Part A: Dollars per Square Foot

TYPE OF HOUSING	COST (Dollars/Square Foot)						
Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*
Manufactured Housing	23.07	22.61	22.63	23.55	25.19	26.79	27.83
Site Built Housing	54.80	53.20	51.59	52.88	54.65	56.28	58.66

Part B: Dollars per Square Meter

TYPE OF HOUSING	COST (Dollars/Square Meter)						
Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*
Manufactured Housing	248	243	243	253	271	288	299
Site Built Housing	590	572	555	569	588	606	631

5.2. Baseline Measures for the Residential Sector

The baseline measures for the residential sector are based on data published by the US Bureau of the Census, supplemented by information from the National Association of Home Builders (NAHB). The Census data cover two key parts of the residential construction process: (1) from the issuance of the building permit until the start of construction; and (2) from the start of construction until the completion of construction. The Census data do not include any estimates of the amount of time required for the permitting process. In the context of this document, the permitting process is the first part of the three part residential construction process. However, because the Census data provide an unbroken time series of statistics on the duration of two of the three key parts of the residential construction process, they are used as the primary source for delivery time estimates for the residential sector.

The information from the NAHB is drawn from a single research report which focused on the Atlanta regional market.[25] Consequently, the NAHB estimates may not be indicative of national averages. Although the NAHB estimates may not be indicative of national

[25] National Association of Home Builders (NAHB) Research Center. 1993. *Cycle-Time Reduction in the Residential Construction Process*. Upper Marlboro, MD: NAHB Research Center.

averages, they are well documented and are based on data provided by practitioners in the field. Furthermore, the NAHB report identifies opportunities for reducing cycle time which translate into significant reductions in delivery time.

5.2.1. Measures Based on US Bureau of the Census Data

The **Current Construction Report** series C20 document, *Housing Starts*, provides the basis for the baseline measures of residential delivery time. Housing starts, or, formally, new privately-owned housing units started, measure when construction activity begins. This definition of starts covers buildings intended for "housekeeping purposes." This definition excludes group homes such as dormitories and nursing homes. Residential structures such as hotels and motels also are excluded. Housing units are defined to exclude mobile homes. However, the C20 report does include prefabricated, panelized, sectional, and modular housing units in addition to conventional "stick built" units.

Housing starts estimates are based on permit data from permit-covered areas and on separate on-site surveys for other areas. For the 17,000 permit-issuing places, a mail-in survey is sent to a sample of 8,300 to estimate the number of permits issued. Next, the Bureau of the Census sends interviewers on-site to an 840 representative subset of the 8,300 sample to determine which units were started for a particular month. This survey of 840 is the Survey of Use Permits (SUP). Follow-up interviews are made if the unit is not started by the end of the month.

From data gathered with the interview process, ratios are calculated of the number of units started to units covered by permits. These ratios, called starts rates, are calculated for each month following (and including) the month of permit issuance. For units with permit authorization, starts estimates are derived by applying the starts rates to permits authorized over the appropriate number of months and by structure type.

The above methodology only covers starts for units that received permit authorization. Given the sample design, approximately 95 percent of start activity typically occurs within permit-issuing places. In non-permit-issuing places, a small sample of the land area is surveyed to provide an estimate of starts. These small sample data are then used to derive starts for the total area not covered by permits. Finally, this estimate of starts in non-permit-covered areas is added to the estimate of starts of the 17,000 permit-issuing places to get an estimate of total private housing starts.

Residential delivery time statistics for permit-issuing places are published on an annual basis as a supplement in the March edition of the C20 report. These statistics are based on data collected via the Census' Survey of Construction. These statistics provide information on the average length of time in months from authorization of construction (i.e., issuance of the building permit) to the start of construction (i.e., excavation begins) ***and*** from the start of construction to completion (i.e., floor finishes are installed).

5.2.1.1. Total Time From Authorization of Construction to Start of Private Residential Buildings

This subsection presents annual statistics on the length of time from authorization of construction to start of new private residential buildings in permit-issuing places. A housing unit is considered authorized when a building permit is issued for construction of the unit. A housing unit is considered started when excavation begins for the footings or foundation. In a multifamily building, all housing units are defined as being started when excavation for the building has begun.

All estimates are based on data collected via the Census' Survey of Construction. Since the Survey of Construction is designed to collect data on a monthly basis, it can only be determined in what month a building was authorized or started rather than the precise day. Because of this, it is assumed that a building authorized and started in the same month was started immediately after the permit was issued. Buildings started in the first month after authorization took the full month to begin; those started in the second month after authorization took 2 months; those started in the third month after authorization took 3 months, and so on.

The estimated average number of months it takes to start construction on a residential building once the permit has been issued is shown in Figure 5-12. The figure records information for the 10-year period, 1987 through 1996. Annual estimates and year-by-year traces are shown for three types of structures: (1) 1 unit (i.e., new single family housing); (2) 2 to 4 units; and (3) 5 units or more. An examination of Figure 5-12 reveals elapsed times until start of construction for new single family housing units holding fairly steady at about 0.75 months. On the other hand, multifamily units, especially multifamily buildings with 5 units or more, exhibit considerable year-to-year variability.

The regional breakdown for the estimated average number of months it takes to start construction once the permit has been issued for *new single family housing* units is shown in Figure 5-13. The same 10-year period, 1987 to 1996, is covered in this figure as in Figure 5-12. Reference to Figure 5-13 reveals substantial differences between the regions. Throughout the 10-year period, the elapsed time—measured in months—until the start of construction was highest in the Northeast and lowest in the Midwest. The elapsed time for the South is in between the two extremes, with no apparent trend either up or down. The elapsed time for the West exhibits a slight downward trend.

The data used to create Figures 5-12 and 5-13 are recorded in Table 5-2. All entries record the number of months—to the nearest tenth of a month—it takes to start construction once the permit has been issued. Each year in the 10-year period, 1987 to 1996, corresponds to a row in the table. The three columns under the heading "Average Number of Months by Type of Structure" contain the data for Figure 5-12. The four columns under the heading "Single Family Housing Units Only" contain the data for Figure 5-13.

Figure 5-12. Average Number of Months from Authorization to Start of Construction for New Housing Units by Type of Structure

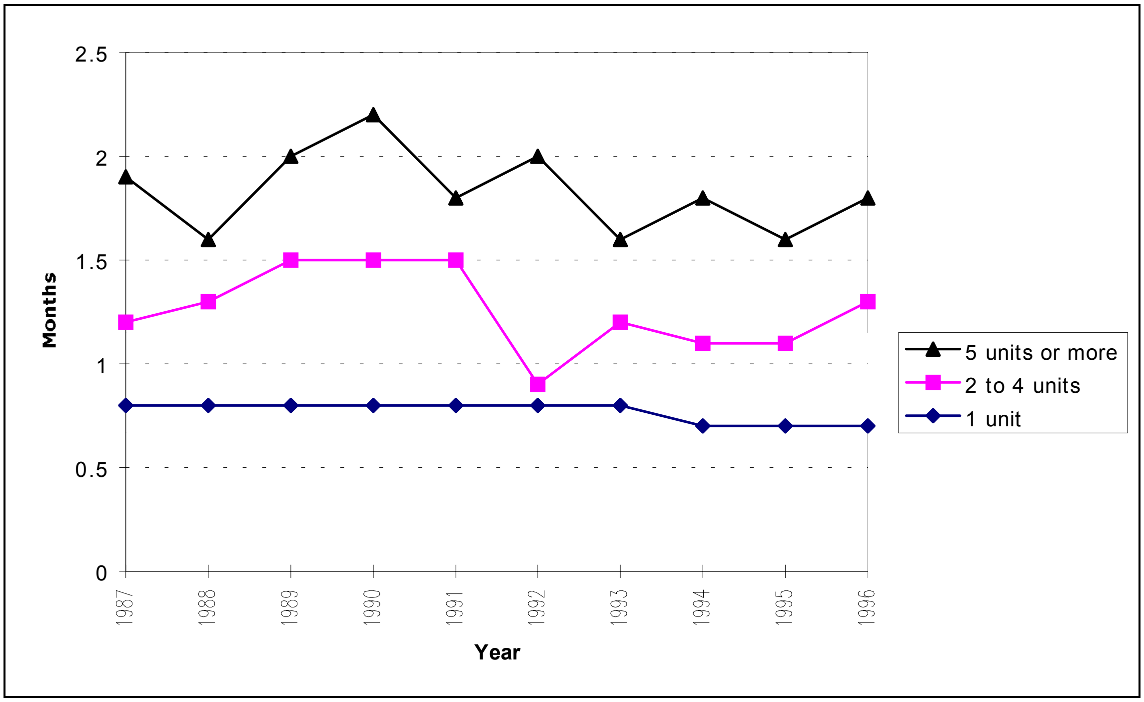


Figure 5-13. Average Number of Months from Authorization to Start of Construction for New Single Family Housing Units by Census Region

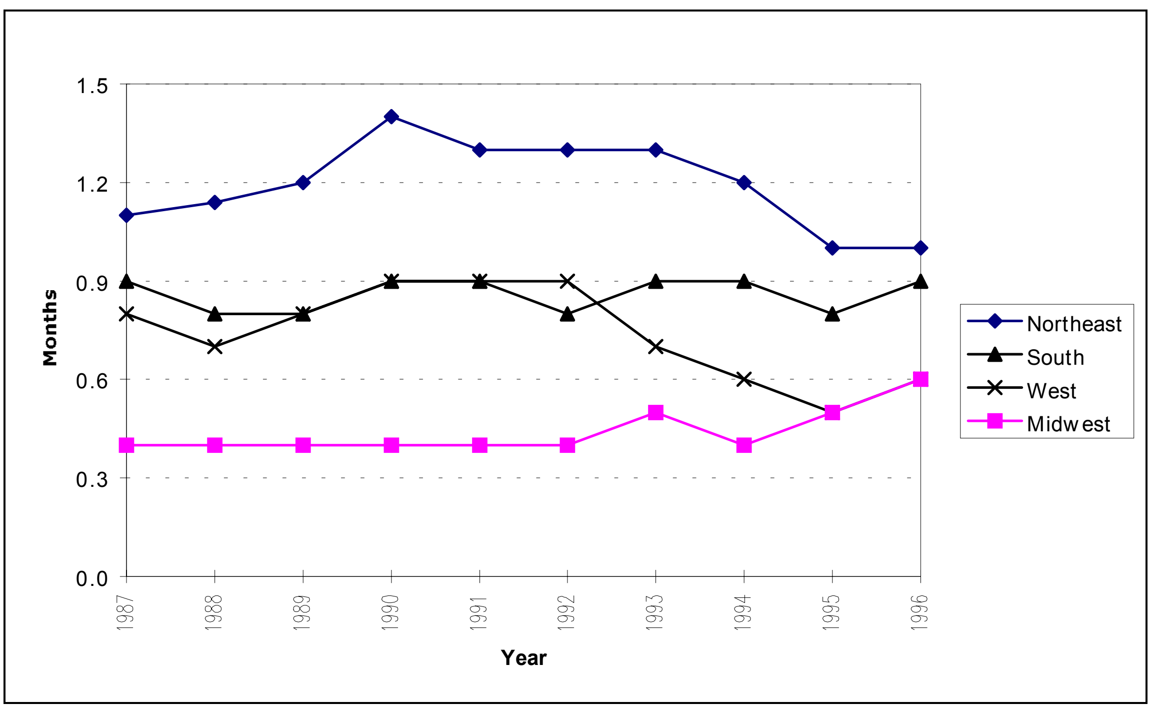


Table 5-2. Average Number of Months from Authorization to Start of Construction for New Housing Units by Type of Structure and Census Region

Year	Average Number of Months by Type of Structure			Single Family Housing Units Only Average Number of Months by Census Region			
	1 unit	2 to 4 units	5 units or more	Northeast	Midwest	South	West
1987	0.8	1.2	1.9	1.1	0.4	0.9	0.8
1988	0.8	1.3	1.6	1.1	0.4	0.8	0.7
1989	0.8	1.5	2.0	1.2	0.4	0.8	0.8
1990	0.8	1.5	2.2	1.4	0.4	0.9	0.9
1991	0.8	1.5	1.8	1.3	0.4	0.9	0.9
1992	0.8	0.9	2.0	1.3	0.4	0.8	0.9
1993	0.8	1.2	1.6	1.3	0.5	0.9	0.7
1994	0.7	1.1	1.8	1.2	0.4	0.9	0.6
1995	0.7	1.1	1.6	1.0	0.5	0.8	0.5
1996	0.7	1.3	1.8	1.0	0.6	0.9	0.6

Figure 5-14 shows a percentage distribution for 1996 of all residential buildings started, grouped by the number of months from authorization. Information is shown on three types of structures: (1) 1 unit (i.e., new single family housing); (2) 2 to 4 units; and (3) 5 units or more. The horizontal axis in the figure records the elapsed time in months from authorization. Cases where authorization and start occurred in the same month are recorded above the heading “Less than 1 month.” Residential buildings started in the first month after authorization are recorded above the heading “1 month.” The vertical axis records the percentage distribution for each type of structure and each elapsed time heading.

The data used to create Figure 5-14 are recorded in Table 5-3. Reference to the first column of data in the table reveals that in 1996 nearly 90 percent of all new single family housing units were started in one month or less (refer to the first two rows of the table). Reference to the third column of data reveals that more than 60 percent of all multifamily buildings with 5 units or more were started in one month or less. Residential buildings experiencing delays of 7 months or more account for only 2 percent of all new single family housing units, 4 percent of all multifamily buildings with 2 to 4 units, and 6 percent of all multifamily buildings with 5 units or more.

Figure 5-14. Percentage Distribution by Number of Months from Authorization to Start of Construction for New Housing Units by Type of Structure

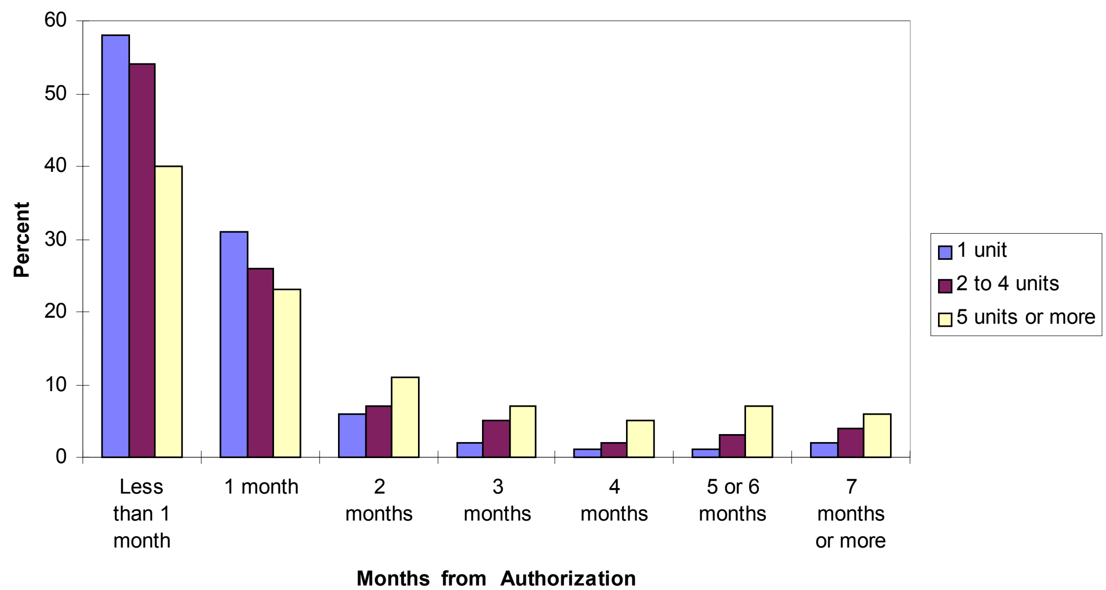


Table 5-3. Percentage Distribution by Number of Months from Authorization to Start of Construction for New Housing Units by Type of Structure

Period	Percentage Distribution by Type of Structure		
	1 unit	2 to 4 units	5 units or more
Less than 1 month	58	54	40
1 month	31	26	23
2 months	6	7	11
3 months	2	5	7
4 months	1	2	5
5 or 6 months	1	3	7
7 months or more	2	4	6

5.2.1.2. Total Time From Start of Construction to Completion of Private Residential Buildings

This subsection presents annual statistics on the length of time from start of construction to completion of new private residential buildings. A housing unit is considered started when excavation begins for the footings or foundation. In a multifamily building, all housing units are defined as being started when excavation for the building has begun. Single-family houses are classified as completed either when all finish flooring has been installed (or carpeting, if used in place of finish flooring) or when occupied. All of the units in a multifamily building are considered as completed when 50 percent or more of the units are occupied or available for occupancy.

All estimates are based on data collected via the Census' Survey of Construction. Since the Survey of Construction is designed to collect data on a monthly basis, it can only be determined in what month a building was started or completed rather than the precise day. Because of this, it is assumed that a building started and completed in the same month took the full month to build. Buildings completed in the first month after start took 1.5 months; those completed in the second month after start took 2.5 months; those completed in the third month after start took 3.0 months; those completed in the fourth month after start took 4.0 months, and so on.

The estimated average number of months it takes to construct a residential building (i.e., construction time) is shown in Figure 5-15. The figure records information for the 10-year period, 1987 through 1996. Annual estimates and year-by-year traces are shown for three types of structures: (1) 1 unit (i.e., new single family housing); (2) 2 to 4 units; and (3) 5 units or more. An examination of Figure 5-15 reveals construction times for new single family housing units holding fairly steady at about 6 months. On the other hand, multifamily units, especially multifamily buildings with 2 to 4 units, exhibit a fair amount of year-to-year variability.

The regional breakdown for the estimated average number of months it takes to construct a *new single family housing* unit is shown in Figure 5-16. The same 10-year period, 1987 to 1996, is covered in this figure as in Figure 5-15. Reference to Figure 5-16 reveals systematic differences between the regions. Throughout the 10-year period, the construction time—measured in months—was highest in the Northeast. The construction time for single family units in the Northeast also appears to be modulated by the business cycle. This effect is also seen, to a lesser extent, in Figure 5-15. The construction time for the three remaining regions—Midwest, South, and West—has remained in a tight band since 1992.

Figure 5-15. Average Number of Months from Start of Construction to Completion for New Housing Units by Type of Structure

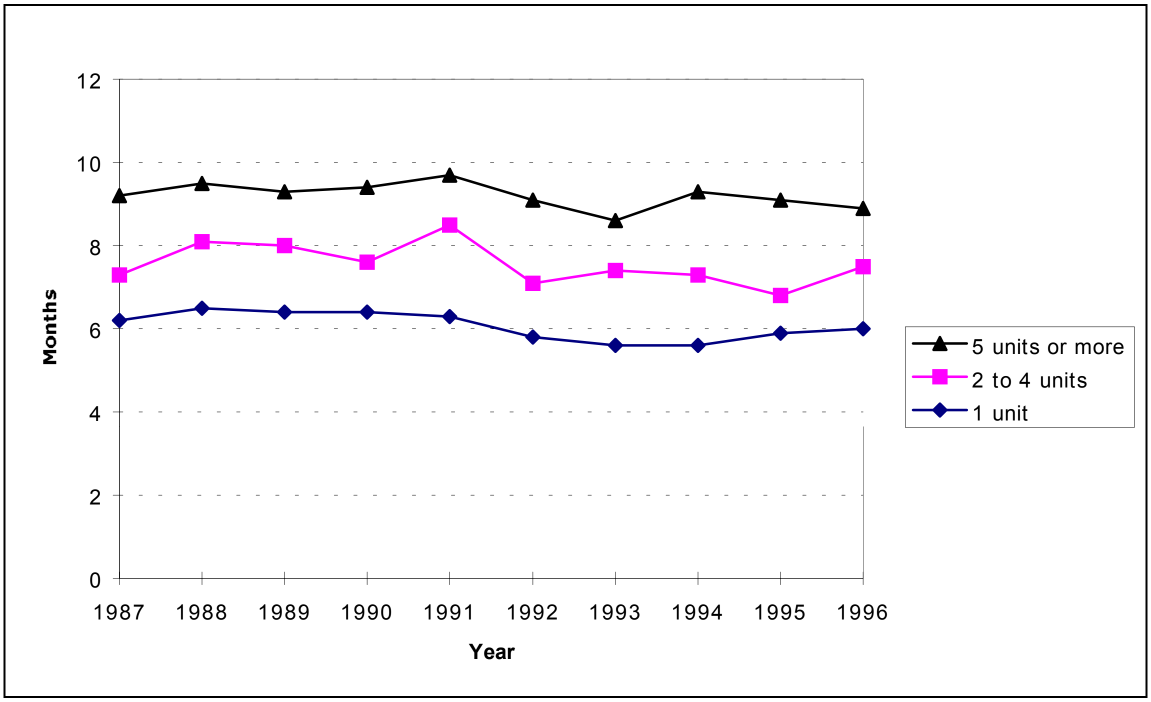
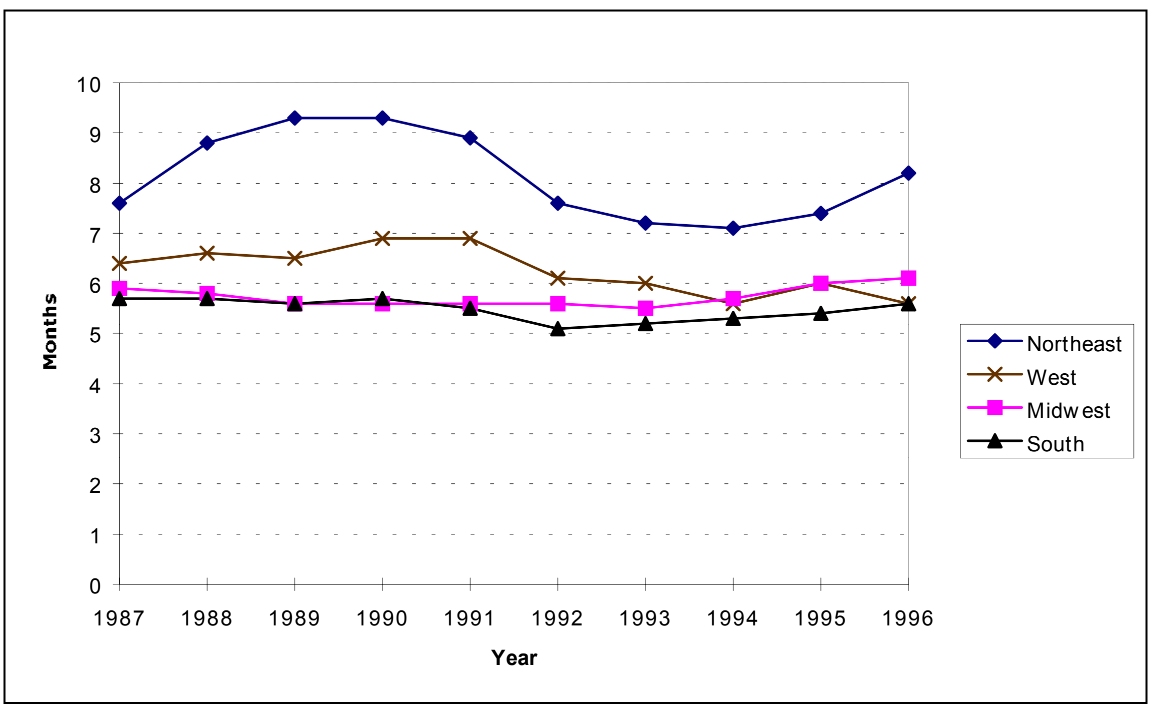


Figure 5-16. Average Number of Months from Start of Construction to Completion for New Single Family Housing Units by Census Region



The data used to create Figures 5-15 and 5-16 are recorded in Table 5-4. All entries record the number of months—to the nearest tenth of a month—it takes to construct a residential building. Each year in the 10-year period, 1987 to 1996, corresponds to a row in the table. The three columns under the heading "Average Number of Months by Type of Structure" contain the construction time data used to create Figure 5-15. The four columns under the heading "Single Family Housing Units Only" contain the construction time data used to create Figure 5-16.

Table 5-4. Average Number of Months from Start of Construction to Completion for New Housing Units by Type of Structure and Census Region

Year	Average Number of Months by Type of Structure			Single Family Housing Units Only Average Number of Months by Census Region			
	1 unit	2 to 4 units	5 units or more	Northeast	Midwest	South	West
1987	6.2	7.3	9.2	7.6	5.9	5.7	6.4
1988	6.5	8.1	9.5	8.8	5.8	5.7	6.6
1989	6.4	8.0	9.3	9.3	5.6	5.6	6.5
1990	6.4	7.6	9.4	9.3	5.6	5.7	6.9
1991	6.3	8.5	9.7	8.9	5.6	5.5	6.9
1992	5.8	7.1	9.1	7.6	5.6	5.1	6.1
1993	5.6	7.4	8.6	7.2	5.5	5.2	6.0
1994	5.6	7.3	9.3	7.1	5.7	5.3	5.6
1995	5.9	6.8	9.1	7.4	6.0	5.4	6.0
1996	6.0	7.5	8.9	8.2	6.1	5.6	5.6

Figure 5-17 shows a percentage distribution for 1996 of all new residential buildings constructed, grouped by the number of months it takes to construct the building (i.e., construction time). Information is shown on three types of structures: (1) 1 unit (i.e., new single family housing); (2) 2 to 4 units; and (3) 5 units or more. The horizontal axis in the figure records the number of months it takes to construct the building. New residential buildings taking three months or less to construct are recorded above the construction time heading "3 months or less." New residential buildings taking 13 months or more to construct are recorded above the construction time heading "13 months or more." New residential buildings taking an amount of time between four months and one year to construct are recorded above the appropriate construction time heading. The vertical axis records the percentage distribution for each type of structure and each construction time heading.

Figure 5-17. Percentage Distribution by Number of Months from Start of Construction to Completion for New Housing Units by Type of Structure

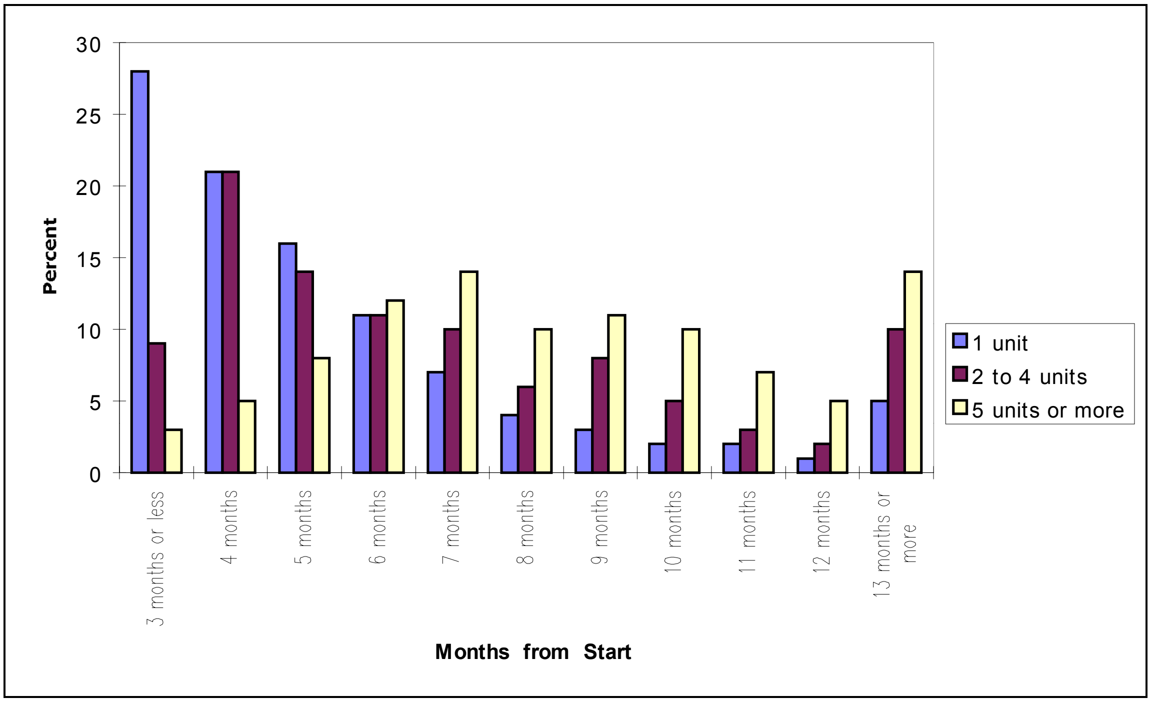


Table 5-5. Percentage Distribution by Number of Months from Start of Construction to Completion for New Housing Units by Type of Structure

Period	Percentage Distribution by Type of Structure		
	1 unit	2 to 4 units	5 units or more
3 months or less	28	9	3
4 months	21	21	5
5 months	16	14	8
6 months	11	11	12
7 months	7	10	14
8 months	4	6	10
9 months	3	8	11
10 months	2	5	10
11 months	2	3	7
12 months	1	2	5
13 months or more	5	10	14

The data used to create Figure 5-17 are recorded in Table 5-5. Reference to the first column of data in the table reveals that in 1996 nearly 50 percent of all new single family housing units were constructed in four months or less (refer to the first two rows of the table). Reference to the third column of data reveals that less than 10 percent of all multifamily buildings with 5 units or more were constructed in four months or less. Residential buildings experiencing construction times of 13 months or more account for only 5 percent of all new single family housing units, 10 percent of all multifamily buildings with 2 to 4 units, and 14 percent of all multifamily buildings with 5 units or more.

5.2.2. Measures Based on National Association of Home Builders Data

The NAHB Report *Cycle Time Reduction in the Residential Construction Process* considers residential housing construction in Atlanta. The Atlanta marketplace was chosen because it was one having significant building activity, with increasing sales and forecasts suggesting economic recovery in 1993 (the year of the report), and a high proportion of prototypical houses. The *prototype house* which is defined in the report is considered to be representative of US residential construction market, and has the following characteristics:

- Single-Family Detached
- Two-Story
- Full-Foundation
- On-Site Construction
- Brick, Aluminum, Vinyl or Wood Product Siding

Of the 65 building firms initially contacted, 6 were selected for detailed study. These firms produced in excess of 100 new units per year, and appeared to use innovative cycle-time reduction practices. To establish a common frame of reference, the report defined a *series of sets of major work activities, with each set composed of more detailed* subsets of activities.

Site activities of the six builders were broken down into categories. Five sets of construction were defined for stick-built houses. These were **foundation, framing, rough mechanical and electrical (M&E), drywall**, and **finishes**. Each set contained subsets of activities as shown below. The construction duration for each primary subset is given for a 242 square meter (2,600 square foot) detached single family house (in 1993, the national median size for occupied detached single family homes and mobile homes was 160 square meters (1,725 square feet)). The schedule duration given below for each set is *representative of best practice* in the building process, and is based upon actual activities of home builders. Activities such as allowances for inspections and delays (e.g., due to inclement weather), and other times that might ordinarily be included in builder production schedules have been deliberately omitted because of their variable nature, and because they represent non-value added time in the construction cycle:

Set		*Sub-set*	*Days*	*Concurrent Activities*
Foundation	-	Excavation	1	
	-	Footers	2	
	-	Walls (concrete)	5	
	-	Ground works (interior/exterior)	4	
	-	Termite	1	
	-	Damp-proof	1	
	-	Prepare slabs	1	
	-	Pour and finish slabs	1	
		Total Working Days	*17*	
		Total Calendar Days	*24*	
Framing	-	Set columns and steel	1	
	-	Framing	7	Fireplace
	-	Interior frame inspection/repair	1	(5 days)
		Total Working Days	*9*	
		Total Calendar Days	*13*	
Rough M&E	-	HVAC-rough	2	Water/sewer
Connections	-	Plumbing-rough	2	(2 days)
	-	Roof shingles	1	Natural gas
	-	Electric-rough	2	sewer
	-	Insulation	1	connection (1 day)
		Total Working Days	*8*	
		Total Calendar Days	*12*	
Drywall	-	Drywall	7	Brick Front (3 days), Siding (3 days) Cornice, Exterior Trim (1 day)
		Total Working Days	*7*	
		Total Calendar Days	*10*	

Finishes	-	Ceramic Bath	2	Shutters, Deck
	-	Receive Materials	0	Garage Door
	-	Interior Trim	2	(2 days)
	-	Interior Paint	3	Driveway
	-	Resilient Flooring	1	(1 day)
	-	Kitchen Cabinets and Vanity tops	1	Exterior
	-	Finish HVAC	1	Concrete
	-	Finish Plumbing	2	(1 day)
	-	Finish Electrical	2	Wire Shelving
	-	Drywall touch-up	1	(1 day)
	-	Wood floor, shower door mirrors, bathroom	1	Exterior trim, Landscaping
	-	Paint touch-up	1	(1 day)
	-	Carpet	1	
	-	Final Clean	1	
	-	Quality Inspection and Work	2	
	-	Customer Pre-settlement	1	
		Total Working Days	*22*	
		Total Calendar Days	*31*	
		Total Working Days (all sets)	**63**	
		Total Calendar Days (all sets)	**88**	

These figures compare with a total of 58 working days/81 calendar days for a 140 square meter (1,500 square foot) house. The figures include 21 working days in the concurrent path of activity. The 'best practice' schedule shown above is validated in the report, and is shown to be similar to that achieved by two mid-Atlantic builders. In order to achieve this schedule, skillful use of pre-manufactured building components, particularly wall panels, roof, and floor joist systems is necessary to reduce total actual cycle-time in residential construction.

The NAHB report also examines comparative cycle times for 7 modular housing manufacturers in detail. A construction schedule was developed similar to that for a site-built house, where the site-built house is replaced by a modular replacement house built off-site concurrently with the installation of the foundation on site. The schedule assumes maximum use of concurrent work activity, and non-value-added time is excluded as before:

	Activity	*Duration (days)*
-	Foundation	17
-	Manufacture of House	Concurrent with Foundation
-	Placing on Foundation	1
-	Finishes	7
-	Pre-Settlement	2
Total Working Days (all operations)		**28**
Total Calendar Days (all operations)		**42**

The NAHB report also identifies a series of site-built and modular 'best practice indicators', which are of significance to the reduction in cycle time. They are shown in the data hierarchies presented in Appendix A. These indicators are of a general nature, given that the survey sample size was too small to be able to correlate particular work practices with reductions in cycle time. However, the NAHB report provides some valuable insights, and merits the attention of the reader.

