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IMPROVING CONSTRUCTION INDUSTRY PERFORMANCE: ISSUES AND OPPORTUNITIES*

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*The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Secretariat of the United Nations Industrial Development Organization (UNIDO). Mention of firm names and commercial products does not imply the endorsement of UNIDO. This document has not been edited.

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INTRODUCTION

This paper was written to assist UNIDO prepare for its first international consultation on the construction industry. The consultation will serve as a forum for developed and developing countries to: 1) discuss current trends in the construction industry, identify and evaluate various constraints affecting productivity and industrial development; 2) assess opportunities for increasing construction industry productivity and development through international trade and technical assistance; and 3) to formulate policy and action-oriented recommendations for improving construction industry performance in developing countries.

The paper is divided into six sections: an overview of the importance of the construction industry to national economies; a description of the U.S. construction industry; identification of major trends in construction industry technological innovation; a description of U.S. construction industry productivity trends; assessment of factors impeding technological innovation in industry; and a series of recommendations for further discussion.

THE ROLE OF CONSTRUCTION ACTIVITY IN THE ECONOMY

The construction industry differs from most other industries in several key ways. First, the construction industry's relative activity is large, accounting for up to 7 percent of gross domestic product in developing countries in 1989, and up to 9 percent in industrialized countries in 1989 (see Table 1). Secondly, value added in construction generally accounts for more than 25 percent of the total value added attributable to fixed capital formation (see Table 2). About half of that is in residential construction. Thirdly, it is extensively linked to almost every aspect of the economy as both a major purchaser of materials and supplier of a product required for further production of goods

TABLE 1

CONSTRUCTION COMPONENT OF GROSS DOMESTIC PRODUCT AND EMPLOYMENT PERCENT OF GDP AND TOTAL EMPLOYMENT

	CONSTRUCTION ACTIVITY PERCENT OF GDP			CONSTRUCTION EMPLOYMENT PERCENT OF TOTAL EMPLOYMENT		
	1981	1985	1989	1981	1985	1989
OECD COUNTRIES						
Canada	7	6	6	6	5	6
United States	5	5	5	6	7	7
United Kingdom	5	5	6	6	6	7
Sweden	7	6	6	7	6	6
Japan	9	7	9	10	9	9
France	7	5	5	8	7	7
Germany	7	5	5	8	7	7
LATIN AMERICAN COUNTRIES						
Bolivia	4	6	7	5	3	3
Brazil	8	6	5	8	6	
Chile	5	4	4	5	4	7
Colombia	5	7	4	6	6	6
Costa Rica	6	4	3	7	5	6
Honduras	6	5	4		5	
Nicaragua	3	5	3	6	5	4
Peru	6	6	6		6	5
Uruguay	6	8	7	5	4	
Venezuela	5	2	3	9	7	8

Sources: International Labor Organization, Yearbook of Labor Statistics, 1991
United Nations, National Accounts Statistics, 1988-89

TABLE 2

VALUE ADDED IN THE CONSTRUCTION INDUSTRY

COUNTRY	YEAR	VALUE ADDED		PERCENTAGE OF GROSS DOMESTIC FIXED CAPITAL FORMATION
		PERCENTAGE OF GDP	MILLIONS OF DOLLARS	
Canada	1984	4.2	$13,929	23.0
France	1984	5.6	27,568	29.8
Germany	1985	5.0	31,172	25.5
Japan	1985	7.3	96,961	25.7
United States	1985	4.7	184,279	24.3
Brazil	1982	4.9	13,861	23.0
Colombia	1983	5.1	1,951	30.0
Mexico	1983	5.1	7,313	29.5
Peru	1983	3.1	545	19.2
Venezuela	1985	3.0	1,486	19.4

Sources: International Labor Organization, Yearbook of Labor Statistics 1987
United Nations, National Accounts Statistics: Main Aggregates and Detailed Table, 1985

and services [Hillebrandt, 1985]. Finally, the government's role impacts construction at both the microeconomic level as a consumer or executor of works, and at the macroeconomic level in its ability to distort market forces through policy making [World Bank, 1984].

While construction may differ from other industrial sectors on these counts, it remains highly linked to them, especially manufacturing. Extensive backward linkages exist to suppliers for a vast array of materials and equipment, whose economic value often exceeds the value added by the construction sector itself [Moavenzadeh, 1987]. Manufacturing is also a key demander of the construction industry's produced factories and warehouses. Construction's importance to economic growth is critical, providing the buildings and the infrastructure to support social and economic activities. As decision-makers and policy analysts deepen their understanding of the construction industry and its function in the national economy, they will be better equipped to facilitate its role in providing directly for human needs, stimulating investment, and generating employment [Moavenzadeh, 1987].

AN OVERVIEW OF THE U.S. CONSTRUCTION INDUSTRY

In the U.S., construction activity is carried out within a complex network of disciplines and firms shifting over time and place. Each of the major players -- architects, engineers, builders, suppliers - typically work independently of each other and often for separate firms. Actual production is undertaken on-site, not in the factory, with seasonal fluctuations. Additionally, these seasonal and geographic fluctuations of production force contractors to rely on a floating pool of labor [Moavenzadeh, 1987]. The product, on the other hand, is immobile, long lasting, relatively expensive, and time consuming to produce. The participation of investors, subcontractors, equipment and material suppliers, users and regulating government agencies only complicates the construction process further. The result is an industry where relationships are intense but temporary, competition formidable, and production highly sensitive to economic conditions.

The construction industry in the U.S. is highly fragmented with a large number of firms performing specific parts of production. There aren't any giants like in the auto industry or computers and most lack any vertical integration (design, organization, implementation) or even horizontal integration (electrical, carpentry, plumbing). For example, the National Association of Home Builders (NAHB) reported that the largest homebuilders in the nation in 1989 accounted for less than one percent of total housing starts.[1]

Structure and Organization of the U.S. Construction Industry

In the United States, as of 1987, there were approximately 544,000 construction establishments with at least one person on the payroll (see Table 3). Of this amount about 120,000 firms are merchant builders or contractors specializing in residential construction. Nearly 40,000 establishments (38,351) specialize in the construction of nonresidential buildings. Another 37,000 establishments are engaged in heavy construction, building pipelines and refineries, civic works and infrastructure. All these firms draw on the resources of 340,000 specialized contractor firms (plumbers, electricians, masons, painters, etc.).

In addition to the approximately 120,000 residential building establishments operating in 1987 with payrolls, there were 285,000 establishments operating without payrolls (see Table 4). Business receipts for firms with payrolls averaged $931,971 per firm compared to $95,380 for those without payroll. Of all the general contractors and operative builders with payroll in the construction industry, three-quarters were primarily engaged in residential construction (see Table 3).

Over the period from 1977 to 1987, construction establishments increased by 13 percent, adding 64,000 new firms with payrolls. Most of the growth, over 85 percent was the result of new specialized trade contractors. Residential builders declined from the late 1970s through the 1980s and are again in steep decline. Over the next ten years, NAHB expects a significant increase in the number of special trade contractors, but not in the number of home builders.

Value of Construction Put In Place

In 1987, the total value of construction put in place was $329 million. Of this amount $262 million was associated with the construction of buildings-- representing nearly 80 percent of the total value of construction put in place. Residential buildings (including hotels and motels) accounted for nearly half of building construction activity-- 47.8 percent. Office, commercial and industrial and warehouse buildings comprise 40 percent of the output. The remaining 12 percent reflects institutional and miscellaneous buildings. In the area of non-building construc-

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1. Gopal Ahluwalia, Director of Research, National Association of Home Builders (NAHB), provided much of the data on the structure of the housing industry from reports generated using the U.S. Census of Construction and NAHB surveys of their membership.

