Chapter 4

# International Competition in Engineering and Construction

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Chapter 4

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## SUMMARY

Through the mid-l970s, American engineering and construction (E&C) firms won far more international contracts than competitors from other countries. For many of the larger U, S.-based contractors-Bechtel, Brown & Root, Fluor-international projects came to account for half Or more of revenues and profits. But as international (construction boomed and U.S. firms did well, others did better. [J. S. market share gradually slipped.

The 1980s brought a new era to the world construct ion industry. Like so many of their counterparts in U.S. manufacturing industries, American E&C firms found themselves in a world w i t h many more quite able competitors, A second factor accelerated the slide in U.S. market share: declining economic growth rates in the Third World, plus the collapse of oil prices, meant fewer international projects.

Over the past two decades, the E&C firms of the less developed and newly industrializing countries (LDCs and NICs) have matured. Meanwhile, the Europeans and Japanese pursued strategies based largely on the development of technological advantages, first in construction methods needed to deal with conditions in their home markets, So long as Third World growth was strong, and Middle East oil revenues high, there were enough international contracts to keep many companies busy. U.S. market share gradually fell, but for practical purposes American companies had all the business they could handle,

Today, deteriorating economic conditions mean fewer of the big construction jobs—dams and water projects, airports and electric generating plants—that have been a staple of U.S. (and European) E&C firms. Third World debt burdens mean that developing countries cannot afford new projects. Falling oil prices have cut sharply into new construction in the Middle East and other oil-exporting regions. The oil-exporting nations already face overcapacities in petrochemical production; they have neither the money nor the need of earlier years. At the same time, these countries can now handle many projects on their own that a decade ago would have been contracted to a foreign E&C company.

Moreover, contractors from NICs including South Korea, Brazil, and Turkey have begun to compete against firms from the developed nations in the international market, With the NICs pushing from below, E&C firms from the other developed countries have invaded markets once the province of American contractors, often with the aid of subsidized financing packages put together with government help, Companies based in Britain, France, and West Germany—major players in the international construction game for many years—have been joined by aggressive competitors from Japan, Italy, and elsewhere.

Three primary factors affect international competitiveness in the E&C industry: costs, financing, and technical capability—the latter including managerial expertise as well as engineering skill. Generally uncompetitive in labor-intensive construction, American companies have concentrated on the professional services portion of the industry-architecture, engineering, construction management, and operations and maintenance. But with rising competence elsewhere, U.S.-based firms have had trouble competing on a cost basis *even for the more* sophisticated jobs; despite hiring growing numbers of foreign nationals for work on international projects—engineers and supervisors, as well as people in lower skilled positions—American companies continue to lose contracts to foreign competitors with lower costs overall.

With more competition for fewer projects, U.S.-based firms will increasingly find themselves members of international consortia. To survive internationally, they must rely more than ever on strengths in putting together financing packages, and on their managerial and technological expertise. The alternatives? Withdraw from the market, or operate internationally only in protected segments created by U.S. Government set-asides (e.g., military projects). With other governments participating in financing—to support exports of materials and equipment as much as E&C services—American companies have been actively seeking joint ventures with foreign partners, in part to tap the financial resources of the latter. This pattern will probably continue even if U.S. efforts to wean other countries away from subsidized financing succeed.

The picture is not all grim. American companies still have excellent and deserved reputations in engineering and project management. If not, as they once were, broadly superior, U.S. firms lead the world in technologies such as computer-aided design and drafting (CADD), and in know-how for designing petroleum refineries and some kinds of power stations and chemical plants. They also retain a lead in managerial expertise—which remains a significant though diminishing source of advantage, given the shift in the market away from massive projects demanding skills in logistics and coordination on jobs involving hundreds of subcontractors and suppliers. Even so, management tools such as computerized inventory control systems and scheduling methods can help cut costs and increase productivity on projects of all sizes, as can advances in construction technologies such as automated earthmoving equipment and pipe bending machines. These technologies can help to reduce the labor cost disadvantages of U.S. construction firms, as can techniques for offsite fabrication of major components and designs that are easier and cheaper to construct.

Taken together, advances in construction technology will, over the next two or three decades, lead to huge increases in productivity. Currently, however, it is foreign companies, not American, that have the lead in fields like tunneling, reinforced concrete construction, and some applications of new materials. Overseas firms—especially the Japanese—do much more research on basic construction processes. Most U.S. R&D has been directed at managerial and design technologies, and at industrial process engineering. While American E&C firms have been seeking to position themselves to take advantage of growth in emerging industries like biotechnology, the common strategy—serving as a broker who can put together a turn-key package of process technology for the customer —today can compensate only partially for lack of a proprietary technological position in the sense of firm-specific know-how.

American companies have begun to adapt to new competitive realities, somewhat hesitantly. The years ahead promise further painful adjustments, Broadly speaking, loss of competitiveness in engineering and construction has implications for the entire economy. Even though only a small portion of U.S. E&C firms seek international business, and even though the linkages between exports of E&C services and exports of goods have been weaker in the United States than in other nations, loss of competitiveness in the E&C industry translates into reductions in the export potential of industries that sell capital goods internationally. These range from computer systems for air traffic or industrial process control, to steam generating units and turbo-alternators, to mining, earthmoving, and construction equipment itself.

Furthermore, as E&C markets have dried up elsewhere, foreign firms have turned their attention to the United States. Using skills honed abroad, some of these companies have begun to make substantial inroads into the huge domestic U.S. construction market; American E&C firms could begin to find themselves uncompetitive at home as well as overseas.

The most immediate government policy impacts in this industry come through financing. Progress in matching or eliminating foreign government subsidies—e.g., mixed credits—would be a real help to U.S. firms internationally, not only in winning contracts they might otherwise lose, but in permitting them to avoid some of the joint ventures with foreign partners they have been forced into. Beyond this, Federal support for R&D that underlies the E&C industry—including new applications of existing technologies, and diffusion of results—could help American companies rebuild their technical prowess. Even in the absence of foreign government subsidies, American firms will need better technology over the medium and longer term to compete. The evolutionary transformation of construction into a high-technology industry, already underway, means new opportunities for American firms that can innovate and establish strong technological positions. While Federal procurements could help the industry, an aggressive strategy based on strengthening the infrastructure for technology development offers the best hope for maintaining competitiveness over the longer run,

## INDUSTRY STRUCTURE AND TRADE

Some firms do business in both the design and construction portions of the industry, others specialize in one or the other. Box I includes examples of typical projects of both types, drawn from recent or current international projects won by American firms. *Design* activities, encompassing both architecture and engineering, include:

- project feasibility studies, ranging from economic analyses to environmental impact assessments;
- conceptual design, for appearance as well as function;
- cost estimating;
- engineering, including site planning, structural analysis and design (foundations, calculations of loads and strength), and—for buildings—heating, ventilating, and air-conditioning, as well as other building systems (e. g., electrical power); and
- preparation of detailed drawings and specifications to guide construction.

The *construction* phase involves procurement and tracking of materials and supplies, mobilization of labor and equipment, site preparation, earthmoving, onsite materials handing, and fabrication and erection. Contractor and purchaser may each have their own inspection and quality control personnel. Development of operations and maintenance (O&M) procedures, and training of the client's work force–while not normally considered part of the E&C industry-fits logically as a part of the engineering process; moreover, a number of E&C firms now undertake ongoing O&M work on a contract basis.

Many E&C firms specialize in certain types of projects—Fluor in energy-related work and petrochemicals, Ebasco in power generation. Other firms specialize by technical function-T. **Y.** Lin in structural engineering, Louis Berger International in planning, design, and construction management. Some companies choose to diversify, and compete for many types of jobs. Even so, a company that builds, say, communications networks would seldom be found putting up residential buildings.

Contract opportunities typically emerge at four stages during large international projects: feasibility studies; design and engineering; construction; and startup, including O&M training. The earlier an E&C firm becomes involved, the better the chances of further contracts. As a rule-of-thumb, feasibility studies account for about 1 percent of the eventual project cost, with design and engineering about 10 percent. Construction management can run between 2 and 6 percent of total costs, while lifetime expenses for operations and maintenance may amount to several times the design and construction cost, depending on the type of facility. E&C firms may make little if any profit on feasibility studies—indeed, because they provide an opening wedge for future design and engineering contracts, may treat them as loss leaders.

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**Box I—Examples of International Design and Construction Projects of American Firms**

- The Guy F. Atkinson Construction Co. leads an international consortium that is building the Guri Dam in Venezuela, the second largest hydroelectric development in the world. With the firm Eulogio Grodo y Cia, Atkinson is also responsible for the Colburn Dam in Chile, which will be that country's largest.
- A group of U.S. firms helped build the 1.8 million square foot Taipei World Trade Center in Taiwan. Bechtel International served as consultant for construction supervision and project management, Hellmuth, Obata & Kassabaum as lead architect, T.Y. Lin International as structural engineer, and William Tao & Associates as the mechanical engineering contractor.
- Saudia Arabian Bechtel Co., Ltd,—the local subsidiary of the Bechtel Group-serves as planner, designer, and project manager for the King Fahd International Airport. Minoru Yamasaki & Associates, of Troy, Michigan, won the contract for architectural design of the terminal complex.
- A joint venture of three American firms—Paul N. Howard Co., Harbert International, and Sadelmi, Inc.—has begun the first stage in what will be a $2.6 billion rehabilitation of the Cairo sewer system. Local subcontractors will do most of the physical work.
- AEGIS Construction has won a contract to design and build 125 units of family housing at the U.S. naval base at Guantanamo, Cuba.
- M.W. Kellogg's British subsidiary recently won a contract for engineering, procurement, and construction supervision for an ammonia plant in Hull, England.
- Scientific-Atlanta has a contract to procure equipment for and build 12 satellite Earth stations in Gabon.
- Morrison-Knudsen International designed and is constructing a $2 billion coal mine and port on the Guarjira Peninsula in Colombia—the Cerrejon Mine/Puerto Bolivar project. This is Columbia's largest development and the world's biggest award to a single contractor. Most of the labor force was hired locally, with 380 Americans in a work force that reached a peak of 11,000.

Contracts take two common forms: design-bid-build, and design-construct. Under the design-bid-build sequence, design and construction take place under separate contracts. Specifications developed in the design phase form the core of a request for bids on the construction work. (Typically, the client selects the design firm based on an evaluation of qualifications.)

Design-construct procedures eliminate the intermediate bidding stage, so long as the client is satisfied with the earlier work. One contract covers the entire project—design and engineering, construction, and perhaps even installation of equipment (for a turn-key project). The lead contractor might later provide O&M services. Turn-key or total package approaches have the benefit of simplicity for the client, who need deal with only one firm,

The design-construct process aims for better cooperation between the design and construction teams; the design-bid-build system fosters separation, even antagonism, between designer and builder–a tradition that persists in the American E&C industry, even within integrated firms. Current policies at both the World Bank and the Inter-American Development Bank permit clients funded through bank programs to award design contracts as follow-ups to earlier feasibility studies without reopening the bidding process. If the client has been satisfied with the feasibility study, the presumption of this "continuity of work" principle is that sticking with the same firm will be more efficient and less disruptive during the design phase, given that the E&C firm has developed an understanding of the client's needs. Likewise during construction, continuity of work implies that staying with the same firm will eliminate the cost of learning and mobilization that a new firm would incur and charge to the client.

Many bidding variations exist. For example, United Arab Emirates picks the lowest five bids for a rebidding process, or negotiates down to the lowest price offered. Indonesia awarded the contract for the Jakarta Airport after three rounds of bidding. Other nations have negotiated selectively with or invited bids from individual companies.[1]

For large and complex projects, which may be broken down into thousands of individual work packages, site management becomes a critical factor in controlling costs and meeting

1A. Demacopoulos and F. Moavenzadeh, "International Construction Financing," TDP Report 85-3, Massachusetts Institute of Technology, Technology and Development Program, June 1985, pp. 73-74.

Information in this chapter not otherwise cited generally comes from interviews,

Photo credit: Bechtel Power Corp.

Construction project under U.S management in Southeast Asia.

schedules, and hence in the ability to put together a winning bid. Tasks such as tracking incoming supplies, onsite warehousing, releasing drawings (and preparing as-built drawings when changes must be made in the field) on a large project can be overwhelming. For example, Morrison-Knudsen's Cerrejon Mine project involved *200* subcontractors and *2,100* suppliers. In order to control costs, construction companies have begun using onsite computer systems (box J). American firms have been leaders in software for onsite management, and in the use of personal computers in the field,

## The Industry

Domestically, construction is one of the largest sectors of the U.S. economy. Well over a million firms, most of them small, employ more than 5 million Americans. New construction in the United States during *1985* accounted for nearly 9 percent of the gross national product. But only a few thousand American E&C firms do business internationally.

Residential building comprises more than *40* percent of domestic construction (figure *26),* with industrial plants and civil works of all types (roads, bridges, dams, irrigation systems, water and sewer systems, pipelines, ports) making up another *30* percent. Commercial and other nonresidential buildings account for most of the rest. z Residential housing remains the domain of local firms, both in the United States and overseas. The international E&C market consists mostly of design and construction for industrial facilities, civil works, and, to a lesser extent, nonresidential buildings.

Of the **400** largest contractors in the United States, only *60* gained new contracts for foreign work during *1985.*[3] A few big companies, in turn, dominate this small export-oriented group, with eight construction firms accounting for more than **80** percent of new foreign awards by value. Similar patterns hold in other countries, with international contracts making up a substantial part of the total revenues of the largest firms and/or those that specialize in this part of the business (table 14). For the [J. S. industry as a whole, foreign revenues—although totaling $7.7 billion to *$8.1* billion in 1983—account for only a few percent of total receipts (3 percent in 1983).[4]

Relatively more design firms do business internationally than construction companies (many of the large E&C firms offer both design and construction services), Of the *500* largest U.S. design firms, *258* reported foreign billings in *1985.*[5] Figure **27 gives** the breakdown by type of project, including both domestic and foreign awards, for 1984 (the latest year for which such data are available), Small design firms, particularly, are more likely to be active in the international market than small construction companies. Nevertheless, of more than 45,000 establishments providing engineering, architectural, and surveying services in the United States, only about 4 percent report foreign receipts. However, those that do have foreign sales get, on the average, more than 20 percent of their revenues overseas.[6] For the design portion of the E&C industry, OTA estimates that foreign revenues came to about 14 percent of domestic revenues during *1983 ($5.1* billion to *$5.6* billion, compared with $37.3 billion domestically), with affiliate sales considerably more important than in construction.[7]

[2] *See Trade in Services: Exports and Foreign Revenues* (Washington, DC: Office of Technology Assessment, September 1986), pp. 58-61 and 65-67. Also 1986 *U.S. Industrial Outlook* [Washington, DC: Department of Commerce, February 1986), chs. 1 and 67.