5.2.3. Summary of Baseline Measures

Table 5-6 shows general information relating to the residential sector, as well as key delivery time baseline data. The 'General Information' section describes the *total expenditures for new construction* in the residential sector in 1994, as well as the *average cost of new housing* in the US. The section also provides overall information about the *size of the residential sector*, and selected *key characteristics for single-family homes*, which are the largest component of the sector.

The 'Delivery Time' section provides baseline measures for residential construction in the US.

Summary of Abbreviations Used in Table 5-6	
VIP	Value of New Construction Put in Place
C20	Current Construction Reports Series C20 - Housing Starts
NAHB	National Association of Home Builders

Table 5-6. Summary of Baseline Measures: Residential Sector

DESCRIPTION	YEAR	BASELINE	SOURCE[26]
GENERAL INFORMATION			
Value of New Construction Put in Place	1994	$156,575 million (constant 1992 dollars)	Census VIP Data
Average Construction Cost - All Housing	1994	$54.54 per square foot/$586.81 per square meter	Statistical Abstract
Total Number of Housing Units	1995	110 million	Census Data
Number of Single-Family (SF) Housing Units	1995	72 million	Census Data
Median Size of SF Unit	1995	1,732 square feet/161 square meters	Census Data
Number of New SF Homes Started	1995	1.1 million	Census Data
DELIVERY TIME			
Total Time from Authorization of Construction to Start of Construction	1996	0.75 months approximately (single family housing)	C20
Total Time from Start of Construction to Completion	1996	6 months approximately (single family housing)	C20
Best Practice Site Built Construction Duration for Single Family Detached House - Size 242 Square Meters	1993	63 Working Days 88 Calendar Days	NAHB
Best Practice Site Built Construction Duration for Single Family Detached House - Size 140 Square Meters	1993	58 Working Days 81 Calendar Days	NAHB
Best Practice Modular Construction Duration for Single Family Detached House - Size 242 Square Meters	1993	28 Working Days 42 Calendar Days	NAHB

[26] See accompanying text for description of abbreviations used in this table.

6. Delivery Time Measures for the Non-Residential Sectors: Commercial/Institutional, Industrial, and Public Works

6.1. Key Considerations for the Non-Residential Sectors

This section of the document addresses the issue of data sources, availability, and constraints in the commercial/institutional, industrial, and public works sectors, and summarizes the key data sources which are used for developing the baseline measures. The section also provides an overview of each of the three sectors.

6.1.1. Data Considerations for the Non-Residential Sectors: Sources, Availability, and Constraints

6.1.1.1. Data Considerations for the Commercial/Institutional Sector

Preliminary data searches for the commercial/institutional sector indicated that there are a variety of organizations carrying out systematic surveys of particular parts of the commercial/institutional sector, particularly with regard to providing information on building operations costs, but that there are few surveys covering the entire sector, and none which appear to provide information regarding delivery time on construction projects in the sector. The most detailed survey of the commercial/institutional sector located by the authors is carried out by the Energy Information Administration (EIA), a part of the US Department of Energy. This survey provides useful information regarding characteristics of the sector, but is primarily energy oriented.

The EIA carries out the **Commercial Buildings Energy Characteristics Survey (CBECS)**. Data from both the 1992 and 1995 surveys are included in this document. Commercial buildings are defined by EIA as all enclosed, roofed, and walled structures used predominantly for commercial purposes, with floorspace greater than 93 square meters (1,000 square feet). The survey also covers the institutional sector (e.g., education, religious, and healthcare facilities), though in the survey these are all collectively referred to as commercial buildings.

The EIA produces a number reports from the survey data. These include *Commercial Buildings Characteristics 1992* and *1995*. Data from EIA are available through its Internet site (URL: http://www.eia.doe.gov), or through paper or electronic publications, including the *EIA Energy InfoDisc Volume 2, No.1, 1997*.

In this document, data from the EIA reports, *Commercial Buildings Characteristics 1992* and *Commercial Buildings Characteristics 1995*, have been used to characterize the commercial/institutional sector.

Data from the Construction Industry Institute

The Construction Industry Institute (CII) has provided the authors with detailed information regarding delivery time in the commercial/institutional sector, as discussed in Chapter 3 of this document. Data from CII are used to establish detailed delivery time baselines for the commercial/institutional sector.

6.1.1.2. Data Considerations for the Industrial Sector

Preliminary data searches for the industrial sector focused upon organizations such as the Department of Commerce, Department of Energy, and National Association of Manufacturers. These searches indicated that the majority of national level data on the industrial sector is collected either by the US Bureau of the Census or the Energy Information Administration. While these sources provide some information regarding the nature of the industrial sector, they do not provide information on delivery time in the sector. Some other sources of information have been located, but data is generally only available on a commercial fee-for-service basis. For further details regarding data sources, refer to Chapter 4.

Data from the US Bureau of the Census

The US Bureau of the Census (USBC) carries out a number of surveys of the US industrial/manufacturing sector, which are useful when characterizing the nature of the industrial sector. Surveys/reports of particular interest are the **Census of Manufactures** and the **Annual Survey of Manufactures**.

The **Census of Manufactures** provides detailed information on selected characteristics of the manufacturing sector. The survey is carried out every five years; data are currently available from the 1992 Census. The **1992 Census of Manufactures** includes all establishments with one paid employee or more, primarily engaged in manufacturing. This includes approximately 380,000 establishments. The SIC Manual defines manufacturing as the mechanical or chemical transformation of substance or materials into new products. The assembly of component parts of products is also considered to be manufacturing. The **Census of Manufactures** covers 20 major industry groups with 2 digit SIC Codes 20-39 inclusive. The USBC provides two report series from the Census which are of particular interest. The first is the *General Summary Report*, which provides aggregated industry statistics in one report. These include information on establishment size, number of employees, selected operating costs, and so forth, up to the 4-digit SIC Code level of detail. A second series of reports, the *Industry Reports* comprises 83 separate, more detailed reports. The latter reports provide historical statistics for the industry, selected operating ratios, capital expenditures statistics, purchased services statistics, product statistics, and material statistics for six-digit SIC codes. This level of detail will not be considered in this document.

The **Annual Survey of Manufactures** presents manufacturing establishments statistical data for years when the **Census of Manufactures** is not carried out. Data from the **1995 Annual Survey of Manufactures** are available at present. Selected data from USBC are available through its Internet site (URL: http://www.census.gov), or via electronic or paper publications.

In this document, data from the USBC have been used to characterize the size and nature of the industrial sector.

Data from the Construction Industry Institute

The Construction Industry Institute (CII) has provided the authors with detailed information regarding delivery time in the industrial sector, as discussed in Chapter 3 of this document. Data from CII are used to establish detailed delivery time baselines for the industrial sector.

6.1.1.3. Data Considerations for the Public Works Sector

This section of the document addresses the issue of data sources, availability, and constraints in the public works sector, and summarizes the key data sources that are used for developing the baseline measures. The section also provides a general overview of the public works sector, as well as a brief overview of each of the sub-sectors. To re-cap, the public works sub-sectors are as follows:

- Transportation (road, rail, transit, air, and water)
- Communications (masts, structures, and cabling services)
- Power Utilities (power generation and distribution)
- Water (storage, supply, treatment, and flood control)
- Solid Waste
- Pipelines (except natural gas)

For the reasons already given in Section 4.1.2 of this document, the communications and solid waste sub-sectors will not be discussed further.

Preliminary data searches for the public works sector indicated that there are a number of organizations that produce reports about some of the sub-sectors identified in Chapter 4 of this document. There do not appear to be any authoritative sources examining the public works sector in its entirety, nor do these reports address the issue of delivery time on construction projects. However, a number of these sources are useful for defining key characteristics of each sub-sector, and are considered separately below.

Data from the Construction Industry Institute

The Construction Industry Institute (CII) has provided the authors with detailed information regarding delivery time in the public works sector, as discussed in Chapter 3 of this document. In this document, data from CII are used to establish detailed delivery time baselines for the public works sector.

Data Sources for the Transportation Sub-Sector

Data from the US Bureau of the Census

The US Bureau of the Census (USBC) carries out the **Census of Construction** and produces the *Current Construction Reports Series C30* publication *Value of Construction Put in Place*, both of which are described in detail in Chapter 3 of this document. It also produces data concerning government investment in transportation. These data are available through the USBC Internet site, or via paper or electronic publications. For this sub-sector, data from USBC have been used to quantify transportation investments and construction expenditures.

Data from the Bureau of Transportation Statistics

The Bureau of Transportation Statistics (BTS) provides a wide range of information about the transportation sector through **The National Transportation Data Archives**, **The National Transportation Library**, and the **Transportation Studies** databases. Documents which are of particular interest are the *Transportation Statistics Annual Report 1995*, *1996*, and *1997*, which provide general information about the sector, and the report *Federal, State and Local Transportation Financial Statistics: Fiscal Years 1982-1994*, which provides data on government expenditures for transportation. These reports are available on the BTS Internet site (URL: http://www.bts.gov).

Data from the Statistical Abstract of the United States: 1996 and 1997

Some information from the *Statistical Abstract* has been used to quantify freight and passenger volumes with the public works sector. Specific data sources are identified in the text as appropriate.

Data from the Federal Highway Administration

The Federal Highway Administration (FHWA) publishes the annual report *Highway Statistics*, which provides very detailed information about highway extent, characteristics, and performance. This is also referred to as the "Yellowbook". The 1994 report has been used in this document, although 1995 data have recently become available. The report is available on the Bureau of Transportation Statistics Internet site (URL: http://www.bts.gov/ohim/1994/index.html) or via paper publications. In this document, data from *Highway Statistics 1994* have been used to characterize the size and nature of the US highway system.

Data from the Association of American Railroads

The Association of American Railroads (AAR) provides statistics for the US national railroad system. Data are available via the AAR Internet site (URL: http://www.aar.org), and have been used in this document to characterize the sector.

Data from the Federal Transit Administration

The Federal Transit Administration (FTA) provides access to a wide range of detailed information about transit systems through the **National Transit Library**, and **National Transit Database**. Documents of particular interest include *FTA Budget Brief*, and *Transit Agency Operating Expenses* for 1995, 1996, 1997, and 1998 and the FTA report *Characteristics of Urban Transportation Systems-Revised Edition, September 1992*. Data are available through the FTA Internet site (URL: http://www.fta.dot.gov). In this document, data from the FTA have been used to characterize the extent of the transit sector.

Data from the Federal Aviation Administration

The Federal Aviation Administration (FAA) report *FAA Statistical Handbook of Aviation 1997* provides information on the size of the aviation sector. This report is available at the BTS Internet site.

Data from the Maritime Administration

The Maritime Administration *Report to Congress on the Status of Public Ports of the United States, 1994-1995*, provides information on the number of ports in the US. The report is available through the Maritime Administration Internet site (URL: http://www.marad.dot.gov).

Data from the US Army Corps of Engineers

The US Army Corps of Engineers (USACE) provides information on domestic waterborne commerce in its report *Waterborne Commerce of the United States, Calendar Year 1995*. The Civil Works Division of the USACE provides information on the scope of its Civil Works activities (see the information paper at the USACE Internet site: http://www.usace.army.mil/inet/functions/cw/prog-man/cwmprog.htm). These include navigation activities, which are considered in this sub-sector, and flood control and other activities, which are considered in the "water" sub-sector.

The USACE provides data on dredging activities through its *Water Resources Support Center/Navigation Data Center*. For details refer to its Internet site (URL: http://www.wrc-ndc.usace.army.mil).

Data from Other Sources

A wide range of other transportation related data sources were examined, some of which are described below:

- US Department of Transportation Surface Transportation Board (STB) *Financial Data for Class I*[27] *Railroads 1996*, available from STB Internet Site (URL: http://www.stb.dot.gov/infoex1.htm#Finance).

- American Public Works Association- provides a range of data and publications relating to all public works sub-sectors. (URL: http://www.pubworks.org).

Data Sources for the Power Utilities Sub-Sector

Data from the Energy Information Administration

The EIA publishes the *Annual Energy Review*, which provides a range of information relevant to power generation, distribution, and consumption in the US. Data from the *Annual Energy Review 1996*, available through the EIA Internet Site (URL: http://www.eia.doe.gov), have been used to characterize the electric power industry by net generation and consumption by sector.

Data from the US Bureau of the Census

The USBC carries out the **Census of Transportation, Communication, and Utilities** every five years; data are currently available for 1992. The Census covers SIC codes 40, 41, 42, 44, 45, 46, 47, 48, and 49. This includes electric, gas and sanitary services (SIC 49), which are relevant to the power utilities sub-sector. Data from this Census have been used to characterize the size of the industry, and provide aggregated data on construction expenditures.

Data from the Energy Information Administration

The EIA publication, *Natural Gas Monthly, April 1997*, provides details of interstate natural gas pipeline capacity and planned additions for 1995-2000.

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[27] Class I railroads are defined as any railroad having an annual operating revenue of at least $255.9 million. As of January 1997, there were 9 Class I railroads in the US.

Data Sources for the Water Sub-Sector

Data from the US Army Corps of Engineers (USACE)

The USACE provides information on domestic waterborne commerce in its report *Waterborne Commerce of the United States, Calendar Year 1995*. The Civil Works Division of the USACE provides information on the scope of its Civil Works activities (see the information paper at the USACE Internet site: http://www.usace.army.mil/inet/functions/cw/prog-man/cwmprog.htm). These include navigation activities, which are considered in the transportation sub-sector, and flood control and other activities, which are considered in this sub-sector.

Data Sources for the Pipelines Sub-Sector

Data from the US Bureau of the Census

The USBC carries out the **Census of Transportation, Communications and Utilities** every five years; data are currently available for 1992. The Census covers SIC codes 40, 41, 42, 44, 45, 46, 47, 48, and 49. This includes pipelines, except natural gas (SIC 46) which is relevant to the pipelines sub-sector. Data from this Census provide aggregated construction expenditure data for petroleum and other types of pipelines in the US.

6.1.2. Overview of the Non-Residential Sectors

6.1.2.1. Overview of the Commercial/Institutional Sector

The overview of the commercial/institutional sector presented in this section expands on the overview presented in Chapter 3 of this document. This section examines the size of the US commercial/institutional sector, grouped by principal building activity, both in terms of number of buildings and total floorspace. It also examines a number of key characteristics of the commercial/institutional sector, such as the age, size, and geographic distribution of facilities.

Figures 6-1 through 6-3 show the size of the commercial/institutional sector by principal building activity. Figures 6-4 through 6-6 examine building characteristics by year of construction.

Data from the 1992 and 1995 *Commercial Buildings Characteristics Reports* have been used to generate Figure 6-1. The figure shows the total number of buildings in the US grouped by principal building activity, as defined by EIA. Reference to Figure 6-1 indicates that of the 4,806,000 buildings in the US in 1992, approximately 26 percent were in the mercantile and service category (which includes automotive sales and services, retail sales, services, shopping centers, and wholesale goods), approximately 16 percent are office buildings, and approximately 16 percent were warehouse and storage buildings (these are considered as part of the industrial sector, but are included in this section, as they are part of the **CBECS**). Approximately 13 percent of all commercial/institutional buildings were government owned. Comparison between 1992 and 1995 data indicates that the total number of buildings in the commercial/institutional sector fell from 4,806,000 in 1992 to 4,579,000 in 1995. The most significant changes were in the number of warehouses and storage facilities (reduced by 181,000), religious worship buildings (reduced by 97,000), and vacant buildings (reduced by 58,000). The only area where there was a significant increase in the number of buildings is public assembly (increased by 48,000). The mean area of all buildings decreased from 1,310 square meters (14,100 square feet) in 1992 to 1,190 square meters (12,800 square feet) in 1995. Similar changes in mean area per worker were 89 square meters (953 square feet) in 1992 to 71 square meters (766 square feet) in 1995, with mean hours of operation increasing from 58 hours in 1992 to 62 hours in 1995.

Figure 6-1. Total Number Of Buildings by Principal Building Activity: 1992 and 1995

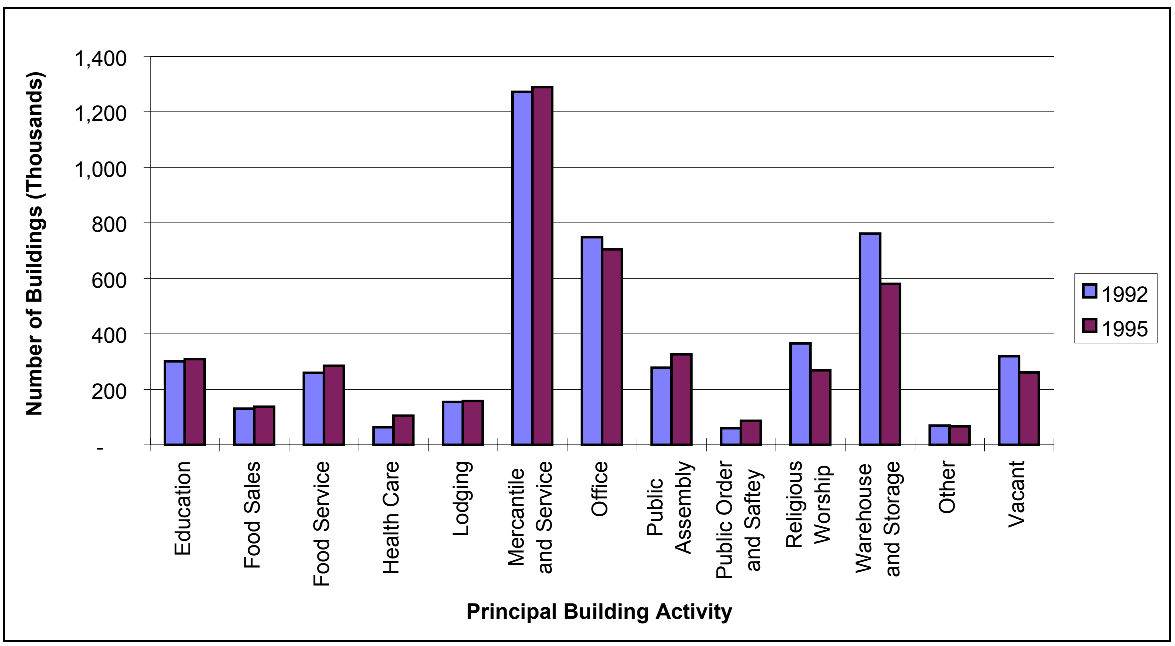
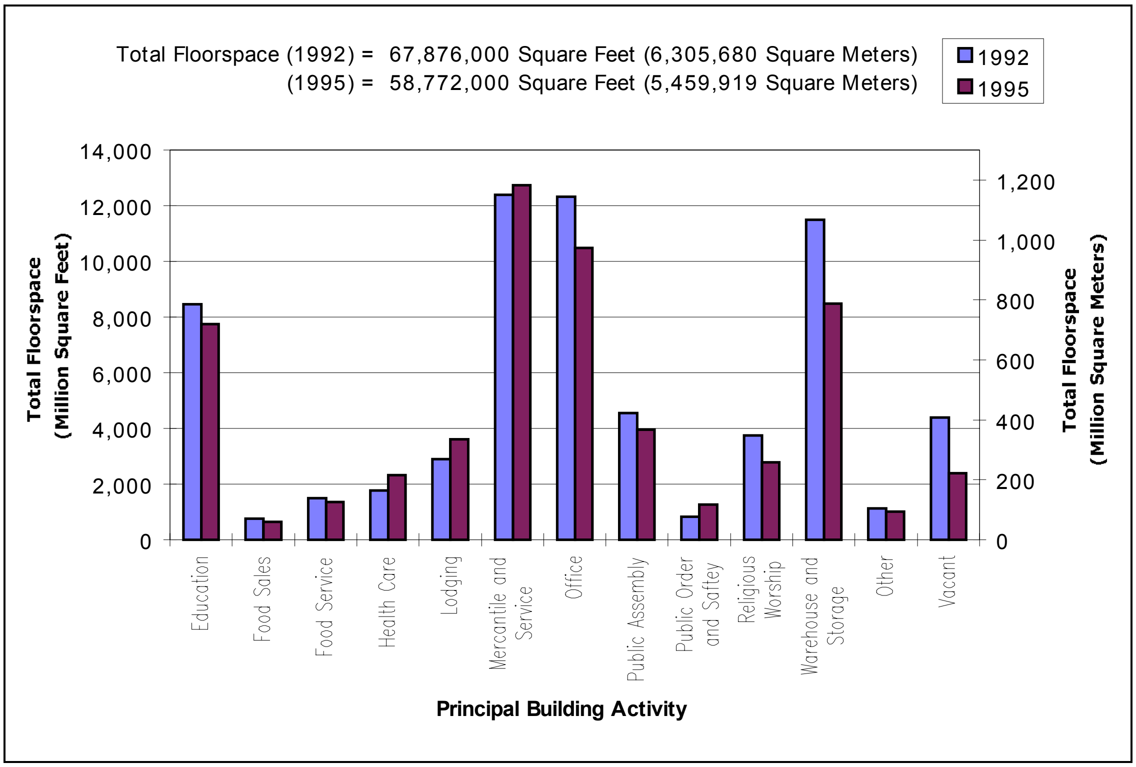


Figure 6-2 shows the total building floorspace in each principal building category for all commercial/institutional buildings in the US in 1992 and 1995. Reference to the figure shows that there were 6,308 million square meters (67,876 million square feet) of floorspace in 1992, compared with 5,462 million square meters (58,772 million square feet) in 1995 (a 13.5 percent reduction). Comparison of Figure 6-1 and Figure 6-2 indicates that while the number of educational buildings is not especially high compared with other building categories, in terms of total floorspace, it is one of the largest categories. This suggests that educational establishments are significantly larger than religious, public assembly, or food service establishments. Similarly, office buildings, although smaller in number to mercantile and service buildings, represent a similar amount of total floorspace, most likely because a significant number of office buildings are multi-story. The other important point is that educational, mercantile and service, and office buildings accounted for over 60 percent of total commercial/institutional sector floorspace in the US in 1992 and 1995 (if we exclude warehouse and storage facilities).

Figure 6-2. Total Floorspace by Principal Building Activity: 1992 and 1995



In Figure 6-3, the distribution of building floorspace across the US census regions, by principal building activity is shown for 1992. Reference to the figure shows that there was significantly more commercial/institutional floorspace in the south census region (approximately 35 percent of the total) compared with the other three census regions, with the least amount in the northeast (approximately 20 percent of the total). This was particularly noticeable in the mercantile and service, office, public assembly, and warehouse and storage categories. These trends are also reflected in 1995 data.

Figure 6-4 and Figure 6-5 show how the number of buildings and total floorspace vary depending upon the year of construction.

Figure 6-3. Total Floorspace by Principal Building Activity and Census Region: 1992

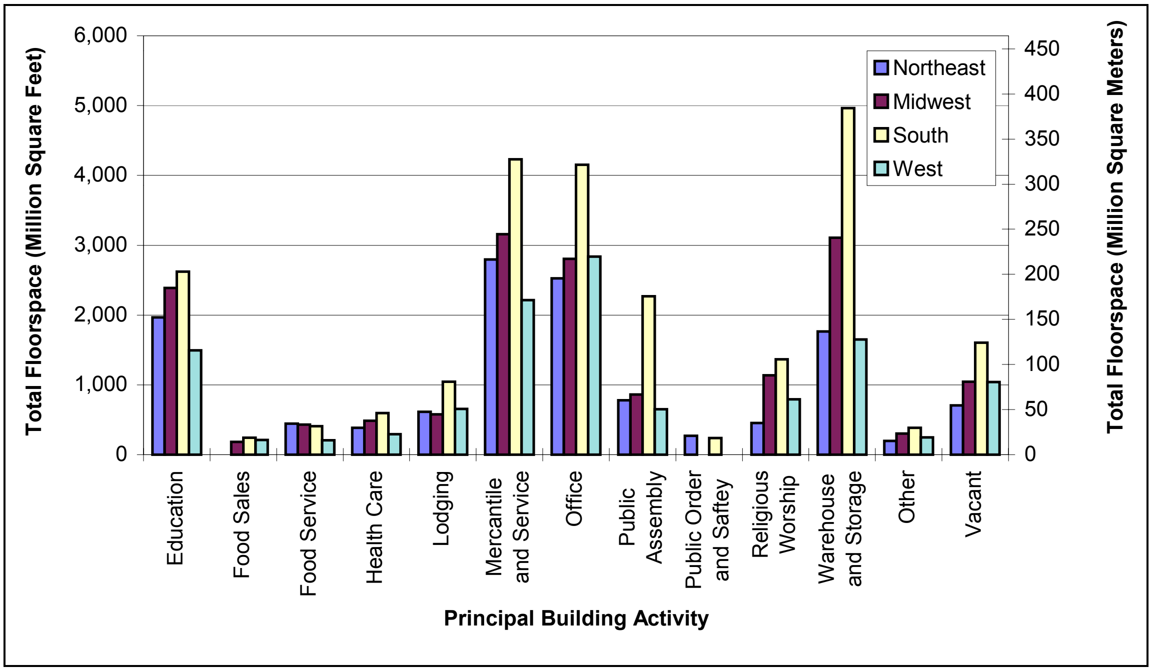


Figure 6-4. Total Number of Buildings by Year of Construction: 1992 and 1995

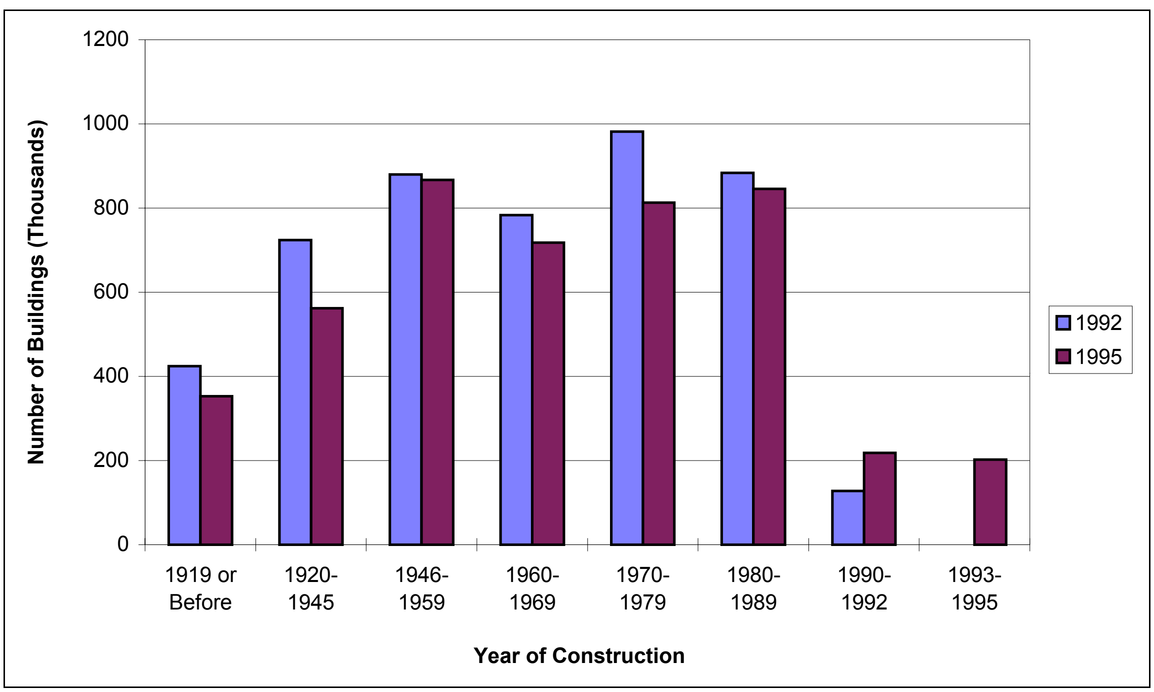


Figure 6-5. Total Floorspace by Year of Construction: 1992 and 1995

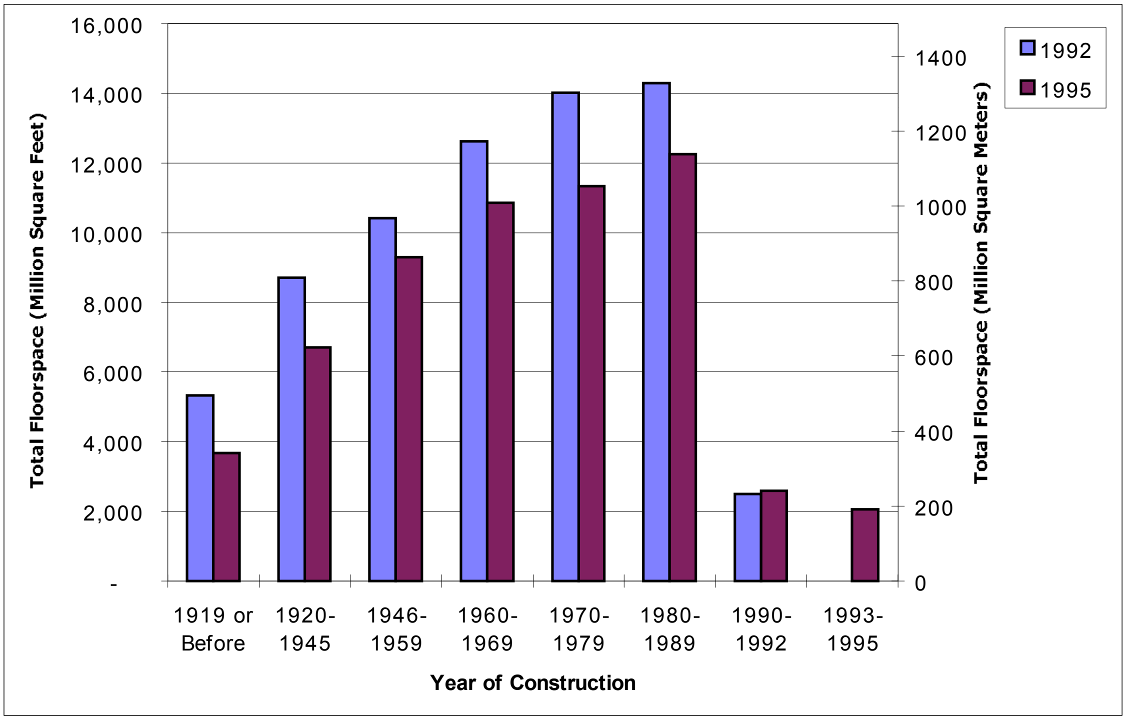


Figure 6-6. Total Floorspace by Year of Construction and Census Region: 1992

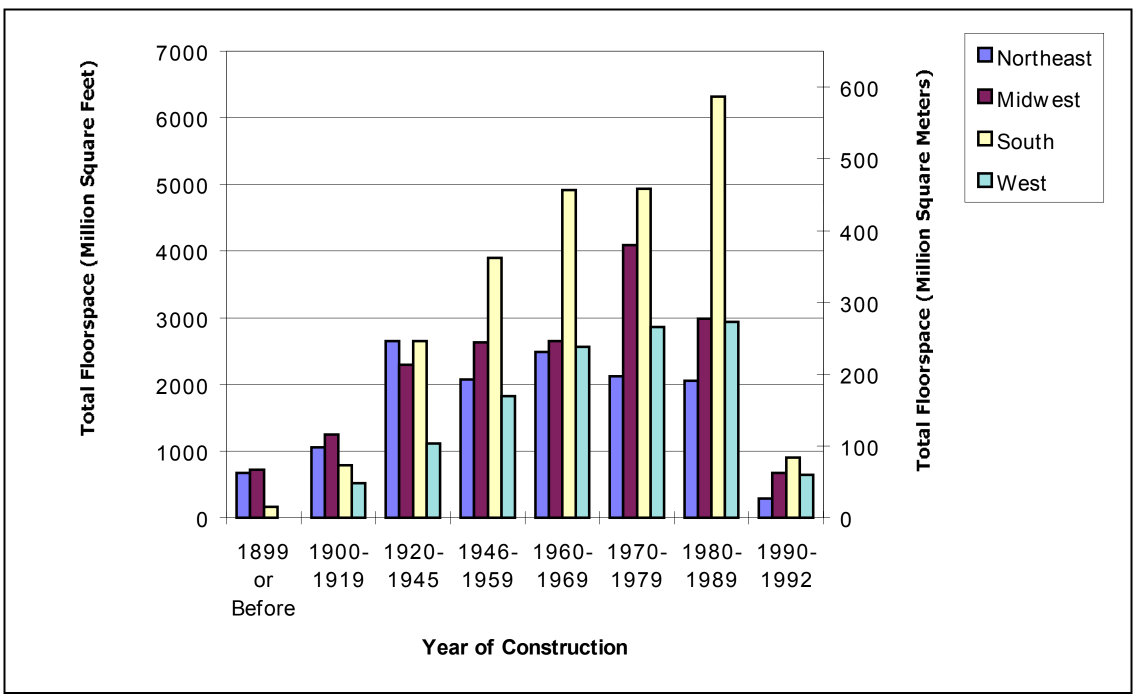


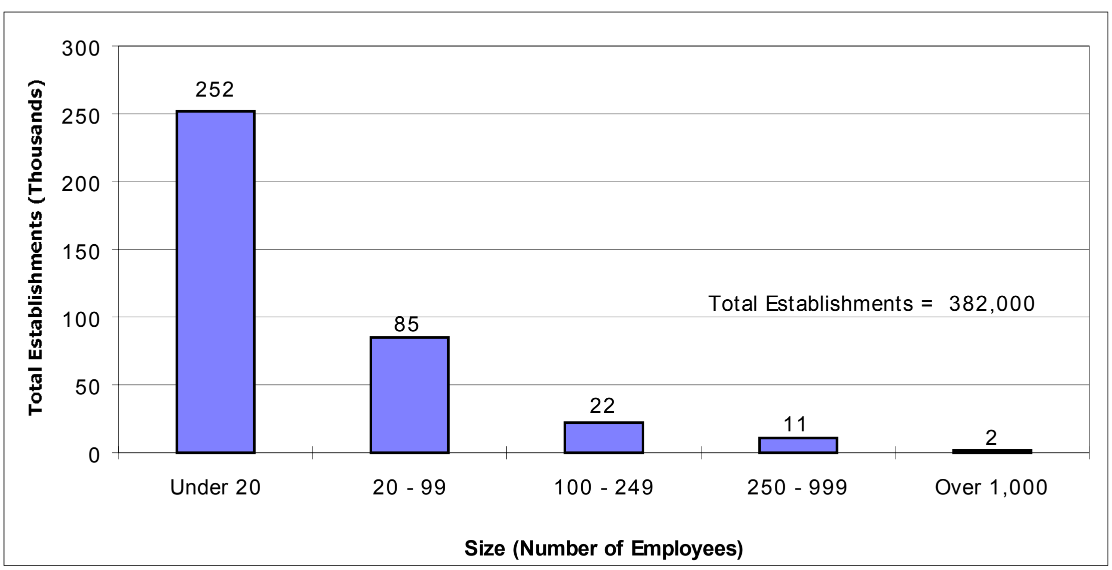
Figure 6-6 shows how total floorspace varies by year of construction and census region. The figure indicates that the relatively high proportion of total floorspace in the south census region has remained consistent over time, thus the geographic distribution of the commercial/institutional sector appears to be relatively stable.