TABLE 3

NUMBER OF ESTABLISHMENTS WITH PAYROLL ENGAGED IN RESIDENTIAL CONSTRUCTION

	1977	1982	1987
RESIDENTIAL BUILDERS	129,245	93,632	119,287
INDUSTRIAL BUILDINGS & WAREHOUSES	8,259	7,435	7,014
NONRESIDENTIAL	18,467	22,112	31,337
SUBTOTAL GENERAL BUILDING CONTRACTOR AND OPERATIVE BUILDERS	155,971	123,179	157,638
HEAVY CONSTRUCTION	31,296	28,187	36,599
PLUMBING, HEATING, A/C	56,435	60,243	69,556
PAINTING, PAPER HANGING & DECOR.	27,369	24,779	29,867
ELECTRICAL WORK	36,764	39,563	49,436
MASONRY, PLASTERING, & TILE	45,451	40,460	46,182
CARPENTRY AND FLOORING	33,357	37,438	44,183
ROOFING AND SHEET METAL	20,577	21,152	25,673
CONCRETE WORK	16,974	19,986	23,422
WATER WELL DRILLING	4,305	3,551	3,414
MISC. SPECIAL TRADE	46,442	52,238	50,290
SUBTOTAL SPECIAL TRADE CONTRACTORS	287,674	299,410	342,023
SUBDIVIDERS AND DEVELOPERS	5,078	5,925	7,955
TOTAL	480,019	456,701	544,215

Source: National Association of Home Builders, 1990

TABLE 4

RESIDENTIAL BUILDERS WITH PAYROLL, 1987

	Establishments With Payroll	Establishments Without Payroll	Total
General Contractors - Residential Builders	98,521	266,074	364,595
Operative Builders	20,766	19,411	40,177
TOTAL	119,287	285,485	404,772
Average Value of Business Receipts by Establishment	$931,971	$95,380	

Source: National Association of Home Builders, 1990 tion, highways, streets, parking and bridges account for nearly 40 percent of activity. Water and sewer systems and treatment facilities account for 23 percent of non-building construction.

In 1982, roughly 70 percent of all construction activity was for buildings. Residential construction accounted for 35 percent of building construction. Office, commercial and industrial and warehouse buildings comprised 50 percent of the 1982 output. The remaining 15 percent reflects institutional and miscellaneous buildings. In the area of non-building construction, highways, streets, parking and bridges accounted for nearly 31 percent of activity. Water and sewer systems and treatment facilities account for 30 percent of non-building construction. Figures 1 and 2 illustrate the distribution of construction activities by type of construction for 1982 and 1987.

Characteristics of Establishments

Unlike other industries, there is little concentration of economic output in the construction industry. Today as well as in the past, construction is highly fragmented. Table 5 shows the distribution of establishments by dollar volume of business done. In 1987, over 54 percent of all construction establishments had gross receipts below $250,000. Only 7,005 firms had receipts in excess of $10,000,000, accounting for 1.3 percent of total employment. Firms grossing less than $250,000 in 1987 accounted for 6 percent of total construction industry receipts. On the other hand firms with receipts over $10,000,000 accounted for nearly 40 percent of total industry receipts in 1987. In 1986, the four largest construction firms (Bechtel, M.W. Kellog, Parsons and Fluor) had foreign and domestic contract awards totaling $26.5 billion, representing about 5 percent of total 1987 construction receipts [United Nations Center on Transnational Corporations, 1989].

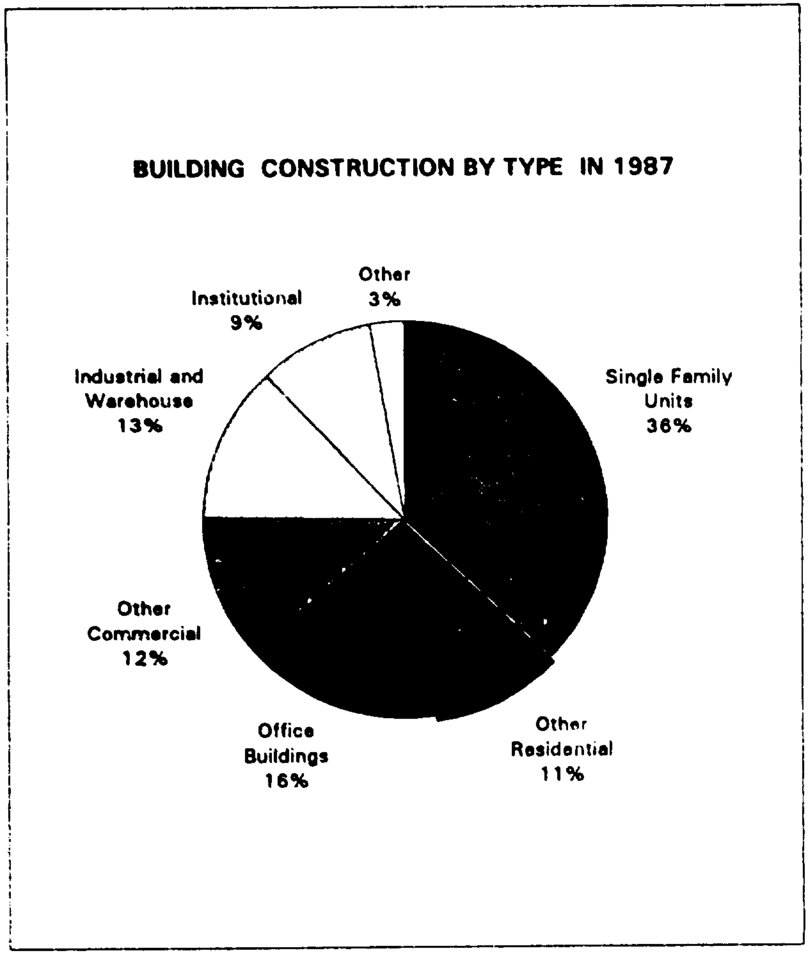
Residential construction activities are even more fragmented. As Figure 3 illustrates, in 1987, 75 percent of residential builder firms built 25 or fewer houses. Medium sized builders (building between 25 to 100 units per year) account for 16 percent of all firms. Large-scale builders (annually producing over 100 units) account for 9 percent of all builder establishments.

Over time, the size of builders has been shifting to smaller firms. In 1969, 58 percent of homebuilders built less than 25 units. By 1987 the percentage had increased to 75 percent. Medium builders (25-100 units) fell from 30 percent in 1969 to 16 percent in 1987. Large builders, those producing over 100 units per year declined from 12 percent to 9 percent of NAHB membership (see Figure 3 for 1987).

Figure 4 illustrates the market share of residential builders by size of establishment. Small firms account for 13 percent of housing starts. Medium firms account for 20 percent of produc-