[3] "U.S. Recovery Fuels Work Again, " *Engineering News-Record*, Apr. 17, 1986, p. 98. The figure was 66 in 1984. This group got 21 percent of its total contract awards overseas during 1985.

[4] These figures are OTA estimates—Trade *in Services*, op. cit,, p 60. Of the $7.7 billion to $8.1 billion, $4,8 billion consisted of direct export s—e. g., construction services produced in the United States for customers overseas; OTA estimates place the sales of foreign affiliates of U.S. construction firms at $2,9 billion to $3.3 billion in 1983.

[5] "Designer Billings Reached Record of$11 Billion, " *Engineering News-Record*, May 15, 1986, pp. 32-50,

[6] *1982 Census of Service Industries: Miscellaneous Subjects* (Washington, DC: Department of Commerce, 1985), p. 5-142.

[7] *Trade in Services*, op, cit., pp. 65 and 67. OTA places direct exports of design services at $1,1 billion to $1.6 billion in 1983, m uch less than the estimated $4 billion in sales by overseas a f-filiates of U.S. design firms.

## Box J.—Piping Design and Construction Management Technologies

For refineries, petrochemical plants, and power stations, fabrication and installation of piping may be the single most expensive part of the construction process. With miles of pipe of many different sizes, thousands of sensors, valves, and pipe hangers, and tens of thousands of welds, the design process itself is laborious and expensive. In earlier years, three-dimensional models were needed to check for clearances; today, much of the spatial design can be done with CADD systems. Particularly in nuclear powerplants, piping systems must be designed so that neither expected nor unusual loads (e.g., earthquakes) will cause ruptures; both piping runs and hangers will affect vibratory modes and the loads at each point. Calculations are very complex; today, they are carried out on large computers.

The pipe itself is expensive, particularly when specialty metals (e.g., nickel-base alloys) must be used to resist corrosion or high temperatures. Welds must be checked, often with X-rays. Pipes may need to be insulated after fabrication. For a large power station, conventional or nuclear, the materials and labor for the piping can run to half a billion dollars or more. Piping may account for 40 percent of total labor hours on the job site. Mistakes leading to scrappage or extensive rework can cost millions.

Piping fabrication—e.g., cutting and bending —normally takes place in an onsite shop. As an alternative to using elbows, induction heating following by bending under computer control can greatly reduce the number of welds and hence cut both fabrication and inspection costs; savings maybe 20 to 40 percent. * While U.S. construction companies have begun to use induction bending, the technology has been developed in Europe and Japan, and continues to be controlled by firms outside the United States.

Offsite fabrication can also lead to savings, particularly for projects in countries with limited pools of skilled labor. For the A1-Jubail refinery, in Saudi Arabia, a Japanese firm built modules weighing up to 2,500 tons at its home facilities. After shipment from Japan by sea, the modules were moved 6 miles on a specially constructed roadway to the refinery site.

Other sources of future savings in piping-intensive construction will include direct control of pipe bending equipment from CADD databases, greater use of automated welding equipment and robotics during installation, and automated real-time inspection of welds (ultimately, closed-loop control of the welding process may obviate inspection except on the most critical welds).

Electrical wiring—also involving many components and labor-intensive installation—presents an analogous set of opportunities for automation and costs savings. Bechtel, for example, has scaled down a mainframe computer program for cable and raceway scheduling to run on PCs at the construction site, Designers enter data on each electrical component into the system at the home office. When parts, components, and subassemblies are delivered, warehousemen log them in using optical scanners to read bar codes and computer-generated control cards. As the job progresses, workers enter discrepancies and field changes into databases maintained both at the home office and the construction site.

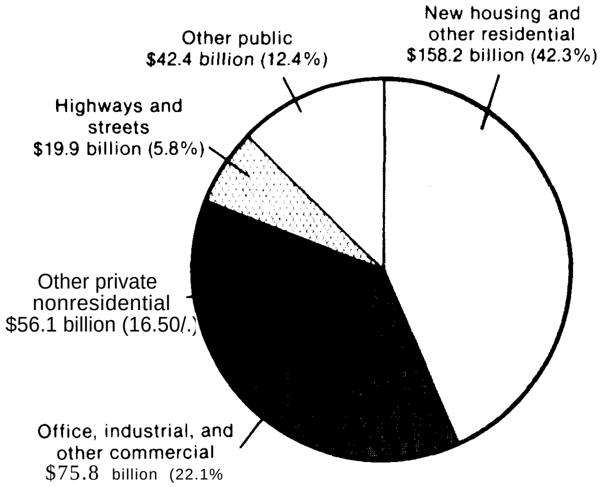
Far more can still be done to improve productivity in construction through improved management systems. On some large projects, workers maybe idle as much as two-thirds of the time while waiting for the materials or tools for the next task.** Such examples suggest the potential of computer-based construction management systems, now in their infancy, for smoothing the flow of work and cutting costs. They will be extensively developed and applied over the next 10 to 15 years, not only for piping and electrical wiring, but for many of the other tasks commonly found in complex construction projects. In principle, components can already be coded and tracked from the design phase (engineering specifications), through fabrication (material lots, delivery and warehousing, construction and inspection), and a database maintained over the life of the plant or facility. In practice, however, most companies still work with a number of independent databases, handing control from one to the next at successive stages in design and fabrication. The companies that develop and apply computer-based construction management systems most effectively will have substantial advantages on large international projects in the future.

*"Final Report, Tasks 1/2, Technology in Architecture, Engineering, and Construe. tion," prepared for OTA by D.W Halpin under contract No. 633-1970, p. 42.

The Al-Jubail example below comes from p. 32, the information on Bechtel's computer management of electrical wiring from pp 26-27.

**"Final Report, Task 3, Technology in Architecture, Engineering, and Construct ion," prepared for OTA by 1). W Halpin under contract 633-1970, p. 2.

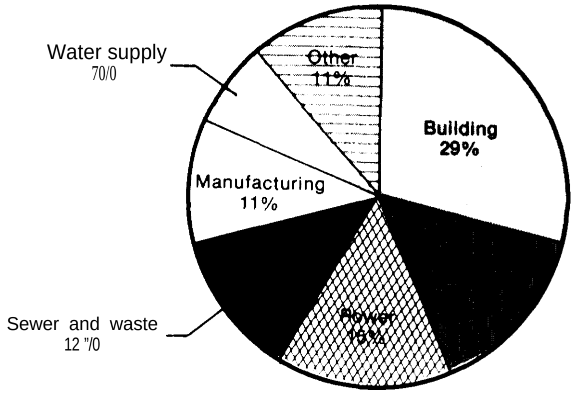
**Figure 26.— New U.S. Construction, 1985**




Total: $342,4 billion

SOURCE “Annual Value of New Constructlon Put in Place in the United States in Current Dol lars and 1977 Dollars, ” *U S Department of Commerce News,* Apr 1, 1966

**Figure 27.—Total Billings, Domestic and Foreign, for 500 Largest U.S. Design Firms by Type of Project, 1984**




Total: $9.6 billion

SOURCE “Design Billings Gain 12 Percent in 1964, ” *Engineering NewsRecord,* May 16, 1985, pp 36-66

## Table 14.–Leading International Contractors, 1980 and 1985

| 1980 | New contracts (billions of dollars) Foreign | Domestic | 1985 | New contracts (billions of dollars) Foreign | Domestic |
|---|---|---|---|---|---|
| ***American firms:*** | | | | | |
| Bechtel Group | $8.5 | $2.1 | M.W. Kellogg | $6.2 | $0.6 |
| Parsons | 8.3 | 1.1 | Parsons | 5.0 | 3.6 |
| Fluor | 5.0 | 4.1 | Bechtel Group | 3.6 | 3.8 |
| Foster Wheeler | 2.8 | 1.8 | Brown & Root | 2.9 | 2.7 |
| C-E Lummus | 2.7 | 1.6 | Lummus Crest | 2.4 | 1.1 |
| ***Japanese firms:*** | | | | | |
| Chiyoda | $1.3 | 0.3 | Kumagai Gumi | $2.2 | *$2.5* |
| JGC | 0.7 | 0.4 | Mitsubishi | 1,4 | 3,0 |
| Toyo Engineering | 0.5 | 0.1 | JGC | 1.0 | 0,4 |
| ***European firms:*** | | | | | |
| Philipp Holzmann (West Germany) | $2.5 | 1.2 | Philipp Holzmann (West Germany) | $1.9 | 1,3 |
| Bilfinger & Berger (West Germany) | 2.4 | 0.6 | SADE/SADELMI (Italy) | 1.8 | — |
| Davy (Britian) | 2.4 | 0.1 | John Brown (Britain) | 1.7 | 0.4 |
| ***Korean firms:*** | | | | | |
| Hyundai | $1.4 | $0.2 | Hyundai | $2.0 | $0.5 |
| Daelim | *0.8* | 0.3 | Daewoo | 0.9 | 0.4 |
| Daewoo | *0.8* | 0.1 | Daelim | 0.5 | 0.4 |
| ***Other:*** | | | | | |
| Mendes Junior (Brazil) | $1.5 | $1.4 | Enka (Turkey) | $1.1 | $0.5 |
| Solei Boneh (Israel) | 1.3 | · | Joannou & Paraskevades (Cyprus) | 0.5 | — |

SOURCE *Engineering News-Record,* various issues

Relatively few Americans work overseas on projects carried out by U.S.-based E&C firms; generally, they fill only the higher level managerial and technical positions. In the past, it was more common for skilled jobs—surveyors, heavy equipment operators—to go to Americans, but most of these are now filled in the host country, or by people from third countries who get lower wages. Laborers and semiskilled workers come almost entirely from host and third countries; U.S. firms with contracts in the Middle East, for example, have hired large numbers of South Koreans. In 1983, U. S.-based E&C firms employed 45,000 Americans on international projects and 99,000 foreign workers, exclusive of subcontracting.[8] Of the Americans, about 19,000 worked outside of the United States and 26,000 at home. In recent years, U.S.-based firms have also tended to let larger numbers of subcontracts to foreign companies, taking advantage of their lower labor costs.

## Downstream Linkages

While E&C firms may underprice their feasibility studies in hopes of landing a follow-on design contract, and may hope that a design contract will carry over to the construction phase, this happens only some of the time. And, while a design contract by one U.S. firm may raise the probability that it or another U.S. firm will get the construction contract-perhaps because the design calls for construction technologies in which American firms specialize—one study of large projects during the 1970s found only 43 percent of projects with U.S. designers/consultants subsequently going to U.S. construction firms.[9] Thus, exports of design do not automatically lead to exports of construction.

A second set of downstream linkages also begins at the design stage. Merchandise sales—e.g., capital equipment—often follow quite directly from exports of E&C services. Part of the reason is simply that design firms tend to specify equipment they are familiar with, so that American E&C firms turn naturally to American-made goods (table 15). Furthermore, American-made equipment commonly demands American-made spare and replacement parts. Contracts for O&M training and management services also follow logic all}' from the export of design services and equipment.

Today, with comparable equipment available in a greater number of countries, this set of linkages is not so strong as a decade ago, and will probably continue to weaken. Under continuing pressure to cut costs, American firms have been purchasing or specifying foreign materials and supplies more frequently than in earlier years. Still, in a survey by the U.S. International Trade Commission, *33* of **38** American E&C firms said that they specified or recommended U.S. equipment.[10] Sometimes, of course, the purchaser (rather than the E&C firm) specifies American (or other foreign) equipment for reasons of price or reputation. Nonetheless, most

[8] "The *Contribution* of Architectural, Engineering and Construction Exports to the U.S. Economy," prepared by Price Waterhouse for the International Engineering and Construe. tion Industries Council, V/ashington, DC, April 1985, p. 17. Comparing total payroll costs, including fringe benefits, for U.S. and foreign worker-s demonstrates the motives for hiring foreigners: payroll costs for the 45,000 Americans totaled $2.2 billion (an average of $49,000], costs for the 99,000 foreign workers on1y $1.4 billion ($14,000, on the average).

Direct exports provide about 1 percent of total (J. S. E&C industry employment. Assuming a 11 45,000 Americans were involved in industrial or civil works, the}' made up perhaps 3 percent of U.S. employment in this sector of the E&C industry. A higher fraction of employment can bet raced to exports in many of the capital goods sectors that depend in part on construction *projects* for sales, For example, according to the U.S. International Trade Com mission. 4.3 percent of [" .S. jobs in the heating, plumbing, and structural metal products industry depended on exports in 1982, 31 percent in construction and mining machinery, and 34 percent in engines and turbines—*U.S. Trade-Related Employment*, USITC publication 1445 (Washington, DC: 1",S. International Trade Commission, October 1983], pp. 49-50.

[9] K. J. Murphy, *Macroproject Development in the Third World* (Boulder, CO: Westview, 1983), p. 138. Other (Downstream linAage percentages: West Germany., 80 percent; Japan, 63 percent: France and Italy, 50 percent; Britain. 13 percent.

IO The *Relationship of Exports in Selected U.S. Service Industries to U.S. Merchandise Exports*, USITC Publication 1290 (Washington, DC: U.S. International Trade Commission, 1982), p. 62.

.4 survey of projects with financing from the U.S. Export-Import Bank found that, when the design firm was American, *80 per*cent of imported equipment was purchased from American companies. With design engineering firms from other foreign countries (not the host country), the percentage dropped to 43 percent. See C. Becker and F. Wilson, "' Addendum to Architectural and Engineering Services Sector Study—June 1984, " Export-Import Bank of the United States, Washington, DC, July 27, 1984.