6.1.2.2. Overview of the Industrial Sector

The overview of the industrial sector presented in this section expands on the overview presented in Chapter 3 of this document. This section examines the total size of the US industrial sector (i.e. SIC codes 20-39), and a number of key industry characteristics.

Data from the US Bureau of Economic Analysis shows that since 1987, all manufacturing industries have accounted for approximately 18 percent of GDP in the US in real terms. Data from the 1987 and 1992 **Census of Manufactures** show that the total number of establishments with payroll has risen slightly from 369,000 in 1987 to 382,000 in 1992. Of these 382,000 establishments, 81,000 were multi-unit companies and 301,000 were single unit companies. Figure 6-7 shows the size distribution of all industrial establishments combined in terms of employee size-classification. Reference to the figure shows that approximately two-thirds of these establishments have less than twenty employees, while only about three percent have greater than 250 employees. This size structure did not change significantly between 1987 and 1992. Single unit companies had a much lower average number of employees (18) compared with multi-unit companies (162). For multi-unit companies, production workers comprised over 60 percent of total employees.

Figure 6-7. Size of Establishments: 1992



6.1.2.3. Overview of the Public Works Sector

Overview of the Transportation Sub-Sector

This section first examines the transportation sub-sector as a whole, before moving on to examine the principal transportation modes in more detail. This overview examines government investment in transportation, especially construction expenditures. The more detailed descriptions of each of the principal transportation modes (i.e., highways, rail, transit, air, and water) consider the extent of the infrastructure associated with each mode, and key operational characteristics.

Transportation plays a pivotal role in the US economy, both by providing mobility for the movement of passengers and freight, and as an intermediate good that is consumed at every stage to create a final product. The Bureau of Transportation Statistics (BTS) estimates that transportation services in 1993 accounted for about 11 percent of Gross Domestic Product.[28]

Consumer expenditures for transportation, of which the largest element is personal vehicle operation, upkeep, and purchase, is the second largest component of total consumer spending (second only to housing). However, it will not be considered further here, as it is beyond the scope of this document.

Government agencies play a significant role in providing transportation infrastructure and services, and are also significant purchasers of transportation equipment and services. Table 6-1, which is based upon data from the *1997 Transportation Statistics Annual Report*, shows how government investment in infrastructure and equipment has changed between 1983 and 1993. The table shows investment by type of government and mode of transport, and compares total investment for all government with investment in construction. Reference to the table indicates that in 1993, all levels of government invested heavily in highways, but that the proportions were quite different, the state government putting 92 percent of their transportation investment into highways, local governments 47 percent, and federal government 32 percent. For all government combined, the states made 75 percent of total government investment in highways. In 1993, local governments invested more in airports and urban transit combined than they did in highways, and were responsible for over 70 percent of government investment in these two modes that year. Investment in highways, transit and airports is heavily slanted toward construction. Almost 90 percent of public investment in highways for 1993 was for construction. The only mode experiencing a loss of investment in real terms between 1983 and 1993 was water transportation and terminals, due to a decrease in construction. Equipment investment, however, increased 67 percent in real terms.

[28] See *Transportation Statistics Annual Report 1995*, pp.33 for details.

Table 6-1. Government Transportation Investment by Mode: 1983 and 1993

Investment in billions of constant 1992 dollars, after transfers										
	All Government		Federal		State		Local		Construction Outlays-All Government	
Mode	*1983*	*1993*	*1983*	*1993*	*1983*	*1993*	*1983*	*1993*	*1983*	*1993*
Transportation Total	34.1	51.3	1.4	2.1	19.9	30.6	13.4	18.7	28.6	43.0
Highways	25.2	37.5	0.3	0.7	18.3	28.1	7.2	8.8	22.1	33.2
Airports	2.3	6.3	0.4	1.0	0.3	0.8	1.8	4.5	1.7	4.6
Parking Facilities	-	0.4	-	-	-	-	-	0.4	-	0.3
Water Transportation and Terminals	1.9	1.2	0.8	0.6	0.3	0.2	0.7	0.4	1.6	0.7
Transit	4.8	6.1	-	-	1.2	1.4	3.8	4.7	3.0	4.2

Table 6-2, which is based upon the **Census of Construction 1987** and *Value Put in Place Series*, examines expenditures by SIC 1611, 1622 and 1629 for each of the transportation modes in 1987. Reference to Table 6-3 shows how expenditures for highways and streets, which is the largest component of transportation construction, have varied between 1989 and 1996. The Value of New Construction Put in Place for highways, streets, and related facilities has risen by about 10 percent over this time in real terms. The second largest component of new construction in the transportation sector is for buildings and other construction, which includes new airport or rail terminals. The data presented in Table 6-2 are shown graphically in Figure 6-8.

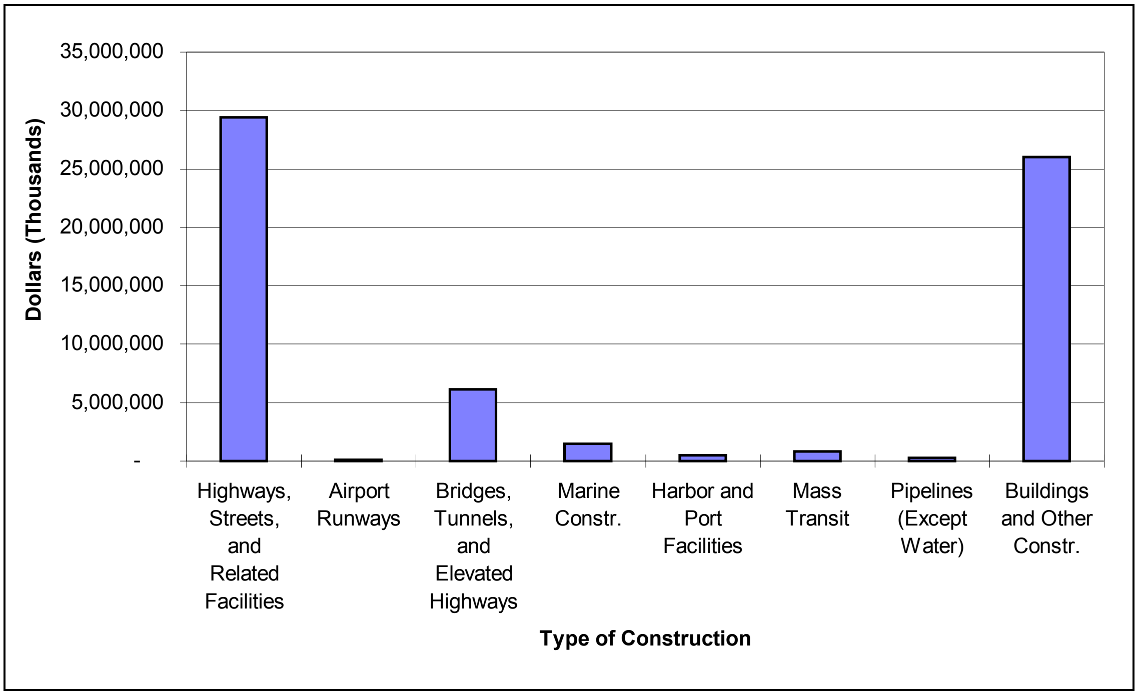
Table 6-2. Transportation Construction Expenditures by Mode: 1987

Transportation Construction, 1987 (Thousands of Dollars)				
	Highway and Street Construction (SIC 1611)	Construction of Bridges, Tunnels, and Elevated Highways (SIC 1622)	Heavy Construction Not Elsewhere Classified (SIC 1629)	Total
Establishments	10,986	1,159	14,532	26,677
Employees	284,380	47,494	297,618	629,492
Value of Construction	34,161,427	5,480,936	25,632,969	65,275,332
Highways, Streets, and Related Facilities	28,123,431	387,161	923,313	29,433,905
Airport Runways	123,809	-	-	123,809
Bridges, Tunnels, and Elevated Highways	1,152,276	4,476,501	532,104	6,160,881
Marine Construction	88,785	29,291	1,379,611	1,497,687
Harbor and Port Facilities		53,509	431,507	485,016
Mass Transit	54,092	-	780,781	834,873
Pipelines (Except Water)	-	-	249,086	249,086
Buildings and Other Construction	4,169,034	534,474	21,336,567	26,040,075

Table 6-3. Value of New Construction put in Place for Highways Streets and Related Facilities in Constant 1992 Dollars: 1989 to 1996

	Value of New Construction put in Place in Millions of Constant 1992 Dollars							
Year	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Highways and Streets	30,407	31,777	30,300	33,132	34,164	36,151	33,500	33,297

Figure 6-8. Government Transportation Investment by Mode: 1987



Highway Transportation

The most widely used form of transportation in the US is the highway. It includes the highway infrastructure, composed of roads, streets and bridges, traffic control devices and additional facilities, as well as vehicles and drivers, and other highways-related services. This section deals only with highway infrastructure, as issues relating to operations, maintenance, and energy costs of vehicles and their users are considered beyond the scope of this document.

The highway network comprises 6.28 million kilometers (3.9 million miles) of public roads, which are operated primarily by state and local governments. The total size of the US highway system has been relatively stable for many years (in 1980, total mileage was

6.435 million kilometers (3.995 million miles), in 1994, it had fallen slightly to 6.285 million kilometers (3.906 million miles)). The US also has a substantial private road mileage, but data to describe its extent and variety are lacking. The public road network is classified according to the traffic functions the roads are intended to serve. The functional types identified in this section are as follows:

- Interstates, freeways, and expressways
- Arterials
- Collectors, and
- Local roads

Figure 6-9. Total Highway Mileage by Functional Type: 1993

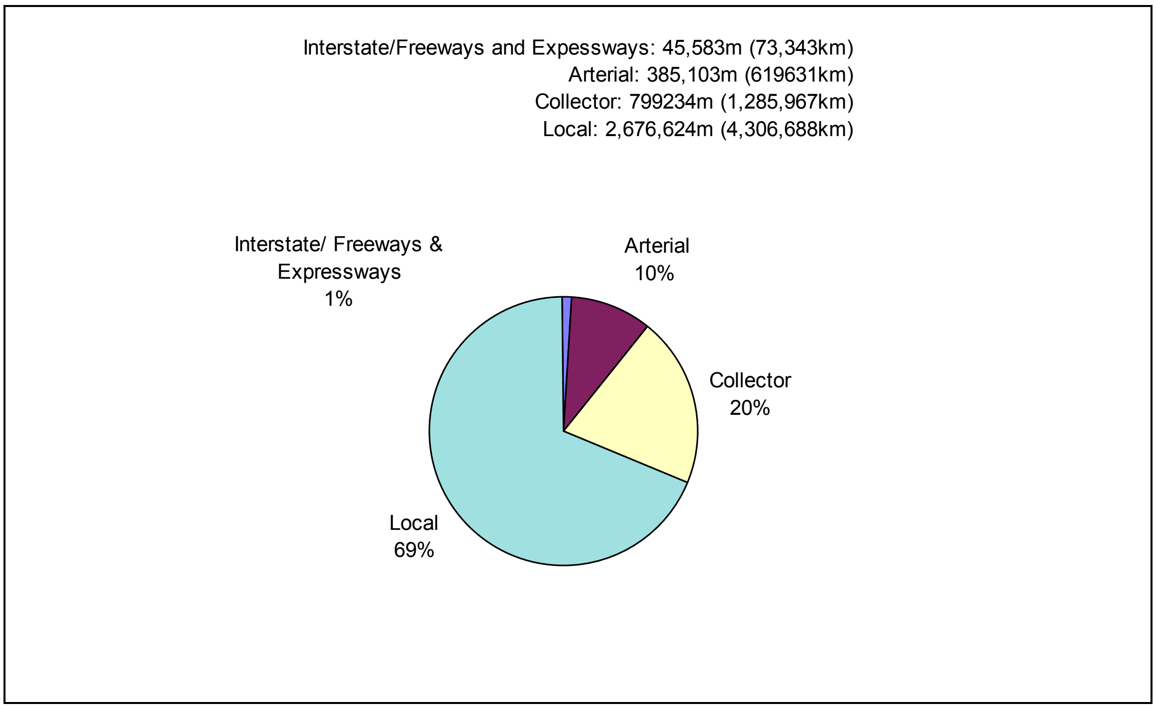
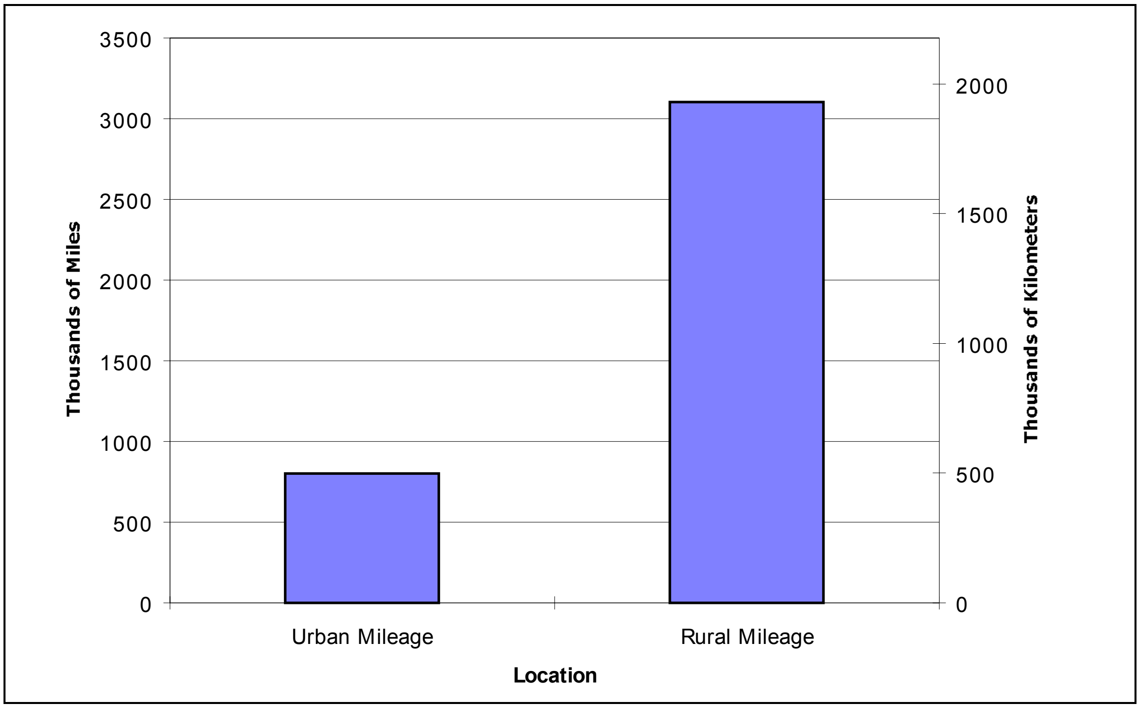


Figure 6-9, which is based upon data from the *1996 Statistical Abstract*, shows the relative proportions of each of these functional types of roads. Local roads represent the largest proportion of the highway network.

Figure 6-10, which is also based upon data from the *1996 Statistical Abstract*, shows how total highway mileage is distributed between urban and rural areas. Reference to the figure indicates that rural roads account for about 80 percent of total mileage. However, if these figures are compared with vehicle usage, in terms of vehicles miles of travel, a different pattern emerges. Urban vehicle miles account for about 60 percent of total vehicle miles. In addition, only about 13 percent of total annual vehicle miles take place on local roads; approximately 71 percent take place on arterials and Interstates, with about one-third of this total on Interstates alone.

Figure 6-10. Total Highway Mileage by Geographic Location: 1993



While the federal government plays an important role in funding and managing US highways, state and local governments control almost all of the roads and bridges in the US. This is shown graphically in Figure 6-11, which shows how total highway mileage was distributed by jurisdiction in 1993.

Figure 6-12 shows how prices for selected highway construction activities have varied between 1980 and 1994. Reference to the figure indicates that most highway construction costs are rising. Further details are available in the FHWA publication *Price Trends for Federal-aid Highway Construction*, prepared by the Federal-aid and Design Division, Office of Engineering.

Figure 6-11. Total Highway Mileage by Jurisdiction: 1993

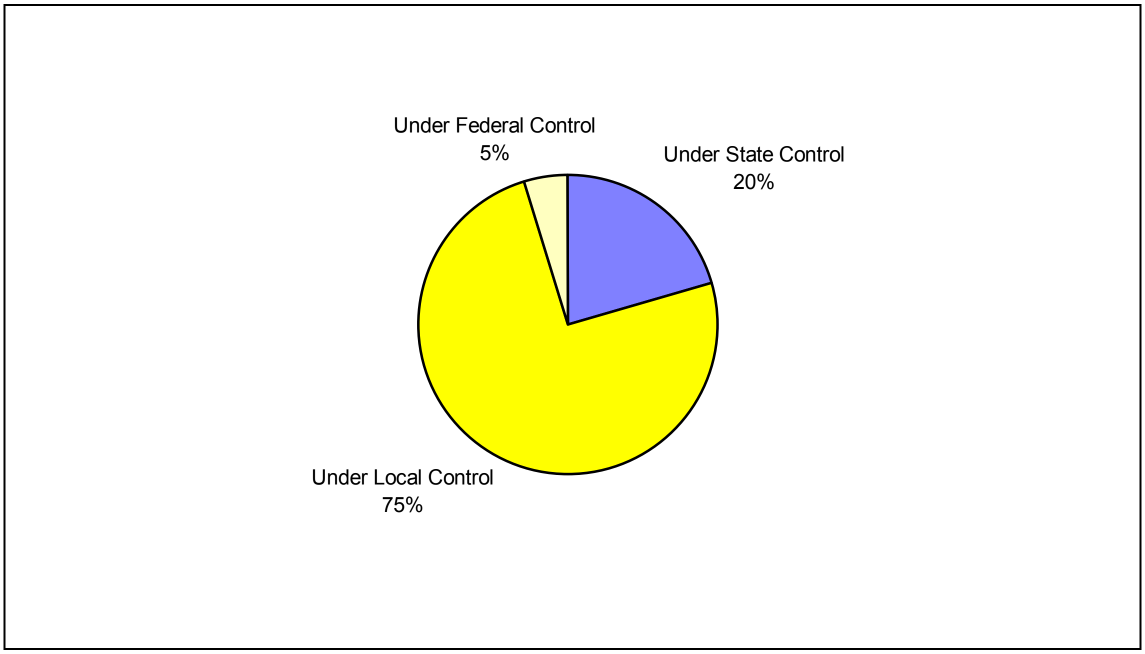
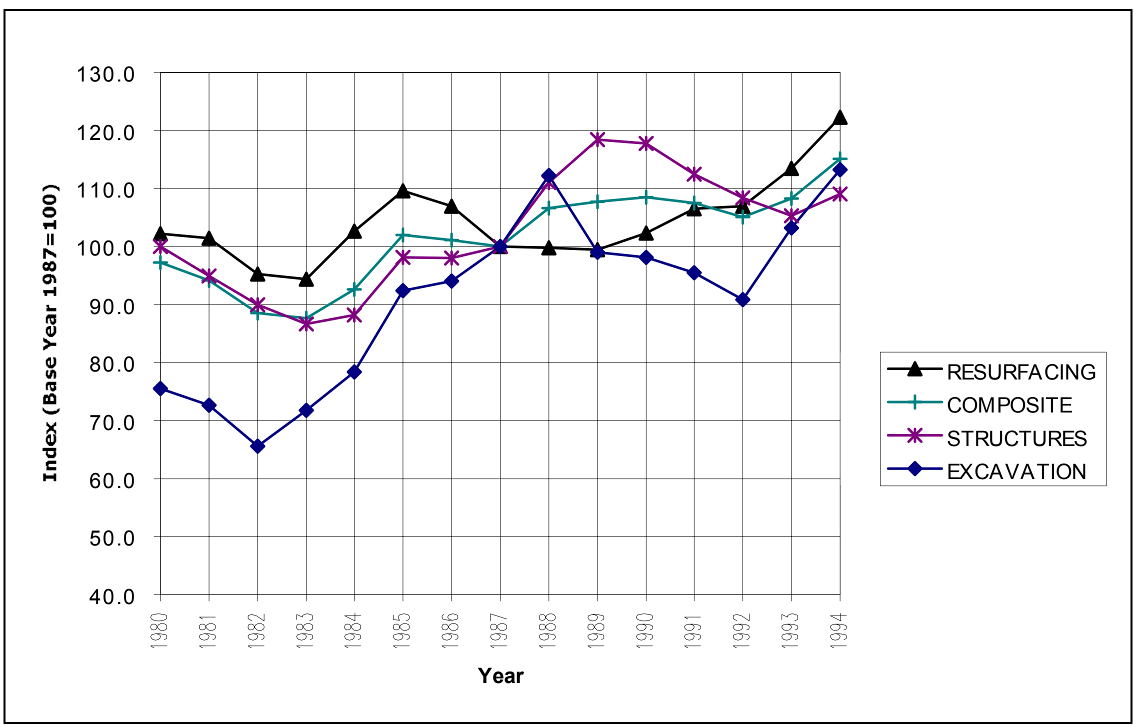


Figure 6-12. Prices for Selected Federal Highway Construction Activities: 1980 to 1994



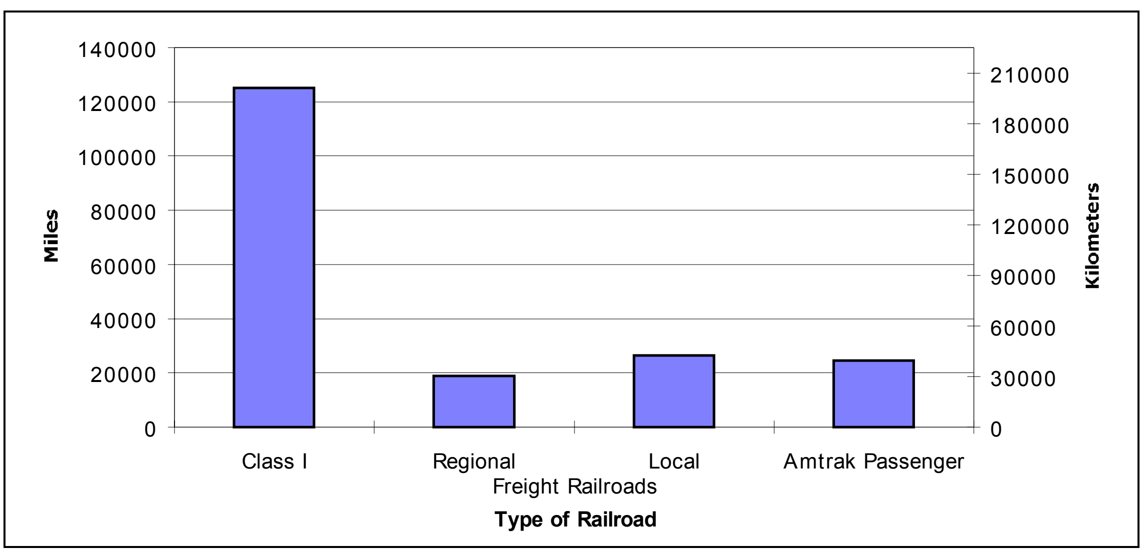
Railroad Transportation

The elements of the US rail system comprise rail tracks, operating equipment, and the additional capital and human resources necessary to produce freight and passenger services. This document focuses only upon rail track and associated infrastructure. For-hire rail freight is provided by a number of freight rail lines, and passenger service is the responsibility primarily of Amtrak. Other rail-related railroads services are classified under "transit" in this document. Railroads are not classified functionally, as are highways, but an approximate equivalent is found in terms of the main-line, secondary-main, and branch line classifications. However, these rail terms are not precise, and no time-series figures report changes in the extent of facilities for each category. The Association of American Railroads (AAR) uses the following definitions for freight railroads:

- Class I Railroads
- Regional Railroads
- Local Railroads

Class I railroads account for 73 percent of the nations rail mileage, and 91 percent of freight railroad revenue. In 1995, there were 201,241 kilometers (125,072 miles) of Class I railroads operated (this excludes multiple main tracks, yard tracks, and sidings), 30,273 kilometers (18,815 miles) of regional railroad, 42,713 kilometers (26,546 miles) of local railroad, and 39,421 kilometers (24,500 miles) of Amtrak railroad. There were 530 local and regional railroad carriers. This information is presented graphically in Figure 6-13.

Figure 6-13. Railroads Operated in 1995 by Type



Transit Transportation

In this document, transit is defined as encompassing commuter trains, heavy-rail (rapid rail) and light-rail (streetcar) transit systems, local transit buses, vans and other vehicles, and ferry boats. Most transit agencies that provide commuter rail service contract with private railroads or Amtrak to operate the service. Passenger use is split about equally between rail and non-rail systems. The operation of transit systems is overseen by public transit authorities. About 2,250 public agencies provided transit services in US cities of which approximately 6 percent operated one or more forms of rail mass transit. Many of the largest cities received service from several transit operators.

Capital expenses are moneys paid for transit infrastructure and its planning, design, land acquisition, and related costs. Data from the American Public Transit Association shows that in 1995, 25 percent of the $7.0 billion total went for vehicles, 53 percent for facilities, and 22 percent for equipment and services. 36 percent was spent on heavy rail, 26 percent on bus, 24 percent on commuter rail, 10 percent on light rail, and the remainder on other modes.

Operating expenses in 1995 were $18.1 billion. Buses accounted for 58 percent, heavy rail for 19.5 percent, commuter rail for 12 percent, demand response for 6 percent, light rail for 2 percent, and other modes for 2.5 percent. About ten percent of operating expenses were devoted to primary facilities maintenance. This figure has varied between about eight and ten percent of total operating expenses between 1985 and 1995.

Air Transportation

The elements of the air transportation system are airports, air traffic control and navigation aids, aircraft, pilots and other personnel, and suppliers of air passenger and freight services. This document focuses only upon airports and the air traffic control system for the development of baseline measures.

Data from the publication *Transportation Statistics Annual Report 1997* indicate that in 1995 there were a total of 18,224 airports in the US (a decline from 18,343 in 1994, but a substantial increase from the 15,161 operated in 1980). Private-use airports constitute 70 percent of these airports, and 96 percent of all airports are used by general aviation aircraft. There were 5415 public-use airports in 1995.

General aviation airports are usually rudimentary facilities; only about half have paved runways, and about one quarter have lighted runways. The number of civil certificated airports (serving air carrier operations with aircraft seating more than 30 passengers) is relatively stable at about 570. The majority of US airports are owned and operated by state and local public bodies. Several publicly owned US airports are operated by private bodies under a management contract. The National Airspace System (NAS), which is operated by the Federal Aviation Administration, comprises over 32,000 facilities and pieces of equipment, including air traffic control equipment, navigation and landing aids, automation systems, communications equipment, and FAA plant facilities. Operations funding for the NAS for FY1996 was $862,595,000, an increase of 2.7 percent from FY1995.[29]

Water Transportation

Water transportation includes domestic movements on the inland waterways, the Great Lakes, and along the coast, as well as between the contiguous 48 states and Alaska, Hawaii, Guam, Puerto Rico and the Virgin Islands. Water transport also encompasses international ocean shipments. Facilities include harbors and ports, channels, navigation aids, piers, wharves, cargo handling equipment, locks and dams, and storage facilities, as well as vessels of various types. This document focuses upon ports, waterways, and associated infrastructure for the development of baseline measures.

Data from the *Transportation Statistics Annual Report 1997* indicate that in 1995 there were 362 terminals on the Great Lakes with 507 berths, 1,811 inland terminals, and 1,578 ocean terminals with 2,672 berths. Of the 19,540 public and private deep-draft terminals at ocean and Great Lakes ports, approximately 75 percent were privately owned. General cargo berths made up 38 percent of all berths (e.g., for coal, grain, and ore) liquid berths made up 20 percent (e.g., for crude and refined petroleum) and passenger berths accounted for 3 percent. The remaining 18 percent were classified as other (e.g., berths for barges, mooring, or inactive). Data from the US Maritime Administration summarize US seaport terminals and berths by coastal region. Inland waterway ports and terminals generally have shallower water depths (4.3 meters/14 feet or less) and can be located on the 40,225 kilometers (25,000 miles) of navigable inland waterways and intracoastal waterways, providing more flexibility than coastal ports. In 1995, there were about 1,800 river terminals in 21 states, of which about 89 percent were privately owned. Of these terminals, approximately 4 percent were for general cargo, 58 percent were for dry bulk cargo, 27 percent were for liquid bulk cargo, and 11 percent were multipurpose.

Overview of the Power Utilities Sub-Sector

This sub-sector is primarily concerned with the production of electricity, gas, or steam from the primary fuel sources. The **1992 Census of Transportation, Communications, and Utilities** provides limited information about the amount of construction activity carried out by establishments in SIC code 49 (electric, gas, and sanitary services), as well as more detailed information about the size of establishments, revenues, and payroll costs. Electric services (SIC 491) includes all establishments engaged in the generation, transmission, and/or distribution of electric energy for sale. Gas production and distribution (SIC 492) includes all establishments involved in the transmission and/or storage of natural gas for sale. Combination utility services (SIC 493) includes all establishments engaged in providing electric or gas services in combination with other

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[29] Source: Management Advisory Memorandum on Resource Requirement Planning for Operating and Maintaining the NAS, FAA Report Number AS-FA-7-004 Jan 1997.

services. The number of establishments in the sub-sector in 1992 is shown in Table 6-4 (note that component figures made not add up to totals due to some establishments not being operated in 1992).

Information for the EIA report *Natural Gas Monthly April 1997*, provides a regional summary of natural gas interstate pipeline capacity and planned additions between 1995 and 2000. In 1995, the total pipeline capacity entering the US was 2,371 million cubic meters (83,746 million cubic feet) per day, while the total pipeline capacity within the US was 8,152 million cubic meters (287,918 million cubic feet) per day. Natural gas throughput in 1994 was about 1,529 million cubic meters (54,000 million cubic feet) per day (refer to source document for further details). Natural gas pipelines totaled 1,923,166 kilometers (1,195,000 miles) in 1994 (a slight decrease from 2,018,117 kilometers (1,254,000 miles) in 1992). Distribution lines account for three-quarters of this total mileage; transmission, field, and gathering lines make up the remaining quarter. Since 1980, the total length of gas pipeline has increased by 24 percent, but transmission pipeline length has only increased three percent over this period. In 1994, there were 150 interstate natural gas pipeline companies employing about 187,000 people. Approximately 19 percent of natural gas pipelines were built before 1950.

All other pipelines are considered in the pipelines sub-sector.

Table 6-4. Number of Establishments in the Power Utilities Sub-Sector: 1992

NUMBER OF ESTABLISHMENTS BY EMPLOYMENT SIZE: 1992					
		Employment Size			
SIC Code	**Total Establishments**	*9 or Fewer Employees*	*10-49 Employees*	*50-99 Employees*	*100 or More Employees*
491 - Electric Services	5,374	1,687	2,139	669	793
492 - Gas Production and Distribution	3,968	1,689	1,535	282	317
493 - Combination Utility Services	1,814	502	568	267	429

Overview of the Water Sub-Sector

The extent of the water sub-sector comprises water storage, supply, treatment, and flood control. Water transportation and related activities are considered in the transportation sub-sector.

The **1992 Census of Transportation Communications and Utilities** provides limited information on the amount of construction activity carried out by establishments in SIC Code 4941 (water supply), and SIC Code 4952 (sewerage systems). SIC code 4941 includes all establishments engaged in distributing water for sale for domestic, commercial, and industrial use. SIC code 4952 includes all establishments engaged in the collection and disposed of wastes conducted through a sewer system, including such treatment processes as may be provided. The number of establishments in the sub-sector in 1992 is shown in Table 6-5 (note that component figures made not add up to totals due to some establishments not being operated in 1992).

Table 6-5. Number of Establishments in the Water Sub-Sector: 1992

NUMBER OF ESTABLISHMENTS BY EMPLOYMENT SIZE: 1992					
		Employment Size			
SIC Code	**Total Establishments**	*9 or Fewer Employees*	*10-49 Employees*	*50-99 Employees*	*100 or More Employees*
4952 - Sewerage Systems	470	331	75	7	
4941 - Water Supply	3,453	2,934	285	75	

The USACE manages 383 major lakes and reservoirs, with a total capacity of 483,778 million cubic meters (392.2 million acre-feet). These include 68 projects with authorized irrigation storage, and 118 projects with authorized municipal and industrial water supply storage. USACE is also responsible for 75 hydro-power projects with an installed generating capacity of 20,720 megawatts. In 1994, these generated 68.2 billion kilowatt-hours, which represented about one quarter of total US hydropower capacity, or 3 percent of total US electric capacity. In addition, 67 non-federal power plants are operated at Corps facilities, with a capacity of 1,957 megawatts. The Corps also manages 13,679 kilometers (8,500 miles) of levees in the US. Total flood control expenditures between 1928-1993 in current dollars were $34.7 billion.

Overview of the Pipelines Sub-Sector

The extent of this sub-sector comprises all pipelines for the transportation of petroleum and other commodities except natural gas (included in the power utilities sub-sector).

The **1992 Census of Transportation Communications and Utilities** provides limited information on the amount of construction activity carried out by establishments in SIC code 46 (pipelines except natural gas), as well as more detailed information about the size of establishments, revenues, payroll costs, and so forth.

Pipelines includes SIC 4612 (crude petroleum pipelines), SIC 4613 (refined petroleum pipelines), and SIC 4619 (pipelines not elsewhere classified).

The number of establishments in the sub-sector in 1992 is shown in Table 6-6 (note that component figures may not add up to totals due to some establishments not being operated in 1992).