FIGURE 1

DISTRIBUTION OF CONSTRUCTION BY TYPE OF CONSTRUCTION



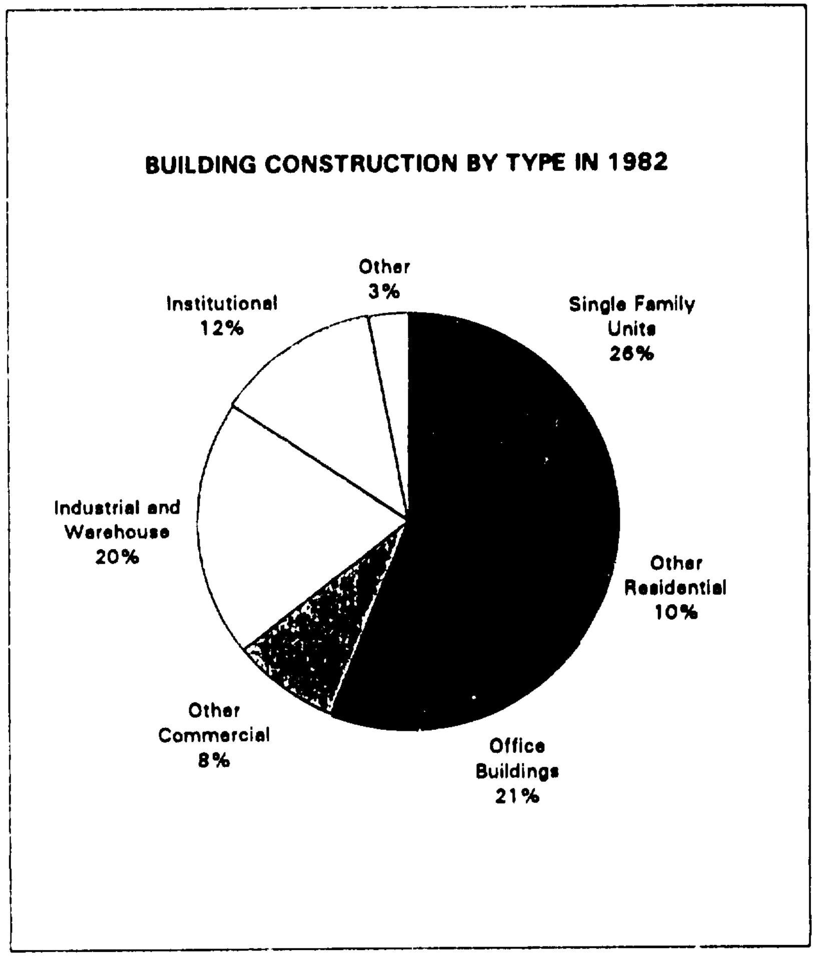


FIGURE 2

NON BUILDING CONSTRUCTION BY TYPE OF CONSTRUCTION

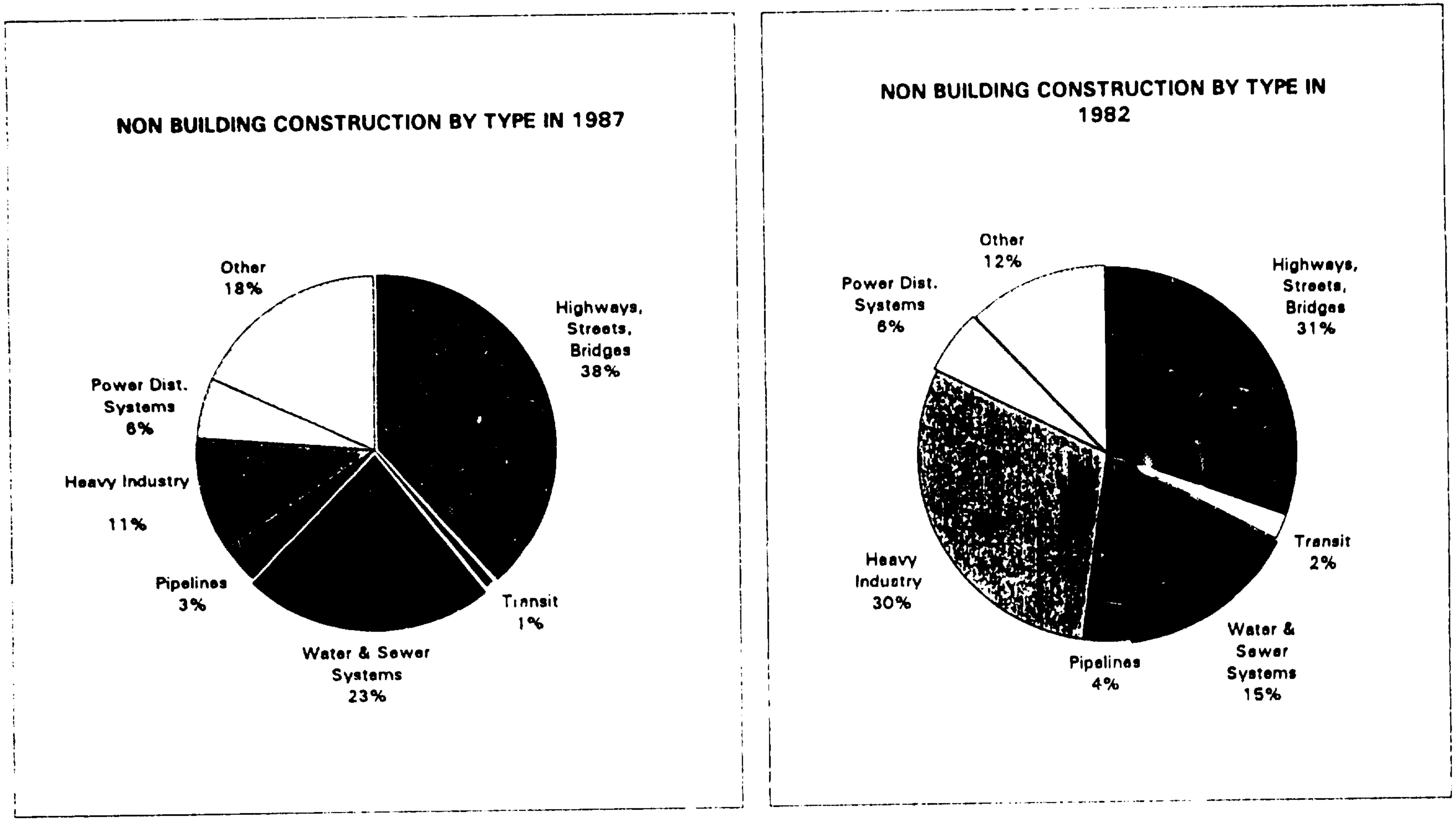


TABLE 5

ESTABLISHMENTS BY BUSINESS VOLUME

RANGE OF BUSINESS VOLUME	ESTABLISHMENTS 1987	PERCENT OF TOTAL	$ VALUE OF BUSINESS (000) 1987	$ VALUE OF BUSINESS (000) 1982	PERCENT OF TOTAL 1987	PERCENT OF TOTAL 1982
Less Than $250,000	296,328	54.4	$31,529,892	$26,052,428	6.0	8.3
250,000 - 499,999	92,359	17.0	32,485,396	21,330,428	6.2	6.8
500,000 - 999,999	65,772	12.1	46,047,972	27,882,464	8.8	8.9
1,000,000 - 2,499,999	52,920	9.7	81,785,070	43,725,112	15.7	14.0
2,500,000 - 4,999,999	20,353	3.7	70,204,161	36,203,324	13.4	11.6
5,000,000 - 9,999,999	9,496	1.7	65,082,781	35,541,475	12.5	11.4
10,000,000 and Over	7,005	1.3	195,330,090	121,442,926	37.4	38.9
TOTAL	544,233	100.0	$522,465,362	$312,178,157	100.0	100.0

Source: U.S. Department of Census, 1987 Census of Construction Industries, July 1990.

FIGURE 3
BUILDERS BY SIZE OF ESTABLISHMENT - 1987

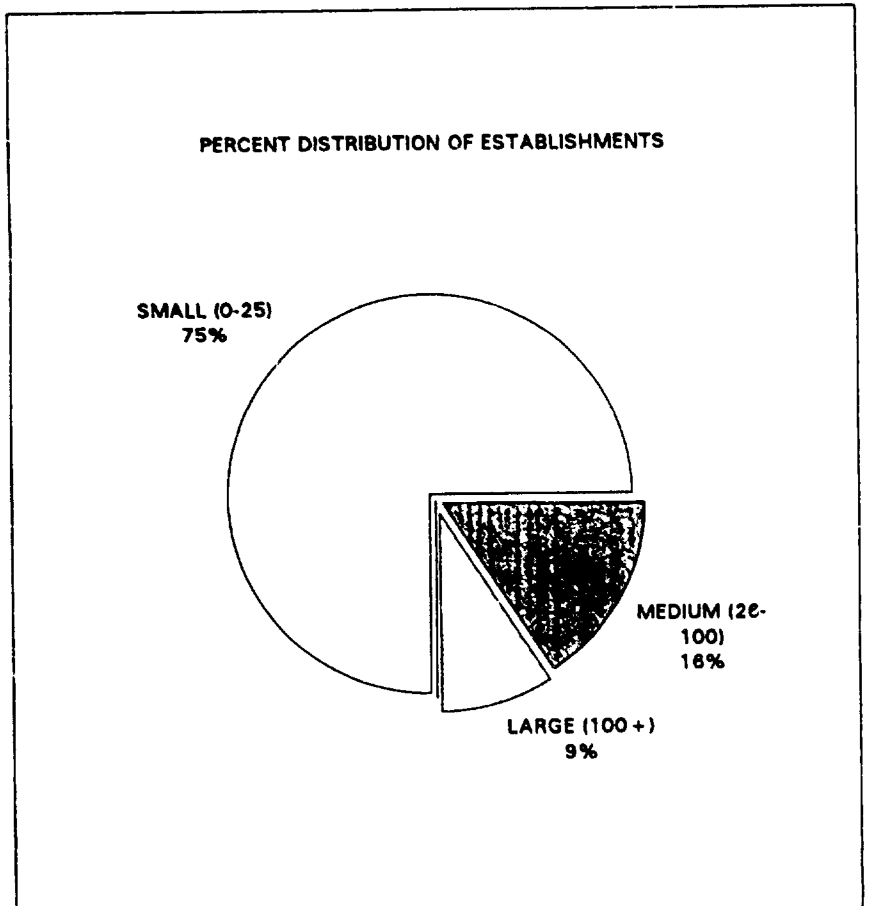
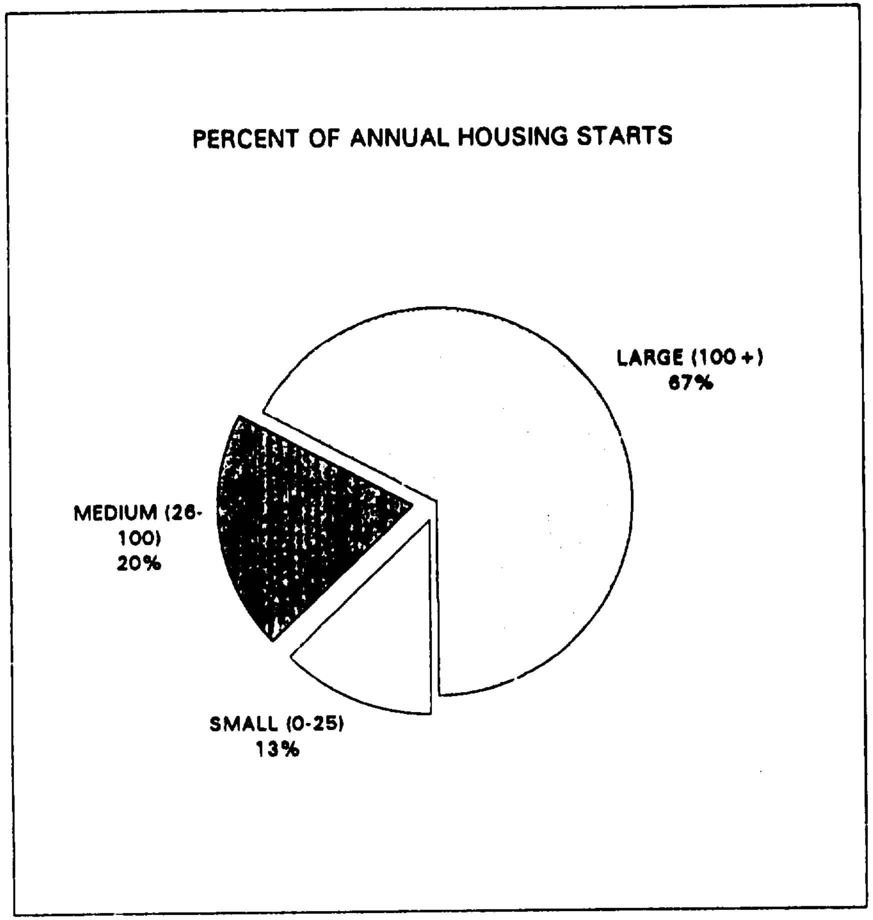


