1 Technology and the Construction Industry: An Introduction

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Technology is reshaping the American economy. Vast improvements in agricultural and manufacturing productivity have outstripped demand to the point where net employment in these areas is falling while employment in business service professions has soared. Economic growth has been buoyed by enormous volumes of sales in office computers, telecommunication systems, and other products not even on the market a decade ago. Whether the rate of change is more or less rapid than it has been in the past, whether the changes are evolutionary or revolutionary, is in some ways not as important as the fact that, taken together, these changes have dramatically reshaped the way the economy combines material, capital, labor, and ideas to provide most kinds of goods and services. The work described below was undertaken because the chairmen of several Congressional committees asked the U.S. Office of Technology Assessment (OTA) to describe the way new technologies are acting to reshape the nation's economy. One of the areas chosen for special attention was the construction industry.

There is a widespread perception that the technologies that are reshaping most of the rest of the economy have left the construction industry behind — that Ramses II would probably recognize most of the operations in today's construction site. Construction is typically considered a low-technology industry operating in sheltered local markets with low or falling productivity. Believing this to be a mistaken impression, OTA convened a workshop of experts with direct experience in construction. The topics were selected after extensive preliminary discussions with industry experts who were asked to identify areas where technology was likely to have its greatest effect on the industry as a whole: the use of information technologies; factory construction techniques; new energy technologies; and new structural designs. Participants were a diverse group drawn from industry, academia, and government. The diversity of the participants was a reflection of a diverse and decentralized industry. Many of the participants met each other for the first time in the workshop even though they had spent careers studying different aspects of construction.

The construction industry, of course, is not really a single industry but a complex cluster of industries somewhat uncomfortably combined under a single classification. Residential construction, commercial buildings, industrial structures, and civil engineering projects are typically bundled somewhat uncomfortably together. Moreover, construction activities combine a wide range of different professions: architects; engineers; and specialists in site work, renovation, and maintenance. Different teams are formed for new projects. Teams assembled for major projects often disperse after the projects are complete. This fluidity and flexibility makes the industry dynamic, resourceful, and adaptable. But the diversity has always frustrated efforts to analyze the net performance of the industry as a whole. In fact, several of the workshop participants argued that while much of the industry's strength lies in its flexibility, excessive fragmentation can also create problems. Often, no one has a perspective on the construction process adequate to detect inefficiencies that result from imperfect coordination among the firms responsible for construction, or adequate to combine an analysis of construction decisions with an analysis of the implications of these decisions for building operation and facilities maintenance. The diversity also makes it difficult to measure progress in the industry since national economic statistics provide a poor picture of the diverse enterprises that combine to make the U.S. construction industry.

We asked the participants to explain how the technologies they knew best were reshaping the construction industry, and we asked them to speculate about the possible impact of the changes that might result on overall growth rates in the industry, the quality and performance of building products, the number and nature of jobs created by the industry, and the international competitive position of the domestic industry. The discussion also considered areas where optimum implementation of new technology may require a review of existing federal, state, and local policies that are used to regulate the industry. The policy consequences of new construction technology will be the subject of a separate study and are not extensively discussed in this volume.

The workshop established two points quite clearly. First, the construction industry is being reshaped, in some cases radically reshaped, by new technology — although the changes are seldom obvious to casual observers. And second, many attractive new technologies are being adopted slowly because of the industry's fragmented nature, the failure of clients to demand innovation (due in part to the fact that they seldom recognize the potential advantages of new technology), the shortage of research funding from either public or private sources, by a regulatory structure poorly adapted to rapid technical change, and fear of litigation. Slow rates of adoption of new technologies can make the industry vulnerable to foreign competition and rob clients of qualitative improvements in buildings that could not only make the building a more attractive place to work or live, but reduce operating costs as well.

The workshop was organized around the premise that technology affects the construction industry in three principal ways: (i) technology has reshaped the national economy in ways that affect demand for different kinds of structures; (ii) technology has changed the nature of the structure itself (including the services provided by buildings); and (iii) technology has changed the way that structures are produced and erected.