Table 6-6. Number of Establishments in the Pipelines Sub-Sector: 1992

NUMBER OF ESTABLISHMENTS BY EMPLOYMENT SIZE: 1992					
		Employment Size			
SIC Code	**Total Establishments**	*9 or Fewer Employees*	*10-49 Employees*	*50-99 Employees*	*100 or More Employees*
4612 - Crude Petroleum Pipelines	405	219	146	15	18
4613 - Refined Petroleum Pipelines	358	220	113	12	5
4619 - Pipelines not elsewhere classified	81	65	9	5	1

Oil pipeline mileage in the US in 1994 was 323,478 kilometers (201,000 miles) (a slight increase from 320,259 kilometers (199,000 miles) in 1992), but is below that which existed in 1980 350,836 kilometers (218,000 miles). Crude oil pipeline mileage decreased from 209,214 kilometers (130,000 miles) in 1980 to 183,465 kilometers (114,000 miles) in 1994 (while oil product line mileage fell slightly from 143,232 kilometers (89,000 miles) to 140,013 kilometers (87,000 miles) over the same period).

6.2. Baseline Measures

This section presents the baseline measures for the three non-residential sectors—commercial/institutional, industrial, and public works. These measures are based on a discontinued data series published by the US Bureau of the Census, and aggregated project-level data made available by the Construction Industry Institute.

The Census data cover the elapsed time from the start of construction until the completion of construction. The Census data do not include any estimates of the amount of time required for the permitting process. Although different data sources are used as the primary source for non-residential delivery time statistics, the Census data are used as a reference point and for purposes of comparison.

As discussed in Chapter 3 of this document, the Construction Industry Institute (CII) has provided the authors with detailed information regarding delivery time information for all three non-residential sectors. Consequently, because the Census data series has been discontinued and the CII data are quite detailed, the CII data are used as the primary source to establish the delivery time baselines for the three non-residential sectors. The key CII-defined metrics which are used to produce the baseline measures presented in this section are summarized in Table 3-8 (see Section 3.4). Table 3-8 includes both the formulas that represent each metric mathematically and the definitions of all the terms used in each formula.

6.2.1. Measures Based on US Bureau of Census Data

Prior to 1993, non-residential delivery time statistics were published as an annual supplement in the October edition of the C30 report. These statistics provide information on the average length of time in months from start of construction until completion. However, since October 1992, no non-residential delivery time statistics have been published by the US Bureau of the Census.

The October 1992 C30 supplement presents data on the monthly progress of non-residential construction projects completed in 1990 and 1991. These data are based on samples from two major groupings: (1) privately owned non-residential building projects; and (2) state and locally owned projects. The estimates of construction duration (in months) presented in the October 1992 C30 supplement are based on a sample of 5,833 privately owned non-residential building projects and a sample of 5,785 state and locally owned projects.

Both privately owned non-residential projects and state and locally owned projects are classified into one of six value categories. These value categories are: (1) $10 million or more; (2) $5 million to $10 million; (3) $3 million to $5 million; (4) $1 million to $3 million; (5) $250 thousand to $1 million; and (6) less than $250 thousand. Projects with values of less than $50,000 are not included.

Projects are then classified by type of structure. Due to differences in the mix of projects between privately owned non-residential projects and state and locally owned projects, there are differences in the type of structure listed under each major grouping. Privately owned non-residential projects are classified into six basic types: (1) all types; (2) industrial; (3) office; (4) other commercial; (5) hospital and institutional; and (6) other non-residential buildings. State and locally owned projects are first classified into two major categories: (1) buildings; and (2) non-building. Building related projects are then classified by type as: (1) educational; (2) hospital; and (3) other buildings. Non-building related projects are then classified by type as: (1) highways and streets; (2) conservation and development; (3) sewer systems; (4) water supply; and (5) other non-building.

Estimated averages for the number of months it takes from start of construction until completion for privately owned non-residential building projects are shown in Figures 6-14 through 6-18 and in Table 6-7. Figures 6-14 through 6-18 are designed to illustrate different perspectives on construction duration for privately owned projects. Each figure is a bar chart recording the average construction duration in months on the vertical axis. The horizontal axis records either the project value category or the type of project.

Figure 6-14 combines all project types and then classifies each project into a value category. The figure also includes an "All Values" category, which is the grand average across all project types and all project values. Figure 6-14 records the construction duration in months on the vertical axis and the project value category on the horizontal axis. Construction duration for the "All Values" category is approximately 15 months. The figure demonstrates how average construction duration in months declines as project value declines. For example, projects valued at $10 million or more take nearly 25 months to complete, while the average project valued at less than $250 thousand takes less than 5 months.

Figure 6-14. Average Number of Months from Start of Construction to Completion by Project Value: All Private Non-Residential Building Projects Completed in 1990-91

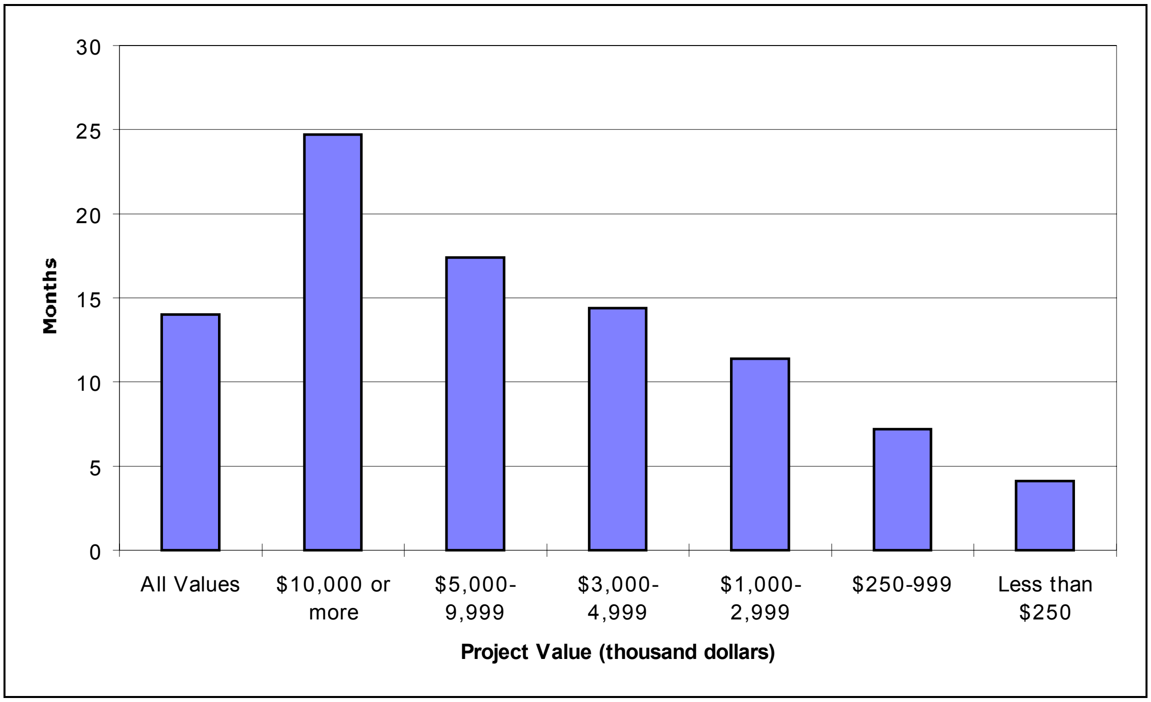


Figure 6-15 illustrates how the type of project affects construction duration for a given value category. All privately owned projects valued at $10 million or more are summarized in the figure. Figure 6-15 records the construction duration in months on the vertical axis and the type of project on the horizontal axis. Reference to the figure shows that hospital and institutional projects have the longest construction duration (more than 30 months) and industrial and other commercial buildings have the shortest construction duration. The second row of Table 6-7 provides the raw data on all projects valued at $10 million or more which were used to create Figure 6-15.

Figure 6-16 provides information on construction duration for private industrial projects. The figure shows some of the same information as was shown in Figure 6-15, namely that industrial projects valued at $10 million or more averaged about 22 months to complete. The figure also exhibits a sharp decline followed by a tapering off in construction duration as project value declines past the $10 million or more value category. Reference to Table 6-7 shows that the average industrial project in the $10 million or more category was valued at $56.4 million. Thus the difference in project value between the average project in the $10 million or more category and the $5 to $10 million category is very large. This large difference in project value helps to explain why reductions in construction duration as project value declines past the $10 million or more value category do not drop as quickly as was seen in Figure 6-14.

Figure 6-15. Average Number of Months from Start of Construction to Completion for Projects Costing $10 Million or More by Type of Project: All Private Non-Residential Building Projects Completed in 1990-91

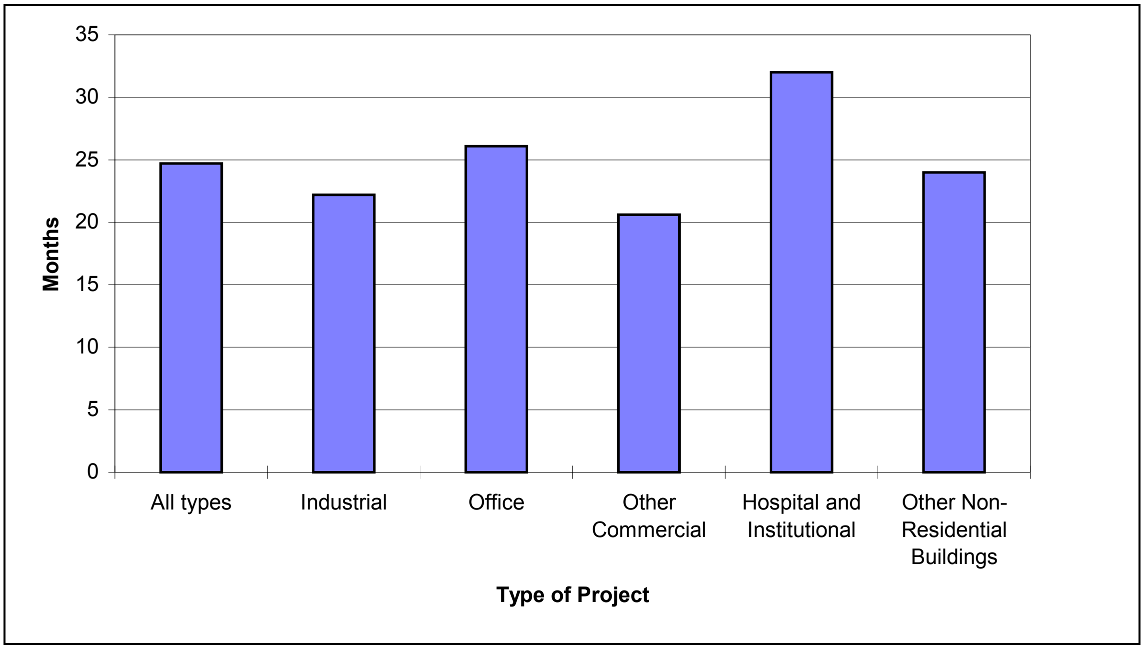
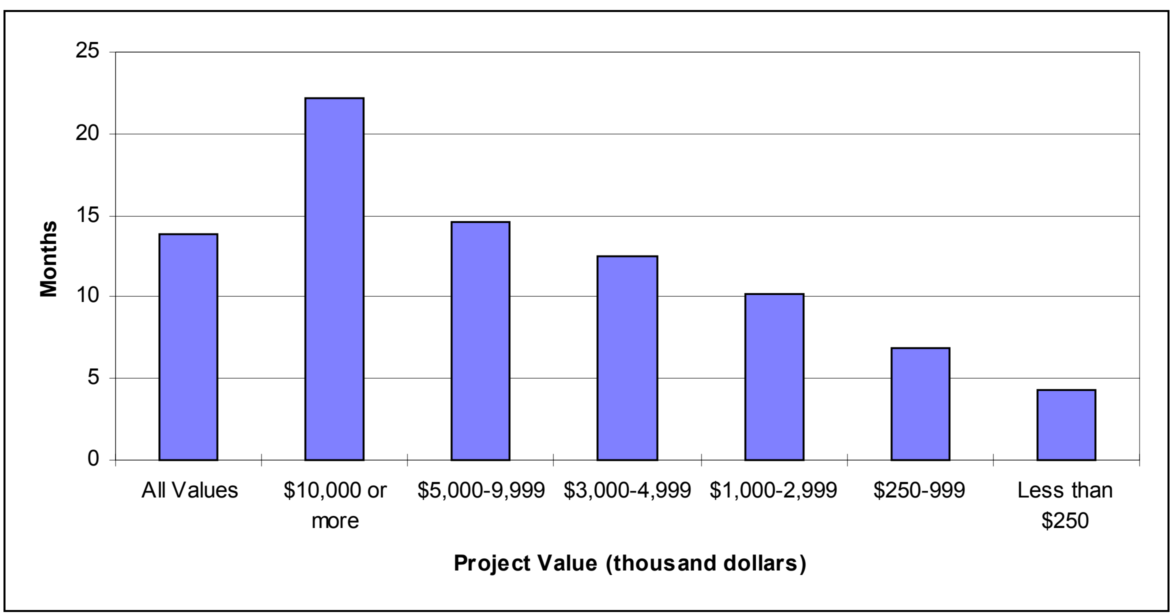


Figure 6-16. Average Number of Months from Start of Construction to Completion by Project Value: Private Industrial Building Projects Completed in 1990-91



Comparison between Figures 6-15 and 6-16 and reference to Table 6-7 reveals an interesting outcome. Table 6-7 reveals that the average industrial project in the $10 million or more category was valued at $56.4 million. This is in sharp contrast to the other building types in the $10 million or more category, which averaged between $22.7 million and $31.6 million. Although large industrial projects (i.e., those valued at $10 million or more) are valued at almost twice as much as other privately owned non-residential buildings, they are on average constructed in a very short period of time.

Figure 6-17 provides information on construction duration for private office building projects completed in 1990 and 1991. The figure shows some of the same information as was shown in Figure 6-15, namely that office building projects valued at $10 million averaged about 26 months to complete. The figure also exhibits a sharp decline in construction duration as project value declines. Reference to Table 6-7 shows that construction duration dropped by almost 9 months between the $10 million or more value category and the $5 million to $10 million value category. Subsequent declines were much lower, although there is a fairly sharp decline associated with projects valued at less than $1 million.

Figure 6-18 provides information on construction duration for private hospital and institutional building projects completed in 1990 and 1991. Recall that large hospital and institutional building projects (i.e., those valued at $10 million or more) had the longest construction duration (see Figure 6-15). The figure shows that hospital and institutional building projects valued at $10 million or more averaged about 32 months to complete (see also Table 6-7). Figure 6-18 also exhibits a sharp decline in construction duration as project value declines. Reference to Table 6-7 shows that construction duration dropped by more than 10 months between the $10 million or more value category and the $5 million to $10 million value category. Subsequent declines were much lower, although there is a fairly sharp decline associated with projects valued at less than $1 million.

Table 6-7 provides a summary of all of the data used to produce Figures 6-14 through 6-18. Information on project value (in thousands of dollars) is recorded in the left most column of the table. The remainder of the table summarizes two types of information for each type of project. This information is recorded under the six remaining column headings of the table. The first type of information records construction duration in months. This information is recorded in the first seven rows of the table. For example, the average industrial project valued at between $5 and $10 million (i.e., the third row of the table) took 14.6 months to complete. Going across the third row reveals that a commercial office building in the $5 to $10 million category took 17.7 months to complete and a hospital and institutional building took 21.2 months to complete. The second type of information records the average value of projects in the $10 million or more category. This information is contained in the last row of the table. For example, project values were $56.4 million for industrial projects versus $30.9 for commercial office buildings and $22.7 million for hospital and institutional buildings.

Figure 6-17. Average Number of Months from Start of Construction to Completion by Project Value: Private Office Buildings Completed in 1990-91

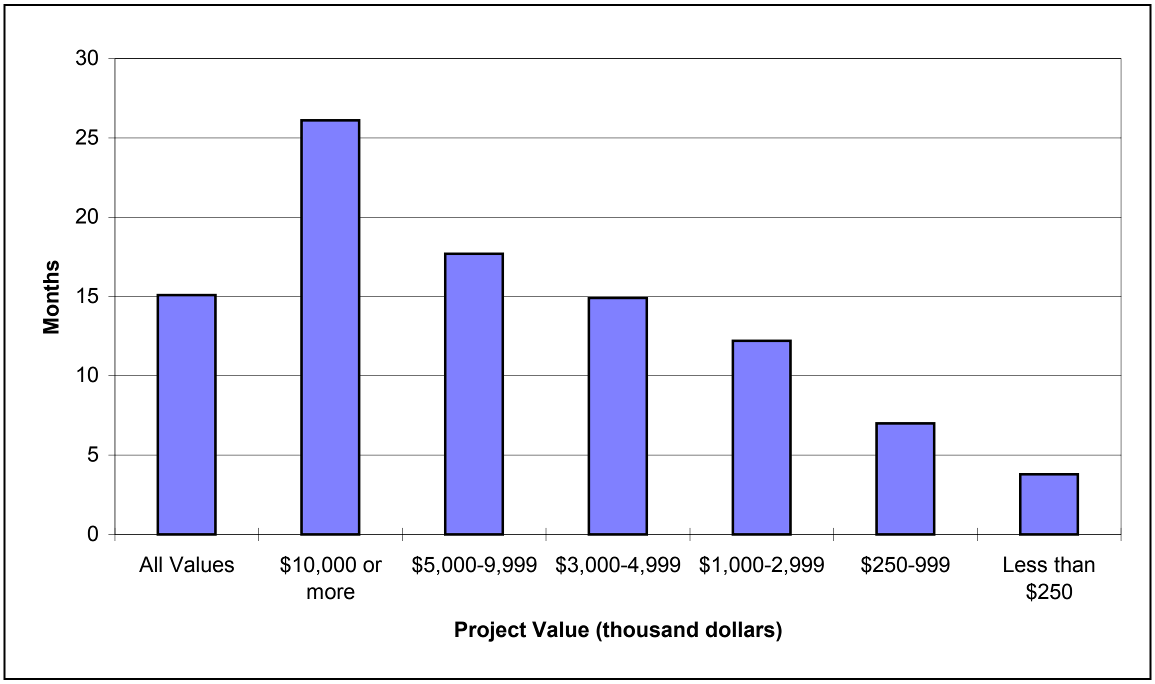


Figure 6-18. Average Number of Months from Start of Construction to Completion by Project Value: Private Hospital and Institutional Building Projects Completed in 1990-91

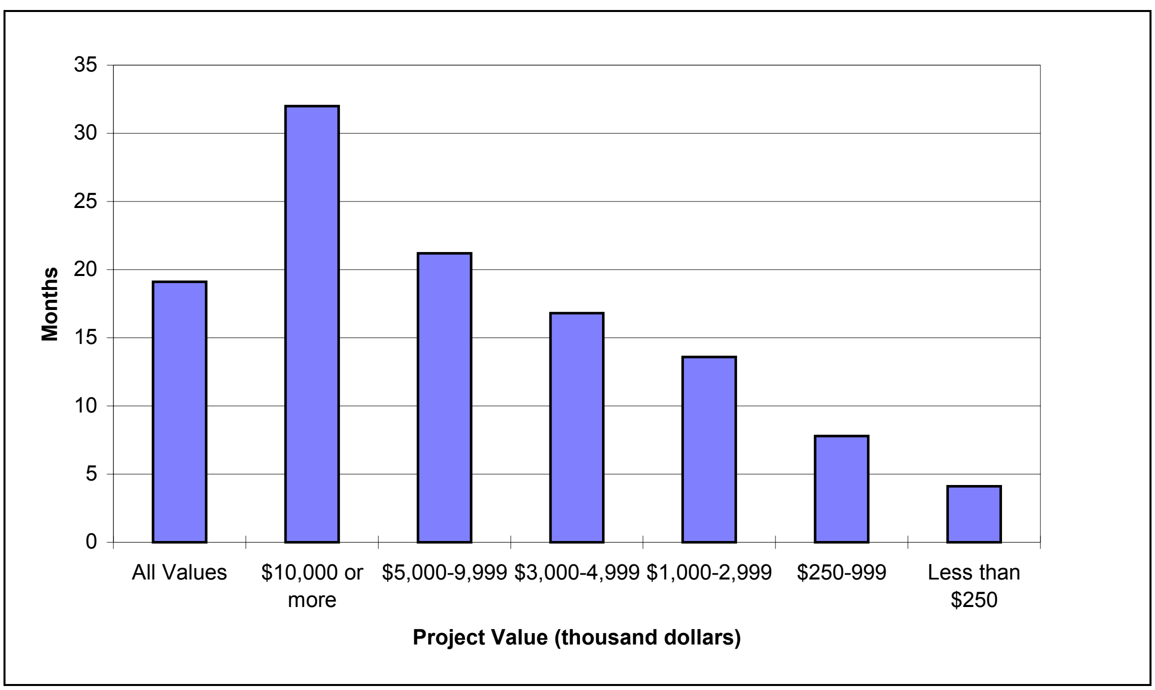


Table 6-7. Average Number of Months from Start of Construction to Completion by Value of Project and Type of Structure: Private Non-Residential Projects Completed in 1990-91

	Average Number of Months by Type of Structure					
Value of Project (thousand dollars)	All types	Industrial	Office	Other Commercial	Hospital and Institutional	Other Non-Residential Buildings
All Values	14.0	13.8	15.1	10.9	19.1	14.4
$10,000 or more	24.7	22.2	26.1	20.6	32.0	24.0
$5,000-9,999	17.4	14.6	17.7	15.4	21.2	18.9
$3,000-4,999	14.4	12.5	14.9	12.3	16.8	15.8
$1,000-2,999	11.4	10.2	12.2	10.3	13.6	12.3
$250-999	7.2	6.9	7.0	6.6	7.8	8.2
Less than $250	4.1	4.3	3.8	3.8.	4.1	4.9
	Average Value of Projects Costing $10 Million or More in Millions of Dollars by Type of Structure					
$10,000 or more	33.8	56.4	30.9	23.8	22.7	31.6

Estimated averages for state and locally owned projects are shown in Figures 6-19 through 6-24 and in Table 6-8. Figures 6-19 through 6-24 are designed to illustrate different perspectives on construction duration for state and locally owned projects. Each figure is a bar chart recording the average construction duration in months on the vertical axis. The horizontal axis records either the type of project or the project value category.

Figure 6-19 illustrates how the type of project affects construction duration for a given value category. All state and locally owned projects valued at $10 million or more are summarized in the figure. Figure 6-19 records the construction duration in months on the vertical axis and the type of project on the horizontal axis. Reference to the figure shows that hospital projects have the longest construction duration (nearly 40 months) and conservation and development projects have the shortest construction duration. The second row of Table 6-8 provides the raw data on all projects valued at $10 million or more that were used to create Figure 6-19.

Figures 6-20 and 6-21 record project duration information for building related projects. The vertical axis of each figure records construction duration in months and the horizontal axis records the project value category. Figure 6-20 records information on educational projects, whereas Figure 6-21 records information on hospital projects. Figure 6-20 reveals that educational projects exhibit a steady decline in construction duration as project value declines. Figure 6-21, on the other hand, exhibits a flatter relationship between construction duration and project value.

Figures 6-22, 6-23, and 6-24 record project duration information for non-building related projects. The vertical axis of each figure records construction duration in months and the horizontal axis records the project value category. Figure 6-22 records information on highways and streets projects. Figure 6-23 records information on sewer systems projects. Figure 6-24 records information on water supply projects. All three figures reflect a strong negative relationship between construction duration and project value (i.e., as project value declines construction duration declines). Although all three project types exhibit a negative relationship between construction duration and project value, the difference in duration between the $10 million or more category and the $5 to $10 million category are most pronounced for highways and streets projects and water supply projects.

Table 6-8 provides a concise summary of all of the data used to produce Figures 6-19 through 6-24. Information on project value (in thousands of dollars) is recorded in the left most column of the table. This information is recorded in the seven rows of the table. The remainder of the table summarizes construction duration information for each of the two major categories: (1) buildings; and (2) non-buildings. For example, the average educational facility valued at $5 to $10 million took 22.7 months to complete and a similarly valued hospital building took 29.3 months to complete.

Figure 6-19. Average Number of Months from Start of Construction to Completion for Projects Costing $10 Million or More by Type of Project: State and Local Non-Residential Projects Completed in 1990-91

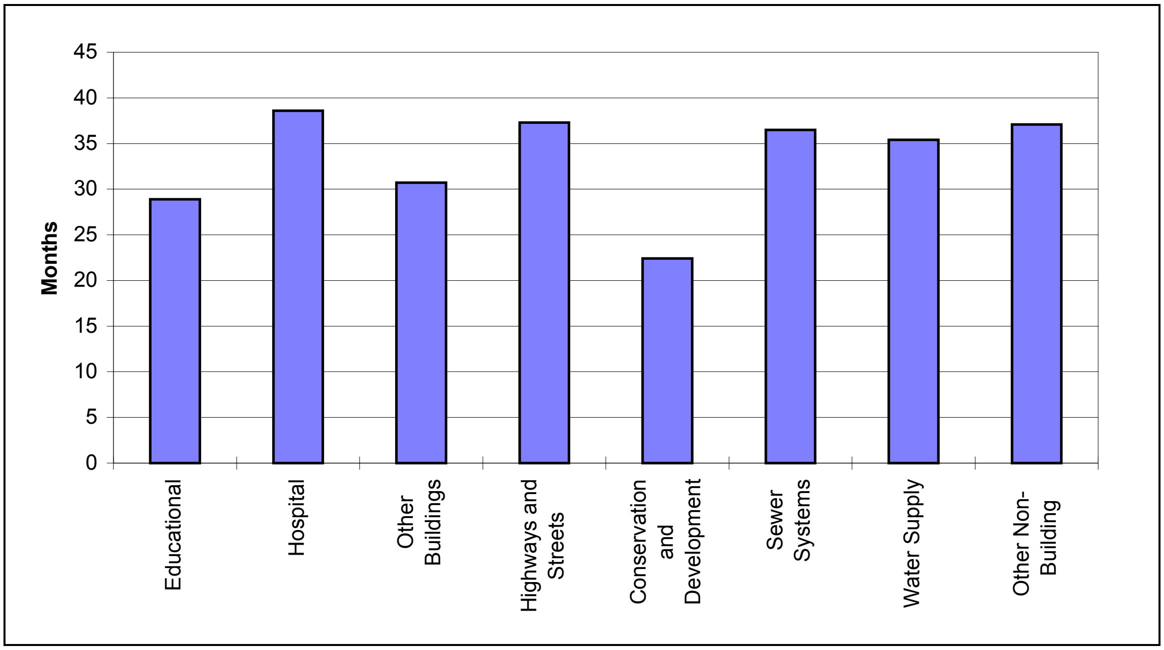


Figure 6-20. Average Number of Months from Start of Construction to Completion by Project Value: State and Local Educational Projects Completed in 1990-91

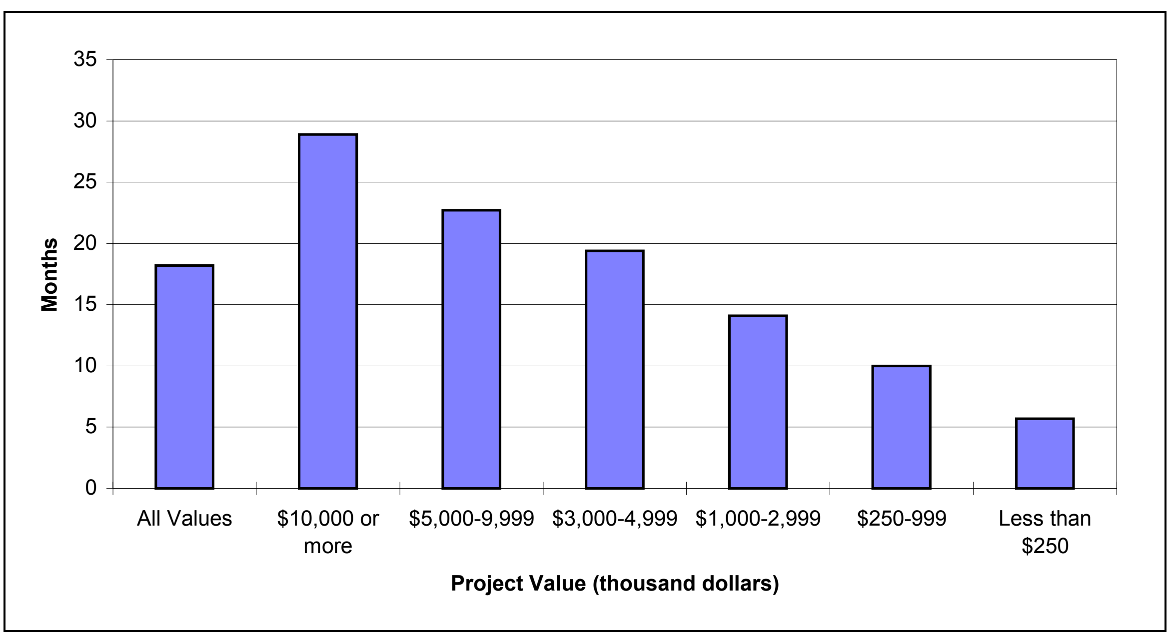


Figure 6-21. Average Number of Months from Start of Construction to Completion by Project Value: State and Local Hospital Projects Completed in 1990-91

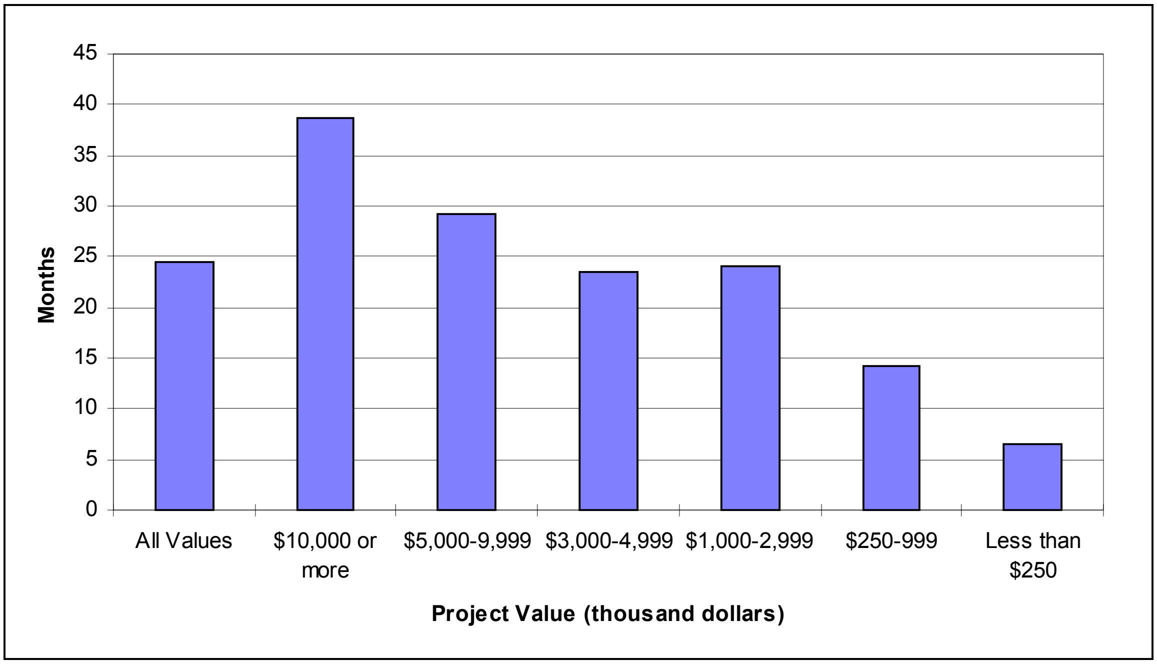


Figure 6-22. Average Number of Months from Start of Construction to Completion by Project Value: State and Local Highways and Streets Projects Completed in 1990-91

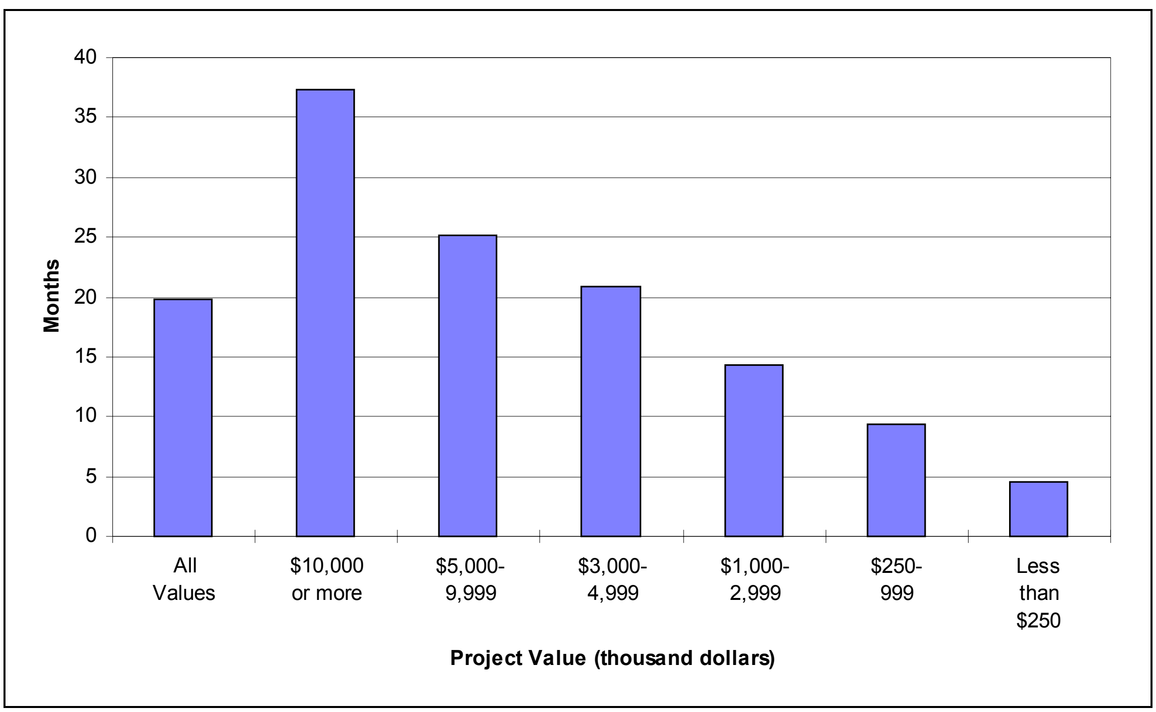


Figure 6-23. Average Number of Months from Start of Construction to Completion by Project Value: State and Local Sewer Systems Projects Completed in 1990-91