FIGURE 4
BUILDERS BY SIZE OF OUTPUT - 1987



Source: National Assoc. of Homebuilders

tion. Large firms account for 67 percent of production. The structure of the homebuilding industry is changing. In 1979, the largest 100 firms accounted for 10 percent of output, ten years later, they comprised 15 percent of total national production. Over the same period the largest 400 builders increased their market share from 17 to 24 percent. The large-scale builders normally orient production of new housing to the mass first-time buyer market. Small and medium size builders, on the other hand, tend to build for the upper reaches of the market. With the continuation of the savings and loan crisis and its restructuring, large-scale firms will capture and even larger market share as lending institutions cut back on construction loans and mortgage commitments to small builders.

Another clear trend among construction firms is that as they increase in size they increase their utilization of subcontractors. The smallest firms subcontract an average of 9 percent of their work (measured in gross receipts). The rate doubles to 18.5 percent for establishments with gross receipts of between $1,000,000 and $2,499,999. The largest firms grossing over $10,000,000 subcontract out 37 percent of their work. The pattern suggests that as firms increase in scale of operation they specialize more and do not attempt vertical integration.

However, some residential builders are attempting to integrate other operations by going "upstream" and developing plots for residential projects, or setting up building materials companies, or going "downstream" and providing buyers with financial, interior decorating or furnishing services. In the 1987 survey, 50 percent of the responding firms indicated that they sometimes develop land for residential projects. For the large builders, 90 percent indicated that they carry out land development activities to support their residential construction activities.

On the other hand, there is apparently considerable diversification into other types of construction activities (residential builders building shopping malls and office buildings). In a NAHB 1987 survey of residential builders, most establishments indicated that they were engaged in nonresidential construction projects. Thirteen percent of responding firms indicated that they were constructing office buildings, 11 percent said other commercial building and 5 percent indicated that they were constructing industrial buildings. Establishment managers explained that they diversified into other projects to reduce market risk and take advantage of tax incentives.

The overall structure of the residential construction industry in North America is highly decentralized. Most firms operate in one geographic area. Approximately 50 percent of the NAHB members operate in only one county, only 4 percent operate in more than five counties. However, the large-scale firms operate in multiple locations centered around major metropolitan areas. Most of the large-scale firms are decentralized, operating as a set of autonomous "profit-centers" similar to medium sized firms in terms of subcontracting and materials procurement. Virtually all firms have very low over-heads, making great use of subcontractors to construct housing. With such low overheads, builders are better positioned to quickly respond to market changes. The next section reviews trends in construction industry technology in the U.S.

TRENDS IN CONSTRUCTION INDUSTRY TECHNOLOGY

> In any given field the term technology may hold a special meaning. In housing, technology can generally be thought of as the application of various sciences and arts to solve problems in the production, construction and operation of housing [Laquarta and McCarty, 1992].

Historically, social progress and the development of regional architectural styles, drove housing technology. Colonialists first duplicated the styles of their homelands with the tools they brought with them. They later adapted them to respond to the climatic and social conditions of the States. The 1700's also saw the emergence of a new trade -- the builder -- as proven and widely used building techniques replaced local and intuitive techniques of construction.

Construction systems and materials started to transform the industry in 1800's. The balloon frame construction system, buoyed by the production of mass-produced nails and milled studs, began replacing the post and beam system in 1833. This system enabled a single man to build the entire frame with fewer tools (it's derivative, the platform frame, is still in use today). Prefabricated frames, walls and roofs, manufactured in one location and shipped to and assembled on site, soon followed [Condit, 1968]. Synthetic materials used to strengthen concrete led to its widespread use in the 1880's. While technological progress was being made in materials, however, the lagging development of the municipal utility systems slowed development of sanitation, lighting and heating systems [Rotsch, 1967].

Over the last 40 years, improvements in materials, tools, transport and equipment have driven progress in the construction industry. The variety of materials and the numerous ways every aspect of a house can be constructed, from foundations to roofs, has made almost every site buildable. Theoretically, such development made it possible to conserve on labor and capital while giving consumers more choice. Most of these improvements, however, have come from the research and development efforts of suppliers (supporting claims that the large-number-of-small-builder structure of the housing construction industry is not conducive to R & D or rapid change). The industry, therefore, has changed in many small ways, but not in the fundamental way a house is built.

Current and Projected Technological Developments

Recent technological improvements in construction fall into four categories: methods, equipment, materials, and components. Diffusion is expected to continue gradually over the next decade, through the use of innovative architectural and engineering design; better management controls for organizing, monitoring and controlling construction activities; more productive equipment and machinery, and new and improved materials, and prefabricated building components [U.S. Department of Labor, 1988].

Table 6 outlines the major technological advances now under way in the construction industry. Included are: design innovations, including computer-assisted design; work-flow management; computers; robots for repetitive, dangerous or remote procedures; hydraulically powered equipment; construction towers and climbing cranes; continuous paving machines; plastics for pipes, shields, panels, and coatings; and prefabricated building methods.

New methods have been introduced into several of the disciplines in the construction industry, often in conjunction with material, component or equipment innovations. Other changes sought to improve quality, better manage material flows, and shorten or maintain schedules by better organizing and controlling the design and production process. Finally, computer aided design, first introduced to facilitate architectural and engineering processes and coordination, played an increasing role in inventory management and even marketing efforts as builders, supply houses, and even home-improvement centers linked CAD to data bases and used the tool to help customers visualize the proposed product.

The lower costs of microcomputers and software has started to transform construction industry design, scheduling and management practices. In the past, only large construction firms would utilize computer-assisted design techniques to prepare plans. Now as consumers are requesting more detailed and varied design proposals firms are utilizing CAD systems. Besides helping contractors be more responsive to client needs, computer-aided design is shortening the design cycle and increasing the overall cost-effectiveness and quality of preconstruction design.