1. Demand

Even if it embraced no new technologies itself, the construction industry would be forced to change in response to the transformation underway in the the American economy. America is becoming a nation of office workers. This means greater emphasis on office structures. Moreover, the nature of office work is itself changing in ways that, in turn, are changing the demands placed on buildings. While we can expect significant growth in the productivity of production-floor operations, many of the most dramatic increases in national productivity during the next decade are likely to occur because of improvements in the technology of office work. This is as true for sales clerks, hospital employees, architects, lawyers, and teachers, as it is for insurance agencies and banks. Offices are becoming much more heavily capitalized as word processors and other more sophisticated computer terminals substitute for routine clerical work. This trend means new office designs and new demands on the building infrastructure. Moreover, modern communications give management much greater freedom to choose locations for 'back office' activities and a variety of other functions. There is seldom an absolute need to locate these facilities near central headquarters buildings or even near the production facilities that they may support. The result has been a decentralization of operations, suburbanization, and rapid movement toward the south and west.

We must also consider the dynamics of change. It is now clear that most buildings will need to be adapted to a variety of different purposes during their design lives. A fast-paced economy means increasing need for flexibility — particularly in office activities where it is simply impossible to predict what equipment will dominate ten years from now or, indeed, what equipment will be available next year. This means that structures dedicated to a single purpose, and structures that cannot be upgraded to accommodate modern communication systems and energy efficiency technologies, are increasingly unattractive investments. Some of the members of the workshop, most prominently Wendel R. Wendel, argued that we should try to move away from the notion that buildings are permanent monuments and recognize that the provision of shelter is a service —

a service that should be tailored to a need as long as the need lasts and then modified or retired.

Several of the participants suggested that buyers' standards and tastes may be changing in a way that affects the market for buildings in qualitative ways. Buyers may become increasingly intolerant of uninteresting structures, or structures that do not create a pleasant work environment. The relationship between the work environment and workplace productivity has received particular attention. James Gross notes that the total wages and salaries paid to people working in a building is an order of magnitude higher than the cost of the building itself. Anything that can increase the productivity of the occupants is therefore likely to be a wise investment.

2. The Structure Itself

a. The 'Smart' Building. The construction industry has responded to changing demands by modifying both what is built and how it is built. It is becoming difficult to know what we mean when we talk about a 'building.' Surely we must include the basic space-conditioning and lighting equipment. Presumably, we also include the systems that operate elevators, security systems, and other equipment key to basic operation of the building. It seems reasonable to include the complex computer systems that are now managing lighting, chillers, and other energy systems. But should other features that come under the broad concept of 'smart buildings' be considered a product of the construction industry? For example, with the breakup of AT&T, telephone wiring should probably be treated in the same way we have treated conventional electrical wiring. Should we also include the more sophisticated infrastructure needed to operate office automation systems: antennas on the roof; fiber-optic cables; computer centers that may perform telephone switching, broadband communication, and data management functions, as well as operate security systems, energy systems, and elevators? How should we treat furniture if the furniture becomes a critical part of the office environment. In many cases, for example, it may be better to make lighting fixtures a part of movable partitions instead of making them permanent fixtures. While 'shared tenant services' have not fared well, the difficulties may lie more with the institutional arrangements offered, and inattention to the real business needs of customers, than with the underlying capabilities of the technology. Relationships between building owners and tenants are likely to change in ways that blur the formerly clear distinction between the building shell and the apparatus introduced into the building by tenants. At a minimum, a premium will be placed on structures that can flexibly adapt to changing needs of tenants. Structures may provide fewer 'built-in' services and tenants may be expected to provide more for themselves. Tenant-supplied lighting, for example, is much more likely to be efficiently matched to particular needs than systems designed to provide the entire building with lighting levels high enough to satisfy the most demanding draftsman. (The advantage of avoiding fixed lighting systems is underscored by the fact that the next generation of draftsmen is likely to want lower-than-average lighting levels in areas where they will be looking at display screens instead of fine print on paper). On the other hand, buildings could provide more services, making building owners, in effect, service companies that offer such things as computer and communication services, along with 'basic' utilities like electricity and heat. Unfortunately, national data is inadequate for measuring the extent to which these new technologies are actually being introduced in new structures. The most impressive examples of 'smart building' concepts have been in proprietary structures.

Leaving aside the revolution in the technology of office work, there are also major changes underway in the technology of the basic structure. The materials used for building components have also changed. Plastic pipe and steel studs are easy to see, but a variety of other new products are being used in insulating materials, floor coverings, exterior wall surfaces, glazing, and floors. Technology has challenged conventional notions about how to provide basic structural support. Optimum design engineering has refined conventional designs. Truss systems, such as the one marketed by Space Structures, can vastly reduce the cost of large, unsupported spans. A variety of new adhesive materials are used to attach everything from decorative paneling to structural members.

b. Building Operations. Building control technologies must also be considered as part of larger systems that are themselves 'smart.' Thinking about this issue requires a consideration of the 'life-cycle costs' of structures including an analysis of operating costs and the costs associated with making modifications that will be needed during the structure's useful life.