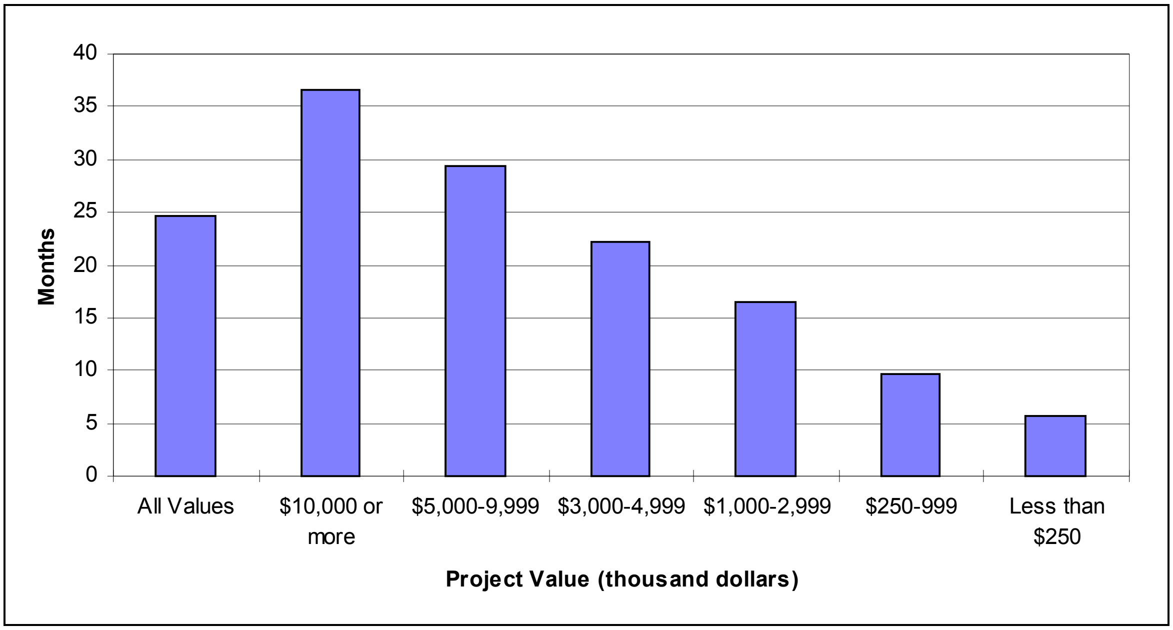


Figure 6-24. Average Number of Months from Start of Construction to Completion by Project Value: State and Local Water Supply Projects Completed in 1990-91

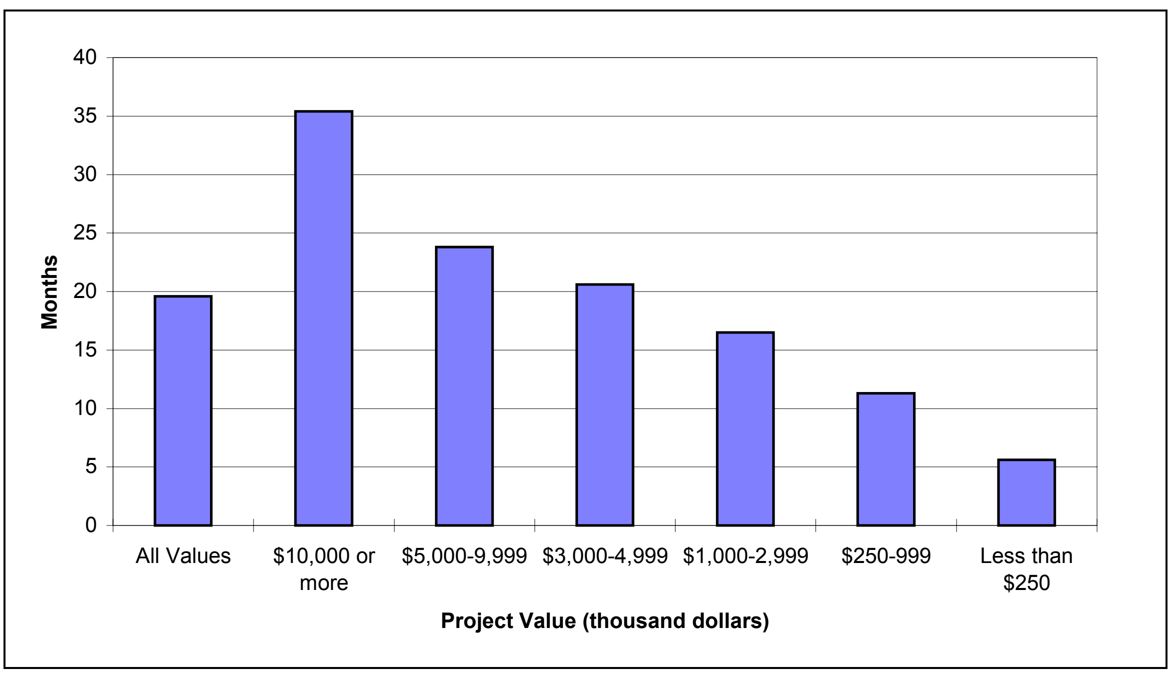


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Table 6-8. Average Number of Months from Start of Construction to Completion by Value of Project and Type of Structure: State and Local Projects Completed in 1990-91

Value of Project (thousand dollars)	Average Number of Months by Type of Structure							
	Buildings			Non-Building				
	Educational	Hospital	Other Buildings	Highways and Streets	Conservation and Development	Sewer Systems	Water Supply	Other Non-Building
All Values	18.2	24.5	22.1	19.8	14.5	24.6	19.6	21.4
$10,000 or more	28.9	38.6	30.7	37.3	22.4	36.5	35.4	37.1
$5,000-9,999	22.7	29.3	24.2	25.1	20.5	29.3	23.8	28.0
$3,000-4,999	19.4	23.4	19.7	20.9	18.6	22.1	20.6	17.3
$1,000-2,999	14.1	24.1	16.5	14.3	12.9	16.5	16.5	16.7
$250-999	10.0	14.3	10.9	9.3	11.2	9.7	11.3	11.5
Less than $250	5.7	6.6	6.5	4.6	6.0	5.6	5.6	6.1

6.2.2. Measures Based on Construction Industry Institute (CII) Data

Data from CII are used to produce estimates for delivery time statistics for the three non-residential sectors. The CII data are used in this document because CII has committed itself to an annual cycle of surveying its member companies, collecting data on an individual project basis, analyzing these data, and publishing its findings. CII's frequency for publishing these data and the methods of data collection meet the criteria established in Chapter 2. In addition, the CII data used in this document include estimated values for four key statistical measures: (1) the 75^{th} percentile; (2) the mean; (3) the median; and (4) the 25^{th} percentile. Because these four measures cover the full interquartile range (i.e., the middle 50 percent of the data) for each subset of the overall CII data set, they provide a wealth of information. The mean—the arithmetic average—and the median—the middle value—are statistical measures of central tendency. These measures of central tendency provide opportunities for comparing the CII data to the Census data described in the previous subsection. The 75^{th} and 25^{th} percentiles provide a measure of variability. They also serve to point out opportunities for performance assessment. For example, users of this document can plot their own project data on the figure of interest to measure their projects' performance against the performance of similar projects in the CII data set.

A limitation of the CII data is that they may not be representative of construction industry "averages" for the three non-residential sectors. This caveat is based on the assumption that CII member companies *may be more aggressively pursuing* performance improvement measures than companies that are not members of CII. Thus the baseline measures derived from these data *may be skewed towards the "best practice" end* of the non-residential construction project spectrum. This concern is mitigated in part by reporting both measures of central tendency and the full interquartile range. A second limitation of the *current* CII data set is that it does not include the full range of structure types included in the Census data (e.g., office buildings, hospitals, and educational facilities for the commercial/institutional sector). However, as more data become available to CII, new subsets providing such detail will be reported. It is worth noting that in some areas the CII data set already provides a finer level of detail than the Census data. For example, the CII data set separates heavy industrial and light industrial projects. Both project groupings were included under the single heading "Industrial" in the Census data. Furthermore, for the heavy industrial grouping, CII already reports data on the following subsets: (1) chemical manufacturing and (2) oil refining.[30]

It is important to note that the CII data include estimates of both total project duration and construction phase duration. Thus, the CII data captures a more complete meaning of delivery time than is provided by an estimate of construction phase duration. However, to facilitate comparisons with the Census data described in the previous subsection, estimates of the construction phase duration are included in this subsection.

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[30] Construction Industry Institute. 1998. *Benchmarking and Metrics Data Report for 1997*. Austin, TX: Construction Industry Institute.

The CII data set also contains information on metrics related to schedule growth and the relationship between the use of best practices and key delivery time metrics. Both sets of information are discussed in this document.

The material presented in this subsection is organized around a series of figures and tables. To facilitate comparisons among the various CII data subsets, Figures 6-25 through 6-42 are arranged in a sequence and use an identical format for data representation. The CII data subset sequence used in this subsection employs the following three major headings: (1) industry group subsets (i.e., buildings, heavy industrial, light industrial, and infrastructure); (2) cost categories ($million) subsets (i.e., <$15, $15-$50, $50-$100, and >$100); (3) project nature subsets (i.e., grass roots, addition, and modernization). Within each figure, the CII data subsets for each major heading are listed on the horizontal axis. The vertical axis records the corresponding value of a response variable, such as total project duration in months. For each subset, four key statistical measures are plotted on the figure: (1) the 75th percentile, represented by a square (■); (2) the mean, represented by a diamond (◆); (3) the median, represented by a triangle (▲); and the 25th percentile, represented by an x (×).

The data plotted on Figures 6-25 through 6-42 are recorded in Tables 6-9 through 6-26. The tables follow the same CII data subset sequence as the figures. For example, the data for Figure 6-25 are found in Table 6-9, the data for Figure 6-26 are found in Table 6-10, and the data for Figure 6-27 are found in Table 6-11.

6.2.2.1. Metrics Related to Total Project Duration

The CII data set is unique in that it includes a fairly comprehensive measure of delivery time for all three non-residential sectors. This measure corresponds to CII's metric total project duration. Total project duration starts at the beginning of the design phase and ends with the custody transfer to the user/operator (see Table 3-7 for additional definitions and descriptions of CII project phases). Total project duration is measured in months. The data presented in this subsection covers four of the five CII project phases (i.e., all but the pre-project planning phase). Because a contractor is not usually involved in all of these phases, only data from owners are used to calculate total project duration.

Figure 6-25 records total project duration by industry group. The data used to construct Figure 6-25 are recorded in Table 6-9. Reference to the figure reveals that the interquartile range is much wider for buildings and light industrial projects than for heavy industrial and infrastructure projects. On average, these projects also take longer to complete (38.9 months for buildings and 24.4 months for light industrial) than the subset of heavy industrial (21.2 months) and infrastructure (21.0 months) projects. The mean values recorded in Table 6-9 are used to define the baseline measures for each of the four CII data sets.

Figure 6-25. Total Project Duration by Industry Group

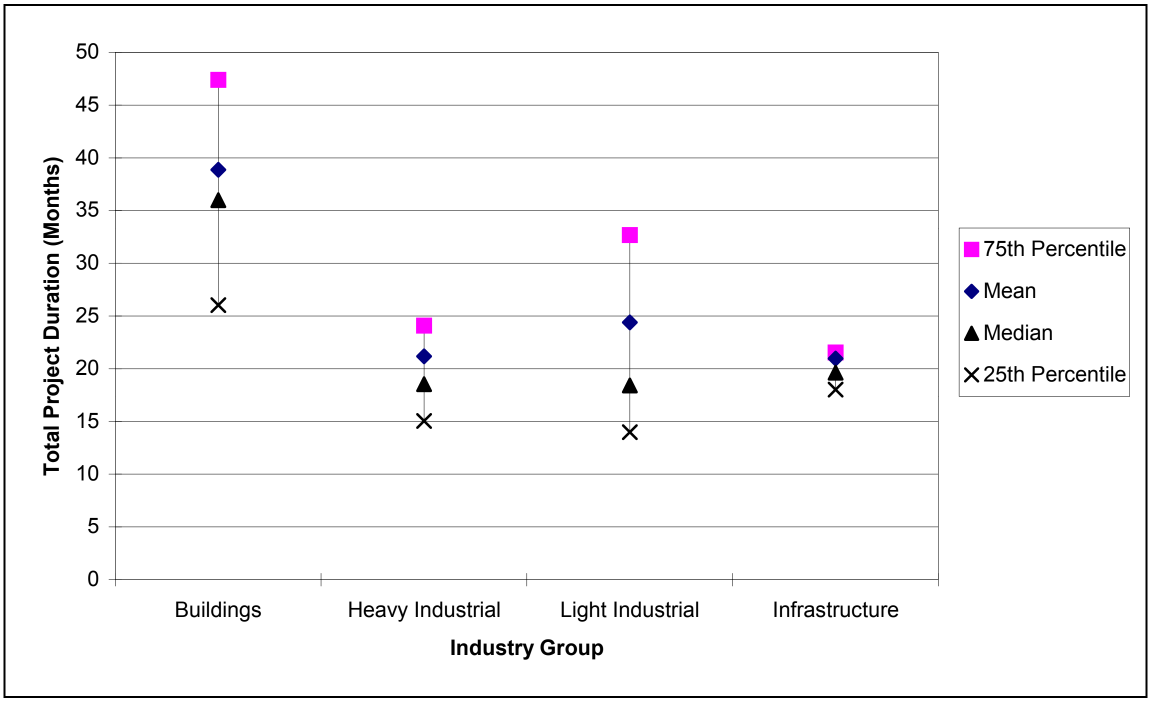


Table 6-9. Total Project Duration: Number of Months by Industry Group

Statistical Measure	Number of Months by Industry Group			
	Buildings	Heavy Industrial	Light Industrial	Infrastructure
75th Percentile	47.4	24.1	32.7	21.5
Mean	38.9	21.2	24.4	21.0
Median	36.0	18.5	18.4	19.6
25th Percentile	26.0	15.0	14.0	18.0

Figure 6-26 and Table 6-10 show how project cost affects total project duration. The following observations provide a better understanding of this relationship. First, the mean value of total project duration increases steadily as project cost increases. This relationship is to be expected since higher cost usually entails greater complexity (e.g., more labor, materials, and subcontractors). Second, for large projects (i.e., those costing in excess of \$100 million), the median value (30.6 months) is approaching the mean value (32.3 months). For projects costing less than \$100 million, the median value is well below the mean value. In addition, the mean is closer to the 75th percentile and the median is closer to the 25th percentile than they are to each other. This is possibly due to a small group of "exemplary" projects below the 25th percentile and a small group of "problem" projects tailing off above the 75th percentile. Third, the width of the interquartile range is much greater for projects costing in excess of \$100 million than for projects costing less than $100 million. Furthermore, the width of the interquartile range for projects costing less than $100 million is approximately 11 months for each of the three cost categories. The increasing complexity of large projects and the presence of mega projects (i.e., those costing more than $500 million) are potential sources of the greater width of the inter-quartile range.

Figure 6-26. Total Project Duration by Cost Category

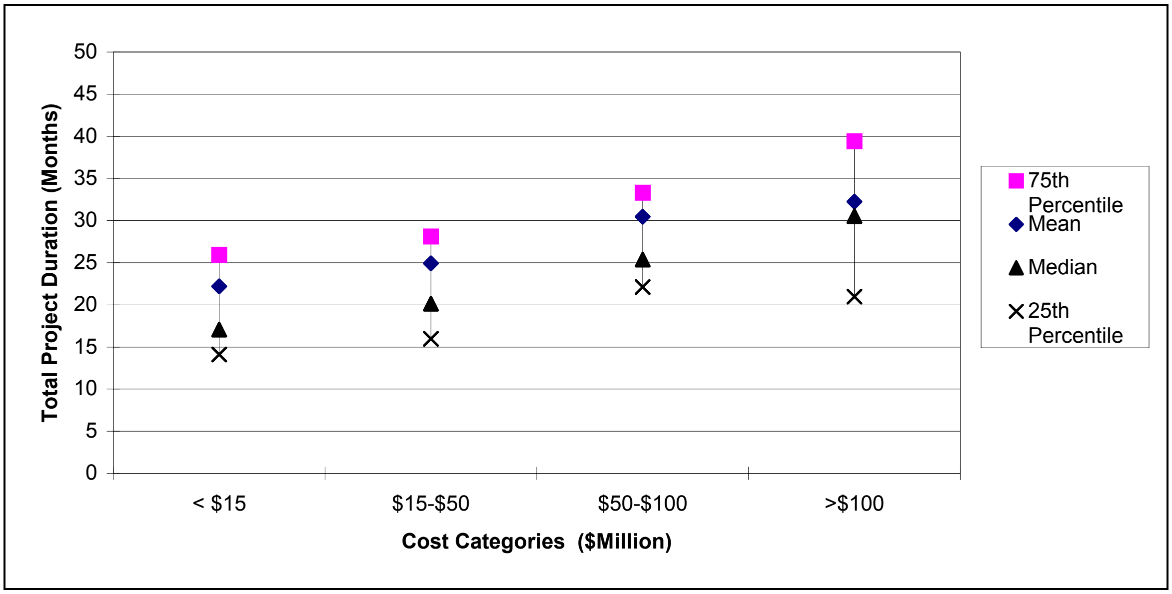


Table 6-10. Total Project Duration: Number of Months by Cost Category

Statistical Measure	Number of Months by Cost Category (Million Dollars)			
	< $15	$15-$50	$50-$100	>$100
75th Percentile	25.9	28.1	33.3	39.4
Mean	22.2	24.9	30.5	32.3
Median	17.1	20.2	25.4	30.6
25th Percentile	14.1	16.0	22.1	21.0

Figure 6-27 and Table 6-11 show how project nature affects total project duration. Reference to the figure reveals that new construction—"grass roots"—projects exhibit the greatest variability. Grass roots projects also take the longest to complete. Total project duration for additions is, on average, the shortest of the three, followed by modernization projects.

Figure 6-27. Total Project Duration by Project Nature

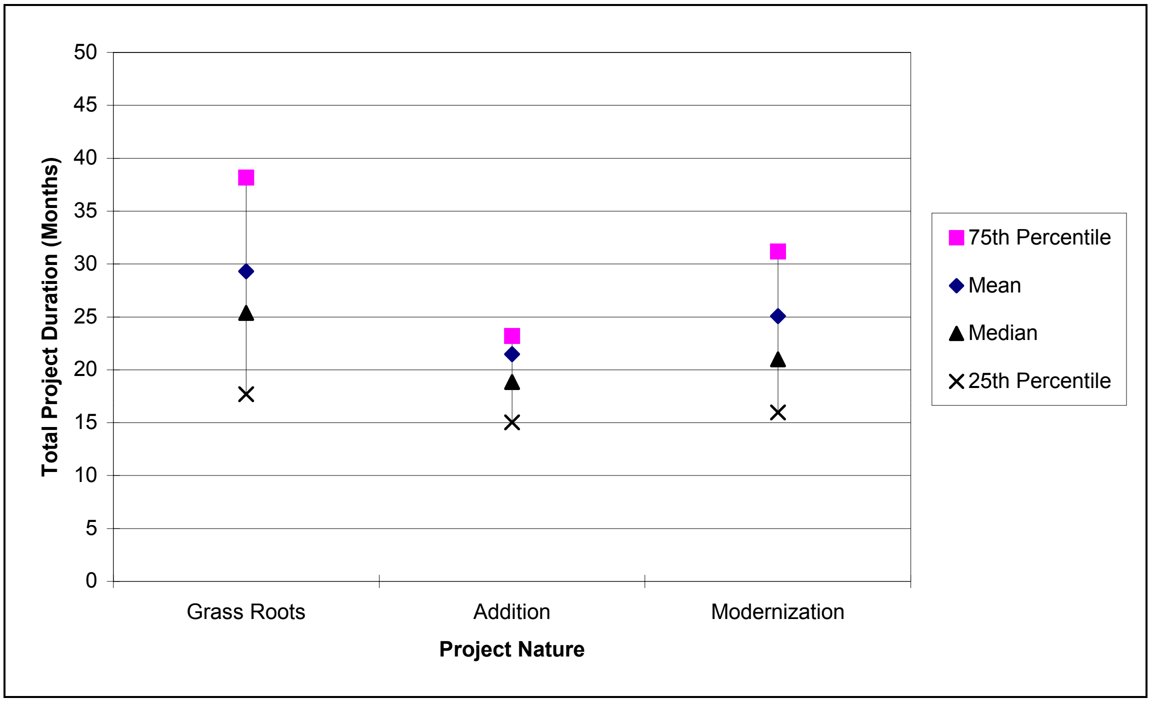


Table 6-11. Total Project Duration: Number of Months by Project Nature

Statistical Measure	Number of Months by Project Nature		
	Grass Roots	Addition	Modernization
75th Percentile	38.2	23.2	31.2
Mean	29.3	21.5	25.1
Median	25.4	18.8	21.0
25th Percentile	17.7	15.0	16.0

6.2.2.2. Metrics Related to the Construction Phase Only

This subsection provides the opportunity to compare some of the CII data sets with published data from the US Bureau of the Census. Figure 6-28 and Table 6-12 record information on construction duration for buildings, heavy industrial, light industrial, and infrastructure projects. These data are based on an aggregate set of data from both CII owner members and contractors who are involved in the construction phase (i.e., contractors performing design services only are not included). Consequently, these data exhibit somewhat different trends than the data on total project duration which were for

CII owner members only. Reference to the figure reveals that buildings and infrastructure projects take, on average, the longest to construct.[31] On average, heavy and light industrial projects take about the same amount of time to construct.

Comparisons between Table 6-12 and Tables 6-7 and 6-8 reveal that the average (i.e., the mean) construction phase duration for CII projects is shorter than the average construction phase duration for the private and state and local projects collected by the Census. Reference to Table 6-7 reveals that industrial projects valued at $10 million or more took 22.2 months to construct and a commercial office building valued at $10 million or more took 26.1 months to construct. The corresponding figures from the CII data base are 17.1 months and 23.7 months, respectively. Reference to Table 6-8 reveals that infrastructure projects valued at $10 million or more took between 22.4 and 37.3 months to construct. The mean value for all infrastructure projects from the CII data base is 21.0 months. Thus, for all three non-residential sectors, the CII projects tend to exhibit shorter construction times than those from which the Census collected data. It is also worth noting that the Census projects are from the 1990-1991 time period while the CII data are from the 1996-1997 time period. Consequently, some of the differences may be explained by improved project execution technologies available to the CII projects which were not available to the projects collected by the Census.

Figure 6-29 and Table 6-13 show how project cost affects construction phase duration. The following observations provide a better understanding of this relationship. First, the mean value of the construction phase duration increases steadily as project cost increases. This relationship is to be expected since higher cost usually entails greater complexity (e.g., more labor, materials, and subcontractors). Second, as project cost increases, the mean and median values are spreading further apart. For projects costing $50 million or more, the median value is well below the mean value. In addition, the mean is closer to the 75th percentile and the median is closer to the 25th percentile than they are to each other. This is possibly due to a small group of "exemplary" projects below the 25th percentile and a small group of "problem" projects tailing off above the 75th percentile.

[31] Recall that that buildings had the longest total project duration and infrastructure projects had the shortest (see Figure 6-25 and Table 6-9). Thus, one might expect buildings to have the longest construction phase duration. One reason why infrastructure projects have changed their position, is the relatively short duration for the design, procurement, and start up phases for infrastructure projects. Another reason is that the bulk of the infrastructure projects in the CII data base are submitted by contractors rather than owners. Thus, the mix of projects may be one source of the observed change in position.

Figure 6-28. Construction Phase Duration by Industry Group

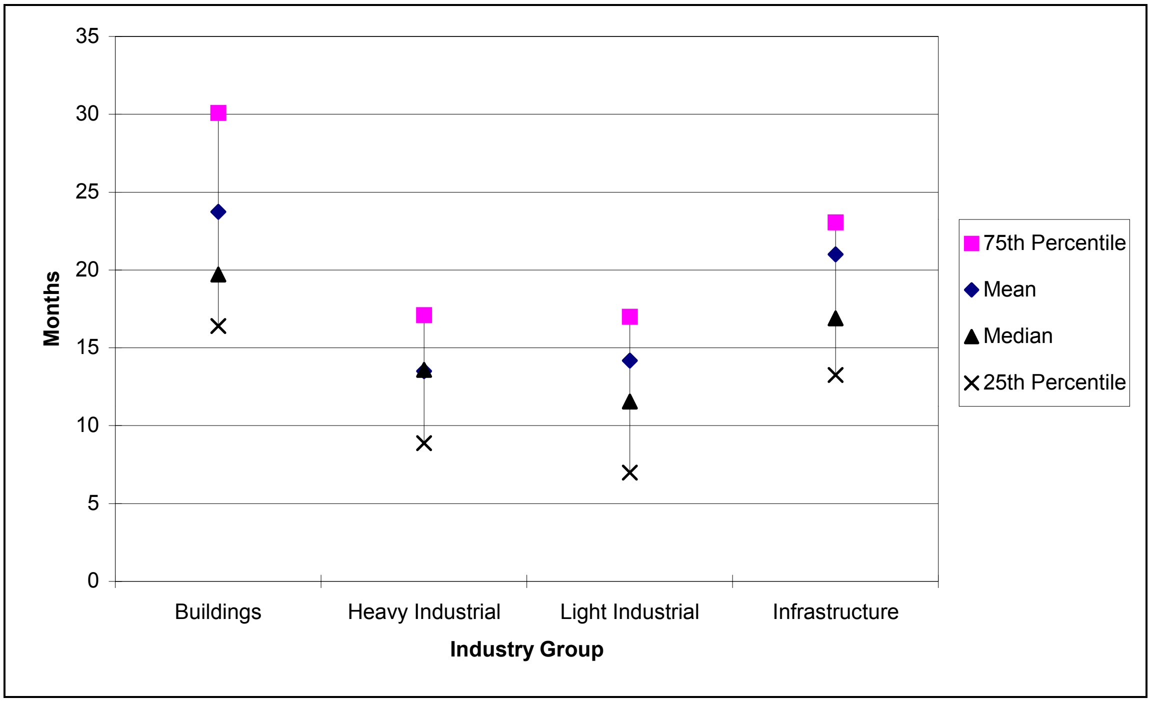


Table 6-12. Construction Phase Duration: Number of Months by Industry Group

Statistical Measure	Number of Months by Industry Group			
	Buildings	Heavy Industrial	Light Industrial	Infrastructure
75th Percentile	30.1	17.1	17.0	23.1
Mean	23.7	13.5	14.2	21.0
Median	19.7	13.6	11.5	16.9
25th Percentile	16.4	8.9	7.0	13.3

Figure 6-30 and Table 6-14 show how project nature affects construction phase duration. Reference to the figure reveals that modernization projects exhibit the greatest variability. However, grass roots projects take the longest to construct. Construction phase duration for additions is, on average, the shortest of the three, followed by modernization projects. It is also worth noting that for addition projects the mean and median values for construction phase duration are very close together, indicating that such projects have a relatively strong central tendency.

Figure 6-29. Construction Phase Duration by Cost Category

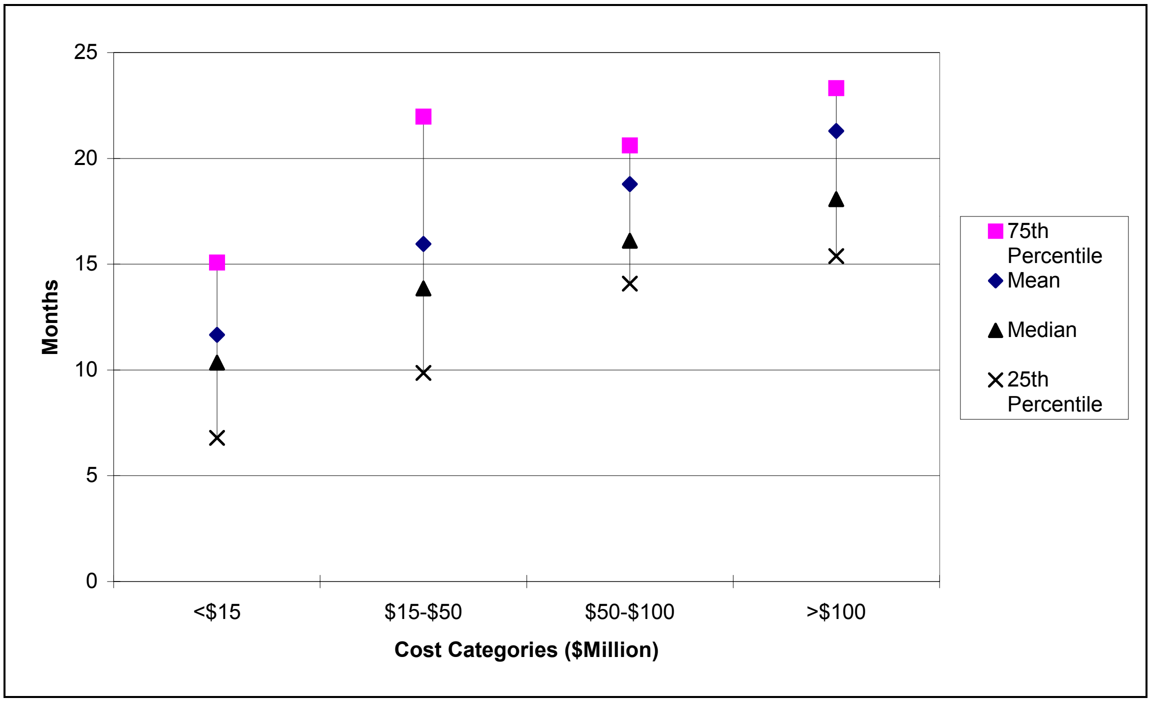


Figure 6-30. Construction Phase Duration by Project Nature

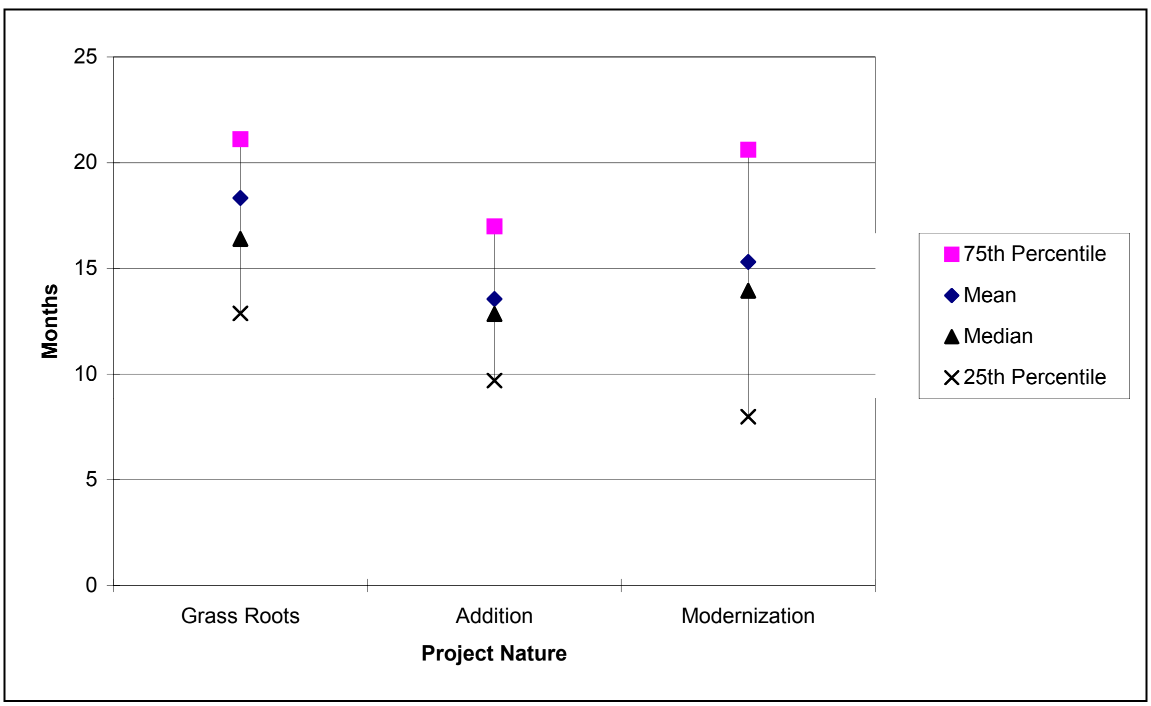


Table 6-13. Construction Phase Duration: Number of Months by Cost Category

Statistical Measure	Number of Months by Cost Category (Million Dollars)			
	< $15	$15-$50	$50-$100	>$100
75th Percentile	15.1	22.0	20.6	23.3
Mean	11.7	16.0	18.8	21.3
Median	10.3	13.9	16.1	18.1
25th Percentile	6.8	9.9	14.1	15.4

Table 6-14. Construction Phase Duration: Number of Months by Project Nature

Statistical Measure	Number of Months by Project Nature		
	Grass Roots	Addition	Modernization
75th Percentile	21.1	17.0	20.6
Mean	18.3	13.5	15.3
Median	16.4	12.8	13.9
25th Percentile	12.9	9.7	8.0

The figures and tables which occupy the remainder of this subsection are concerned with the construction duration factor. The construction duration factor is calculated for CII owner projects only, since owners are by definition involved in all phases of project execution. The construction duration factor is bounded below by 0 and above by 1. The numerator of the construction duration factor is the construction phase duration. The denominator of the construction duration factor is the actual overall duration, a metric which also includes the time consumed for the pre-project planning phase (see Table 3-8).

Figure 6-31 records the construction duration factor by industry group. The data used to construct Figure 6-31 are recorded in Table 6-15. Reference to the figure reveals that the interquartile range is much wider for heavy and light industrial projects than for buildings and infrastructure projects. Notice also that the mean and the median are nearly identical in value for all but light industrial projects. It is interesting to note that light industrial projects exhibit the highest values of the construction duration factor.