**Table 15.—Typical Examples of U.S. Goods Exports Resulting From an Overseas Energy Project**

| Likelihood of U S goods purchases relative to foreign goods | | |
|---|---|---|
| Above average | Average | Below average |
| Fired heaters, including furnaces, ovens, boilers, flues, and related products | Pressure vessels and columns, Including towers, and reactors. | Fabricated piping of all types |
| Pumps and drives, all types | Heat exchangers, including condensers and evaporators | Tanks, bins, and hoppers, |
| Vacuum equipment (vacuum pumps, ejectors) | Instruments, including safety valves, Indicators, and panels, | Materials-handling equipment– e.g., bucket elevators, conveyors, cranes, hoists, weighing devices. hoppers |
| Sawmill and planing mill equipment | Electtric motors, motor controls, and transformers | Plywoods and veneers. |
| Equipment for refining petroleum, and miscellaneous products of petroleum and coal | Compressors and drives, including blowers and fans. | Plumbing fixtures, fittings, and trim, |
| Miscellaneous plastic products | Crushers, pulverizers, and blenders, | Fabricated structural metal products |
| Heating and refrigeration equipment | Water and waste treatment equipment, including clarifiers, chemical feeders, mixers, and agitators. | Pipes, valves, and fittings. |
| Switchgear and switchboard apparatus | Paints and allied products | |
| Wiring devices | Nonferrous wire drawing and insulating equipment | |
| | Lighting fixtures and equipment | |
| | Fabricated plate work | |

SOURCE E C Stokes Vice President Procurement Bechtel Power Corp

of the total project budget on a large international project normally goes for non-U.S. goods and services, even when the contractor is based here. A 1983 survey of American firms by Price-Waterhouse found that only about a quarter of their spending on international projects went to cover expenses incurred in the United States, On the average, about 11 percent went for salaries and fringe benefits of U.S. employees (excluding employees of U.S. subcontractors), 10 percent for the purchase of equipment and materials from other American firms, and 5 percent for subcontracts to U.S. firms.[11] Most of the remaining 74 percent paid for goods and services purchased overseas,

When comparable goods (or subcontract services) are available from many sources, price will usually be the determining factor. Basic building products—lumber, cement, and fabricated steel—tend to be purchased in the host nation or from low-cost third-country suppliers, Today, American firms will also normally specify standardized or commodity-like products—e.g., many kinds of piping and materials-handling equipment—based largely on price. In addition, protected markets for host country construction and supplier industries may limit an E&C firm's ability to specify foreign goods and services, with local procurement requirements often written into contracts. As table 15 suggests, American suppliers begin to have advantages where proprietary technology makes a difference, as for refinery equipment, In other countries, E&C firms may work more closely with suppliers, particularly where one or both are publicly owned, or when governments participate by providing export credits; the president of Italy's state-owned industrial group, IRI, has said, "The first priority . . . is to promote the work of Italian suppliers. "[12]

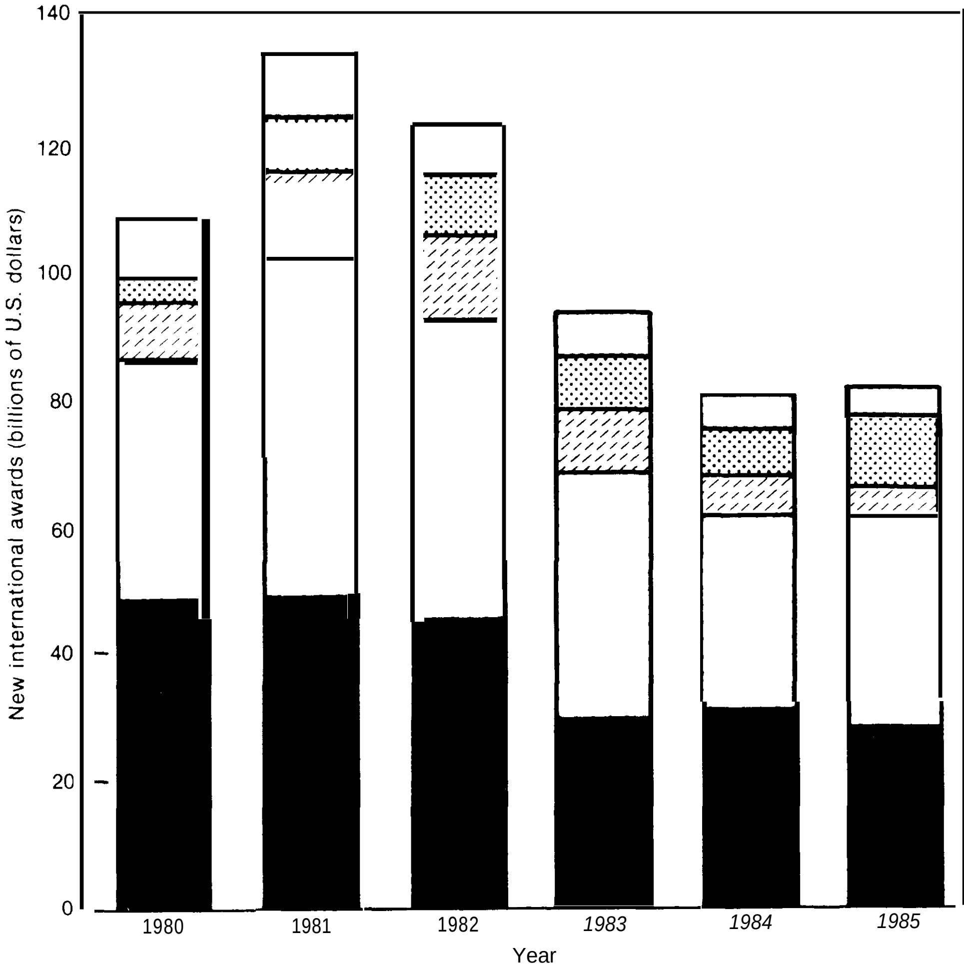
## The International E&C Market

Figure 28 summarizes conditions facing American construction firms: a shrinking world market, caused in large part by economic problems in the LDCs, coupled with intense competition as firms from many countries strive to maintain hard-won positions. Economic growth rates have been declining in the developing world—figure 29. At the same time, the exter-

[11] Such figures can vary a good deal from year to year, with a few major projects producing large swings in the proportions spent here and abroad. Those quoted are from "The Contribution of Architectural, Engineering and Construction Exports to the U.S. Economy, op, cit., with corrections supplied by Price-Waterhouse to OTA. This survey found that, in 1983, foreign contracts to U.S. E&C firms totaling $19.6 billion resulted in $2.2 billion in U.S. salaries and fringe benefits (excluding subcontractors), $1.9 billion in purchases of U.S. goods, and $1,4 billion in U.S. subcontracting. A total of$13,4 billion went for goods and services purchased in the host nation or in third countries (foreign expenses), with the remainder for miscellaneous items such as tax payments. For 1982, $21,7 billion in contracts resulted in purchases of $2.8 billion in U.S. materials, $2.2 billion for U.S. salaries and fringe benefits, and only $800 million for U.S. subcontracting, with $15,3 billion for foreign expenses.

[12] "Italian Engineering & Construction 1986, " *Engineering News-Record*, June 12, 1986, p. 1-6.

**Figure 28.— New Contract Awards of the 250 Largest International Contractors**




SOURCE *Engineering News-Record,* various issues

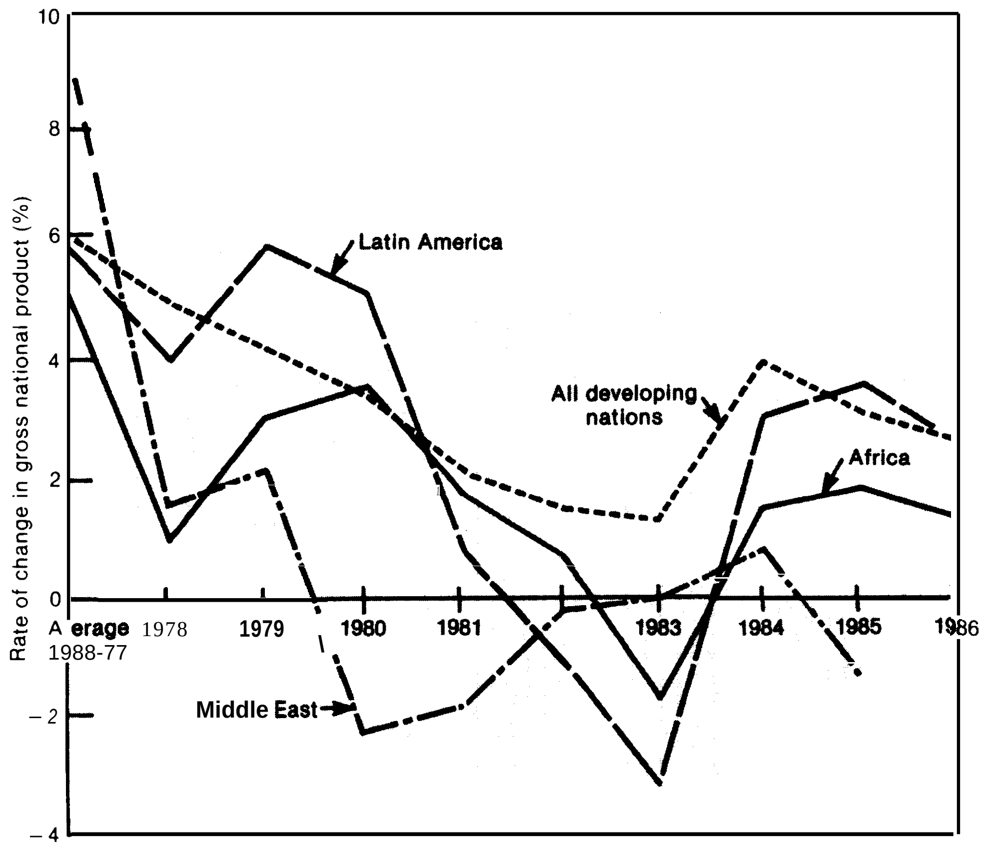
nal debt of the LDCs has grown—from almost $400 billion in 1978 to an estimated $1 trillion in 1987.[13] Many developing countries cannot service their existing debt, much less contemplate expensive new construction projects.

Among the reasons for the deteriorating economic picture illustrated by figure 29, perhaps the most significant has been the fall in prices for non-oil commodities–particularly food and primary metals, For the Middle East, of course, the problem has been declining oil exports, and, more recently, falling prices, leading to economic slowdown; the current account of the oil exporting nations as a group shifted from a surplus of $95 billion in 1980, to an estimated

[13] *World Economic Outlook* (Washington, DC: International Monetary Fund, October 1986), p. 100. For the current account figures for oil exporting countries, below, see p. 78.

in 1977, 15 percent of revenues that the indebted developing nations earned through exports went to debt payments: by 1982, debt service payments had peaked at 24,6 percent of total exports. For many individual countries, the situation was much worse; in the Western Hemisphere, over half the exports of the indebted developing nations in 1982 went toward debt payments, (An indebted nation has external debts greater than external assets; in practice, this includes all LDCs with the exception of Middle Eastern oil exporters.)

Figure 29.— Economic Growth in the Developing World




SOURCE" *World Economic Outlook* (Washington, DC. International Monetary Fund, October 1986), p 37

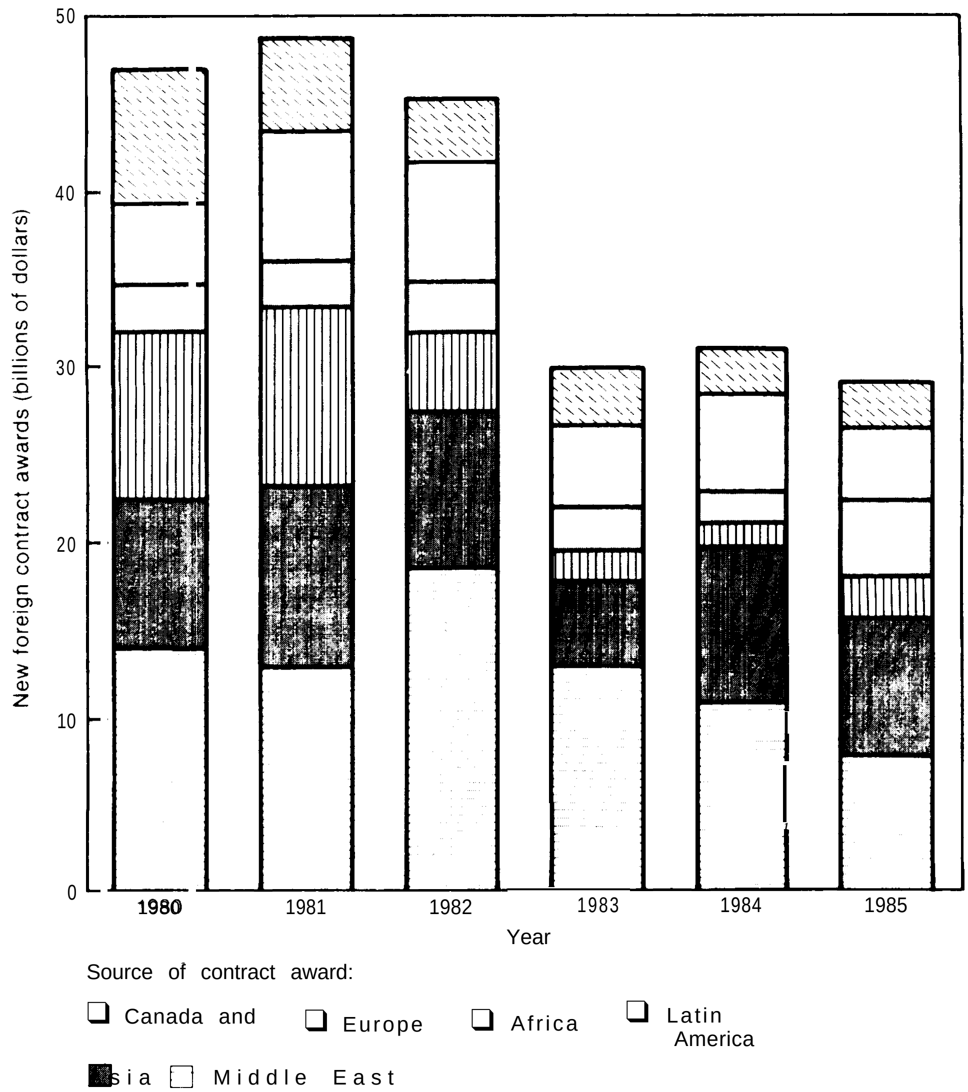
$39 billion deficit in 1986. Given their debt servicing problems, and the fall in commodity prices (including oil), developing nations have generally been unwilling or unable to borrow capital to finance major development projects. This is the context for viewing the declining U.S. share of international E&C projects.

## Construction

American construction firms (design and engineering are treated later) get much of their international business in Asia and the Middle East. Figure 30 shows the extent to which the Latin American market, large in the early 1980s, has dried up—a casualty of the economic problems summarized above; since 1982, U.S. firms have done as much or more business in Canada as in all of Latin America.