Computers are also improving the quality of project management. Many medium and small firms are now using a variety of computer assisted management tools such as CPM (critical path method) and PERT (Program Evaluation and Review Technique). Other innovations include value engineering, where designs are tested for their relative costs and benefits and total quality assurance methods to better monitor work activities and avoid construction defects.

The development of many new materials such as glazings, insulations, and sheathings has been driven by energy conservation demands while others like concrete additives, engineered wood, and composite fiber boards have been introduced to improve

TABLE 6
MAJOR TECHNOLOGY CHANGES IN CONTRACT CONSTRUCTION

Technology	Description	Labor Implications	Diffusion
Design innovations, including computer-assisted design.	Architectural and engineering plans, drawings, and specifications for the construction of a project, including use of computers.	Many new design concepts have made possible cost savings and reductions in labor requirements. plastic design and tubular and staggered truss frames, for example,have reduced steel usage, weight, , and cost of building, as well as labor requirements. Computer assisted design has fostered the development and further refinement of design concepts, significantly reducing drafting requirements.	Widely used on large projects, increasingly used for medium-sized projects.
Work flow management techniques: Critical Path Method, Program Evaluation and Review Technique, etc.	Management systems that chart the work activity of a construction project in detail for control and planning and scheduling.	These methods reduce total construction time and cost, allow more efficient use of labor, and timely delivery of materials to job site.	Widely used by large and medium-sized firms. The systems were used, until recently, primarily for project planning by
Computers	Use of computers to design structures, develop bid-estimates, schedule and review work flow, and control machinery and equipment.	Reduces design, bid and construction time and costs. Reduces labor requirements both in office and at the site. Increases productivity of equipment, but does not reduce need for operators.	Great potential for growth. Mainly used by largest firms in past. Now used by most medium-sized firms as well. Low cost , more powerful minicomputers and software availability make computers accessible and affordable to most firms.
Robots	Mechanical arm or machine capable of repetitive and remote operation.	Reduction of labor requirements less important than safety considerations. Primarily for work in areas considered too inaccessible or hazardous for workers such as inside pipes, on superstructure of bridges, and underwater.	Very few applications at present. Anticipate rather limited use in the near future. Rate of diffusion expected to be gradual. More difficult to apply than most manufacturing operations. Will continue to be used primarily for the most dangerous jobs.
Hydraulically powered construction equipment	Hydraulic motors set in motion by gasoline or diesel-powered hydraulic pump are used t provide direct power the movement and activity of construction machines.	Increases efficiency, reliability, capacity, and mobility. Reduces costs and labor requirements by replacing less efficient systems such as steam power.	Near saturation. Although hydraulic backhoes and cranes have been used in construction for many years, very rapid growth has occurred in the last 10 to 20 years due to increased power, larger capacity, and more automatic operation.

Table reproduced from: U.S. Department of Labor, Technological Change and Its Labor Impact in Four Industries; December, 1988

TABLE 6
MAJOR TECHNOLOGY CHANGES IN CONTRACT CONSTRUCTION

Technology	Description	Labor Implications	Diffusion
Tower or climbing crane	A machine featuring a horizontal or diagonal boom on a tower that can rise with the building by climbing or by adding additional sections to the tower. It incorporates the fast boom and line capability of mobile or crawler cranes, but it is not limited by mast reach.	Reduces material handling, and reduces labor requirements by being able to hoist materials to the spot they needed atop tall buildings.	Widely used and continuing to increase in popularity, particularly in high-rise structures where crane mobility is not an important consideration.
Continuous paving (concreting) machine	A machine that pulls along its own side forms, reducing the need for fixed forms; hardens a ribbon of concrete enough for it to stand without slumping after the movable forms slide forward.	Use of this technique speeds production, improves surface quality, and increases efficiency. A substantial reduction is brought about in the size of crews needed to set up and remove forms and finish the surface, by one-half in some instances.	Widely used on large and medium -sized projects, particularly for highway and airport runway surfacing. Modifications and improvements of the machine and techniques have enabled applications in parking lots, sidewalks, curbs, building cores, and walls.
Plastics	Plastics are used for a variety of construction applications; often combined with other materials because of their favorable strength to weight ratio, high resistance to corrosion, ease of application and low maintenance costs.	The use of plastics reduces costs and labor requirements for many applications. Recent trends include the development of stronger composite structural panels, plastic foamcore panels, moisture barriers for dam and road foundations. Other developments have occurred in pipe, duct work, siding, and paint. All of these applications tend to reduce labor requirements.	Widely used. Continued rapid diffusion anticipated. Application and use of plastics products are expected to expand rapidly due to the many excellent qualities of this material. In home building, for example, where the application has been limited by building codes, the use of the material is continuing to expand.
Prefabricated building methods	Factory production of mechanical, electrical, or structural components or complete structure.	Application of these techniques speeds construction, reduces on-site labor costs, changes skill requirements, reduces impact of adverse weather, and increases production efficiency.	Vast potential for growth, Particularly in housing construction. Limitations are high transportation costs, restrictive local building codes, and consumer acceptance. Despite problems, builders will increasingly rely on prefabricated components, which require less skill to assemble at the site.

Table reproduced from: U.S. Department of Labor, Technological Change and Its Labor Impact in Four Industries; December, 1988 material consistency [Jones, 1992]. Components in two categories have been used to reduce on-site construction: industrialized, which are produced or assembled before a house design is known; and, prefabricated, which is made to a specific house design parameter [Kendall, 1986]. (Pre-hung doors and windows are typical examples of the former, and trusses, wall panels or modules are examples of the latter.) Probably the most significant equipment development has been the introduction of cordless power tools, freeing the worker of the cumbersome extension cord. High-tech has also been making inroads, however, as instruments like laser-levelers replace bubble levels and office and project management are automated on desktop computers.

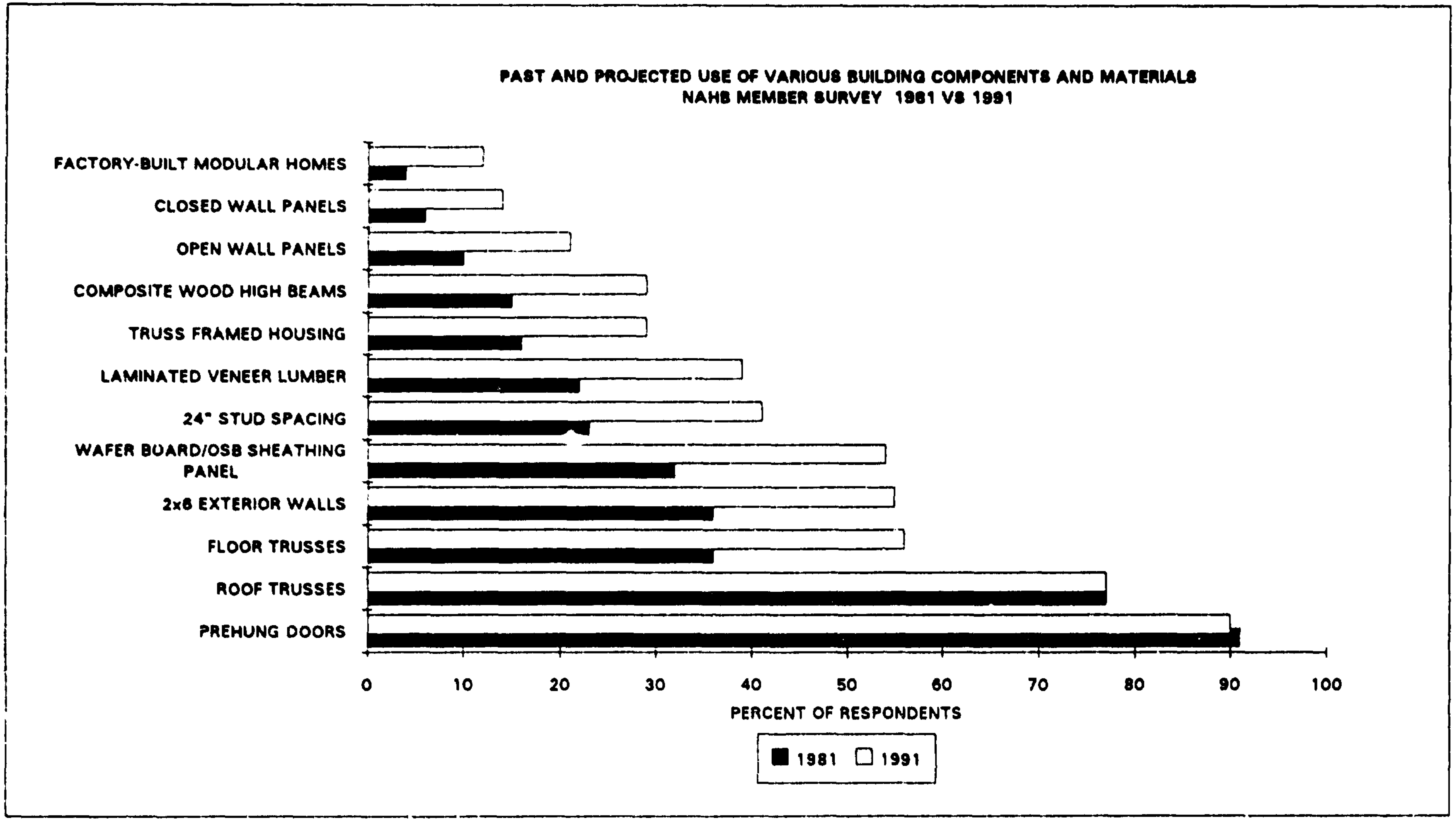
A Closer Look at Technological Innovations in Residential Construction