Figure 6-31. Construction Duration Factor by Industry Group

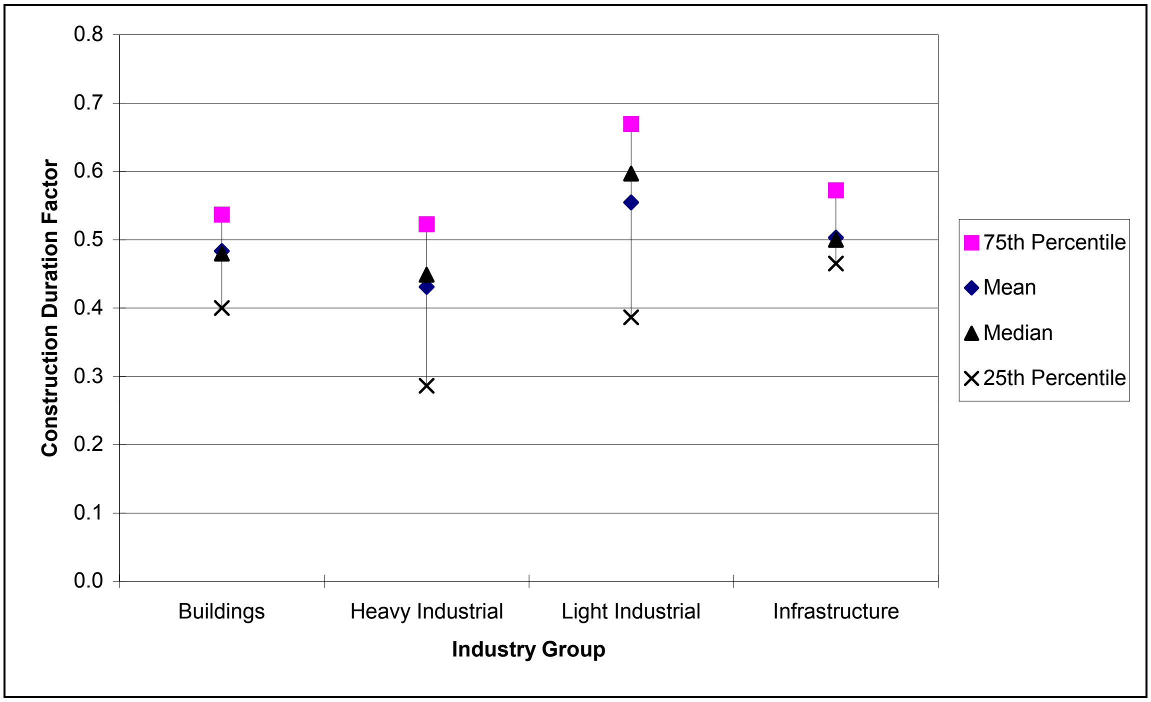


Table 6-15. Construction Duration Factor: Ratio of Construction Phase Duration to Total Project Duration by Industry Group

Statistical Measure	Construction Duration Factor by Industry Group			
	Buildings	Heavy Industrial	Light Industrial	Infrastructure
75th Percentile	0.54	0.52	0.67	0.57
Mean	0.48	0.43	0.55	0.50
Median	0.48	0.45	0.60	0.50
25th Percentile	0.40	0.29	0.39	0.47

Figure 6-32 and Table 6-16 show how project cost affects the value of the construction duration factor. With the exception of projects costing less than $15 million, the mean and median values of the construction duration factor are remarkably stable. Basically, for all projects costing $15 million or more, the mean and median values of the construction duration factor range from a low of 0.48 to a high of 0.50. The relatively lower mean and median values for projects costing less than $15 million may be due to the less complicated nature of these "smaller" projects.

Figure 6-32. Construction Duration Factor by Cost Category

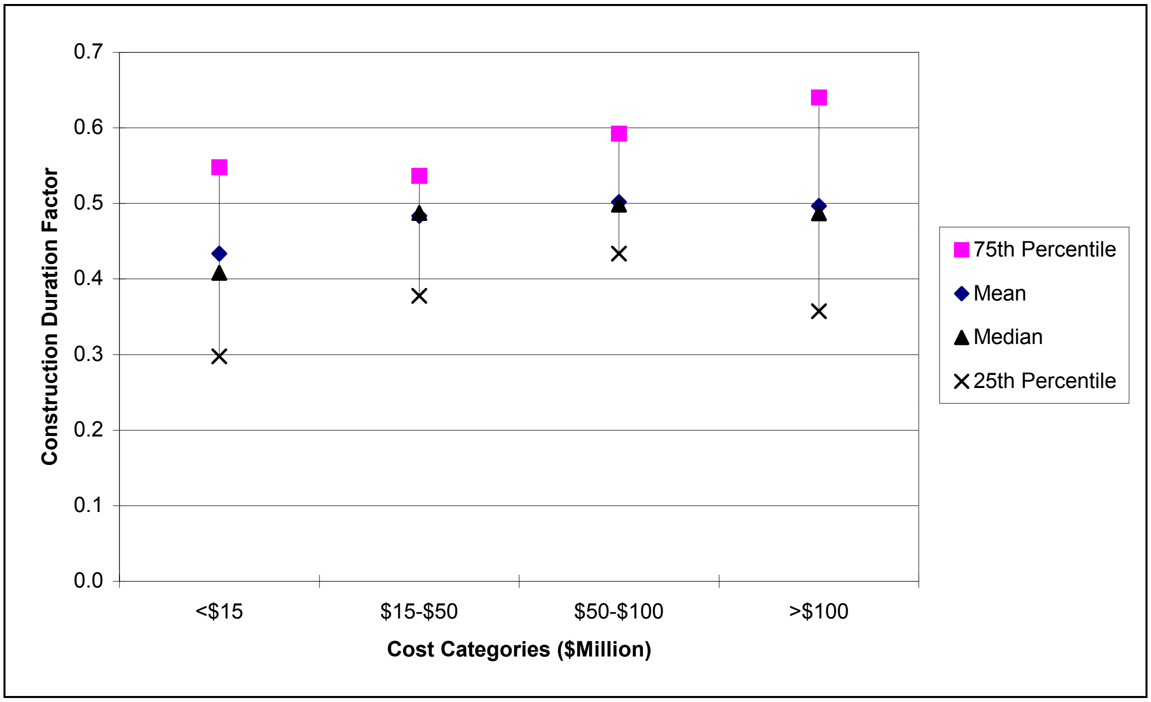


Table 6-16. Construction Duration Factor: Ratio of Construction Phase Duration to Total Project Duration by Cost Category

Statistical Measure	Construction Duration Factor by Cost Category (Million Dollars)			
	< $15	$15-$50	$50-$100	>$100
75th Percentile	0.55	0.54	0.59	0.64
Mean	0.43	0.48	0.50	0.50
Median	0.41	0.49	0.50	0.49
25th Percentile	0.30	0.38	0.43	0.36

Figure 6-33 and Table 6-17 show how project nature affects the value of the construction duration factor. Reference to the figure indicates that grass roots projects exhibit the least variability. This observation is reinforced through reference to Table 6-17 which reveals that the width of the interquartile range is 0.17 for grass roots projects, whereas it is 0.33 for additions and 0.34 for modernization projects. It is also worth noting that the mean and median values are very close together for all three project natures, indicating that within each "data subset" the projects have a relatively strong central tendency.

Figure 6-33. Construction Duration Factor by Project Nature

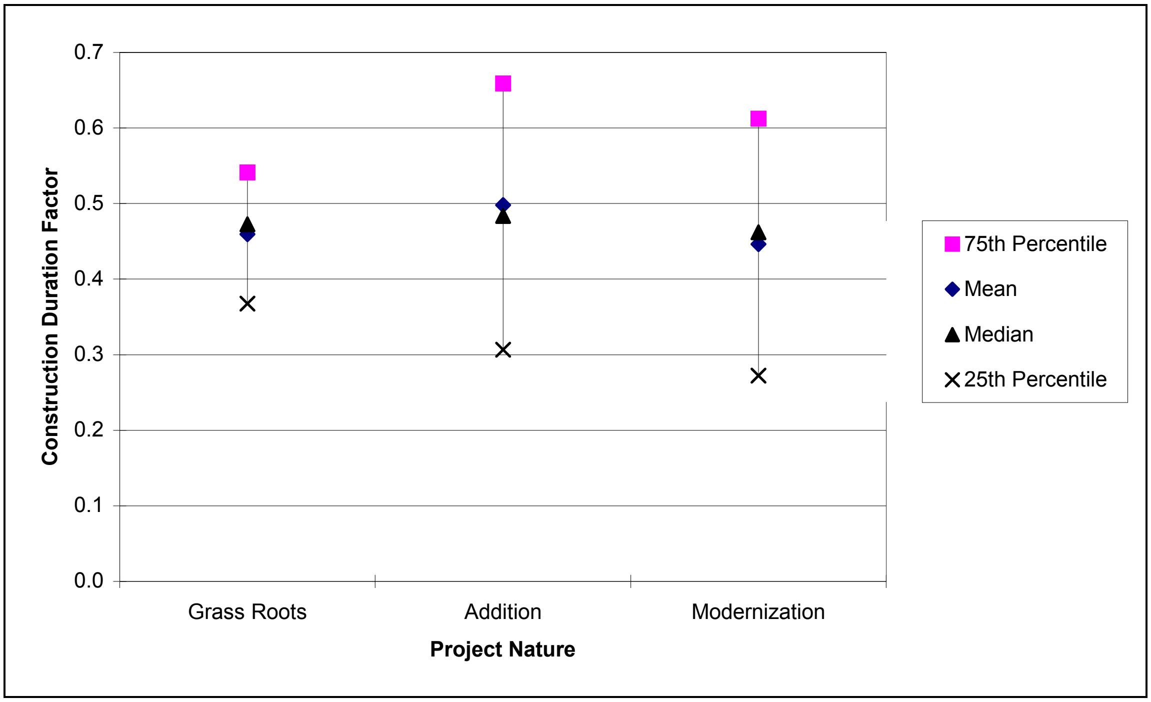


Table 6-17. Construction Duration Factor: Ratio of Construction Phase Duration to Total Project Duration by Project Nature

Statistical Measure	Construction Duration Factor by Project Nature		
	Grass Roots	Addition	Modernization
75th Percentile	0.54	0.66	0.61
Mean	0.46	0.50	0.45
Median	0.47	0.48	0.46
25th Percentile	0.37	0.31	0.27

6.2.2.3. Metrics Related to Schedule Growth

The figures and tables presented in this subsection are concerned with project schedule growth. Project schedule growth is a ratio metric; it may be either positive, negative, or zero. The computed value for schedule growth is recorded on the vertical axis of the figures presented in this subsection. All values shown in the figures and recorded in the tables are given as decimals. Consequently, a value of 0.10 implies a schedule growth of 10 percent.

The numerator of project schedule growth is the difference between total project duration and initial predicted project duration. The denominator of project schedule growth is initial predicted project duration. A value of zero, 0.00, represents the anticipated outcome, in that total project duration just equals initial predicted project duration. Negative values indicate that the predicted schedule has been compressed. Schedule compression is generally accepted as a desirable outcome. Positive values indicate that the project has taken longer to complete than was initially estimated. Due to the close relationship between schedule slippage and cost overruns, a positive value for schedule growth is generally taken to be an undesired outcome.

Figure 6-34 records the construction duration factor by industry group. The data used to construct Figure 6-34 are recorded in Table 6-18. Reference to the figure reveals that the interquartile ranges are much wider for buildings and light industrial projects than for heavy industrial and infrastructure projects. Notice also that the median for both heavy and light industrial projects is 0.00. Comparisons between the means for schedule growth between heavy and light industrial projects reveal that schedule growth for heavy industrial projects is 2.4 percent whereas it is 11.3 percent for light industrial projects. This undesirable outcome is undoubtedly due to high rates of schedule growth which are "pulling up" the mean for light industrial projects (i.e., values which exceed the 75th percentile). The mean values for schedule growth for buildings and infrastructure projects are 10.3 percent and 9.8 percent, respectively.

Figure 6-35 and Table 6-19 show how project cost affects the calculated value for schedule growth. Figure 6-35 presents an interesting relationship, namely, as project cost increases, schedule growth tends to decline. This trend probably results from normal project risk management practices. For example, as more money becomes at risk with increased project cost, there is a greater incentive to bring the project in on schedule and within budget. Notice also that the interquartile range for projects costing less than $15 million is much wider than the interquartile ranges for projects costing $15 million or more. Finally, as cost increases, the spread between the mean and the median values tends to be reduced.

Figure 6-36 and Table 6-20 show how project nature affects the calculated value for schedule growth. Reference to the figure reveals that grass roots projects have the greatest spread of schedule growth and additions have the smallest spread. Data from Table 6-20 shows the width of the interquartile range to be 17.7 percent for grass roots projects. The corresponding figure for additions is 13.1 percent. Average schedule growth is highest for modernization projects (7.9 percent) and least for additions (3.6 percent).

Figure 6-34. Schedule Growth by Industry Group

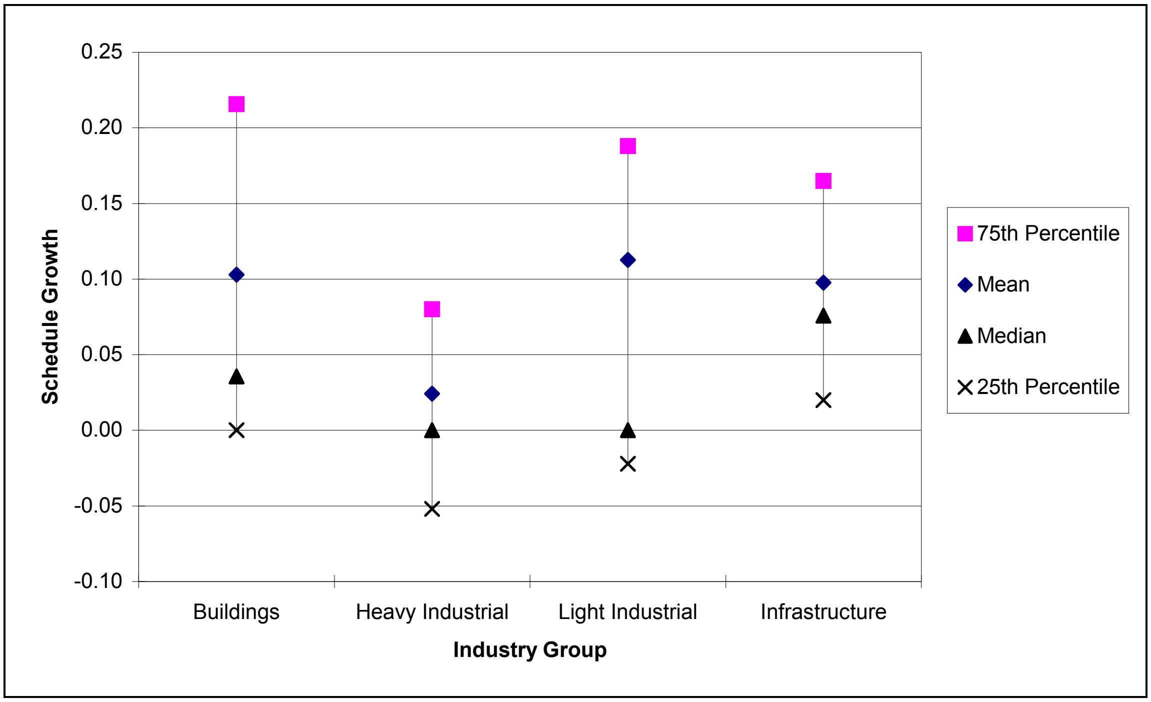


Figure 6-35. Schedule Growth by Cost Category

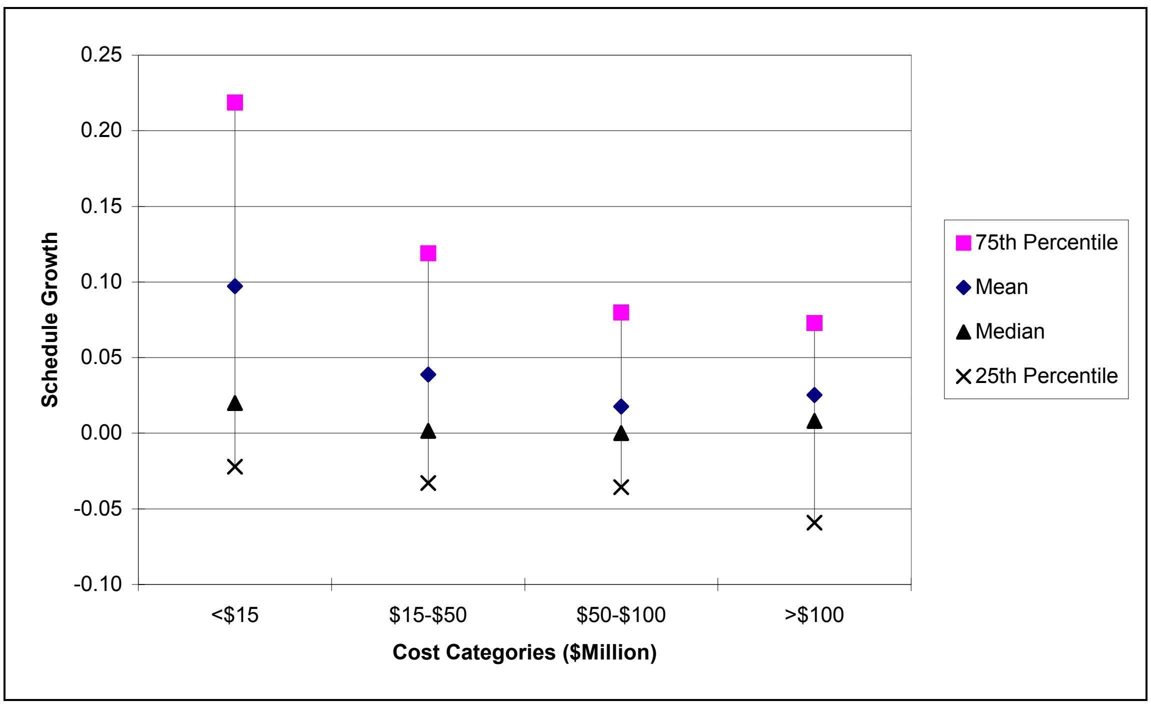


Table 6-18. Schedule Growth by Industry Group

Statistical Measure	Schedule Growth by Industry Group			
	Buildings	Heavy Industrial	Light Industrial	Infrastructure
75th Percentile	0.216	0.080	0.188	0.165
Mean	0.103	0.024	0.113	0.098
Median	0.036	0.000	0.000	0.076
25th Percentile	0.000	-0.052	-0.022	0.020

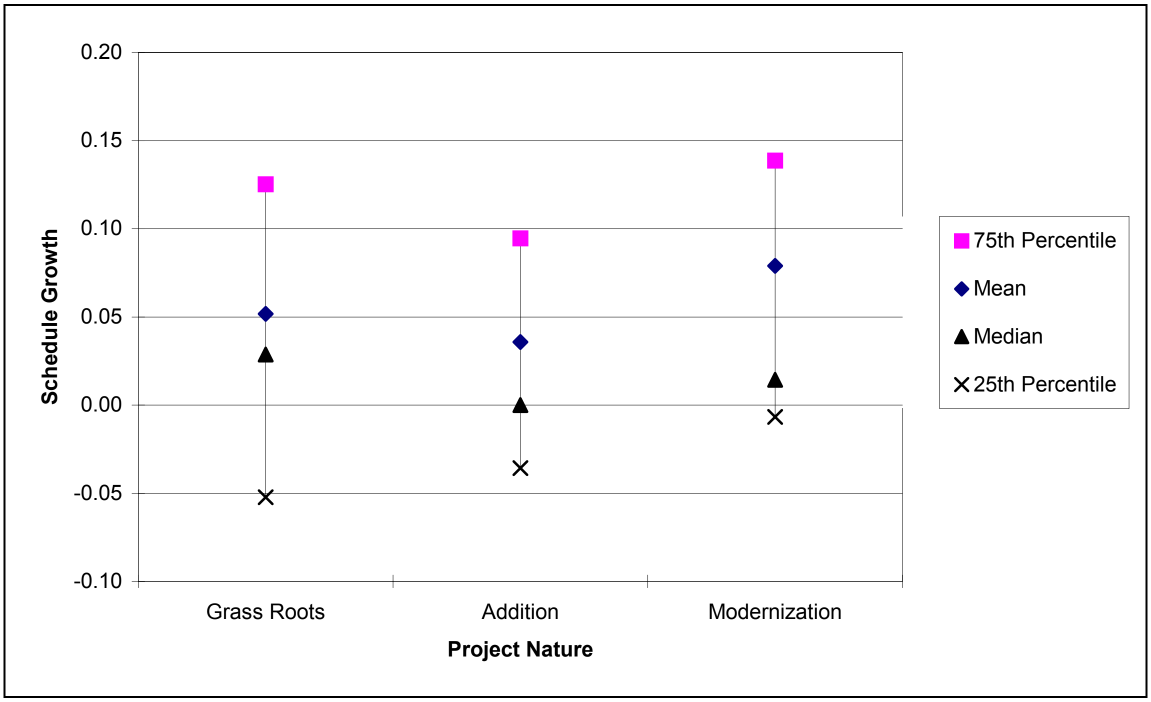
Table 6-19. Schedule Growth by Cost Category

Statistical Measure	Schedule Growth by Cost Category (Million Dollars)			
	< $15	$15-$50	$50-$100	>$100
75th Percentile	0.219	0.119	0.080	0.073
Mean	0.097	0.039	0.018	0.025
Median	0.020	0.002	0.000	0.008
25th Percentile	-0.022	-0.033	-0.036	-0.059

Table 6-20. Schedule Growth by Project Nature

Statistical Measure	Schedule Growth by Project Nature		
	Grass Roots	Addition	Modernization
75th Percentile	0.125	0.095	0.139
Mean	0.052	0.036	0.079
Median	0.029	0.000	0.014
25th Percentile	-0.052	-0.036	-0.007

Figure 6-36. Schedule Growth by Project Nature



6.2.2.4. Relationships Between the Use of CII Best Practices and Delivery Time Metrics

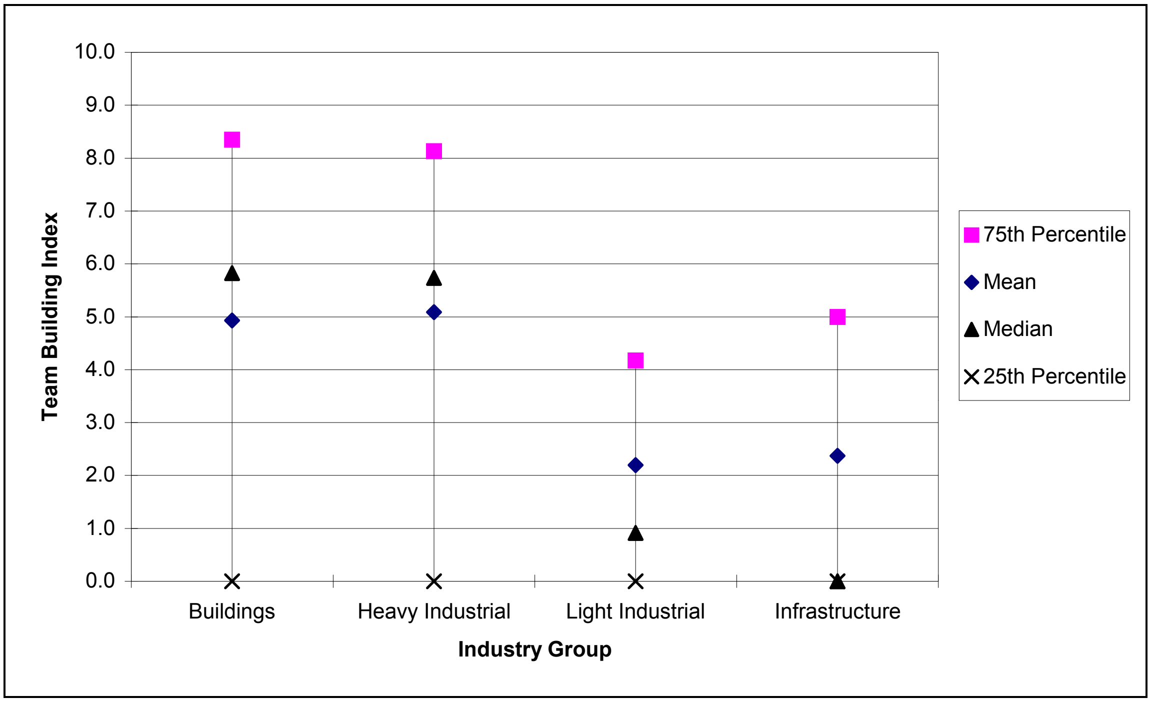
This subsection focuses on developing norms for characterizing the use of two key CII best practices. Relationships between the use of these practices and a key delivery time metric, the construction duration factor, are also developed.

The two practices treated in this subsection are team building and constructability. Team building is a process that brings together a diverse group of project participants and seeks to resolve differences, remove roadblocks, and proactively build and develop the group into an aligned, focused, and motivated work team that strives for a common mission for shared goals, objectives, and priorities. Constructability practices seek to achieve overall project objectives through the optimum use of construction knowledge and experience in planning, design, procurement, and field operations. Constructability is achieved through the effective and timely integration of construction input into planning and design as well as field operations.

Information from the CII annual survey was used to construct a use index for each practice.[32] The use index ranges from 0 to 10. Lower values of the index imply low use, while higher values of the index imply high use.

Figure 6-37 records team building use by industry group. The data used to construct Figure 6-37 are recorded in Table 6-21. Reference to the figure reveals that buildings and heavy industrial projects make more extensive use of team building than do light industrial and infrastructure projects. Note that the median value of the team building index is less than 1.0 for light industrial projects and is 0.0 for infrastructure projects. Thus, one would conclude that team building is only in the early stages of use for light industrial and infrastructure projects.

Figure 6-37. Team Building Use by Industry Group



[32] *Benchmarking and Metrics Data Report for 1997*, Appendix C.

Table 6-21. Team Building Use by Industry Group

Statistical Measure	Value of Team Building Index by Industry Group			
	Buildings	Heavy Industrial	Light Industrial	Infrastructure
75th Percentile	8.35	8.13	4.18	5.00
Mean	4.93	5.09	2.19	2.37
Median	5.83	5.74	0.91	0.00
25th Percentile	0.00	0.00	0.00	0.00

Figure 6-38 and Table 6-22 show how project cost affects the use of team building. The figure shows a distinct positive relationship between the value of the team building index and project cost as project cost increases. Notice how the use of team building jumps for projects costing more than \$100 million. For large projects (i.e., more than \$100 million), the 25^{th} percentile value of the team building index exceeds both the mean and median values of the team building index for projects costing less than \$15 million.

Figure 6-38. Team Building Use by Cost Category

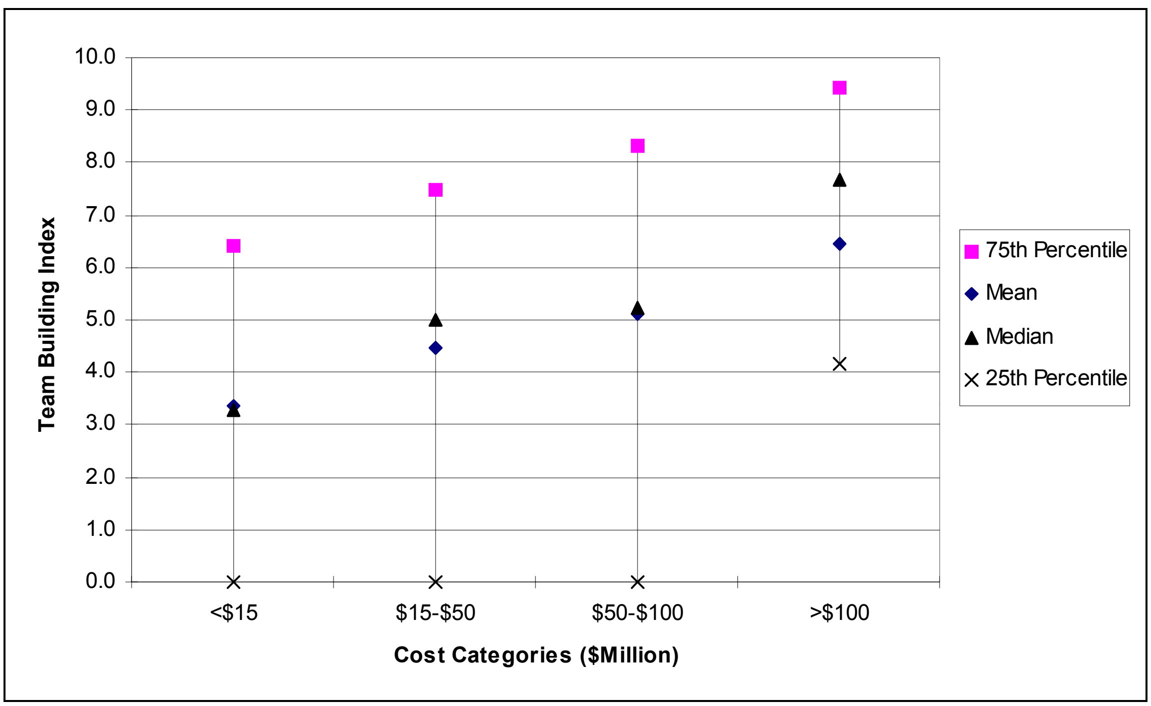


Table 6-22. Team Building Use by Cost Category

Statistical Measure	Value of Team Building Index by Cost Category (Million Dollars)			
	<$15	$15-$50	$50-$100	>$100
75th Percentile	6.40	7.50	8.34	9.42
Mean	3.35	4.46	5.12	6.43
Median	3.29	5.00	5.25	7.67
25th Percentile	0.00	0.00	0.00	4.18

Figure 6-39 and Table 6-23 show how project nature affects the use of team building. Reference to the figure reveals that grass roots projects exhibit the most extensive use of team building. Additions exhibit the lowest use of team building. The value of the key summary statistics for the team building index for modernization projects is in between the values for grass roots projects and additions.

Figure 6-39. Team Building Use by Project Nature

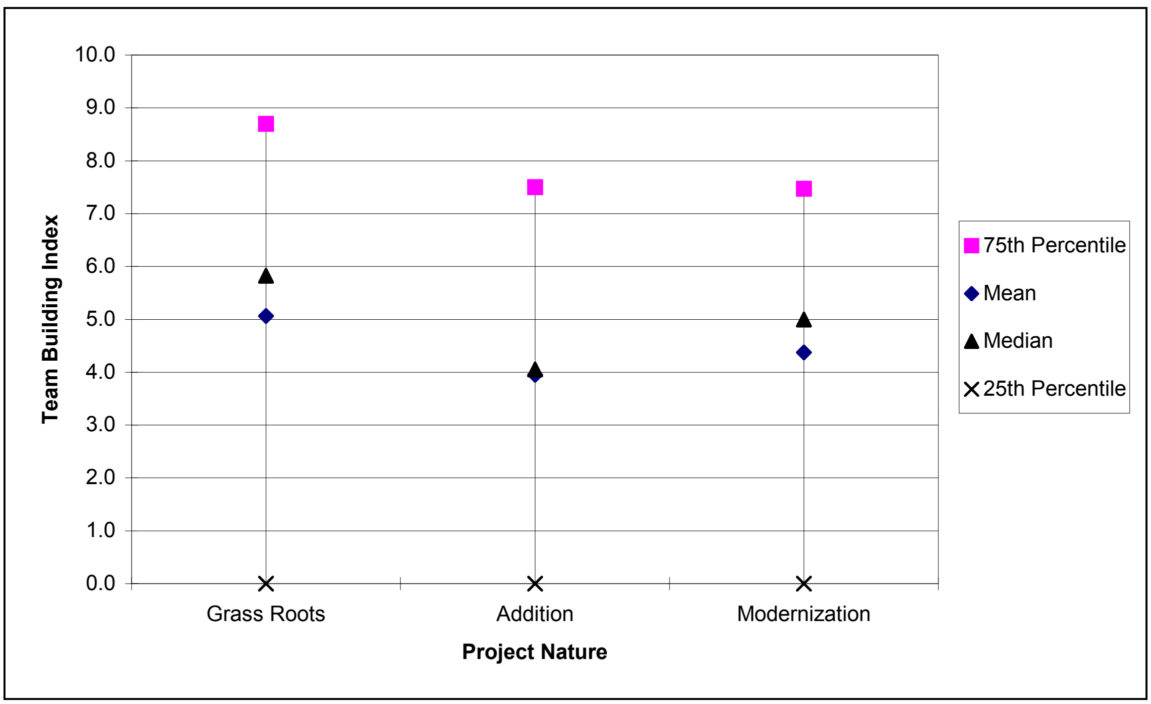


Table 6-23. Team Building Use by Project Nature

Statistical Measure	Value of Team Building Index By Project Nature		
	Grass Roots	Addition	Modernization
75th Percentile	8.70	7.50	7.47
Mean	5.06	3.95	4.37
Median	5.83	4.06	5.00
25th Percentile	0.00	0.00	0.00

Figure 6-40 records constructability use by industry group. The data used to construct Figure 6-40 are recorded in Table 6-24. Reference to the figure reveals that heavy industrial projects make the most extensive use of constructability whereas buildings projects make the least use. Notice also that the mean and median values of the constructability index for heavy industrial projects matches or exceeds the values of the 75th percentiles for the three remaining industry groups.