Energy

The energy price increases of the 1970s resulted in an explosion of new ideas for improving the efficiency of energy use in buildings. New residential and commercial buildings can be built which use a fifth as much energy per square foot as comparable structures built during the early 1970s. Some of the improvements are straightforward — improved insulation, for example. Some result from a better understanding of heat-flows in structures. And some result from clever new equipment and control systems. A flood of highly efficient furnaces, air conditioners, lighting equipment, and other appliances has been introduced during the past few years. Many are several times more efficient than the equipment they are designed to replace. But while component improvements provide important new tools, their full value can only be recognized if they are used as a part of an integrated analysis of building energy that includes an assessment of the dynamic performance of a building's shell. Overall levels of savings can be remarkable. The code likely to be adopted as an industry standard in 1986 recommends levels of energy use that are less than half the levels typical of the early 1970s. The savings are not achieved from a single 'breakthrough' technology but rather from the combined effects of a large number of improvements in structural designs, equipment, and control strategies.

Integrated analysis of energy use should probably include an assessment of the way buildings operate as a part of regional networks. Equipment capable of integrating the energy management controls of individual structures with the dispatch controls of electric utilities can significantly improve the dynamic performance of electric networks taken as a whole. Experiments are already underway abroad and in the U.S. by which utilities can continuously vary their electric rates according to an instantaneous estimate of marginal costs of production, and can transmit this information periodically to buildings of all kinds (including residences). Control systems in each structure can respond to these price signals by adjusting the performance of equipment in prearranged ways. The response can be as simple as postponing the start of a water heater or chiller when prices exceed some threshold level. Dynamic control over demand can allow utilities to meet a larger fraction of total electric demand from relatively inexpensive 'base-load' plants using coal or nuclear fuels.

Sophisticated new building technologies are, in a very direct way, substitutes for electric generating technologies. Trade-offs between investments in new generating capacity and investments in buildings are not a trivial matter. More than two thirds of all electricity in the U.S. is consumed in residential and commercial buildings — most of it for commonplace purposes: lighting, refrigeration, and air conditioning. Improved analytical tools, coupled with a few technical tricks, have permitted vast reductions in the amount of energy required to heat and cool a building. Changes range from reprogramming air-handling systems, to the development of high-technology light bulbs. Taken together, they can reduce the net energy consumption of typical residential or commercial structures by factors ranging from two to ten. Effective use of these new technologies will require an approach to electric utility management that allows potential investors to make an unbiased comparison of investments in electric generation and investments in technologies that make efficient use of electricity in buildings. Several workshop participants noted that the existing system badly biases decisions, since the financing available to regulated utility monopolies (allowing investments with twenty-year paybacks) is much different than the financing available for entrepreneurial investments in buildings where annual returns of 100 to 200 percent are expected on investments in building efficiency.

Facilities Management

The issue of facilities management and building operations has about as much sex appeal as a week-old cheese sandwich. But the issue has taken on growing importance as demands for building modifications increase as a result of the increasing volatility and uncertainty in demands for residential and commercial space — including changing interest in the energy consumption of buildings. Facilities management can be greatly simplified by using computer-based drawings and records of the kind that will be discussed in greater detail in the next section. A set of digital 'drawings' of a building that can be conveniently updated after each building modification greatly reduces the uncertainties and costs of structural modifications. There is less trepidation as you drill through a wall (famous last words: "Where did they put the high-voltage cable?"), and there is less need to track old Fred to his trailer in Florida so that he can explain what he meant by the note scrawled on the margin of the original drawings. A continuously updated building design can also facilitate analysis of changes in structures and heating and air-conditioning systems.

3. The Construction Process

Turning to the question of how structures are actually made, three themes seem to dominate: (i) improvements in the process by which an idea goes from a gleam in a designer's eye to a set of working drawings; (ii) greater use of factory-based construction techniques; (iii) and use of more sophisticated equipment in the field.

a. Design. New computer-based systems can improve the productivity of building design and analysis. They can rapidly convert concepts to drawings, convert drawings to analysis and convert all of this to estimates of initial costs and operating costs. The systems can be used to prepare working sketches and detailed drawings. Routine building components (repeated window and door treatments, for example) can be called from digital files that need be entered only once by a draftsman. The equipment thus substitutes for the most tedious aspects of drafting. Price lists can be built into the systems, allowing an instantaneous estimate of the cost of different design alternatives. Advanced systems allow a computer-based 'tour' of building interiors and exteriors. Once entered, the design information can be used as the basis for computer-based structural analysis, an analysis of lighting, or an assessment of energy consumption.