If new technologies now being developed could ever be broadly applied, houses would be easier and less costly to build, more energy efficient, and easier to service. Still improvements happen at a snail's pace [Jones, 1992]. This section reviews the results of the National Association of Home Builders (NAHB) surveys.

Despite efforts to revolutionize the homebuilding industry by way of such government programs as "Operation Breakthrough", residential construction technology is still oriented to "site-built" methods. Manufactured housing or modular housing accounts for about 20 percent of annual housing production. The remainder, 80 percent is site-built, where a multitude of building materials are joined together to construct a housing unit. What is starting to happen is that increasingly, more and more of housing components are being assembled in factories and trucked to building sites. Builders are using factory produced open and closed wall systems, pre-hung window and door systems, floor and roof trusses, and wet core bathroom systems.

The NAHB's survey of the methods and materials employed in 1981 and expected to be used in 1991 is presented in Figure 5. The percentage of firms already using pre-hung doors and roof trusses is already high at 90 and 77 percent respectively. Substantial gains in utilization are forecasted for floor trusses, 2x6 exterior walls, 24 inch stud spacing, and laminated veneer lumber. Another part of the NAHB survey captured the increased utilization of tools and materials and other methods. Cordless power tools were used by 83 percent of the firms, automatic nailing devices by 87 percent, glue nailed construction techniques by 76 percent. Collectively, these incremental technological changes are changing the industry, seemingly bit by bit. Site-based assessments of labor productivity indicate that the adoption of these technologies are increasing labor productivity.

FIGURE 5


PAST AND PROJECTED USE OF VARIOUS BUILDING COMPONENTS AND MATERIALS
NAHB MEMBER SURVEY 1981 VS 1991
FACTORY-BUILT MODULAR HOMES
CLOSED WALL PANELS
OPEN WALL PANELS
COMPOSITE WOOD HIGH BEAMS
TRUSS FRAMED HOUSING
LAMINATED VENEER LUMBER
24" STUD SPACING
WAFER BOARD/OSB SHEATHING PANEL
2x6 EXTERIOR WALLS
FLOOR TRUSSES
ROOF TRUSSES
PREHUNG DOORS
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF RESPONDENTS
1981
1991

Despite these advances, technology diffusion is generally slow, even where a new product or process is clearly perceived to produce a benefit. Energy efficiency improvements, for example, drove the use of 2x6 inch exterior walls to allow increased insulation. However, notwithstanding immediate cost-saving advantages, many builders have not yet increased spacing of studs (from the 16 inch standard with 2x4 inch studs to 24 inch stand for 2x6 inch studs). Similarly, though industrialized housing[1] has existed for decades, only about 20 percent of new starts have been built using mobile or modular systems. In contrast, factory made housing dominates 89 percent of the Swedish single family market and 92 percent of its multi-family market [U.S. Congress, Office of Technology Assessment, 1986]. Its use has also grown to 15 percent in Japan where, like the U.S., the industry is dominated by small, local builders.

Methodological changes in the organization and execution of the building process, from design to construction to operation are another major area of change in the industry. As is evident from the rise of construction management services, design and construction processes are increasingly overlapping and coordinated in an effort to drive down costs, improve project delivery, and assure quality. Such efforts may greatly dictate the cost of implementation through scheduling, subcontractor recruitment, mobilization of labor, materials procurement, quality control, and financial management. Construction management firms are now doing what general contractors or master builders once did as an aspect of site execution. Such firms have evolved as large and complex projects increasingly required more sophisticated record keeping and the use of computer-based data systems [Strassmann and Wells, 1987]. Other forms of integrating the entire design and construction process address one or more of the gaps created by the traditional contracting and project delivery methods. Variants like design-build attempt to shorten schedules and value engineering is used to reduce costs while meeting user needs.

These examples of technological advances (by no means exhaustive) provide a reasonable overview of the types of incremental change being made in the construction industry. New technologies, whether they pertain to materials, equipment and machinery, construction processes or management play an important role in determining the level and growth rate of construction productivi-

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1. The Office of Technology Assessment in Technology, Trade, and the U.S. Residential Construction Industry, Sept. 1986, describes industrialized housing as manufactured (mobile) homes, modular homes, and panelized homes. Manufactured homes are produced extensively at the factory (often including interior finishes and appliances) and wheeled to the site. Modular homes are essentially "boxes" configured on site in different designs. Panelized systems have preconstructed sections and often come with prefabricated floor and roof systems.

ty. The next two sections review trends in U.S. construction productivity and assess what factors limit productivity growth.

TRENDS IN CONSTRUCTION INDUSTRY PRODUCTIVITY

Over the years a number of studies have attempted to assess productivity trends in the construction industry. While far from conclusive, most studies argue that productivity growth in the sector has been sluggish. Quigley [1982] provides a comprehensive review of studies up to 1979. Covering the period from 1947 to 1979, these studies estimate that construction industry growth has increased slowly, ranging from a low of 0.5 percent per year to a maximum of 2.8 percent, depending on the method of calculation and the period of analysis. A consistent pattern evident in all comprehensive studies of productivity is that construction industry productivity growth rates are lower than for other sectors of the economy.

Assessments by Stokes [1981], Allen [1985, 1989], Shriver and Bowlby [1985] and Pieper [1989] have shown actual declines in construction industry productivity trends. According to Stokes, construction industry labor productivity growth increased by 2.4 percent per year between 1950 and 1968, but between 1968 and 1978 it declined by -1.2 percent per year. Allen estimates that between 1968 and 1978, construction industry total factor productivity declined by 8.8 percent over the ten year period. Shriver and Bowlby estimate total factor productivity in the construction industry was constant over the 1972-79 period, but that it fell from 1980-1981. The Business Roundtable's Construction Industry Cost-Effectiveness (CICE) Project [1983] concluded that construction industry productivity has been declining since the 1960s. The study's conclusion is worth quoting:

> By common consensus and every available measure, the United States no longer gets its money's worth in construction, the nation's largest industry. Since the closing years of the Sixties, productivity in construction has been declining at a rate many industry leaders find appalling. The figures should not be regarded as precise because of statistical deficiencies in the data on which they are based, but they all contain the same disturbing message: a large and increasing gap has opened between the performance of construction and that of U.S. industry as a whole.... Since 1965, according to the American Productivity Center, construction has been the only industry with consistently negative productivity growth.

While these data trends are far from conclusive, and there are many who argue that construction industry quality has increased dramatically over the past two decades, most analyst agree that the rate of increase of total productivity in the construction sector is below that found in other industries.

The next section describes factors that influence the level and rate of change of construction industry productivity. However, before doing so it is important to first address the lack of adequate measures of construction industry output. At present, data reporting construction industry activity, such as cost indexes prepared by Engineering News Record, Boeckh, and F.W. Dodge do not fully capture changes in construction technique and shifts in materials. They certainly do not capture changes in quality. Research by Allen [1985, 1989] and Pieper [1989] address these measurement issues. Allen estimates that construction industry productivity declined by 8.8 percent in contrast to a 21.4 percent decline reported by the U.S. government. He argues that price deflators used to estimate the real value of construction projects accounts for over 50 percent of the reported decline in productivity. Pieper also concludes that measurement errors over-estimate productivity declines, and account for 35 percent of the reported decline between 1968-1978. Research and policy analysis cannot be based on faulty construction industry data; better, more accurate construction data are necessary.