Figure 6-40. Constructability Use by Industry Group

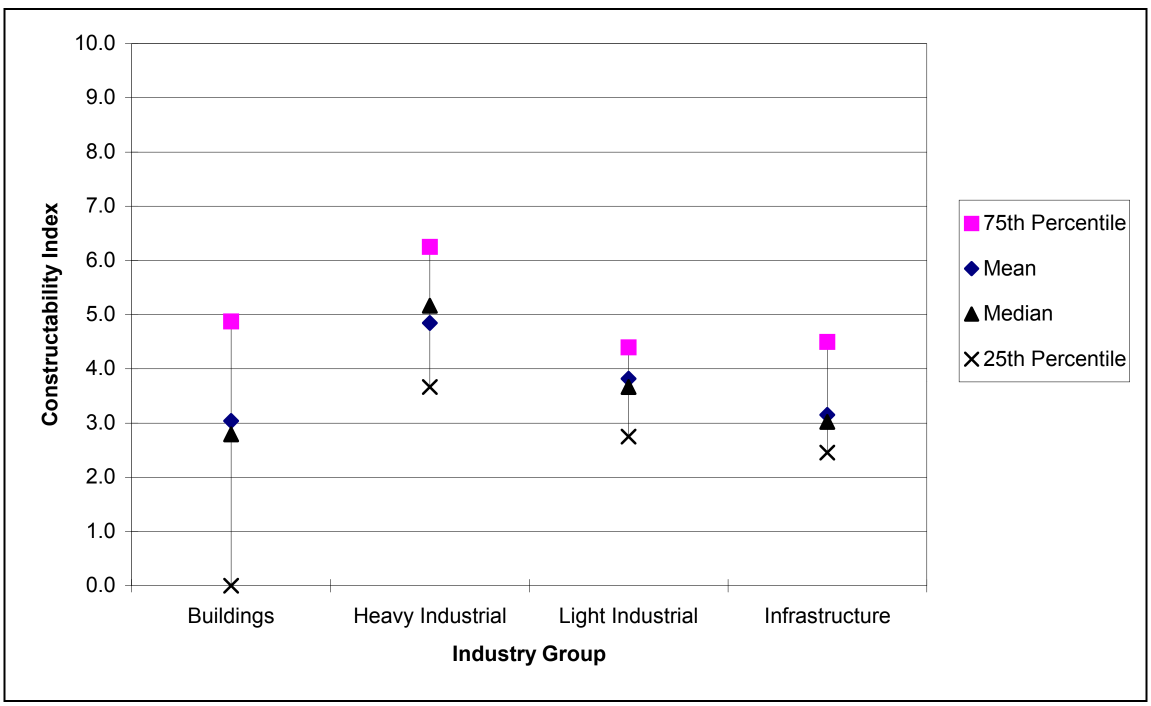


Table 6-24. Constructability Use by Industry Group

Statistical Measure	Value of Constructability Index by Industry Group			
	Buildings	Heavy Industrial	Light Industrial	Infrastructure
75th Percentile	4.88	6.25	4.40	4.50
Mean	3.04	4.84	3.82	3.15
Median	2.79	5.17	3.67	3.02
25th Percentile	0.00	3.67	2.75	2.46

Figure 6-41 and Table 6-25 show how project cost affects the use of the constructability practice. The figure shows a relatively constant use of the constructability practice for projects costing $100 million or less. Use of the constructability practice jumps for projects costing more than $100 million. For large projects, both the mean and median values of the constructability index approach or exceed the values of the 75th percentiles for projects costing $100 million or less.

Figure 6-41. Constructability Use by Cost Category

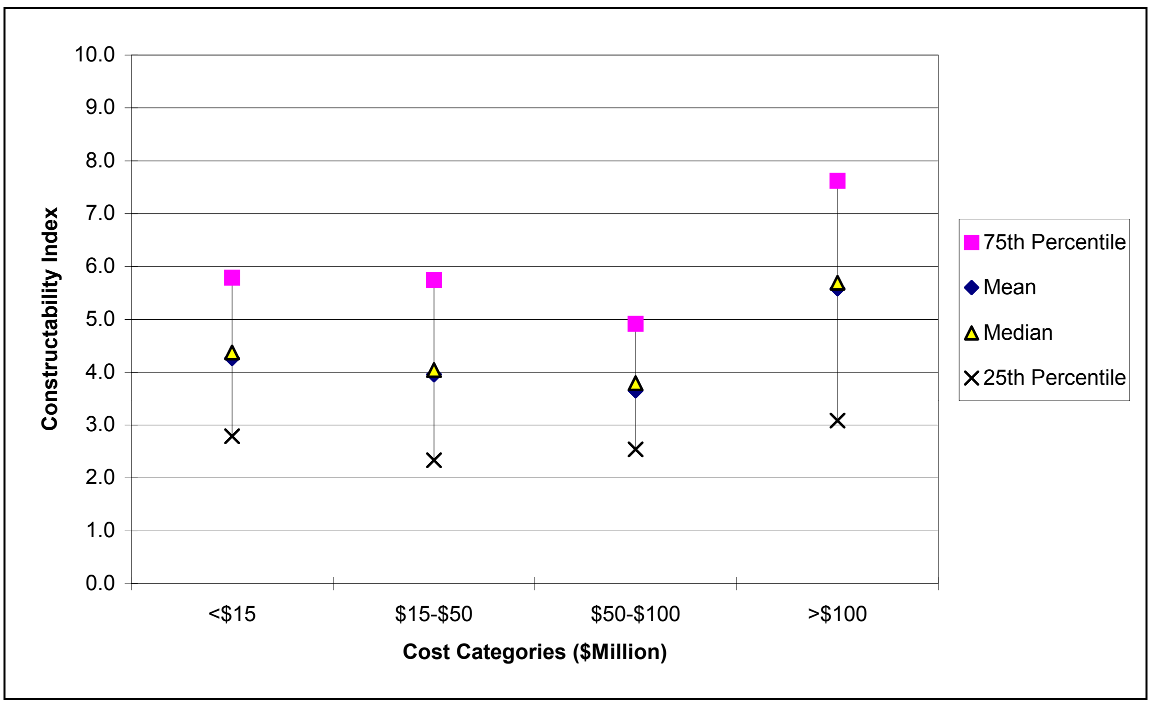


Table 6-25. Constructability Use by Cost Category

Statistical Measure	Value of Constructability Index by Cost Category (Million Dollars)			
	<$15	$15-$50	$50-$100	>$100
75th Percentile	5.79	5.75	4.92	7.63
Mean	4.27	3.95	3.65	5.58
Median	4.38	4.04	3.79	5.69
25th Percentile	2.79	2.33	2.54	3.08

Figure 6-42 and Table 6-26 show how project nature affects the use of the constructability practice. Reference to the figure reveals that grass roots projects exhibit greater variability in the use of the constructability practice. An examination of the statistical measures of central tendency, however, reveals that use of the constructability practice is, on average, fairly constant across all three project natures.

Figure 6-42. Constructability Use by Project Nature

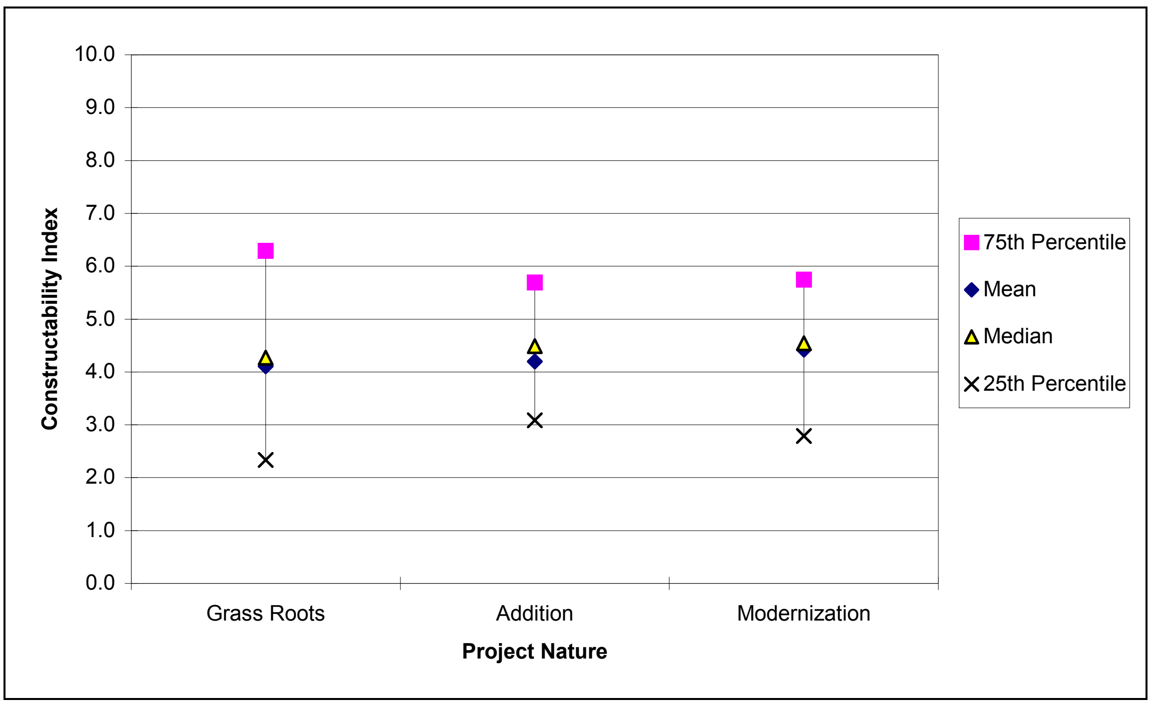


Table 6-26. Constructability Use by Project Nature

Statistical Measure	Value of Constructability Index by Project Nature		
	Grass Roots	Addition	Modernization
75th Percentile	6.29	5.69	5.75
Mean	4.11	4.20	4.42
Median	4.27	4.49	4.54
25th Percentile	2.33	3.08	2.79

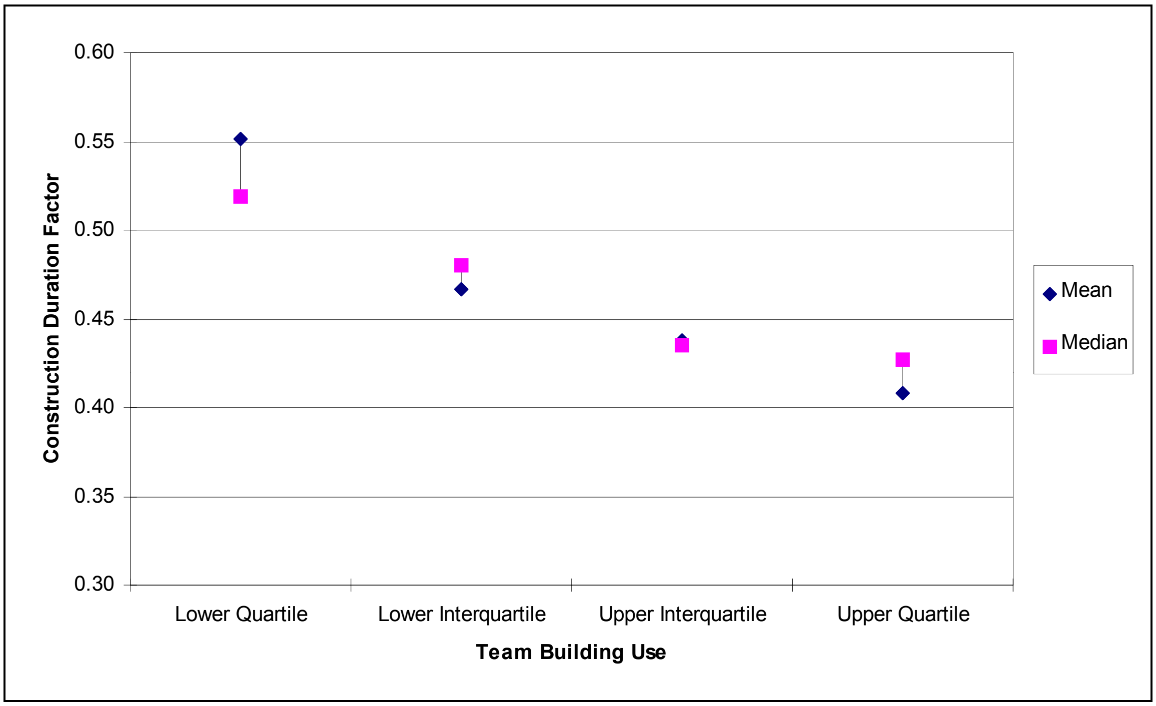
Figures 6-43 and 6-44 illustrate the relationship between practice use and a key delivery time metric, the construction duration factor. Recall that the construction duration factor is calculated for CII owner projects only. Figure 6-43 measures the impacts of team building use on the construction duration factor. Figure 6-44 measures the impact of constructability use on the construction duration factor.

It is important to note that the format for Figures 6-43 and 6-44 differs from the format used in Figures 6-25 through 6-42. Consequently, before interpreting the results shown in Figures 6-43 and 6-44, it is useful to review the new format. In each figure, the vertical axis records the value of the construction duration factor. To help in interpreting the results presented in the two figures, lower values of the construction duration factor are considered desirable. The horizontal axis provides information on practice use. The horizontal axis is divided into four quartiles. The four quartiles span the entire range of calculated values of the practice use index for all owner projects. The quartiles measure the degree to which owner projects have made use of each of the two best practices—team building and constructability. The calculated value of the practice use index is used to rank all owner projects from lowest use to highest use. The four quartiles are: (1) the lower quartile (i.e., the bottom 25 percent of practice use among all owner projects); (2) the lower interquartile (i.e., projects with practice use index values between the 25th and 50th percentiles); (3) the upper interquartile (i.e., projects with practice use index values between the 50th and 75th percentiles); and (4) the upper quartile (i.e., the top 25 percent of practice use). The lower interquartile and the upper interquartile taken together are equivalent to the interquartile range. Two statistical measures of central tendency, the mean and the median, are plotted on each figure for each quartile. The mean value is designated with a diamond (◆) whereas the median is designated by a square (■). Both statistical measures are connected with a line to help visualize any spread between the two.

Figure 6-43 demonstrates a clear relationship between the team building practice use and the calculated value of the construction duration factor. An examination of each quartile reveals that both the mean and median values of the construction duration factor decline as the use of the team building practice is increased (i.e., as we move from the first to the fourth quartile). The mean value of the construction duration factor for each quartile exhibits a somewhat stronger relationship with practice use than the median. The mean declines from a high of 0.55 to a low of 0.41. The median declines from a high of 0.52 to a low of 0.43.

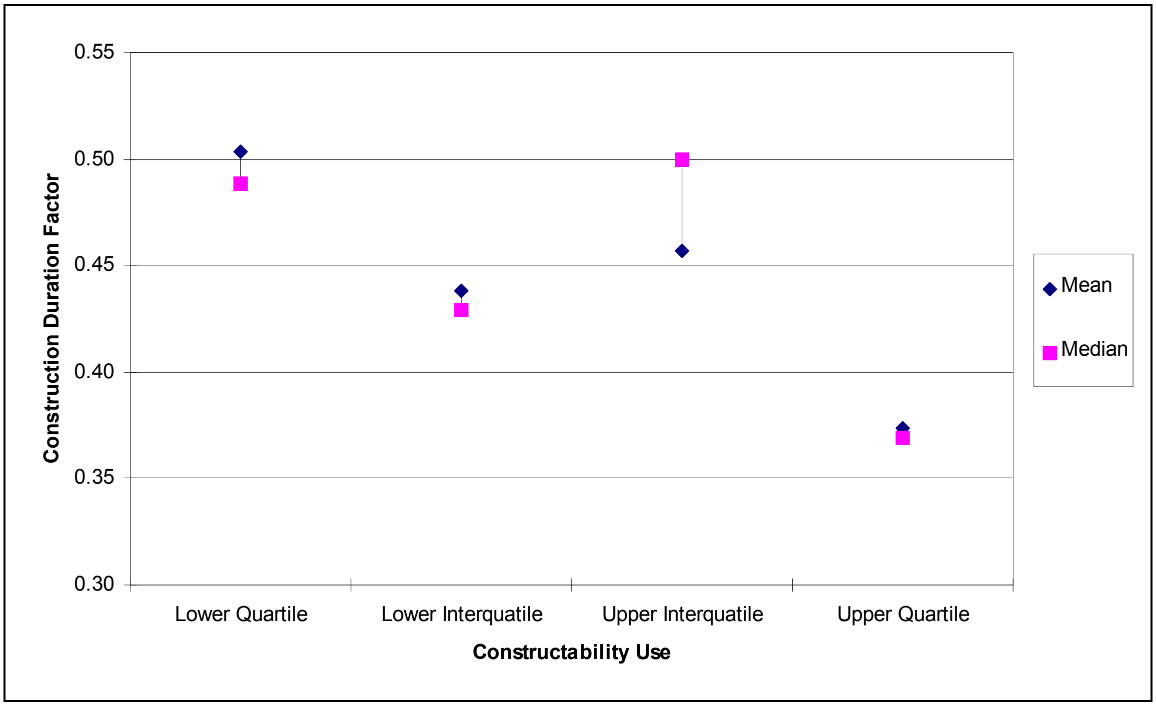
The relationship between the use of the constructability practice and the construction duration factor, shown in Figure 6-44, is less clear than for the use of the team building practice. Although the mean value for each quartile demonstrates a downward trend as we move from the first to the fourth quartile, the median values show less structure. In terms of calculated values between the *first* and *fourth* quartile, both measures of central tendency decline. The mean declines from a high of 0.50 to a low of 0.37 and the median declines from a high of 0.49 to a low of 0.37.

Figure 6-43. Team Building Versus Construction Duration Factor



The results shown in Figures 6-43 and 6-44 are very encouraging. In both cases, the construction duration factor was reduced by approximately 25 percent from a high value (i.e., low practice use) to a low value (i.e., high practice use). Thus, intensive use of "best practices" may provide an opportunity for dramatically reducing the deliver time of constructed facilities. Unfortunately, the results presented in the two figures lack sufficient detail to enable us to determine how practice use affects a particular industry group (e.g., heavy industrial projects), cost category, or project nature. As more project data become available to CII, information on each of these subsets (e.g., grass roots, heavy industrial projects costing between $50 million and $100 million) will become available. This information will enable more detailed relationships to be established, such as how practices used individually and in concert affect key delivery time metrics.

Figure 6-44. Constructability Versus Construction Duration Factor



6.2.3. Summary of Baseline Measures

Table 6-27 shows general information relating to the three non-residential sectors, as well as key delivery time baseline data. The 'General Information' section describes the *total expenditures for new construction* in the three non-residential sectors in 1994, as well as the *average cost of new non-residential buildings* in the US.

The 'Delivery Time' section provides baseline measures for non-residential construction projects in the US. Two sets of delivery time information are provided: (1) total project duration and (2) construction phase duration. Because the data used to generate the baseline measures included several statistical measures covering a range of values, two measures of central tendency are reported in Table 6-27: (1) the mean and (2) the median.

Summary of Abbreviations Used in Table 6-27

VIP	Value of New Construction Put in Place
CII	Construction Industry Institute

Table 6-27. Summary of Baseline Measures: Non-Residential Sectors

DESCRIPTION	YEAR	BASELINE	SOURCE[33]
GENERAL INFORMATION			
Value of New Construction Put in Place: All Non-Residential	1994	$259,637 million (constant 1992 dollars)	Census VIP Data
Value of New Construction Put in Place: Commercial/ Institutional	1994	$128,116 million (constant 1992 dollars)	Census VIP Data
Value of New Construction Put in Place: Industrial	1994	$28,161 million (constant 1992 dollars)	Census VIP Data
Value of New Construction Put in Place: Public Works	1994	$103,360 million (constant 1992 dollars)	Census VIP Data
Average Construction Cost: Non-Residential Buildings	1994	$81.67 per square foot $878.72 per square meter	Statistical Abstract
DELIVERY TIME			
Total Project Duration: Commercial/Institutional	1996-1997	38.9 months Mean 36.0 months Median	CII
Total Project Duration: Heavy Industrial	1996-1997	21.2 months Mean 18.5 months Median	CII
Total Project Duration: Light Industrial	1996-1997	24.4 months Mean 18.4 months Median	CII
Total Project Duration: Public Works	1996-1997	21.0 months Mean 19.6 months Median	CII
Construction Duration: Commercial/Institutional	1996-1997	23.7 months Mean 19.7 months Median	CII
Construction Duration: Heavy Industrial	1996-1997	13.5 months Mean 13.6 months Median	CII
Construction Duration: Light Industrial	1996-1997	14.2 months Mean 11.5 months Median	CII
Construction Duration: Public Works	1996-1997	21.0 months Mean 16.9 months Median	CII

[33] See accompanying text for description of abbreviations used in this table.

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7. Summary and Suggestions for Further Research

7.1. Summary

The Construction and Building Subcommittee of the National Science and Technology Council is developing baseline measures of current construction industry practices and measures of progress for each of the seven National Construction Goals (NCGs). The seven NCGs are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. Baseline measures are being produced for each of the four key construction industry sectors. The four sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works. This document provides a detailed set of baseline measures for NCG 1 (reductions in the delivery time of constructed facilities). These baseline measures will assist in determining the success of actions taken to improve the competitiveness of the US construction industry.

Chapter 1 provides background information about the project, its purpose, and scope. Chapter 2 describes the NCGs in more detail, explains BFRL's strategy for collecting information on each NCG, and the limitations of this approach, and reports on progress to date. Chapter 3 provides an overview of the construction industry, including the size of the industry, and its importance to the US economy. The chapter also presents general non-sector specific data relevant to the generation of baseline measures. Chapter 4 presents the data classification hierarchies that were used to define each sector, to identify critical factors influencing NCG 1, and to establish data linkages. The chapter also discusses data sources and availability. Chapter 5 presents the baseline measures for the residential sector. These measures are based on data published by the US Bureau of the Census, supplemented by information from the National Association of Home Builders. Chapter 6 presents the baseline measures for the three non-residential sectors—commercial/institutional, industrial, and public works. These measures are based on a discontinued data series published by the US Bureau of the Census, and aggregated project-level data made available by the Construction Industry Institute.

Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed. Sufficient data have been collected to establish baselines for the delivery time of constructed facilities across all four sectors. However, the level of detail of the baselines varies considerably, depending upon data availability. In general, the residential baselines are more detailed than the non-residential baselines, due to the wealth of data published by the US Bureau of the Census.

7.2. Suggestions for Further Research

The work for this document uncovered areas of research that might be of value to government agencies and private bodies who are concerned about reducing the delivery time of constructed facilities. These areas of research are concerned with: (1) the duration of the permitting process for all four sectors; (2) the collection of additional delivery time data for the commercial/institutional sector and the public works sector; (3) the collection of additional project-level data to analyze the relationships between best practice use and reductions in delivery time; and (4) the measurement and evaluation of progress toward achievement of NCG 1.

During the production of this document, several important questions associated with the duration of the permitting process arose. Unfortunately, no definitive sources of information on the duration of the permitting process were identified.[34] Although detailed and definitive data are available on the duration of the residential construction process once a permit has been issued, no information on the duration of the permitting process is available. For the three non-residential sectors covered by data from the Construction Industry Institute (CII), elements of the permitting process are included under pre-project planning. However, because several other important factors are also included under pre-project planning (see Table 3-7), it is unclear what influence these elements of the permitting process have either on overall project duration or on the duration of the pre-project planning phase. Research and additional information on the permitting process are needed for all four construction industry sectors for two reasons. First, there are wide regional variations in the average duration of the residential construction process once a permit has been issued. Do similar regional variations exist in the permitting process? If so, how significant are these variations? Second, for non-residential projects, there are significant differences in total project duration ***both*** within a given sector (e.g., the difference between the 25th and 75th percentile) ***and*** across sectors. How important are specific elements of the permitting process and the duration of the permitting process in explaining these differences?

In order to be able to generate useful baseline measures, detailed source information is required. As this document has shown, there are a number of areas where delivery time data are only of a very generalized nature. In particular, *additional data collection* is warranted in the following areas:

- The commercial/institutional sector in general and commercial office buildings, educational facilities, and hospitals in particular.

[34] The National Conference of States on Building Codes and Standards (NCSBCS) has launched a project aimed at streamlining the Nation's building regulatory process. To date, NCSBCS' Streamlining Project has focused on locality-based data on the duration of the permitting process. However, due to the strong interest expressed by many of the representatives of Federal, state, and local governments participating in the Streamlining Project, NCSBCS may undertake the production of national/regional data on the duration of the permitting process.

- The public works sector in general and the transportation, power utilities, water, and pipelines sub-sectors in particular.

Information presented in Subsection 6.2.2.4 showing the relationship between the use of CII best practices and delivery time metrics provides an indication of the potential of these practices for reducing delivery time. More research and analysis is needed in order to better understand these relationships and to identify ways in which this understanding can be used to drive performance improvement.

Finally, in order to be able to measure progress toward achievement of NCG 1, *periodic reports* need to be produced which re-visit the same data sources used to generate the original baselines, and refine or expand the original baselines as necessary to meet the changing needs of the construction industry stakeholders. This subject is discussed briefly in Chapter 2.

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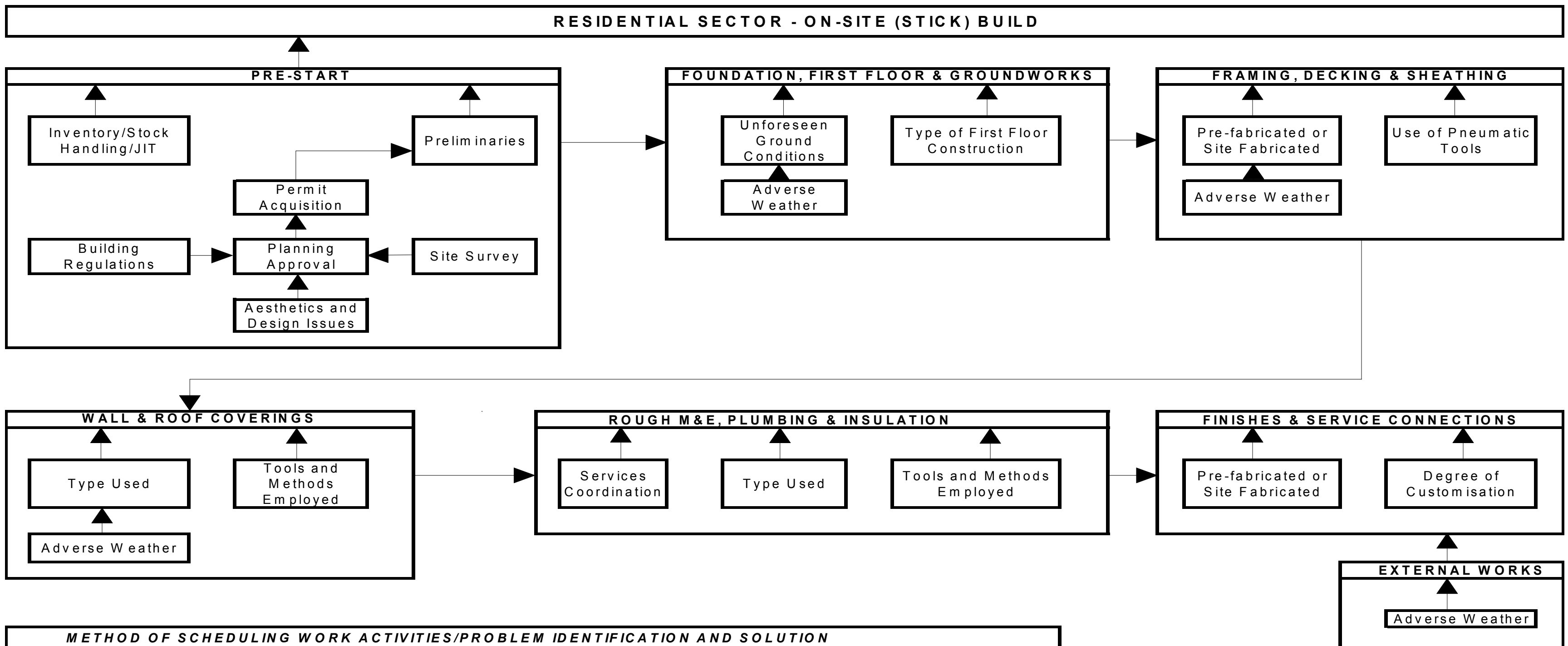
Appendix A. Data Classification Hierarchies for the Residential Sector

This appendix includes two data classification hierarchies for the residential sector. The first hierarchy covers on-site (stick built) residences. The second hierarchy covers modular construction.

The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies is to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints. The data oriented hierarchies correspond to cases for which data were collected ***and*** which are summarized in Chapter 5.

NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



METHOD OF SCHEDULING WORK ACTIVITIES/PROBLEM IDENTIFICATION AND SOLUTION

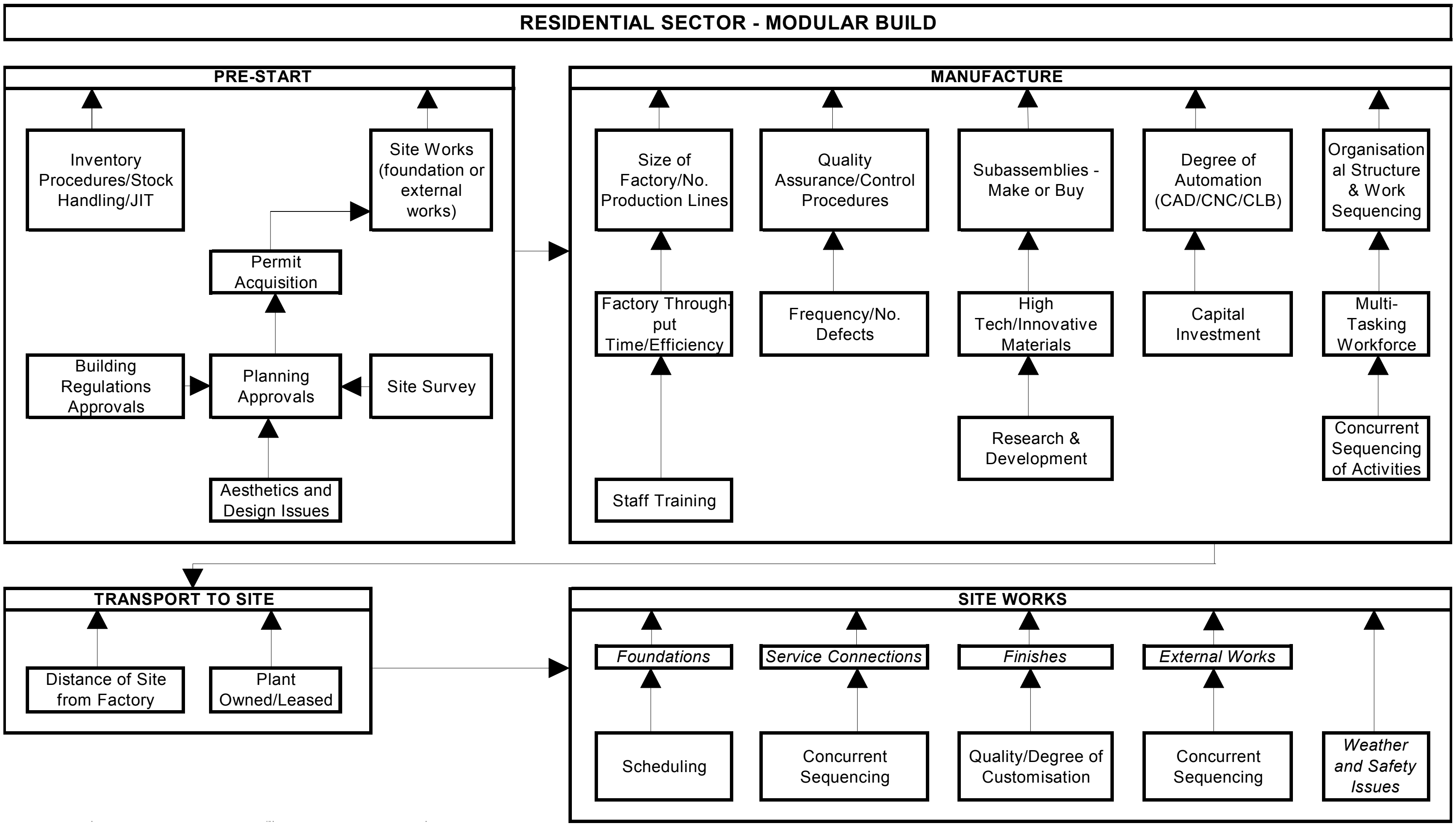
Factors affecting delivery time throughout site processes:-

*centralised or decentralised systems
*type of site/office communications systems (phone/fax/modem)
*concurrent or sequential scheduling of activities using CPM or similar, minimisation of gaps between trades on site
*system for controlling Change Orders
*use of coded purchase order system/JIT procedures
*bonus/incentive package in place rewarding time/quality achievement
*method for sytematically monitoring and reviewing sytems
*quality assurance/control systems in place
*staff training provided
*emphasis upon good safety record

Definitions:-

(a) Delivery Time is defined as being from date of acquisition of permit to date at which building is ready for occupancy unless noted otherwise
(b) All buildings are new buildings on greenfield or otherwise uncontaminated sites
(c) Buildings are grouped according to geographic location, type, size, etc.
(d) Period prior to permit acquisition considered separately as may be more dependent upon legislative delays compared with construction issues

NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



Definitions:-

(a) Delivery Time is defined as being from date of acquisition of permit to date at which building is ready for occupancy unless noted otherwise
(b) All buildings are new buildings on greenfield or otherwise uncontaminated sites
(c) Buildings are grouped according to geographic location, type, size, etc.
(d) Period prior to permit acquisition considered separately as may be more dependent upon legislative delays compared with construction issues

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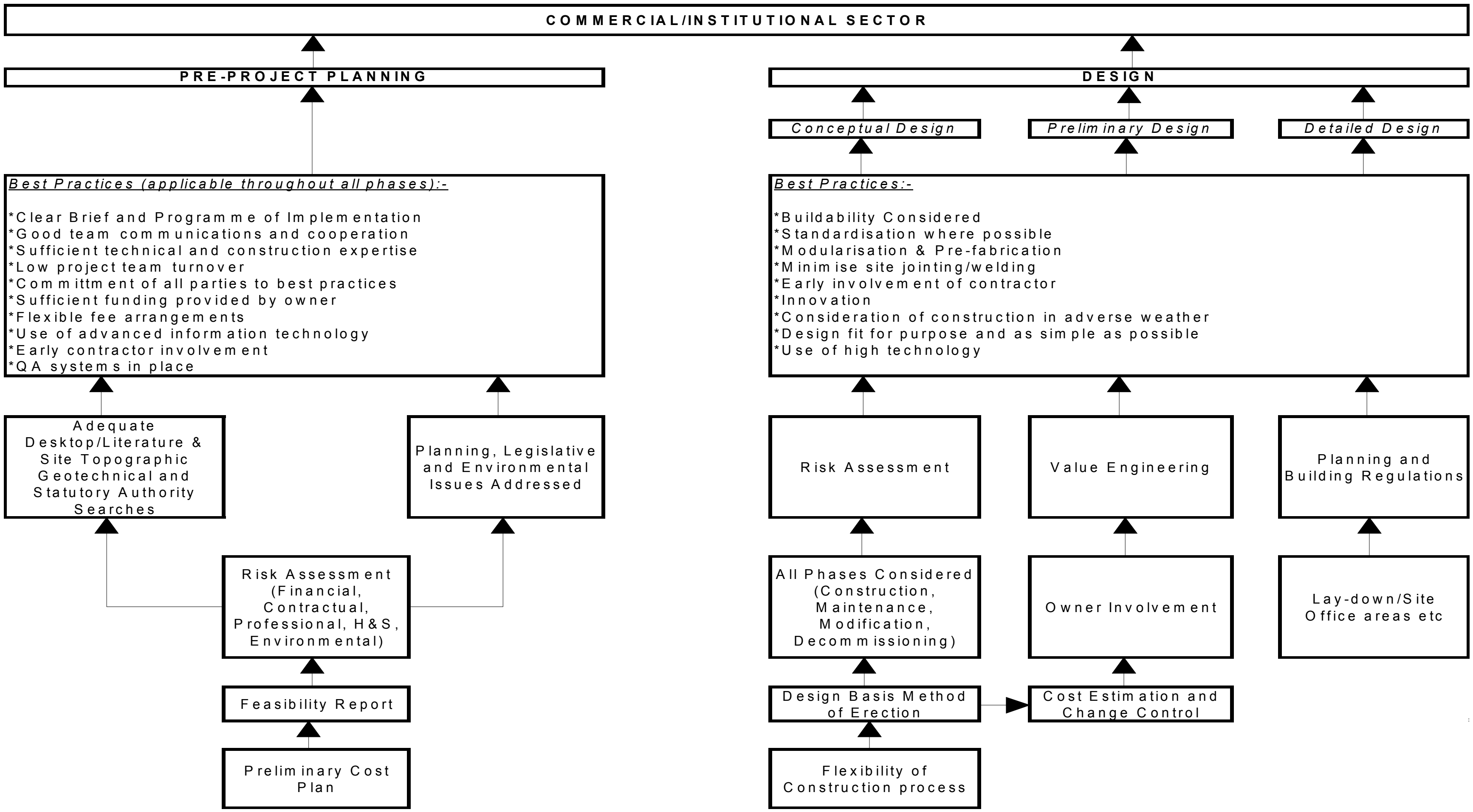
Appendix B. Data Classification Hierarchies for the Commercial/Institutional Sector

This appendix includes two data classification hierarchies for the commercial/institutional sector. Both hierarchies are organized around a modified version of the Construction Industry Institute (CII) system for classifying project activities into phases (see Section 3.4 for a description of the CII system and for the definitions of each CII phase). Modifications to the CII system, including any changes in phase definitions, are discussed in detail in Chapter 4. The first hierarchy covers the pre-project planning and design phases. The second hierarchy covers the tender, construction, and commissioning phases.