The dropoff in the Middle East has also been severe. Nonetheless, table 16—which gives new contract awards by region during 1985 for construction firms from different countries—shows that the Middle Eastern market continues to be particularly important for American contractors. European firms do especially well in Africa, a result in many cases of continuing ties with former colonies. In 1984, the 41 U.S. firms among the 250 largest international contractors (in that year) had a share of the international market slightly greater than that of the European firms (38.1 compared to 37.1 percent). In 1985, however, the U.S. market share fell below that for the Europeans, as the table indicates. Indeed, it has been dropping steadily for 15 years. Over the period 1966-71, American firms captured nearly 70 percent of the foreign construction orders won by companies from

**Figure 30.— Foreign Construction Awards of the 400 Largest U.S. Contractors**




SOURCE *Engineering News-Record*, various issues

**Table 16.— New Contract Awards for the 250 Largest International Contractors, 1985**

| | | Total new awards by region (billions of dollars and percentage) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of firms | Country of ownership | Total awards | | Middle East | | Asia | | Africa | | Europe | | Latin America | | 'North America | |
| 43 | United States | $282 | 34.6% | $ 78 | 36.0% | $7.1 | 39.9% | $ 4.5 | 29.1% | $4.2 $4.2 | 42.3% | $2.3 | 34.8% | $ 23 | 23 0°10 |
| 116 | Europe | 326 | 399 | 61 | 284 | 43 | 24.3 | 75 | 487 | 55 | 55.3 | 3.6 | 53.2 | 5.5 | 542 |
| 39 | Japan | 11.6 | 143 | 19 | 88 | 54 | 306 | 1 6 | 108 | 02 | 23 | 05 | 7.1 | 20 | 19.2 |
| 17 | South Korea | 48 | 58 | 34 | 156 | 04 | 21 | 10 | 6.5 | | | —a | — | — | a |
| 35 | All other | 44 | 5.4 | 2.4 | 11. 2 | 05 | 30 | 07 | 05 | | | 03 | 49 | 04 | 36 |
| 250 | A l l | $81 .6 | 100% | $2.1 6 | 100% | $178 | 100% | $153 1 | 100% | $100 | 100% | '$6.6 | 100% | $1 0 | 2700"/(0 |

[a]Less than $50 million

NOTE Totals may not add because of rounding

SOURCE *Engineering News Record* July 17 1986 p 41 six major industrialized nations.[14] By 1980, the U.S. share of new contracts going to these six nations had dropped to 60 percent, and 1984 saw a still smaller share of 49 percent.

Why did the U.S. share drop? Largely because exports of E&C services from other countries grew faster, With the rapid increase in new construction projects in the Middle East during the 1970s, U.S. E&C exports jumped, rising from about $3.6 billion in 1972 to some $22 billion in 1975. However, this growth did not necessarily translate into a larger share of the international construction market for U.S. firms; construct ion exports from other nations rose as fast or even faster during the peak years of' the Middle East building boom. South Korea's rise was especially striking; Korean construction exports rose from $83 million in 1972 to $8 billion by 1978, peaking at $13,9 billion in 1981.[15] Meanwhile, for American firms, 1975 marked the beginning of a plateau, although exports from countries like Korea continued to climb.

U.S. market share has been sliding ever since. As figure 28 indicated, the U.S. share of all international contracts was 35 percent in 1985; it had been 45 percent in 1980, While the United States continues to export far more construction services than any other nation, the relative slide has been rapid. Foreign firms have been continually nibbling area} at the U.S. position. With a growing number of competent firms, and increasing} homogeneous technologies, the pattern is one of convergence in Competitiveness; particularly since 1982, price competition in a shrinking overall market has been very intense. As in so many other industries where the international standing of U.S. firms has been threatened, many of the causes lie as much in improvements elsewhere as in problems here.

Foreign government policies have contributed to this convergence. Governments dictate the conditions under which foreign-owned E&C companies do business within their borders. In the 1950s and 1960s, an American firm could bid on and win contracts calling for most of the engineering and design work to be undertaken in the United States. Today, many governments insist that the work take place locally. They also seek transfers of proprietary technologies. In many cases, this means that U. S.-based E&C firms station a small nucleus of highly skilled specialists in the host country, where they supervise and train local residents. Through such policies, developing countries have nurtured their own E&C capability, and today depend less heavily on foreign expertise.

### Design and Engineering

overseas work for American design firms has remained relatively stable, in contrast with the slump in construction. Foreign billings of U.S. design firms fluctuated between $1.1 billion and $1.4 billion over the first half of the *1980s* (table 17). Figure 31 shows the market shares of the top international design firms. U.S. design firms have been, by and large, holding their own internationally, The Middle East has been a ma-

**Table 17.— Revenues of the 500 Largest U.S. Design Firms (billions of dollars)**

| | Foreign revenues | Domestic revenues |
|---|---|---|
| 1980 . . . . . . . . . . . | $1.1 | $6.1 |
| 1981 . . . . . . . . . . . . | 1.2 | 7.1 |
| 1982 ... . . . . . . . . . | 1.4 | 7.1 |
| 1983 . . . . . . . . . . . . | 1.3 | 7.3 |
| 1984 . . . . . . . . . . . . | 1,1 | 8.5 |
| 1985 . . . . . . . . . . . . | 1.3 | 9.7 |

SOURCE *Engineering* News-Record, various issues

[14] R.BahNeo, *International Construction Contracting* (Epping, Essex: Gower Press, Bowker Publishing Co., 1976), p. 38. The shares over the 1966-71 period were:

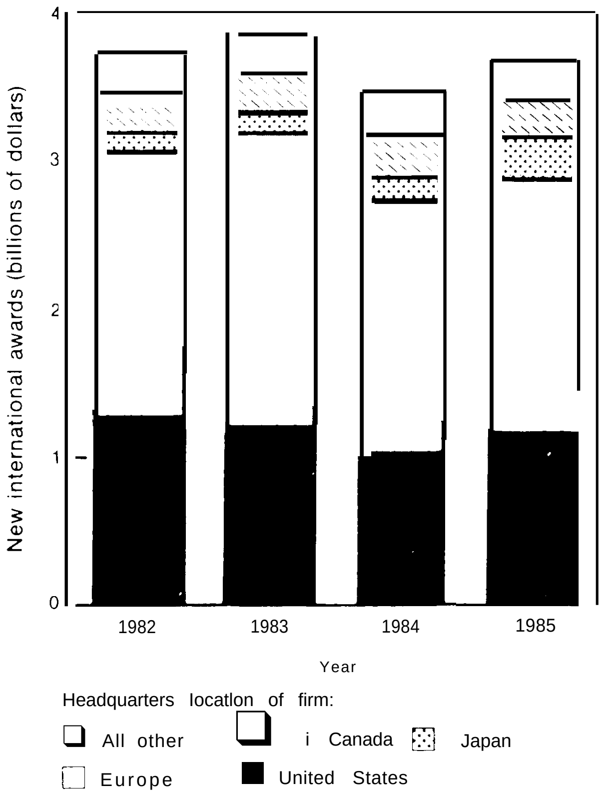
| *United States* | *France* | *Britain* | *Italy* | *West Germany* | *Japan* |
|---|---|---|---|---|---|
| 68.9% | 11.1% | 9 1% | 6 3% | 3.2% | 1.3% |

Historical data on the international E&C market are hard to come by, and not necessarily comparable from year to year. In general, the annual surveys conducted by *Engineering News-Record* (EN R), drawn upon where possible in this chapter, provide the most useful data. Nonetheless, these surveys are of questionable accuracy: some firms in some years, for instance, may understate their business, while others have reasons for overstating their awards. EN R's surveys of the top 250 international contractors did not begin until 1980, while their coverage of international design firms only became standard ized at 200 firms in 1982.

[15] R Cortincvis and M. Colombard-Prout, *La Coree du Sud et la Question des Exportations de BTP (* Paris: Centre Experimental de Recherches et d' Etudes du Batiment et des Travaux Publics, 1982), p. 150.

More recently, tbe collapse of the Middle East market has badly hurt the South Korea construction industry. Exports of South Korean firms ranked among the largest 250 international firms declined from their 1981 peak to $4,8 billion in 1985.

**Figure 31 .— New Contract Awards of the 200 Largest International Design Firms**




SOURCE *Engineering NewsRecord.* various issues

jor international market for U.S. design firms (figure *32].* While the recent drop in opportunities in the Middle East has hurt, U.S. design firms—unlike their counterparts on the construction side of the business—have been able to find replacement markets in other parts of the world—e. g., Latin America.

As table 18 indicates, the industrialized nations—basically the members of the Organization for Economic Cooperation and Development (OECD)—continue to monopolize the international market for design and engineering contracts. None of the NICs has carved out an international position comparable to that of the Koreans in construction. This does not mean that the NICs are not active. *Engineering News-Record's* listing of the *200* largest international design firms includes companies from South Korea, Taiwan, Brazil, and Venezuela. But as table *18* shows, the international billings of the four Korean firms making the *1985* list totaled less than *$50* million.

## Outlook for the Future

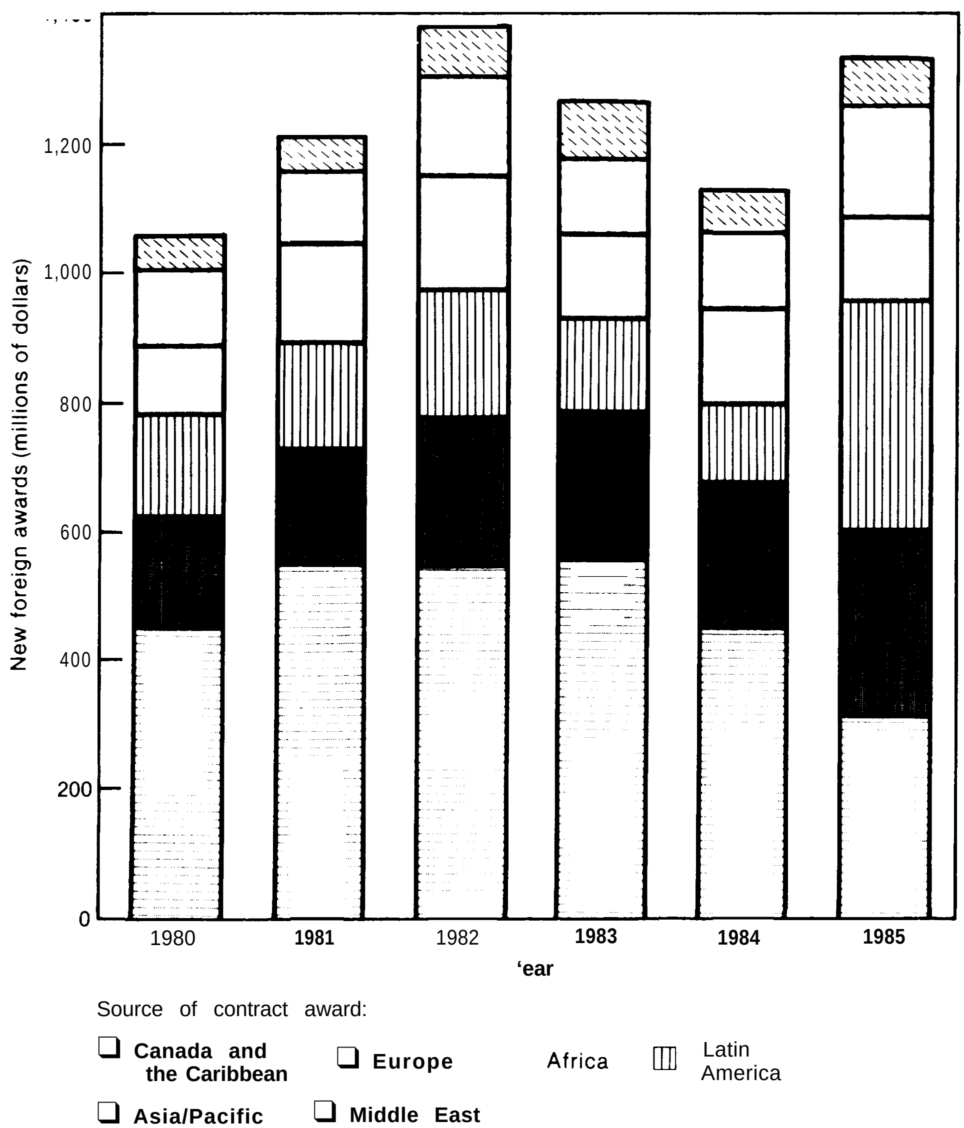
Given the past importance of the Middle Eastern and Latin American markets, f'ailing oil prices and increasing LDC debt have drastically affected the competitive fortunes of American E&C companies. Is it possible that the deteriorating U.S. position outlined above is temporary, subject to reversal with improving economic conditions in the developing world? Certainly an economic upturn would bring new demand for construction and help American firms. Nevertheless, the international E&C market has changed fundamental}', and in ways that make it unlikely that American companies will return to the positions they held in the early *1970s.*

The primary reason has already been mentioned: rising competence elsewhere, as demonstrated most spectacularly by the rise of the South Korean construction industry during the *1970s.* And it is not only the E&C firms in the NICs that have matured, but those in the LDCs as well, aided by participation alongside U.S. and other foreign firms on past projects. (Man}' South Korean firms learned their trade on projects in the Middle East and Vietnam, often under the supervision of American companies. ) Developing countries can now handle many construction projects on their own that once would have been opened to foreign bids. From *1980* to *1985,* World Bank disbursements within host nations nearly doubled (this covers both goods and services for civil works projects); only one-quarter of these expenditures now go to outside firms.

Improvement in local E&C capability, of course, has been a major goal of the development process, and a cornerstone of industrialization.[16] In countries with low per-capita in-

[16] *The Construction Industry: Issues and Strategies in Developing Countries* (Washington, DC: World Bank, *1984];* P.G. Abbott, *Technology Transfer in the Construction Industry*, Special Report No. 223 (London: Economist Intelligence Unit, 1985). on the examples later in the paragraph, see "Third Saudi Airport Fit for Kings, " *Engineering News-Record*, Dec. 19, 1985, p. 48; and " Disney Park To Smooth Weak French Market, ' *Engineering News-Record*, Jan. 2, 1986, p. 14.