IMPEDIMENTS TO HIGHER CONSTRUCTION INDUSTRY PRODUCTIVITY

A major concern about the construction industry is its apparent backwardness in the adaptation of new construction technologies and practices which can reduce cost and/or increase quality. As discussed earlier, there was little technological advance in residential construction industry from the turn of the century to the early 1950s. Since the 1950s, there has been considerable innovation in the production of building components such as roof and floor trusses, pre-hung doors and windows, closed and open panel wall systems; tools and equipment; and new software for project design, scheduling and cost control. On another front, manufactured housing is gaining acceptance and market share. These new advances, if widely adopted, can increase construction productivity.

Unfortunately there are pervasive roadblocks to technological innovation and productivity-enhancing changes in ways of doing business. They stem from the industry's own highly fragmented and disjointed material and project delivery systems; the inability of small, undercapitalized firms to fully exploit promising new technologies; high degrees of uncertainty resulting from the cyclical nature of the building industry; the uneven quality of labor and constraints to innovation posed by union work rules and practices; and formidable institutional barriers imposed by government building codes and development regulations.

The Fragmentation Factor: Multiple Players and Linkage Problems

The high incidence of subcontracting and the heavy reliance on raw and manufactured inputs impedes the diffusion of new technologies and innovative management practices. Each player in the construction team only knows their part and little effort is expended to create a team. From the material supplier to the builder, a product is transformed and handled in multiple disconnected steps. Finally at the building site, it is the subcontractor, not the builder (now more a broker than a construction worker), who installs the product. The final buyer (one of several over time) isn't even in the picture, and when they show up a specialized agent represents their interests. This structure makes it difficult to develop the strong linkages between producers and users of new products that are essential for rapid technological advancement. Taking a product from the laboratory to the marketplace is extremely complicated. As an innovation plods through each link, it takes up more time and meets different forms of resistance.

An example of subcontractor resistance pertains to the diffusion of insulated concrete wall forms. These forms provide builders with a fully insulated form for pouring concrete that is left in place. A wall with an R-value of 20, can be built for $3.50/square foot ($.65/s.f. less than a standard wall) mainly by reducing labor and the number of subcontractors required. Again, however, strong resistance amongst foundation subcontractors has resulted in a market share of less than 1 percent of starts. Even in Alaska where its use would extend the building season by allowing concrete pouring in colder weather, a distributor claimed that demand only picked up once subcontractors were better informed.

An example of builder resistance is the case of foam core sandwich panels which combine insulation and sheathing into a lightweight, energy efficient unit. Builders who have used them claim savings of $20 per square foot on hard costs and the ability to cut crew sizes while maintaining production levels. However, the product's distribution network is poorly defined and concerns about long-term deterioration are keeping its utilization level down. The manufacturer needs to expand its marketing efforts to attract the interest of builders.

An example of consumer resistance is the slow diffusion of surface raceway electrical systems, common in commercial installations, into residential construction. Residential consumers don't like the product because of the institutional look of the races, despite the fact that they allow easier access to wiring, maintain the thermal integrity of exterior walls and permit rough and finish work to be combined. Surface raceways can increase quality (better energy efficiency) and lower construction costs. Manufacturers and distributors need to sharpen their assessment of consumer preference to determine how to modify the product to best meet consumer demands.

The fragmented structure of the industry results in every part being supplied by a separate, highly specialized company. They focus on their own products and have little incentive to integrate their products with others. Builders, also small and numerous, lack the power to push for improvements and integration. Contrast such patterns to Ford or G.M. where many suppliers, are directly controlled by the car company, and must comply with their stringent requirements, even utilizing shared computerized communication networks.

On the other hand intense competition between constructors forces them to identify new cost-cutting products and methods. In countries with limited competition and domination of the sector by state-owned enterprises (SOEs) poor quality and technological backwardness is a common attribute of SOE-produced housing. As a recent World Bank Discussion Paper comments: "despite massive investments in science education and technical training, socialist country SOEs have tended to be relatively poor technological innovators, and indeed they have tended to operate below existing technology frontiers [Lee and Nellis, 1990].

Inability of Small Firms to Exploit New Technologies

If firms are too small, they will not be able to fully exploit the advantages of capital goods, and will either have higher costs because they must spread the cost of a piece of equipment over a low level of output, or they will forego the purchase of the equipment and continue to use less efficient tools or procedures.

Smaller firms lack the capacity to devote considerable attention to surveying new technologies, practices and systems. They certainly do not have the resources to conduct research and development, and are usually unwilling to take risks on new, untested materials or procedures. Small firms are also less likely to make greater use of subcontractors and instead work as "jacks-of-all-trade" trying to complete all tasks themselves. This pattern makes it difficult for firms to specialize and increase their productivity.

Changes in the quantity and quality of capital (equipment and tools) provided to workers will profoundly influence labor productivity. If firms are unable to adjust the amount of capital combined with labor, productivity will not grow. Recent advances in the hand tools and excavating equipment have boosted productivity. Pneumatic nail guns, staplers, cordless drills and screwdrivers have increased productivity. Small and highly mobile excavating equipment (bobcats, power shovels, backhoes) have increased the efficiency of site work. Without increases in capital expenditures for new equipment, productivity will not grow, as workers to make do with fewer older and inefficient tools.

As firms expand they increase their employment and procure more capital equipment. Table 7 illustrates patterns of employment and capital stock by size of construction firm. Table 8 illustrates patterns of gross receipts and value added per employee. While the typical construction establishment has an average of 9.3 employees and $115,052 of capital equipment, as firms expand they increase their utilization of capital and labor. However, employment expansion does not outpace the growth in receipts and as Table 8 illustrates, receipts per employee increase significantly with the size of the firm.

Firms increase their capital labor ratios as they expand operations. As Table 7 shows capital stock per worker increases from $8,934 per worker for the smallest firms to $15,206 for the largest. A clear outcome of increasing receipts per worker and higher capital labor ratios is the consistent increase in value added per worker, rising from $24,155 for the smallest firm to $65,014 for the largest establishments. Pieper [1989] estimates that construction industry capital labor ratio increased substantially between 1968 and 1978 and accounted for a 4.6 percent increase in construction industry productivity.

The drawback of small firms led many analysts to suggest that housing production should be organized into large-scale vertically integrated firms. Housing production in Eastern Europe, Cuba, Algeria and the former USSR is largely organized this way. Many large firms have adopted rigid construction systems which provide little flexibility. As a consequence, building systems are standardized and can not quickly respond to changes in consumer preferences, input costs or new technologies. Now that housing markets in the transition economies are more demand-driven and more competitive, large firms are having difficulties adjusting. In Poland for example, productivity and output in the construction sector is declining rapidly. The overall structure of the construction sector in terms of firm size, levels of competition, barriers to entry and exit, linkages with materials and service providers must be considered when assessing how to best promote construction industry productivity [Dowall, 1992].

Building Cycles Limit Diffusion of New Technologies

By setting monetary and fiscal policy which indirectly determines the demand for housing, offices, commercial and industrial facilities, governments largely shape the market for construction activity. Frequently, governments pursue short term fiscal policies which produce wide swings in demand. Such variation effects construction industry in various ways: first there is considerable turnover of construction firms from peak to trough to peak and as a consequence many firms have limited experience. In times of extreme economic stress, many firms go out of business. Given the cyclical nature of construction, the level of experience, especially in the residential sector is low. In 1987, 18 percent of NAHB members had been in business for less than five years. Firms with limited experience my not be able to

TABLE 7

AVERAGE NUMBER OF EMPLOYEES AND CAPITAL STOCK BY SIZE OF ESTABLISHMENT 1987

SIZE OF ESTABLISHMENT BY BUSINESS VOLUME	AVERAGE NUMBER OF EMPLOYEES	AVERAGE CAPITAL STOCK PER ESTABLISHMENT*	AVERAGE CAPI STOCK PER EMPLOYEE
Less Than $250,000	3.3	$29,483	$8,934
250,000 - 499,999	5.8	60,800	10,483
500,000 - 999,999	9.4	103,893	11,052
1,000,000 - 2,499,999	16.5	207,238	12,560
2,500,000 - 4,999,999	31.5	437,658	13,894
5,000,000 - 9,999,999	55.7	764,021	13,717
10,000,000 and Over	161.8	2,460,396	15,206
TOTAL	9.3	$115,052	$12,371

* Depreciable assets (buildings, equipment)

Source: U.S. Department of Census, 1987 Census of Construction Industries, July 1990.