The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies is to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints. The data oriented hierarchies correspond to cases for which data were collected ***and*** which are summarized in Chapter 6.

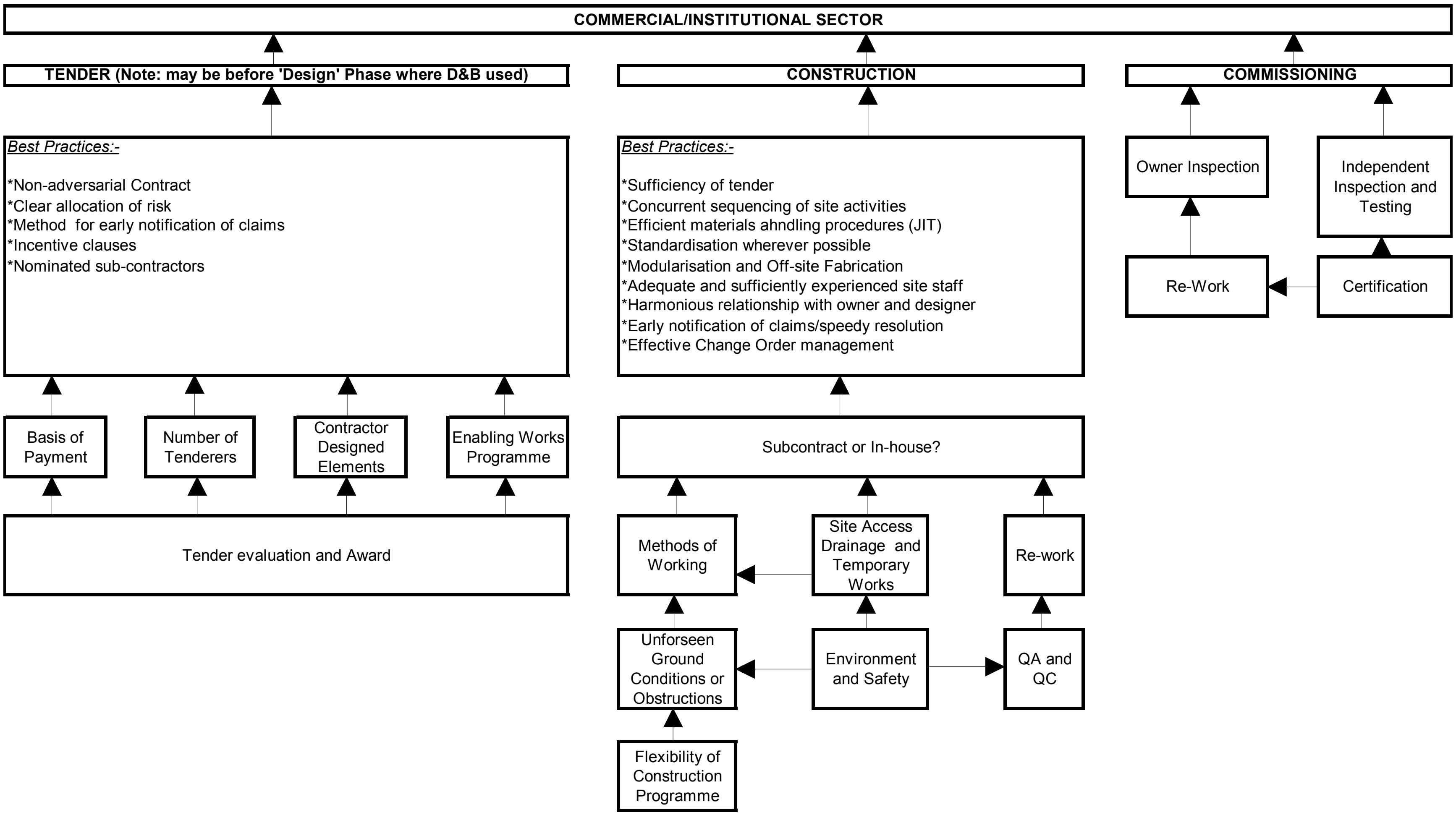
NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



Definitions:-

	(a)	Three primary construction categories are new build, addition/extension, and modernisation
	(b)	Delivery Time is taken as time from commencement of design phase
	(c)	Buildings are grouped according to size, cost, geographic area and type.
	(d)	Building types are Assembly, Education, Food Sales, Food Service, Health Care, Laboratory, Lodging, Mercantile and Service, Office, Public Order, Skilled Nursing, Warehouse and Other

NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



Definitions:- (a) Three primary construction categories are new build, addition/extension, and modernisation
(b) Delivery Time is taken as time from commencement of design phase
(c) Buildings are grouped according to size, cost, geographic area and type.
(d) Building types are Assembly, Education, Food Sales, Food Service, Health Care, Laboratory, Lodging, Mercantile and Service, Office, Public Order, Skilled Nursing, Warehouse and Other

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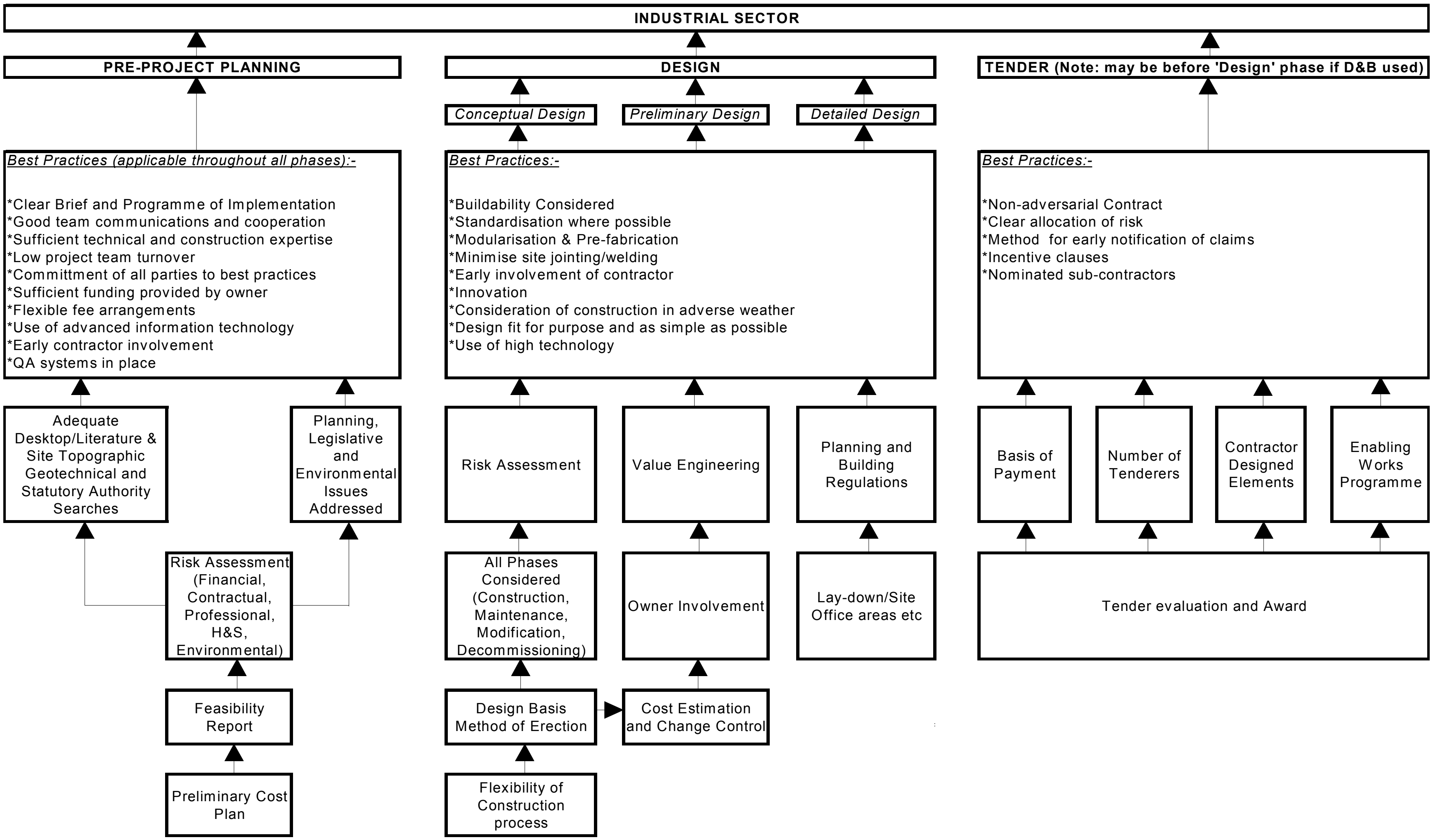
Appendix C. Data Classification Hierarchies for the Industrial Sector

This appendix includes two data classification hierarchies for the industrial sector. Both hierarchies are organized around a modified version of the Construction Industry Institute (CII) system for classifying project activities into phases (see Section 3.4 for a description of the CII system and for the definitions of each CII phase). Modifications to the CII system, including any changes in phase definitions, are discussed in detail in Chapter 4. The first hierarchy covers the pre-project planning, design, and tender phases. The second hierarchy covers the construction, procurement, and start up phases.

The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies is to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints. The data oriented hierarchies correspond to cases for which data were collected ***and*** which are summarized in Chapter 6.

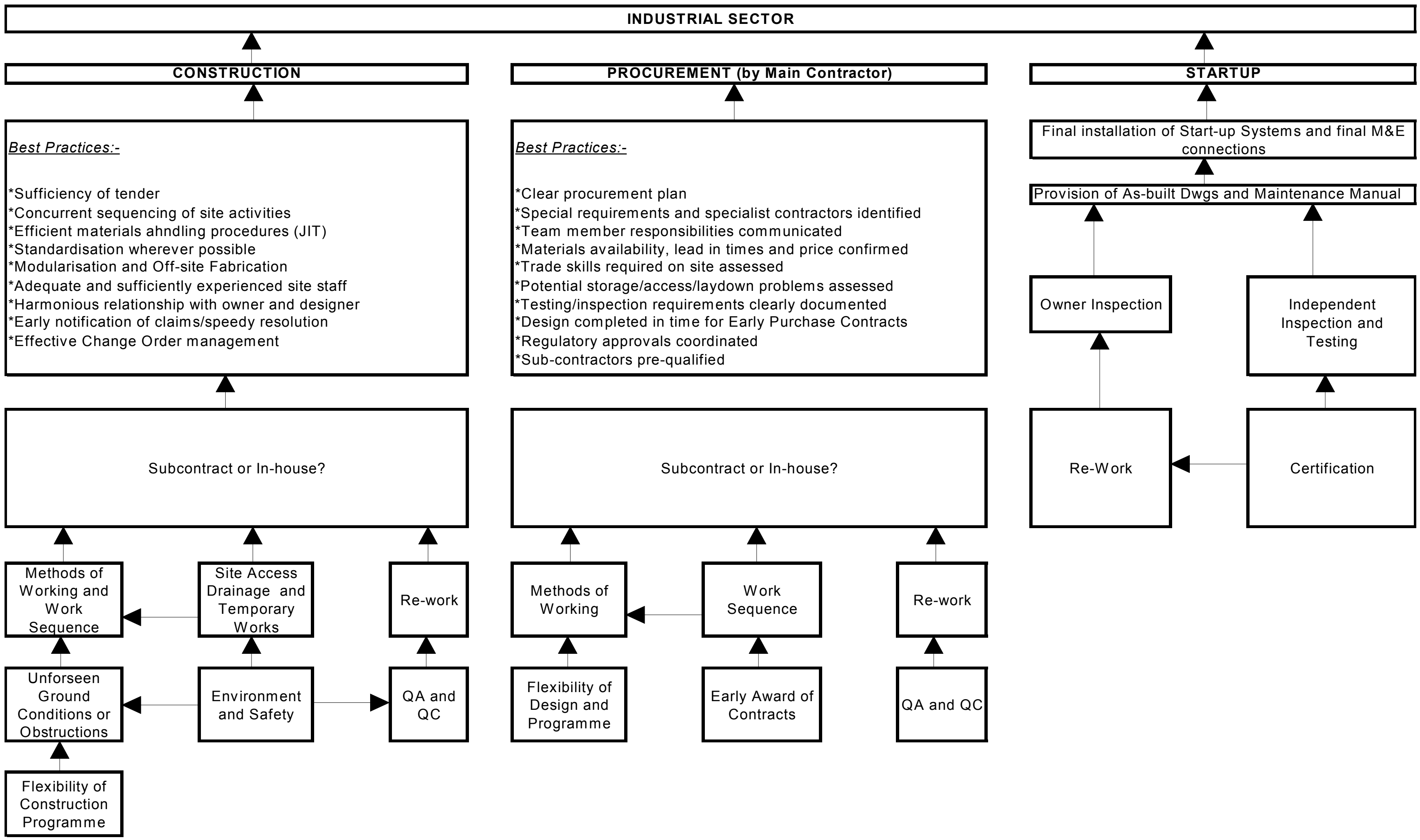
NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



Definitions:-

(a) Three primary construction categories are new build, addition/extension, and modernisation
(b) Delivery Time is taken as time from commencement of design phase
(c) Projects are grouped according to size, cost, geographic area and type.

NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



Definitions:-

(a) Three primary construction categories are new build, addition/extension, and modernisation
(b) Delivery Time is taken as time from commencement of design phase
(c) Projects are grouped according to size, cost, geographic area and type.

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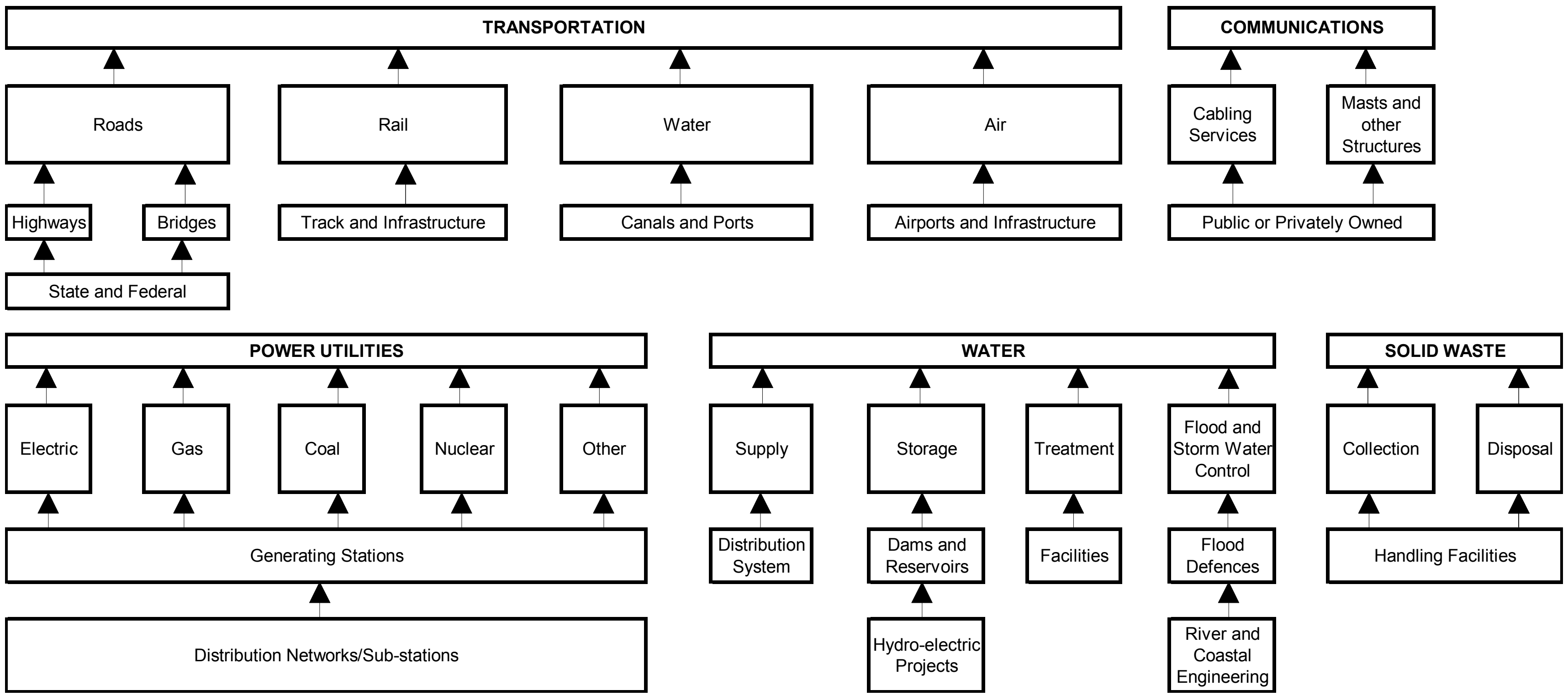
Appendix D. Data Classification Hierarchies for the Public Works Sector

This appendix includes three data classification hierarchies for the public works sector. The first hierarchy covers the entire public works sector; it serves to define each of the five key sub-sectors covered in this document. The two remaining hierarchies are organized around a modified version of the Construction Industry Institute (CII) system for classifying project activities into phases (see Section 3.4 for a description of the CII system and for the definitions of each CII phase). Modifications to the CII system, including any changes in phase definitions, are discussed in detail in Chapter 4. The second hierarchy covers the pre-project planning, design, and tender phases. The third hierarchy covers the construction, procurement, and start up phases.

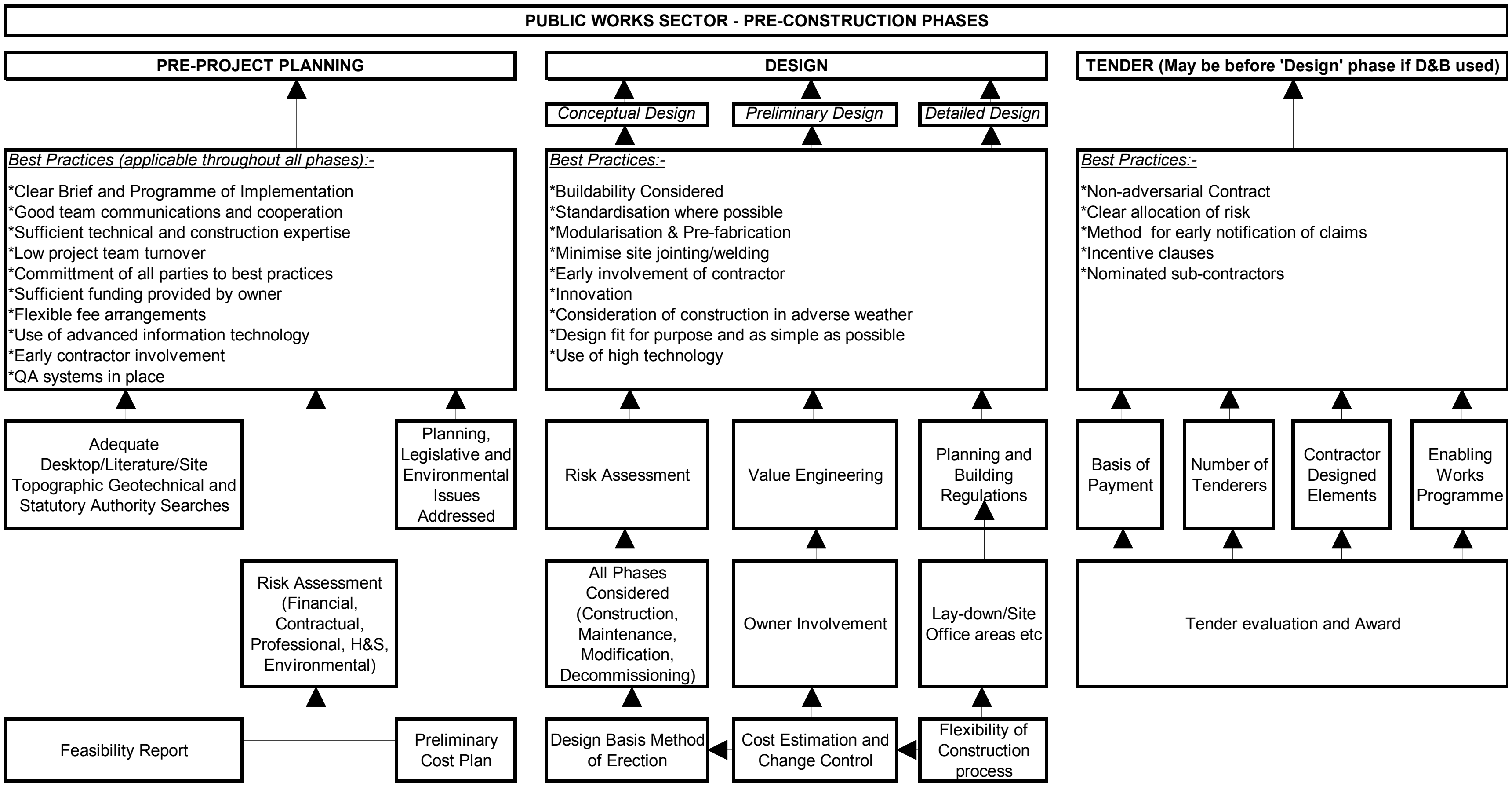
The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies is to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints. The data oriented hierarchies correspond to cases for which data were collected ***and*** which are summarized in Chapter 6.

NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS

PUBLIC WORKS SECTOR - DEFINITION OF SUB-SECTORS



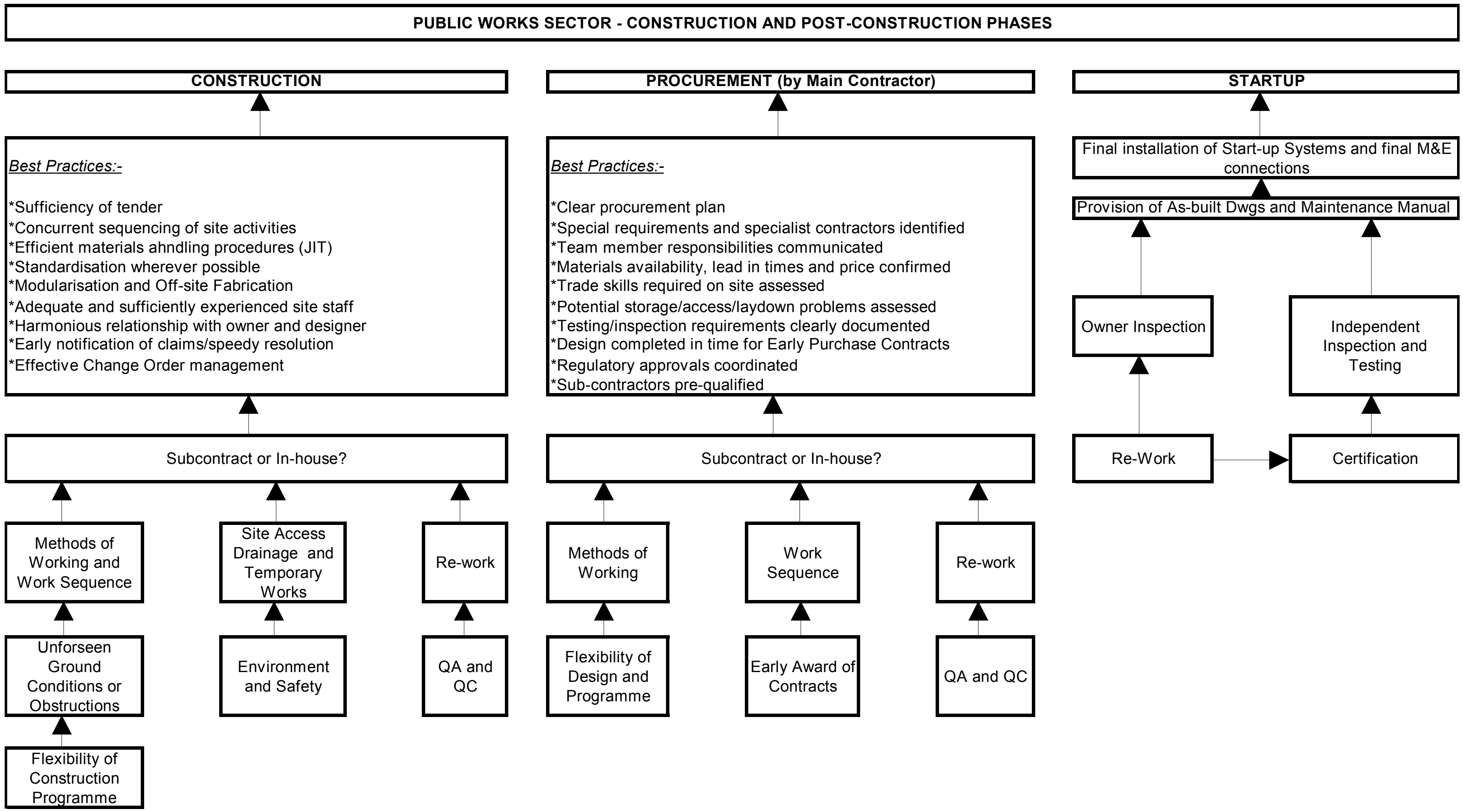
NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



Definitions:-

(a) Three primary construction categories are new build, addition/extension, and modernisation
(b) Delivery Time is taken as time from commencement of design phase
(c) Projects are grouped according to size, cost, geographic area and type.
(d) Project types are Transportation, Communications, Power Utilities, Water and Solid Waste

NATIONAL CONSTRUCTION GOAL 1 - 50% REDUCTION IN DELIVERY TIME FOR PROJECTS - FACTORS INFLUENCING GOAL



Definitions:-

(a) Three primary construction categories are new build, addition/extension, and modernisation
(b) Delivery Time is taken as time from commencement of design phase
(c) Projects are grouped according to size, cost, geographic area and type.
(d) Project types are Transportation, Communications, Power Utilities, Water and Solid Waste

Appendix E. Assignment of States to Census Regions

NORTHEAST	**SOUTH**
New England States	**South Atlantic States**
Connecticut	Delaware
Maine	District of Columbia
Massachusetts	Florida
New Hampshire	Georgia
Rhode Island	Maryland
Vermont	North Carolina
Mid Atlantic States	South Carolina
New Jersey	Virginia
New York	West Virginia
Pennsylvania	**East South Central States**
	Alabama
MIDWEST	Kentucky
East North Central States	Mississippi
Illinois	Tennessee
Indiana	**West South Central States**
Michigan	Arkansas
Ohio	Louisiana
Wisconsin	Oklahoma
West North Central States	Texas
Iowa	
Kansas	**WEST**
Minnesota	**Mountain States**
Missouri	Arizona
Nebraska	Colorado
North Dakota	Idaho
South Dakota	Montana
	Nevada
	New Mexico
	Utah
	Wyoming
	Pacific States
	Alaska
	California
	Hawaii
	Oregon
	Washington
Source: US Bureau of the Census	

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Appendix F. Two-Digit Standard Industrial Classification (SIC) Codes

SIC Code	Label
01	Agricultural production - crops
02	Agricultural production livestock and animal specialties
07	Agricultural services
08	Forestry
09	Fishing, hunting, and trapping
10	Metal mining
12	Coal mining
13	Oil and gas extraction
14	Mining and quarrying of nonmetallic minerals, except fuels
15	Building construction - general contractors and operative builders
16	Heavy construction other than building construction - contractors
17	Construction - special trade contractors
20	Food and kindred products
21	Tobacco products
22	Textile mill products
23	Apparel and other finished products made from fabrics and similar materials
24	Lumber and wood products, except furniture
25	Furniture and fixtures
26	Paper and allied products
27	Printing, publishing, and allied industries
28	Chemicals and allied products
29	Petroleum refining and related industries
30	Rubber and miscellaneous plastic products
31	Leather and leather products
32	Stone, clay, glass, and concrete products
33	Primary metal industries
34	Fabricated metal products, except machinery and transportation equipment
35	Industrial and commercial machinery and computer equipment
36	Electronic and other electrical equipment and components, except computer equipment
37	Transportation equipment
38	Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
39	Miscellaneous manufacturing industries
40	Railroad transportation
41	Local and suburban transit and interurban highway passenger transportation
42	Motor freight transportation and warehousing

43	United States Postal Service
44	Water transportation
45	Transportation by air
46	Pipelines, except natural gas
47	Transportation services
48	Communications
49	Electric, gas, and sanitary services
50	Wholesale trade - durable goods
51	Wholesale trade - nondurable goods
52	Building materials, hardware, garden supply, and mobile home dealers
53	General merchandise stores
54	Food stores
55	Automotive dealers and gasoline service stations
56	Apparel and accessory stores
57	Home furniture, furnishings, and equipment stores
58	Eating and drinking places
59	Miscellaneous retail
60	Depository institutions
61	Nondepository credit institutions
62	Security and commodity brokers, dealers, exchanges, and services
63	Insurance carriers
64	Insurance agents, brokers and service
65	Real estate
67	Holding and other investment offices
70	Hotels, rooming houses, camps, and other lodging places
72	Personal services
73	Business services
75	Automotive repair, services, and parking
76	Miscellaneous repair services
78	Motion pictures
79	Amusement and recreation services
80	Health services
81	Legal services
82	Educational services
83	Social services
84	Museums, art galleries, and botanical and zoological gardens
86	Membership organizations
87	Engineering, accounting, research, management, and related services
88	Private households
89	Miscellaneous services

Appendix G. List of Acronyms

Acronym	Definition
AAO	Average Actual Occupancy
AAR	Association of American Railroads
AER	Annual Energy Review
AFUE	Annual Fuel Utilization Efficiency
AHS	American Housing Survey
APPA	The Association of Higher Education Facilities Officers
APTA	American Public Transit Association
ATA	Airline Transport Association
BFRL	Building and Fire Research Laboratory
BOMA	Buildings Owners and Managers Association
BTS	Bureau of Transportation Statistics
C&B	Construction and Building
CBECS	Commercial Buildings Energy Consumption Survey
CCI	Census of the Construction Industry
CDD	Cooling degree days
CSI	Census of Service Industries
DOE	Department of Energy
DOT	Department of Transportation
DSM	Demand-Side Management
EER	Energy Efficiency Ratio
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EREN	Energy Efficiency and Renewable Energy Network
FAA	Federal Aviation Administration
FEMP	Federal Energy Management Program
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FTE	Full-Time Equivalent
GDP	Gross domestic product
GSF	Gross square foot
GSM	Gross square meter
HDD	Heating degree days
HEP	Hydro-electric power
HID	High intensity discharge
HUD	Department of Housing and Urban Development
HVAC	Heating, ventilation and air conditioning
IFMA	International Facility Management Association
IREM	Institute of Real Estate Management

M&R	Maintenance and Repair
MA	Metropolitan Areas
MADA	Multiattribute Decision Analysis
MARAD	Maritime Administration
MECS	Manufacturing Energy Consumption Survey
MHI	Manufactured Housing Institute
NAHB	National Association of Home Builders
NAS	National Airspace System
NCG	National Construction Goal
NIST	National Institute of Standards and Technology
OIT	Office of Industrial Technologies
OM&E	Operations, Maintenance and Energy
RD&D	Research, development and deployment
RECS	Residential Energy Consumption Survey
ROW	Rights of Way
RSF	Rentable Square Foot
RSM	Rentable Square Meter
SEER	Seasonal Energy Efficiency Rating
SIC	Standard Industrial Classification
STB	Surface Transportation Board
USACE	US Army Corps of Engineers
USBC	US Bureau of the Census
USGS	United States Geological Survey
VIP	Value of Construction Put in Place
3R	Resurfacing, Restoration, and Rehabilitation

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Water Resources Support Center
http://www.wrc-ndc.usace.army.mil

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Energy Information Administration
http://www.eia.doe.gov

US Department of Transportation

Bureau of Transportation Statistics
http://www.bts.gov

Federal Transit Administration
http://www.fta.dot.gov

Maritime Administration
http://www.marad.dot.gov

Surface Transportation Board
http://www.stb.dot.gov

Other Sources

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http://www.pubworks.org

Association of American Railroads
http://www.aar.org

Manufactured Housing Institute
http://www.mfghome.org

National Conference of States on Building Codes and Standards
http://www.ncsbcs.org