**Figure 32.— Foreign Awards of the 500 Largest U.S. Design Firms**




SOURCE *Engineering News-Record,* various issues

## Table 18.—Billings of the 200 Largest International Design Firms, 1985

| Number of firms | Country of ownership | Total foreign billings | | Middle East | | Asia | | Africa | | Europe | | Latin America | | North America | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 59 | United States | $1.1645 | ***32.0%*** | ***$3036*** | 31.1% | $267.6 | 29.1% | $127.6 | 16 1% | $1499 | 41 .9% | $2944 | 64.6% | ***$21.5*** | ***15 2%*** |
| 96 | Europe | 1,7094 | 47.0 | 5023 | 51.6 | 3670 | 400 | 501 5 | 63,3 | 199,0 | 556 | 102,7 | 22,5 | ***37.0*** | ***262*** |
| 13 | Canada | 2658 | 7,3 | 162 | 1,7 | 71,4 | 78 | 787 | 9.9 | 2.1 | 06 | 279 | 6.1 | ***695*** | ***493*** |
| 12 | Japan | 2622 | 62 | 154 | 1.6 | 151.2 | 165 | 443 | 56 | 1.9 | 05 | 134 | 29 | —a | — |
| 4 | South Korea | 46.6 | 1,3 | 244 | 2.5 | 16.4 | 1 8 | 58 | 07 | —a | — | — | — | — | — |
| 16 | All other | 2272 | 62 | 1123 | 11,5 | 455 | 50 | ***34.2*** | ***4,3*** | ***4,9*** | 1.4 | 172 | 3.8 | 13.1 | 93 |
| 200 | All | ***$3,675.7*** | 100.0% | *$9741* | 100% | *$9190* | *100%* | *$792.0* | *100%* | *$3577* | 100% | *$455.5* | 100% | $141 0 | 100% |

[a]Less than $100000

NOTE Totals may not add because of rounding

SOURCE *Engineering* News *Record* August 7 1986 p 28 comes, the World Bank gives bids from local contractors a 7½ percent preference. Many 1,1X governments have protected their supplier and E&C industries, following infant industry strategies. Regulations may require subcontracting to local firms, as well as local purchases of' materials and supplies, In Indonesia, by presidential decree, subcontracting to domestic companies must accompany all awards to foreign E&C firms. The aim is to speed technology transfer. Saudi Arabia's Government hopes to see three-quarters of the contracts for the King Fahd International Airport go to Saudi companies. In pursuing such approaches, developing countries are simply following the lead of the First World, When it comes to military and other federally funded projects, the U.S. Government maintains its own set of preferences for American firms, as discussed in chapter 10 (see box II). In France, over 90 percent of' the work on the new Euro-Disneyland-to be built outside Paris at a cost of more than $3 billion-has been promised to French architects, engineers, and construction firms.

Beyond the growing capabilities of indigenous firms, three decades of Third World development also mean that many of the large infrastructure and industrial projects are already in place. A resumption of economic growth will certainly bring new opportunities, but not on the scale of the past, In the petrochemical industry, for example, overcapacity in commodity products means movement toward high-value-added specialty chemicals. New plants will be smaller in scale, the contracts less lucrative. The success of the green revolution has likewise reduced the immediate need for massive irrigation and other agricultural projects. As many in the industry put it, the era of the mega-project is past, (China's **$20** billion Three Gorges hydroelectric station, if it goes forward, may prove the outstanding exception.)

Structural change in this industry means more than stronger competition in overseas markets, For American E&C firms, as for American manufacturing firms, it means new competition at home. With the slowdown in the Third World, foreign contractors have begun to view the United States as the next major growth market. Companies with headquarters in Europe, Japan, and South Korea have announced plans to expand into the U.S. E&C market. Many already have operations here—table 19. The rapid rise in U.S. revenues of foreign-owned E&C firms indicates that they have been taking market share from American-owned competitors (also see figure 5 in ch. 1).

**Table 19.— Foreign E&C Firms in the United States**

| | Number of U.S. affiliates | | |
|---|---|---|---|
| | 1978 | 1980 | 1983 |
| Design and engineering services (including architecture) | 40 | 53 | 58 |
| Construction | 45 | 70 | 82 |
| | U.S. receipts of foreign-owned E&C firms (millions of dollars) | | |
| Design and engineering affiliates | $ 669 | $ 594 | $ 892 |
| Construction affiliates: | | | |
| European | $1,142 | $3,896 | $5,394 |
| Canadian | 61 | 243 | 144 |
| Japanese | 24 | 50 | 81 |
| Other | 317 | 415 | 1,308 |
| Construction total | $1,544 | $4,604 | $6,927 |

SOURCES: *Foreign Direct Investment in the United States Operations of U S Affiliates 1977-80* (1985); *1980 Benchmark Survey* (October 1983) and *Preliminary* 1983 *Estimates* (December 1985), tables 5 and E 5 All Department of Commerce, Bureau of Economic Analysis

In some cases, foreign E&C firms have purchased American companies. One of Britain's largest construction companies, the Davy Corp., bought Arthur G. McKee & Co. of Cleveland in 1978 to form Davy-McKee. ” The German firm Philipp Holzmann acquired a large American company, J.A. Jones Construction, of Charlotte, NC, in 1979, and later added Lockwood Green Engineers. The South Koreans and Japanese seem to prefer to establish their own subsidiaries and branch offices (Samwhan American, Kajima International), rather than purchase American competitors or enter joint ventures. As both table 19 and figure 5 show, European E&C firms had a greater presence

[17]"Overseas Firms Closing In on U.S.," *Engineering News-Record*, Aug. 2, 1984, pp. 10-11.

More recently, a Norwegian company purchased a majority share of E.W. Howell of Port Washington, NY, the 162nd largest U.S contractor—"Norwegians Buy N.Y. contractor," *Engineering News-Record*, Jan. 23, 1986, p. 158.

in the United States than the Koreans or Japanese in the past. But recently the Japanese have invaded the U.S. market with startling success; their construction contracts in the United States jumped from the $81 million shown in table 19 for 1983 to $700 million in 1984, and $1.8 billion for 1985.[18]

[18] %. H. Farnsworth, "Japanese Accused On Bidding, " *New York Times*, Jan. 6, 1987, p. D2; also R. Koenig, "Toyota Learns To Live With U.S. Unions, " *Wall Street Journal*, Feb. 25, 1987, p. 21.

## COMPETITIVE STRATEGIES

Competitive advantages in the international E&C industry hinge on three interrelated factors: costs, financing, and technology (including management expertise). In part, technology determines costs, but a bidder that can assemble an attractive financial package may get a contract despite direct costs for construction higher than for the competition.

Labor is a big part of construction costs, regardless of the type of project. In the developing world, labor costs for roadbuilding can range up to 70 percent of total project costs, depending on construction method. With wages in the LDCs far lower than in the industrial countries, extensive hiring in host country labor markets is a fact of life. The average construction wage in the United States in 1983 was $12 per hour, while laborers in Ecuador earned less than $2 per day.[19] In the United Kingdom, the 1983 figure was $4.47 per hour; in Mexico, $0.65 per hour, Large wage differentials exist at technical and managerial levels as well, helping contractors from the NICs undercut those based in industrial nations. A Korean engineer or project manager working on an international project earns less than half the salary of an American in a similar job.[20]

As a result, American E&C firms seeking overseas business not only hire local workers, but often establish subsidiaries in low-wage countries. A great deal of scope remains for improving labor productivity through automation of construction processes, and high productivity—hence management skills and technology—can offset high wage costs. But at present, E&C firms from the industrialized world can generally compete for Third World projects, even hiring local labor, only in special circumstances: 1) when projects are too demanding technically for local firms; or 2) where they can offer attractive financing packages. Such financing, often arranged with the help of the E&C firm's home-country government, may include loans with below-market interest rates or unusually long payback periods.

[19] *The Construction Industry: Issues and strategies in Developing Countries*, op. cit., p. 41; *Year Book of Labour Statistics—2985* [Geneva: International Labour Office, 1985), table 1499.

[20] Even so, in the early 1980s, a Korean manager or engineer could expect a salary of more than $35, ooo per year on an overseas project, Plumbers and welders could earn about *$15,000* per year, and bricklayers about $6,000—double what a worker could make in South Korea. Nonetheless, these costs are low compared to salaries for Americans stationed overseas; indeed, U.S. firms complain that the $70,000 tax exemption for Americans working abroad is too little, and raises their wage costs even higher. See R. Cort incvis and M. Colombard-Prout, op. cit., p. 227.

### Financing

Currently, few nations (or enterprises) in those parts of the world where the majority of international contracting takes place can assemble the necessary financial packages for large projects on their own. To be successful, bidders must offer not only competent engineering, but access to financing. This is not a new problem for the major U.S. E&C firms, which, since the 1960s, have accumulated much experience in working, not only with international lending agencies, but with aggressive private U.S. financial institutions. Nonetheless, with Third World governments strapped for cash, and with governments in other OECD countries often willing to help their own firms win contracts, the U.S. E&C industry has been operating under a considerable handicap.

Today, LDCs commonly ask foreign contractors to submit financing proposals along with their bids; Bechtel Financial Services has been involved in well over 50 major projects since

1977.[21] In cash-poor countries, outside financing may be necessary to *create* a market. For those American firms which, unlike Bechtel and other very large companies, have quite limited financial resources of their own—and no more than peripheral experience in the mechanics of international financing—the competitive difficulties will prove severe. Many commercial banks already have unacceptable exposures in countries that otherwise would offer attractive opportunities. Winning new jobs will mean assembling imaginative financing packages on a project-specific basis. This, in turn, will call for much greater familiarity on the part of E&C companies with the intricacies of rapidly evolving international financial markets (ch. 3), At the same time, banks and other players in global capital markets will need to develop a better grasp of the financing problems peculiar to international construction.

Managers of American E&C firms face a related strategic problem, one partially outside their control: the roles taken by other OECD governments in project financing. In countries including France, Italy, and Japan, government agencies have stepped in, not only with development aid, but with export credits at below-market interest rates. The objectives have been not only to support their own E&C firms, but to secure orders for materials, supplies, and capital goods. A Japanese-led consortium, for example, won a major contract from the Turkish Government to build a bridge over the Bosporus with a package including a $205 million Japanese loan at 5 percent, at least $130 million in Italian export credits at 2 ½ percent to 7 ¾ percent, and commercial loans totaling $230 million.[22]

While the U.S. Government has sought international agreements to limit the use of financial subsidies, especially mixed credits, progress has been slow—not surprising, given the indirect as well as direct benefits that governments expect from their financial participation, Aside from appeals to the U.S. Government for assistance in combating foreign government interventions (or in matching foreign subsidies), American companies are not entirely powerless in pursuing offsetting strategies. They can, for instance, enter joint ventures with foreign firms that have access to subsidized financing; while such a strategy may not be ideal, it helps preserve some international business. American E&C firms can also use existing forms of assistance, including the services of the U.S. Export-Import Bank. Furthermore, the major American E&C firms are among the largest and financially strongest in the world; this has permitted them, in some cases, to take equity positions in new projects. Bechtel Power Corp., for instance, recently signed a protocol with the Turkish Electric Authority to build a $1 billion coal-fired powerplant. Bechtel and its partners will not only design, build, and finance the project, but will also enter a 15-year joint venture with the Turkish Government; some of their revenues will come from the sale of power.[23]

In the last analysis, if a foreign government wants one of its firms to get a particular contract, and if financing is a critical part of the bid package, there will be little that other bidders can do without aid from their own governments. Realistically, U.S. E&C firms will continue to have trouble competing wherever government-supported financing comes into play. Progress in the OECD toward moderating the use of mixed credits and other forms of subsidies will help, but subsidies will not disappear in the foreseeable future,

[21] More than 40 countries sought contractor participation in financing during 1984—"Foreign Contracts Slump Further," *Engineering News-Record*, July 18, 1985, p. 55. On Bechtel, see "Financial Engineering Wins Jobs, " *Engineering News-Record*, Aug. 2, 1984, p. 30,

[22] L. Ingrassia, "How Japan Sealed Deal To Build Big Bridge Spanning the Bosporus," *Wall Street Journal*, May 29, 1985, p. I.

Ch. 10 discusses policy issues raised by subsidized financing, including mixed credits, a special case of tied aid. Tied aid refers to development grants or loans that require purchases of specified goods and services, generally from the donor nation; mixed credits combine development aid with export credits.

[27] " Buying Into Turkey, " *Engineering News-Record*, Mar. 13, 1986, p. 17; D. Barchard, "Ozal Model Sets Pattern for the Future. " *Financial 'rimes*, Dec. 18, 1986, p. 6.

Not many E&C firms can venture into such arrangements, which not only demand an unusual commitment of capital, but may force the contractor into an uncomfortable entrepreneurial role. Few firms have the skills, and even fewer would view the role of owner/operator as a desirable strategy (rather than a recourse after other options were closed).

## Technology[24]

In contrast to many of their foreign competitors, American E&C firms have seldom operated their own R&D laboratories or invested heavily in proprietary construction technologies. Although successful companies provide their clients with highly competent engineering advice, most U, S.-based E&C firms have seemed content to adopt construction technologies pioneered elsewhere. Even in the area of process engineering—e.g., for petrochemical plants—where American firms excel, not all have wished to develop proprietary technical positions. Although control of chemical engineering technologies has meant construction contracts in the past, managers typically rationalize this choice by pointing out that a client-oriented E&C firm should scan the terrain, maintain a high level of technical knowledge, and select the best available technologies for each client's particular needs. Independent development of proprietary technologies would, in this view, compromise the interests of clients.

Indeed, most U.S. R&D relevant to the E&C industry takes place outside the industry—in university civil engineering departments (where industry funding has been rare), in Federal laboratories (notably those of the Department of Defense and the National Bureau of Standards), by owners of large facilities (e.g., utilities, through the Electric Power Research Institute), and in firms that supply equipment and materials (Caterpillar, DuPont, Monsanto). A later section treats Federal Government support for R&D in more detail.

While world leaders in petrochemical and other process technologies, American companies start out behind in construction methods, In contrast, proprietary technical positions in construction have been a mainstay of competitive strategies in Europe and Japan for years, with E&C firms from these countries now well-entrenched. They have invested in R&D in construction and also in the development of specialized equipment. The German firm Dykerhoff & Widmann holds many patents covering pre-stressing and post-tensioning of reinforced concrete. The company gets a substantial share of its earnings from licensing its patents and know-how. Another German company, Philipp Holzmann, controls a set of proprietary techniques for tunneling in frozen ground, while Japanese firms are leaders in boring where geological conditions are unstable.

### The Role of Technical Expertise

Traditionally, many American E&C firms have specialized: T.Y. Lin in structural engineering of pre-stressed concrete; Guy F. Atkinson in heavy construction; Brown & Root in offshore oil projects; M.W. Kellogg in petrochemicals. Some have continued with such strategies, while others have diversified. Bechtel, with its past experience in heavy construction, including the Hoover Dam—augmented by expertise in process engineering and management—has moved into design and construction management for all types of projects, Specialized expertise determines which firms will compete for contracts. Before turning to the firm's bid and the details of financing packages, a client is likely to ask: Can this firm do the job? In fact, under design-bid-build procedures, technical qualifications become the primary criterion for awards to the design firm, Construction companies may have to pre-qualify before bidding on a job. Clients must often judge the capabilities of prospective bidders based on past performance.