TABLE 8

VALUE ADDED PER WORKER BY SIZE OF ESTABLISHMENT - 1987

SIZE OF ESTABLISHMENT BY BUSINESS VOLUME	GROSS RECEIPTS PER EMPLOYEE	VALUE ADDED PER EMPLOYEE
Less Than $250,000	$43,667	$24,155
250,000 - 499,999	60,773	31,542
500,000 - 999,999	74,280	36,783
1,000,000 - 2,499,999	93,533	44,306
2,500,000 - 4,999,999	109,521	50,286
5,000,000 - 9,999,999	122,964	53,703
10,000,000 and Over	172,377	65,014
AVERAGE	$103,369	$45,540

Source: U.S. Department of Census, 1987 Census of Construction Industries, July 1990.

accurately evaluate the potential usefulness of new technologies since they lack an institutional memory of how past technologies improved construction cost-effectiveness and quality.

Second, variations in demand disincline firms from adopting some building technologies which are cost-effective when demand and production levels are relatively constant. But the biggest impediment to innovation is that most construction industry managers are focused on short-term survival. Varying economic conditions and fluctuations in output limit construction establishments interest in and ability to successfully adopt new technologies.

Third, firms are more likely to rely on subcontractors than long-term employees to perform services, even though employees may be more cost-effective [Manski and Rosen, 1978]. Given wide cyclical swings, builders rely on outsiders for technical support and assemble subcontractors to build projects. It is the subcontractor, not the builder who puts an innovation in place, and since they go off to another job, they frequently carry the knowledge with them. Consequently, there is little incentive for a builder to invest in a new innovation if he thinks that his subcontractors will "borrow" the idea and use it with a competitor.

<u>Labor Quality and Unionization</u>

An important determinant of construction productivity is the quality of labor. High labor turnover and low skill levels work to reduce labor quality and productivity. Fortunately, the average level of schooling of construction industry laborers and craftsmen has been increasing and has helped to increase labor productivity. Allen [1985] reports that increases in training accounted for a 2.4 percent increase in productivity between 1968 and 1978. Data from the NAHB indicate that the overall level of education of homebuilders has increased substantially from 1969 to 1987. In 1969, 34 percent of heads of firms had completed at least a college degree. In 1987, 52 percent of heads surveyed had at least a college degree [NAHB, 1988].

Unionization can also effect productivity. The most direct way is that union work rules limit worker flexibility and lower productivity. By dividing tasks among individual workers, labor is often idled and jurisdictional disputes arise. Other factors also affecting productivity are wage rates, work time, and stoppages. Allen estimates that unionization accounted for a 1.2 percent decline in construction productivity over the 1968-78 period.

Many of the new construction industry technologies will reduce the demand for construction industry labor. As a consequence, labor unions are resistant to new technologies and support innovation only if it reduces costs without reducing requirements for labor, requiring changes in skill level or replacing local with off-site labor.

A good example of such resistance is the difficulty manifold plumbing systems are encountering in gaining market share. These manifold systems work like a breaker box for water lines, controlling water flow and pressure and allowing the use of smaller pipe diameters. They also provide a central and easy to get to access to a house's plumbing. Its use adds material costs, but one manufacturer claims it will reduce labor time by 20 percent. Plumbing subcontractors and unions are resistant to the product. In part this is due to the residual impact of old PVC piping problems, but its use also reduces labor and subcontractor profit, and requires an understanding of water flow calculations for smaller diameter pipes.

Management Effectiveness

Another critical determinant of construction productivity is the overall effectiveness of construction industry management. Managing the construction of a building or project is extremely complex, moving from project conceptualization, preliminary design, detailed design, bidding, construction and finally project operation and management. Management practices can significantly influence the overall cost of project execution and the extent to which the end-user is satisfied with the product.

Effective supervision of site work can lead to high levels of productivity. This means that foremen must accurately plan work, communicate with workers, provide motivation and direct work activities. Studies by the CICE Project found that many foremen are not effective managers. The most common problems of ineffective job site activities are: lack of materials; 2) confusion over roles and responsibilities; 3) incompetent supervision; 4) breakdowns in communications; 5) redoing of work; 6) lack of tools; 7) lack of cooperation between crafts; 8) incomplete or inaccurate engineering drawings and 9) restrictive or burdensome regulations [The Business Roundtable, 1983].

Many of these problems could be removed with closer attention to detail and better supervision and training. Management tools such as total quality assurance; program review and evaluations and critical path methods can be applied to anticipate work problems. Education and access to computer tools are essential for increasing construction productivity. The Business Roundtable's Construction Industry Cost-Effectiveness Project placed considerable attention on management shortcomings and offered sound advice for improving management systems including: accident prevention; reduction of scheduled overtime; better trained foreman; more effective supervision; openness to improved technology; use of new scheduling and management tools such as Critical Path Method [1983].

Government Regulation

Building codes have been found to increase the cost of housing in the United States. A comprehensive study by the U.S. General Accounting Office [1978] found that unnecessary building code requirements increased housing costs by an average of $1,700. At one level, building codes make construction costly because they require expensive but unnecessary materials or construction procedures. On an other level, codes make the adoption of new technologies difficult by raising the costs of gaining approval for new products.

The diffusion of new building materials could be accelerated if manufacturers could turn to a single building code to guide product design. Instead it is often up to the builder to determine whether a new product or process is acceptable. The lack of uniformity, at least in interpretation if not in the actual code, places the burden on the builder to prove an innovation is acceptable. Even if the codes allow application, if it isn't "standard practice" the builder may risks possible future liabilities if something should go wrong.

There are more subtle forms of resistance to new technologies than just the codes themselves. Sackett found that although 36 states have provisions in their building codes permitting the use of manufactured systems, local building officials have been known to subvert the process [1990].

Governments at all levels set land use and environmental regulations which greatly control the location, intensity, character and cost of construction. Land use and environmental regulations can add 20 to 25 percent to the cost of residential construction in some highly regulated jurisdictions [Dowall, 1984]. While these regulations enhance the quality of these residential environments it is not clear whether they offset increased costs.

Summary of Impediments to Higher Productivity

A number of factors conspire to impede the diffusion of new innovative construction products and methods. First, the construction industry is highly fragmented and it is difficult and expensive for manufacturers to market new products. Second, the small size and limited capital base of most firms makes it difficult for them to adopt innovations. Building cycles force firms to concentrate on short run issues and to ignore the long run benefits of new construction technologies. Only when an innovation is necessary to maintain or increase market share or will clearly improve bottom-line profitability will construction firms take up new technologies. Third, labor unions and government regulations stand in the way as significant institutional forces restraining the advance of innovation. Lastly, the effectiveness and quality of construction industry management, especially at the foreman level, must be upgraded to increase productivity.

Firms need to implement new management systems for project design, construction scheduling and control and quality assurance.

RECOMMENDATIONS

This paper provided an overview of the structure of the U.S. construction industry, described trends in technological innovation and construction industry productivity. It also described the factors impeding increases in productivity and cost-effectiveness. On the basis of our review we offer the following recommendations for discussion:[1]

1). Construction industry performance data should be improved. UNIDO should provide leadership in organizing such activities. The UNCHS-World Bank Housing Indicators Project might serve as a model.

2. UNIDO should undertake case studies of construction industries in a variety of developing countries to assess trends in construction productivity and cost-effectiveness.

3. UNIDO should initiate case studies in a variety of countries to determine the extent to which prefabricated and manufactured building components can be adapted for use in developing countries.

4. UNIDO should help to organize and strengthen professional construction associations and help them to design and execute action plans for increasing construction industry productivity and cost effectiveness.

5. UNIDO should initiate case studies to determine how to strengthen linkages between building product industries, contractors and government building code agencies.

6. UNIDO should work with other UN and international agencies to increase the range of innovative low-cost construction techniques and materials.

7. UNIDO should work with other UN and international and national agencies to develop more appropriate building and construction standards which can provide good quality but low-cost products [UNCHS, 1989].

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1. See Professor Tassios's paper on construction industry issues and recommendations pertaining to developing countries [Tassios, 1992].

8. UNIDO should work with professional construction associations to develop professional training courses on construction management, construction technology, and computers in construction design and management.

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