Technical expertise in engineering and construction, then, stems in considerable degree from the accumulated experience of the firm. Even companies that depend heavily on international contracts tend to remain strongest in technologies important in their home market. It is no surprise to find American companies leaders in offshore drilling technologies, simply because much of the original work took place in the Gulf of Mexico. And, while American firms have a great deal of experience in telecommunication projects, they would have trouble competing with French or Japanese

[24] This section, and most of the detailed information on E&C technology, comes from "Final Report, Tasks 1/2, Technology in Architecture, Engineering, and Construct ion," op. cit., and "Final Report, Task 3, Technology in Architecture, Engineering, and Construct ion," op. cit.

companies for work on high-speed railroads. The Swiss and the French have well-honed skills in bridges and tunnels for mountainous terrain. So do Japanese firms, while the additional pressures of high population density in Japan have led to unusual emphasis on underground construction. Many other examples (box K) illustrate the point: E&C expertise comes in large measure from experience in solving problems of a local nature. Thus U.S. capability in construction management stems from past experience with large and complex projects at home as well as abroad, and the U.S. lead in applying computers to management tasks throughout the economy.

## Computer Applications

With many more computers installed in the United States than in any other country, American E&C firms have a good deal more accumulated experience than their foreign competitors, They can hire people with the latest skills, and draw on the know-how of a large independent software and services industry (ch. 5). In common with other American corporations, U.S. E&C firms have already automated standard business functions like payroll and accounting. They are leaders in applications of computers to construction management and in computer-assisted design and engineering.

Firms like Bechtel, Fluor, and Ebasco have developed proprietary CADD software, generally starting with packages available from vendors. Compared with manual drafting, CADD systems cut labor hours by factors of three or more. Interactive CADD, with software that maintains an online database and automatically issues change notices, revised drawings, and updated bills of materials will lead to further savings. With integrated databases, CADD systems will be tied directly into construction processes, where U.S. firms already take advantage of the best software for estimating, project scheduling, cost accounting and control, and materials tracking (Box J). Computer-assisted engineering calculations—for structural analysis, foundation design, slope stability, earthquake resistance—have also become routine for American E&C firms.

The next step will be to apply expert systems (a form of artificial intelligence) to the more standard design calculations (and to other E&C applications—cog., operations and maintenance). Stone & Webster, for instance, has developed expert systems for optimizing welding parameters, and for diagnosis of operating problems with pumps. Eventually, computer-assisted automation of many construction processes will become practical.

Field use of small computers will accelerate the trends outlined above, and multiply the benefits. Today, the larger American E&C firms typically operate with two levels of computer support: mainframes or powerful minicomputers for complex design, engineering, and management packages, with PCs for running smaller programs both at the head office and on the job. Where once a scheduling problem caused by, say, late delivery of materials would have been referred back to the home office, today a revised production plan can be prepared in a branch office or in the field.

Foreign E&C firms make use of some of the same techniques, but the American industry remains the leader, notably in integrating engineering and management databases—a critical step for cutting costs, and one with great potential for further savings. While Japanese and European firms have been developing computer-aided systems for management, as well as design and engineering, most fall well behind the U.S. state-of-the-art. Nor can foreign firms match the Americans in the intensity with which they use computers; Bechtel, for instance, has more than 10 times as many CADD work stations installed as the large Japanese E&C firms. For the time being, with American firms continuing to develop applications such as three-dimensional CADD, the U.S. lead should remain secure. But without continuing investments, these sources of advantage could quickly shrink or vanish.

The U.S. edge in computer-based technologies has helped American design firms hold their own in the international market, and also works to the benefit of large integrated E&C firms that offer turn-key projects. Nevertheless, when it comes to projects less demanding tech-

## Box K.-Technical Knowledge in the E&C Industry: Three Examples

### 1. New **Austrian Tunneling** Method

**The so-called New** Austrian Tunneling Method (NATM), developed more than 20 years ago for projects in the Austrian Alps, has **more** recently helped foreign firms penetrate the U.S. market. With NATM, shotcrete-a fast-drying concrete-based mixture-is sprayed onto tunnel walls to stabilize them as boring proceeds. Temporary supporting structure can be minimized, with the shotcrete replacing steel or reinforced concrete tunnel liners. Polyvinyl chloride (PVC) sheeting between the layers of shotcrete provides waterproofing.

Widely **used** in Europe, NATM was introduced into the United States in 1983 for the Wheaton station portion of the Washington, DC subway system. **The** lead contractor, the Austrian firm Ilbau, won the job with a lowbid of $51 million, and then submitted a proposal **to use** NATM **at a cost of only $45 million;** the **job had been estimated at $84 million based on** conventional methods.* This is only one example where U.S. firms appear to be well behind foreign competitors in ground stabilization techniques and tunneling technology generally.

### 2. **Up/Down Construction****

**The** Up / Down construction process provides an example in which U.S. firms adopted a technique first developed in Europe. As used in the Rowes Wharf project in Boston, the Up / Down process entailed excavation of five below-ground levels while simultaneously erecting a building above. In a conventional project, the foundation would first be excavated and the below-ground structure put in place, with the building erected last. With the Up / Down process, the contractor digs a trench for the perimeter walls, while sinking interior columns to provide the foundation. Then the building goes up, while at the same time the below-ground levels are dug out around the columns. At Rowes Wharf, as each below-ground level was excavated, a floor slab was laid, and anchored to the pm-sunk columns. The floor slabs were complete except for a 30-square-foot access hole, through which the earth excavated below **could be** removed. In essence, the structure is built upward and downward at the same time.

On the Rowes Wharf project, the developer was willing to pay an extra $2 million in construction costs to save 4 to 6 months in schedule time. The architect, who had previous experience with the necessary design techniques, originally suggested the Up / Down method, which was independently proposed by an English construction firm. After reworking the project design, schedule, and cost estimates, the client decided to proceed. Resign and construction plans were further refined by several pre-qualified construction firms. After a good deal of consultation among client, designer, and the construction firms, the developer chose an American contractor for the job, even though this firm had no previous experience with the Up / Down method. The client took out a largo insurance policy.

### 3. **Partially** Automated **Fine Grading**

**Here, the innovation came** from an American company. Grading in preparation for paving roads, highways, parking lots, and airport runways must be carried out to tolerances of 1/8 inch or less. Surfaces must be accurately contoured, not only for drainage, but to minimize consumption of expensive paving materials, Given tight tolerances, grading typically begins with a crawler tractor (bulldozer)that makes a rough cut to bring the surface to within about an inch of the required elevation. Then, in the fine grading step, **a highly skilled operator uses a motor grader to cut the surface to the required specification. The operation is slow and expensive. A surveying crew places stakes every 10 feet or so to guide the grader. With this conventional approach, a crew can grade about 30,000 square feet [or about two-thirds of an acre) in an 8-hour shift.**

**Grade-Way Construction Co., a small contractor in San Francisco, began work on automating this process in 1977. Unable to interest US. equipment manufacturers, Grade-Way's employees designed, built, tested, and refined a system that permits a bulldozer, rather than a more ex-**

*S. Neustadtl, "Tbe New Underground," *High Technology*, February 1SS$, pp. 46-52.
● *WA on "Examples of Innovation on Engineering and Construction Projects and Implications for the Construction Innovation System," prepared for OTA by C.B. Tatum under contract No. S33-2725. This report is also the source for the fine grading example, below.

pensive motor grader, to carry out fine grading. A rotating laser beam defines the plane of the cut, replacing the surveying stakes. The bulldozer carries a sensor that registers the laser beam and signals a microprocessor-based control system tied into the bulldozer's hydraulic system. Manual control of the blade in response to an operator read-out is also available, and has proved useful for training purposes.

It takes about 8 years' experience for an equipment operator to master the art of manual fine grading, but the laser-based system can be used by an apprentice. Productivity has gone from 30,000 square feet per shift to 200,000 square feet, costs from 80 per square foot **to 1¢. (Despite this,** few of Grade-Way's competitors have sought **to** automate their own grading operations.) Since developing its system for bulldozers, Grade-Way has adapted it to graders, bucket scrapers, compactors, and trenching equipment. As of mid-1986, the company had eight laser-based systems **in use. Grade-Way's annual revenues** have grown from about $1 million when development began, to more than $80 million, despite a declining local market.

Grade-Way now plans to integrate its grading system with a CADD database. At present, a design firm specifies the grade, frequently using a computerized drafting system. The resulting drawings are passed along to Grade-Way, which must enter the specifications in its own database, first for estimating, and then, if the company wins the job, for carrying out the work. Grade-Way produces a new set of drawings for use in setting up the rotating laser guidance system. Cutting out this step would lower costs still further.

ically, and for much construction, the cost savings from computer applications have generally been insufficient to counter U.S. disadvantages in labor costs. Nor, with few exceptions, does the United States lead in computer applications for engineering and management extend to construction processes themselves.

#### Productivity in Construction

In sharp contrast to factory production of standardized manufactured goods, construction remains a craft-based industry. Automation will change this on the job site, just as CADD has changed it in the drawing office. The eventual payoffs in the field will be enormous, although they may take many years to realize. Those companies that master computer-aided construction processes—e. g., automation applied to earthmoving or steel fabrication—will be able to carve out strong competitive positions. Some of these technologies will lead to advantages even for projects in the LDCs, most of which have abundant labor but lack skilled workers; automated construction equipment will greatly reduce the need for skilled operators (see the third example in box K).

Two paths, broadly speaking, lead to greater productivity: 1) better techniques on the job site, including automation and onsite prefabrication (e.g., using mobile shops); and 2) offsite prefabrication, With some exceptions, the United States is behind in both; indeed, productivity in the American construction industry has changed little since the 1960s. Examples of productivity improvements through better techniques include slipform construction for high-rise buildings and onsite precasting of concrete, While continuous pouring of concrete using slip forms has been adopted by U.S. companies, the Europeans continue to push into more sophisticated applications. The vast majority of U .S. companies still use manually constructed forms, while universal formwork has begun to penetrate job sites elsewhere. To take an example of onsite precasting, Ilbau, an Austrian contractor, recently built an arch bridge in Bavaria by setting in place two half-arches, fabricated on site, with the aid of a computer-controlled cable support system. Notable examples of off site prefabrication include ocean drilling platforms —generally built in drydocks, then floated to their final destinations. Similarly, the steel caissons and parallel strand cables for the Bisan

**Photo** *credit: Beloit Corp.*

Two generations of engineering design, turn-of-the century and 1960s era. Today, computer-based graphics systems are taking over much of the drafting and design work.

Straits suspension bridge in Japan were prefabricated in their entirety, with the caissons towed to sea and sunk in place. In many parts of the world, structures such as high-tension towers can now be prefabricated and placed by helicopter.

Major productivity improvements often require new approaches to design. The European lead in concrete technologies begins with design experience and extends to the manufacture of high-capacity concrete pumps; the Japanese have begun testing still more advanced methods, with automated booms for pouring and for spreading and finishing concrete. The Danes and Swedes, especially, have become known for high-quality precast concrete. Both Japanese and European firms are working to automate the highly labor-intensive tasks of cutting, bending, and placing reinforcing bars and cables. At one time, the United States led the world in bridging, especially suspension bridges. This is no longer true. With concrete replacing steel for many bridges, the Europeans have gained the advantage. The Saudi Arabia-Bahrain causeway, built by the Dutch firm Ballast Nedam, made use of piles and spans cast on site for most of its 7¾ mile length. Ballast Nedam's experience with heavy lifting barges for assembly made this approach possible.

If U.S. firms generally lag in technologies for concrete construction, they have thus far remained at the forefront in fabricated steel structures. Here, however, the Japanese have been making considerable progress in automation, exemplified by their well-publicized robots for spraying fireproofing insulation onto girders and columns. Japanese firms have also spent heavily on R&D for automated earthmoving equipment, a technology that Komatsu has been pursuing in its efforts to win sales from U.S. heavy equipment manufacturers like Caterpillar. The Japanese are also clear leaders in soft ground tunneling, while European firms have superior technology for hard rock tunneling. Although the Japanese have successfully developed modular prefabrication methods for piping, electrical wiring, and industrial control systems—e.g., for portions of the A1-Jubail refinery in Saudi Arabia—U.S. firms have also been quick to pursue these techniques, As a final example, improvements in construction materials—e.g., synthetic fibers for use in pavement bases and drains—have again often originated overseas. While the United States has been generally strong in materials R&D, relatively little of this work has been directed toward construction, Few American E&C firms have pursued innovative applications of materials, or pushed their suppliers to develop new products.

### Implications for Competition

Poor showings by U.S. firms in construction technologies can be traced back to the common strategy of seeking a position as technology broker or service provider, rather than technology originator, and also to bidding procedures in the United States. The design-bid-build system splits the responsibility for design and construction. The result? Weak incentives for E&C firms to adopt cost-saving design features, or to move toward a design-for-cost or design-for-constructability approach. Under design-bid-build, the contractor will be constrained by specifications typically established by another company, Not only may superior construction methods be precluded, but the system rewards conservative choices. Once the contractor has won a job with a fixed-price bid, there is little incentive to do anything but follow the specifications the bid was based on. In contrast, engineering firms in Europe must often submit proposals covering construction methods; with evaluation of alternative construction techniques an explicit part of the competition, they have incentives to design projects so as to take advantage of new, low-cost methods.

In focusing on the services portion of the industry, U, S.-based E&C firms have stressed management of complex projects rather than construction techniques themselves. Instead of developing their own technologies, American companies have preferred to serve as technology brokers, relying on their ability to match available knowledge with their clients' needs. This brokering strategy does sometimes lead to acquisition of technologies through licensing or joint venture agreements, but U.S. E&C

firms—except for some that have specialized in fields like petrochemical processing—have seldom invested their own funds in proprietary developments. European and Japanese E&C firms spend more heavily on R&Din construction methods, with the larger Japanese companies maintaining substantial R&D programs. In Japan, research staffs of several hundred people working on construction technologies, with annual budgets of $10 million or more, are not unknown. In contrast, few of the large U.S. firms have anyone at all working directly on new construction methods, although staff engineers do monitor developments elsewhere.[25]

R&D undertaken by U.S. E&C firms generally focuses on the computer applications outlined earlier, or on petrochemical and other industrial process technologies, rather than construction. In industrial process technologies, a small group of relatively specialized companies—e. g., Kellogg Rust in ammonia, Lummus Crest in ethanol—have developed strong proprietary positions. When a firm owns the process technology for, say, production of ammonia, it maybe able to insist on a turn-key contract, avoiding the need to bid separately on design and construction. Even when the firm does not control the process technology, it can trade on its skills in process engineering. But the position of technology broker can be dangerous when it comes to construction methods such as tunneling or bridge building. Here, an E&C firm without a proprietary position may find itself forced to rely on its competitors for know-how, with predictable results—having to settle for second best. Technologies do diffuse to the United States–e. g., tunnel boring techniques from Europe—but foreign firms will try to protect their position through continuing refinements in methods and by maintaining a work force well-trained in the latest techniques.

American E&C firms plainly have *access* to the expertise necessary for designing projects that would make greater use of industrialized production techniques—offsite fabrication of subassemblies, automated construction (as much a function of design as of construction equipment), innovative uses of new materials. But U.S.-based E&C firms will need to reshape their corporate strategies before they can hope to take the lead in reshaping construction processes; over the past several decades, American E&C companies have adopted and adapted, but have seldom been innovators.

[25] During a visit to a Japanese research laboratory, a vice president of a major U.S. construction firm has been reported as saying that, if he were in charge, he would fire all the R&D staff and save the company $25 million a year— ''Final Report, Task 3, Technology in Architecture, Engineering, and (construct ion," op. cit., pp. 6-7.

## The Future

Battered by rapid decline in traditional markets abroad, an overvalued currency during the early 1980s, and stiffer foreign competition, large U.S.-based E&C firms have undertaken agonizing reappraisals of their strategies. Some have retrenched, scaling back business development programs aimed at overseas contracting—a choice that means participating in the international market as opportunities arise, but at a much lower levels than before. Morrison-Knudsen, for instance, has closed its foreign offices and consolidated its international sales force in San Francisco. Other companies have begun rethinking their sources of competitive strength, and how these might be nurtured or extended. Another response—common among industries threatened by foreign competition—has been to appeal for Federal assistance. In particular, American firms have sought help in matching foreign financing packages. This and other steps the Federal Government might take, as discussed below, could help the industry, But the long run ability of U.S. E&C firms to maintain a competitive position internationally will depend on their own responses to changing conditions in markets here and abroad. Different firms will choose different directions, within a range of strategic possibilities that has already become apparent. This range is not a broad one, The nature of international competition leaves few real choices.

American E&C firms face four primary constraints:

1. For projects with a heavy component of relatively unskilled labor (which may in-

clude supervisory labor), competition is already stiff; it will grow still more intense in the future,

2. Many foreign E&C firms, including those in the Third World, can now adapt and apply a relatively broad range of technologies as needed. Once the backbone of the U.S. industry, technologically based strategies are now open even to firms from the NICs, many of which have become quite competent in design and engineering.
3. When it comes to innovation, particularly in construction processes, European and Japanese firms are ahead in some technologies. No matter the counter-efforts of U. S.-based firms, it will be difficult to regain useful leads.
4. Governments will continue to intervene in competition for international E&C projects, with this involvement taking two primary forms—aid for domestic firms seeking foreign contracts (e. g., through subsidized financing), and protection of markets at home.

Perhaps needless to say, these conditions are not unique to the E&C industry. They can also be found in many sectors of manufacturing. American E&C firms, which dominated international markets into the 1970s, have joined other U.S. companies in facing new foreign competition. This, in turn, suggests that the strategic responses in engineering and construction will show parallels with industries ranging from steel to electronics?

### Technologically Based Strategies

What, then, are some of the possible strategies? First, and perhaps most obvious, American E&C firms could develop new product offerings for the international market, much as American banks and financial service firms have been doing. Second, they could put more resources into management technologies and construction methods that will reduce costs and improve productivity.

In this industry, most new product development begins with existing technologies that can be applied in new ways—e.g., computer-controlled heating, ventilating, and air-conditioning systems for buildings. Operations and maintenance services provide many other examples; M.W. Kellogg forecasts that 15 percent of its revenues and 30 percent of its gross margins over the next 5 years will come from maintenance and training. In other cases, new industrial processes—and new industries, like biotechnology—mean new opportunities for E&C firms. American companies are attempting to adapt their expertise in chemical process engineering to scale-up in biotechnology. Japanese and German firms, however, may have a head start in bioengineering techniques for the production of specialty chemicals.[26]

O&M services have the great advantage that the work does not end when construction has been completed (although ongoing contracts will normally be small compared to construction contracts). By making use of skills available in the United States—ranging from remote sensing to computer-based process control, production scheduling, and database management —American firms can hope to maintain competitive advantages in contract O&M services. Training local personnel offers complementary opportunities. It may even be possible for American firms to adapt training methods originally developed by the U.S. military; the problems of teaching poorly educated Americans to maintain high-technology military systems are not unlike those of training unskilled workers in LDCs.

U.S.-based E&C firms can also turn their know-how toward renovation and rehabilitation of existing facilities—in part, an extension of the O&M strategy. At some point, equipment becomes obsolescent; replacement, rather than maintenance or modification, will be called for, Particularly for complex industrial plants, many companies look to external contractors when redesign and renovation are called for. Once again, most of the contracts will be small relative to those for new facilities, but opportunities will grow faster.

[26] *Commercial Biotechnology: ,-in International Analysis* (Washington, DC: Of fic c of Technology Assessment, January I 984), pp. 83-84.

New technologies—mostly originating in other industries—create another set of opportunities for American E&C firms to develop new products. Developments like fiber-optic communication systems or bioengineering stimulate capital investment, with one of the consequences greater demand for E&C services. While many of these opportunities will depend on technical advances beyond their control, E&C firms with the expertise to apply new knowledge should be able to establish competitive margins. Such abilities have been a traditional U.S. strength, but the technology broker strategy will not be as effective in the future as in the past. With other nations—notably Japan–moving into fields like optical communications and biotechnology as rapidly as the United States, it will be harder for American E&C firms to capitalize on new opportunities arising from new technologies.

To be competitive in the future, American E&C firms will probably have to make their own investments in proprietary know-how ranging from control of hazardous wastes to the design and construction of clean rooms for manufacturing integrated circuits. Thus far, international markets for many of these specialized design and engineering projects have been slow to materialize. At some point they will, and the companies prepared to take advantage will reap the rewards.

It will take more than success in developing new E&C products—whether O&M services or knowledge of bioengineering—for U.S. firms to rebuild their competitiveness in engineering and construction. They will need to continue building on their strengths in computer applications and in management, while seeking ways to keep up in construction methods. Expertise in engineering and design gives American firms something to trade: while the United States imports construction technologies, foreign firms come here seeking software and management know-how. So long as they stay ahead in these fields, American E&C firms will have leverage for negotiating joint venture deals and technology transfer agreements. In particular, American companies will need to extend their managerial advantages beyond the large and complex projects in which they excel. With fewer such projects internationally, management skills on smaller and more routine jobs will take on greater significance. There is no reason why U.S. firms should not be able to move from skills in the management of complexity to equal reputations in management for increased productivity and reduced costs. While they have not yet done so, their lead in computer applications gives them a powerful weapon.

Management for productivity and constructability will plainly take on greater importance in the future. With construction know-how widely available to firms in the NICs and LDCs, the grounds for competition will shift from technology itself to the management of technology. In the past, for example, earthmoving in the LDCs depended on cheap labor and simple equipment that relatively unskilled operators could use. Meanwhile, cost pressures in the developed nations led to capital-intensive methods. Contractors turned to very large pieces of equipment, with which a few skilled operators could achieve high levels of output. They also sought specialized equipment for small jobs or for work in congested areas (e.g., laying pipelines). Similar cost pressures lie behind the R&D on automated earthmoving procedures mentioned above—automation that will eventually make it possible for an unskilled labor force to use advanced machinery and equipment. Already, partial automation—e, g., laser-guided grading (box K)—has reduced skill requirements. When companies anywhere can lease or purchase the same equipment, management ability, in the sense of tailoring operations to local conditions, will become a prime source of competitive advantage—one that American firms may still be able to exploit.

The demands of customers and the innovations that emerge elsewhere in the U.S. economy will help shape the future strategies of American E&C firms. In the longer term, the more successful companies will be those willing to invest their own resources in adapting technologies from other industries to the problems of engineering and construction. American firms should be able to do well, given the

U.S. position at or near the forefront of so many technologies, but they will have to put money into R&D. E&C firms in other industrialized countries face the same choices and the same opportunities. As in manufacturing, part of the task for U.S. E&C companies will be to more aggressively monitor and learn from their foreign competitors.

### International Contracting Practices

American E&C firms enter into international consortia not only to take advantage of the strengths that foreign firms can bring to such ventures, but to meet bidding requirements; U.S. companies contribute management and technical skills, while foreign firms may provide less expensive labor, access to low-interest financing, and their own specialized expertise. A recent example saw Bechtel team with the Japanese firm Kumagai Gumi to build a $170 million dam in Canada.[27] Such arrangements seem bound to increase, given the current realities of global competition.

Among these realities, government intervention looms large: often, the formation of international E&C consortia follows quite directly from government policies that permit foreign participation in local projects only through joint ventures with domestic firms. In this way, governments seek to speed technology transfers—e.g., by requiring that engineering and design work be shared. Where they do not seek joint ventures, governments may require local hiring by foreign contractors. In other cases, domestic firms receive preferences on contract awards—common in industrialized countries as well, where employment has been a primary motive. In the United States, construction projects paid for with public funds have often been restricted to U.S. companies, while Buy American clauses may cover materials and supplies. Canada places restrictions on foreign architects. The United Kingdom requires that engineering contracts for North Sea oil projects go to firms with majority British ownership.[28]

What do government pressures for local participation mean for corporate strategy? Primarily this: any foreign firm that resists government pressures to join with local companies will lose out, in the absence of literally enormous advantages in technology or financing, One or a few foreign firms may decline to participate, but others will be only too happy to take their places. While the United States certainly needs to continue pressing Third World countries to abandon such policies, LDC governments will continue to seek advanced technology in one guise or another—leaving American managers seeking ways of remaining responsive to these requests while also preserving technically based competitive advantages, a dilemma E&C firms share with those in high-technology manufacturing. At the same time, the nature of the international E&C business often makes it necessary to have a local partner, regardless of government involvement.

Beyond entering joint ventures and consortia with foreign companies, American E&C firms have begun to explore joint development with manufacturing firms as a route to proprietary technologies and possible competitive advantages. For example, Bechtel and Varian Associates have combined to supply clean-room facilities for the microelectronics industry, while Fluor has joined with the Allen Group to offer a package of services for the design and construction of automated factories. Although these efforts are in their early stages, they will probably expand in size and scope. If hard-pressed American firms in several industries can join, taking advantage of the technical po-

[27] Japanese financing was part of the original aim. While this did not work out, the project nonetheless proceeded —"U.S.-Japanese Team Speeds Canadian Dam," *Engineering News Record*, Oct. 23, 1986, p. 20.

[28] J. Randolph, "Foreign Government Targeting of Engineering-Construction Services," memorandum, Department of Commerce, Washington, DC, February 1986.

In preparation for the Uruguay Round trade negotiations, the U.S. Government has compiled a long list of violations of national treatment—the principle that domestic and foreign firms be treated the same—in the awarding of E&C contracts. See "Trade Issues in the Engineering and Construction and Related Consultancy Services Industry," background paper, Office of the United States Trade Representative, Washington, DC (no date).

Many in the U.S. E&C industry have strong reservations concerning the new trade round. Managers fear the United States may back away from current policies that support the industry—e.g., preferences and set-asides on foreign projects such as military bases—in exchange for liberalization elsewhere. The industry opposes the extension of the GATT procurement code to engineering and construction services for similar reasons, sitions that each retains, they should fare better internationally. For the E&C industry, these joint endeavors suggest somewhat belated recognition that a continuing technological edge depends on advances in other sectors of the U.S. economy.

Finally, American firms have the option of eschewing international markets entirely, and retrenching inside the Nation's borders, Although the size of the U.S. market makes this option potentially attractive, the choice is a risky one, as the experiences of American manufacturing corporations demonstrate. While foreign penetration of U.S. construction markets has thus far been minor relative to the overall size of the industry, firms in Japan and Europe clearly see in the overseas problems of American contractors evidence of vulnerability at home, With foreign E&C companies making penetration of the U.S. market a major element in their own strategies, American firms that pull back internationally may quickly find the competition following them here. So long as the U.S. economy remains a relatively open one, the home market will not necessarily be a safe haven for American E&C firms.

Moreover, abandoning the international market carries implicit costs. First of all, reentry in later years—e.g., when the world economy has picked up—will be difficult, Reputations will be tarnished if not lost, along with critical stores of overseas experience. Mobilization of resources will be difficult once foreign bases have been abandoned; companies will face new expenses. Furthermore, a corporate view limited to the United States could cause E&C firms to overlook potential sources of competitive advantage valuable, not only in international competition, but at home—e.g., technologies pioneered overseas. Again, the analogy with U.S. manufacturing, where many purely domestic companies remain ignorant of foreign innovations, seems appropriate. Today, a provincial view of technology development is an invitation to competitive obsolescence. And ultimately the real worry is that inability to compete abroad may foreshadow inability to compete at home.

## POLICY ISSUES: TECHNOLOGY DEVELOPMENT AND DIFFUSION

As earlier sections of this chapter suggest, the major policy issues for the U.S. E&C industry center on financing and technology. When it comes to financing, success in U.S. efforts to combat foreign government subsidies would be a major step toward equalizing the terms of competition. The Export-Import Bank's Engineering Multiplier Program, through which the bank extends loans to foreign purchasers of U.S. architectural and engineering services, has also provided some help, as has the Trade and Development Program. Chapter 10 discusses these and other topics related to financing, including specific policy options. This section focuses on technology.

As noted earlier, U.S. E&C firms do little R&D. Most of the support for research related to construction comes from the Federal Government (box L), from suppliers to the industry, and from the owners of large facilities. There are no authoritative figures on total U.S. expenditures for construction R&D, but spending is probably in the range of half a percent of construction revenues; Japan's construction R&D, in contrast, has been put at 3 percent of total industry revenues, [29] Not only is spending in the United States low, but the military focus of federally supported R&D contrasts sharply with the typical approach in Japan and Europe, Many European governments have ministries of construction. Among their other activities, these ministries sponsor and coordinate R&D, In the United States, as box L indicates, the Department of Defense accounts for most government R&D related to construction. Much of the money goes toward the water and port projects of the Army Corps of Engineers; technology

[29] R. Tucker, "CII Project Overview," presentation to the First Construction Industry Institute Annual Meeting, Keystone, CO, Aug. 7, 1985, p. 4.

## Box L.—Federal Government R&D Support for Construction-Related Technologies

While a good deal of Federal support goes toward technologies tangentially related to the E&C industry —e.g., new materials, robotics and automated manufacturing—directly relevant work outside the military totals less than $30 million per year. Spending by the National Bureau of Standards (NBS, part of the Department of Commerce) accounts for about $20 million of this total.

### Civilian Agencies

The fiscal year 1987 budget for the NBS Center for Building Technology (CBT) comes to $12 million. The Center for Fire Research, also part of NBS, gets another $8 million. (Both figures include work undertaken on a reimbursable basis for other agencies.) In past years, the Reagan Administration has sought to eliminate both NBS centers, arguing that their activities could be undertaken by State and local governments; the current Administration proposal for fiscal year 1988 calls for merging the two centers and reducing funding.

Consistent with NBS's overall mission, the CBT develops measurement techniques, databases, and testing methods—a set of technologies with broad and general relevance to the construction industry. Because of this, support at State and local levels seems unlikely. Why should one State pay for R&D that the other 49 will also benefit from? Although Congress has kept the CBT's programs going, funding has declined from a high point of $14.7 million in 1980 to the 1987 level of $12 million, while man-years have fallen from 199 to 126 over the same period. With two-thirds of the Center's work undertaken on a reimbursable basis for other organizations (mostly government agencies), a continued decline in direct appropriations means that more of CBT's research will reflect the narrow missions of these agencies, Congressional appropriations—some $3.4 million in 1987—provide most of the support for generic R&D at the Center.

The National Science Foundation (NSF) funds construction-related research in civil engineering, almost all of it at universities. Three programs account for most of the relevant NSF grants. The Structures and Building Systems program funds research on construction processes, including automation, at a 1987 level of $3.8 million. A program focused on infrastructure and on existing buildings, entitled Systems Engineering for Large Structures, has a 1987 budget of $2.7 million. NSF's Earthquake Hazards Mitigation program ($14.4 million) funds some R&D related to construction. In addition, NSF has awarded a grant for an Engineering Research Center on Advanced Technology for Large Structural Systems to Lehigh University; this center is scheduled to receive $10.4 million over 5 years, with additional support from the Pennsylvania State Government.

Finally, the Federal Highway Administration spends something less than $1 million per year on research, development, and technology transfer related to highway pavements and bridges. Some State highway departments also maintain research programs. Currently, the National Research Council's Transportation Research Board is coordinating the Strategic Highway Research Program, with a 5-year budget from several State and Federal organizations of $150 million. About half the budget will be spend on materials-related research; little will go to R&D on construction processes.

### Defense-Related R&D

Military projects at six Federal laboratories run to much higher levels—a total of about $270 million in 1986. The Army maintains a combat engineering laboratory at the Belvoir Research and Development Center, while the Army Corps of Engineers operates three facilities—the Construction Engineering Research Laboratory, the Cold Regions Research and Engineering Laboratory, and the Waterways Experiment Station. The total R&D budget for the Corps of Engineers came to $67 million in 1986, with 1987 estimates of $62 million to $75 million. The Air Force and the Navy each maintain civil engineering laboratories of their own, while the Department of Defense began in 1986 to fund Centers of Excellence on Advanced Construction Technology at MIT and the University of Illinois.

Some, though not all, of the military research is relevant to civilian construction problems—most commonly, the work of the Army Corps of Engineers, which is responsible for heavy construction on many U.S. dams and waterways. But work that *could* be used in the civilian E&C industry finds its way only slowly and sporadically to the one million-plus American E&C firms.

transfer from the Corps' laboratories to industry has been occasional.

The analysis in earlier sections of this chapter indicates that, to be competitive in the future, U.S. E&C firms will have to rely heavily on advanced construction technologies. Over the next several decades, construction will gradually emerge as a high-technology industry, with extensive automation replacing the craft-based methods in current use. Rapid productivity gains will cut costs for firms that lead in applications of high technology; the need is as much for creative use of tools and techniques that already exist (perhaps in embryo form) as for new research. At present, American firms do a good job of applying computer-based technologies during the design stages of E&C projects, and for construction management, but they are well behind in construction methods, automated and otherwise. That is where most of the costs are incurred, and where the big payoffs lie.

That future international advantages for the U.S. E&C industry will be based in part on technology could, in itself, justify higher levels of Federal funding for construction research. But the potential domestic impacts—through greater productivity y and lower costs for projects ranging from residential building through infrastructure improvement (roads, waterworks) to heavy construction—argue much more powerfully for higher levels of R&D. But why should government pay? Because much of the work required falls in the category of generic or precompetitive R&D. For reasons explored in greater detail in chapter 6, private firms in the United States seldom pursue such R&D very extensively. Simply put, no one firm can expect to capture the rewards from R&D that benefit's an entire industry.

For the U.S. construction industry, the immediate opportunities lie in utilization of existing knowledge, including technology from other industries and know-how originating overseas (e. g., European approaches to reinforced concrete construction). Institutionally, perhaps the most pressing need—given the vast size and fragmented character of the industry—is for better-developed mechanisms for diffusing technology, and the lessons of experience in applications of new technologies. so

Again, note the parallels with U.S. manufacturing. The Nation's base in scientific research and in high technology is unmatched in the world. Much of this research, in principle, can be applied to industrial problems. But relatively few of the firms, in construction or in manufacturing, that might draw on this research base have staffs capable of picking and choosing what is needed for a particular problem. Nor do that many firms have the strategic vision at executive levels necessary for reshaping their operations over periods of years (which would include recruiting and training the right kind of employees) to take advantage of new technological opportunities. Such difficulties exist around the world. But particularly in the United States—where the gap between advanced research and applications is widest—attempts at technological solutions to problems in either construction or manufacturing too often fail because of a mismatch between the company's real needs and the means brought to bear (technology for the sake of technology), because of an inappropriate mix of people and machines (integrating the work force out of the process rather than into the process), or for lack of commitment (management backs out after initial failures, rather than seeking to learn from experience). In essence, U.S. E&C firms have not been very good at appropriate technology.

A positive Federal role, then, would be to help create infrastructural mechanisms for: 1) conducting R&D on construction methods; and 2) transferring know-how and results to the E&C industry, in part through ongoing company involvement in the R&D projects themselves. NSF's Engineering Research Centers provide a possible model (although one center for construction might fill 1 percent of the need); other

[30] Poor attendance at meetings on technology' transfer organized by military laboratories that conduct construction-related R&D shows, not that there is no problem, but how deep-seated the problems are—" Military R&D Up for Grabs, " *Engineering News-Record*, Mar. 6, 1986, p. 11.

models also exist, both here and overseas.[31] Given the size of the E&C industry, and the range of applicable technologies (including those originating in other industries), a robust and self-sustaining infrastructure for developing and transferring construction-related technologies might involve dozens of such centers.

Certainly there appears to be room for one or more industry-cooperative R&D consortia on the lines of Microelectronics& Computer Technology Corp. The Federal Government could facilitate the creation of such consortia by contributing seed money and/or incorporating some of the ongoing activities of the existing NBS Center for Building Technology. Furthermore, ongoing Federal funding of some percentage of the work conducted by R&D consortia could serve the public interest. For example, government support for testing and commercialization of new construction technologies would help ensure the safety and long life of structures built with public funds. (NBS, the Federal Highway Administration, and the Army Corps of Engineers do some of this already,)

Government agencies might also help speed innovation by experimenting with contract procedures that would permit bidders to propose alternative techniques, following the European model, to be evaluated by an independent board of experts. Alternatively, government agencies could move toward design-build contracts, or greater use of performance-based specifications, Congress has already directed the Department of Defense to pursue nontraditional approaches to construction projects in an effort to reduce costs.[32] Related needs and mechanisms range from a national system for information exchange on construction technologies to upgraded teaching equipment in trade schools and university engineering departments.[33]

[31] See "Development and Diffusion of Commercial Technologies: Should the Federal Government Redefine Its Role?" staff memorandum, Office Of Technology Assessment, Washington, DC, March 1984.

[32] *Military Construction Appropriations Bill, 1987*, Report 99-648 to accompany H.R. 5052, Committee on Appropriations, House of Representatives, June 19, 1986, p. 13.

[33] *Technology and the Future of the U.S. Construction Industry*, Proceedings of the Panel on Technical Change and the U.S. Building Construction Industry, Office of Technology Assessment and the American Institute of Architects (Washington, DC: AIA Press, 1986), p. 75.

## CONCLUDING REMARKS

Into the 1970s, developing countries looked to U.S.-based E&C firms to design and build electric generating plants and power distribution networks, refineries and petrochemical complexes, pipelines and offshore oil platforms, steel mills and cement plants. American companies, with a great deal of experience from work in the U.S. energy industry, were able to transfer their skills quite directly to competition for international projects in the Middle East. In the poorer LDCs, much of the work consisted of infrastructural development, often financed by international lending agencies. Here, U.S. advantages were based on domestic experience with large water and highway projects and on political and economic ties with Latin America.

These once comfortable patterns have broken down. In part, the shrinking U.S. share of international markets has been a consequence of Third World debt and declining oil prices. So long as developing countries face demands for austerity programs to qualify for additional loans—often needed simply to service their debt–new construction undertaken by outsiders will be the exception rather than the rule.

But much more is at work than the credit crunch and declining oil revenues. E&C firms in the developing world have themselves matured technologically; taking advantage of low labor costs, they can now win some kinds of contracts in competition with companies based in the advanced nations. Government policies in the LDCs and NICs have helped the process along. Viewing construction as a vital industry for development, governments have protected local entrants and forced international contractors to enter joint ventures and transfer technology. And when it comes to construction methods, American contractors generally lag behind competitors in Europe and Japan, while typical U.S. contracting procedures discourage innovation. With financing a major element in winning new contracts, and a troubled world economy, competition will remain stiff, and the U.S. share of E&C markets will probably continue to decline.

Nor can the U.S. industry afford to feel that its current lead in management expertise will be secure. With O&M contracts accelerating the spread of expertise, any strategy based on superior managerial skills will probably fail unless complemented by a major effort to make up lost ground in construction technologies. Indeed, U.S. firms need to catchup in construction know-how simply to protect their domestic markets from foreign incursions.

Today, the competitive environment facing American E&C firms resembles that for many manufacturing companies. Some E&C firms have reacted much like those manufacturers that have called for government assistance while retrenching or withdrawing from international markets. But reactive strategies will not rescue this industry, although government preferences and set-asides might help provide needed cash flow (while also meaning higher construction costs for Federal agencies). On the other hand, those American firms that take the initiative in technology development, and in tapping the skills of U.S. financial institutions, will—when they cannot win projects on their own—often be able to enter international consortia and joint ventures on favorable terms. Certainly, these international combinations will become more common; to the extent that such consortia become standard features on the competitive landscape, firms that can bring distinctive advantages to them will do better, while those that cannot will lose ground.

Relatively few American E&C firms are active in the international market, and loss of competitive advantage internationally, in and of itself, would not be a devastating blow to the U.S. economy, Greater dangers come from possible losses of downstream sales by suppliers of materials and equipment. While exports of American E&C services do not automatically translate into exports of goods, such linkages continue to benefit the Nation's balance of payments, as well as U.S. employment. By encouraging the formation of cooperative ventures between E&C companies and other American firms–e.g., trading companies–the Federal Government could help strengthen these linkages. Team America, a consortium assembled to bid on China's huge Three Gorges project offers a suggestive model (the group includes U.S. E&C firms, suppliers, and banks).

In terms of Federal policies, however, the greatest short-term need is simply to force other OECD nations away from subsidized financing for international projects. For years, the major industrial economies have used export credits to sweeten deals, particularly those with developing countries. When it comes to E&C projects, most of the industrialized nations offer generally similar development assistance and export credit packages, Several of the NICs, notably South Korea, also provide financing assistance to support their E&C industries. s*

Once some governments began offering subsidized financing packages, others followed suit to avoid losing sales. While an agreement within the OECD (see ch. 10) established consensus interest rates on loans, with lower rates and longer maturities on credits for the poorest developing countries, the agreement did not cover tied aid or mixed credits, leaving a loophole exploited by France and other European nations, along with Japan. Congress approved a $300 million mixed credit war chest in 1986, with the intent of creating leverage for negotiations aimed at moderating the use of mixed credits by other nations. A revised OECD agreement, in the spring of 1987, promises to be a step in the right direction. But the United States will probably have to keep the pressure on,

Over the longer run, Federal support for innovation and technology development carries

[34] In addition South Korea's Government offers tax incentives to encourage R&D by construction firms—W. Arnold, "Rescue Package for Construction Sector," *Development Forum*, June 17! 1985, p. 1.

the greatest promise for helping this industry rebuild its competitiveness. Currently, American E&C firms do almost no R&D. Meanwhile, the larger European companies have many years experience in turning proprietary construction technologies to competitive advantage. precasting, pre-stressing, and post-tensioning techniques for concrete, for instance, have been developed mainly in Europe.

Given the continuing inability of American companies to compete on costs for routine international projects, successful strategies will necessarily entail technological leadership beyond that already achieved in design and management. American E&C firms are in much the same position as countless manufacturing companies. Without strenuous and continuing efforts in R&D and technology development, U.S. contractors can look forward, first, to further deterioration of their competitive positions abroad. This will almost inevitably be followed by an increase in competitive pressures at home. The pattern has long since become clear in other industries.

Renewed technical leadership will depend in considerable measure on developments elsewhere in the U.S. economy. Much as they have done in the past with computer-assisted construction management techniques, E&C firms will have to draw on other American industries in building proprietary technical positions. Most of these companies have avoided strategies based on proprietary technologies in the past. For that reason alone, long-term efforts will be necessary.

Future international success will probably also require more diversification than American E&C companies have preferred. Narrow expertise tied to the energy industry or to power generation carries high risks in a period of slow economic growth and volatile energy prices; specialized firms will be vulnerable to both cyclical (or secular) decline in their clients' industries, and to the competitive thrusts of targeted policies by foreign firms and foreign governments, Diversification can reduce the vulnerabilities only too evident over the past few years among E&C firms that depended heavily on energy projects.

While new corporate strategies are evolving in some American E&C firms, old habits will die hard in others; for those in the latter camp, international competition will be harsh and potentially devastating. Many companies still appear at sea, unable to home in on new strategies suited to new competitive conditions. While some U.S.-based E&C companies have begun to place more emphasis on R&D, they are in the minority. Those that aggressively seek and adapt technologies from other industries, and from foreign E&C firms, will be better positioned to gain with respect to competitors both at home and abroad. Eventually, prefabrication and automation will be common in the construction industry. Productivity will jump. If American firms take the lead in developing new approaches to construction methods, they may be able to renew their competitive ability internationally. If they fail, their markets within the United States could be deeply penetrated by able foreign competitors.