Many architects, however, greet the prospect of computer-assisted design with the enthusiasm of a cat facing a pail of water. Their perception is that computers will substitute mechanical decisions for taste, and formulas will be substituted for inspiration. All this is plainly possible. But increasing competitive pressure for speed and cost control make it extremely difficult for the **average** architect to produce an **average** building with much imagination, unless there are some fundamental changes in the design process. Computer-assisted design systems may enable such changes. While the full potential of the systems is unknown, it is apparent that the systems can remove many barriers between inspiration and execution. They can improve communication between designers and their clients, allowing vastly more 'what if' excursions and discussions about options at different levels of investment. There is no good way to calculate the benefits of greater client satisfaction, but surely improvements in this area are among the most important contributions a new technology can make to the construction process.

Computer-based technologies can significantly reduce the cost of making modifications to existing plans while preventing errors from creeping into areas unaffected by the change. The penalty for trying a radical new idea can be reduced since the concept can be subjected to a detailed analysis, and reduced to drawings that permit a realistic feeling for exterior views and interior spaces without a major investment in time or money. Automated design systems coupled with communication systems can facilitate the performance of geographically dispersed teams, allowing clients, engineers, construction firms, and architects to cooperate effectively during the evolution of a design. They can facilitate the process by which specifications are sent out for competitive bids, reduce the uncertainties associated with bidding, and decrease the burdens associated with the submission and analysis of proposals,

Once the basic design has been entered into a computer-based system, a variety of analytical programs can use the data to assess such things as the energy-consumption consequences of different design decisions. Until now, one of the greatest barriers to energyefficient building designs has been the fact that heating, ventilating and air conditioning (HVAC) analysis is typically conducted after it is too late to change any major feature of a building's basic design. There is also a considerable 'pain-in-the-neck' factor involved in submitting drawings to a specialized group for energy modeling. It is tempting to hand completed drawings to an HVAC engineer and say, "Just make sure it doesn't overheat. "

Design flexibility is not limited to commercial structures since it is now relatively easy to offer prospective home buyers the opportunity to design their own floor plans, and compare the appearance of different interior and exterior wall coverings in the spaces they have designed. Though only a fraction of new houses are designed with the help of an architect, it is possible that the new systems may permit prospective home buyers greater flexibility in selecting and refining home designs, using the services of an architect, at least indirectly in the form of skillfully designed software. The Japanese have a system in place for doing this that is connected directly to production equipment capable of delivering preassembled units to a construction site in two to three weeks.

b. The Construction Process. If computer-assisted design is the first major revolution in the making of buildings, factory construction is the second. Construction has always been something of a craft, with each structure fabricated from basic components in the field. The literature is replete with predictions that this primitive form of fabrication was about to end and the industry would evolve in a way that would make it more like conventional manufacturing. A commission organized for Franklin Roosevelt in the mid-1930s made this claim. Truman appointed a 'housing expediter' who was determined to solve the housing shortage at the end of the second World War with factory-built housing. Only a fraction of the goal was met. George Romney rekindled the dream a generation later with his 'operation breakthrough,' which similarly fell far short of its goal. When forecasters have a track record like this, it is easy to be cynical about new claims. But we may have become so cautious that we may not have noticed how far, and how fast, we have moved toward factory-based construction of homes and small commercial structures.

No one in the workshop challenged the estimate that nearly half the homes built today involve a significant amount of factory construction, with the other half making very heavy use of factory-built components: roof trusses, pre-hung windows and doors, 'wet-cores' (bathroom and kitchen units), and the like. In Sweden today over 90 percent of all new houses are made in the factory. Is our industry headed in the same direction?

One of the barriers to factory construction has always been its association with inexpensive, monotonous 'pre-fab' construction. And indeed, drab, low-quality houses and mobile homes have been produced in factories. In Sweden, on the other hand, factory-built structures are considered to be of a higher quality and have a higher status than site-built homes.

Factory construction offers several clear advantages. It permits uniform assembly, testing, and inspection. It permits relatively rapid onsite erection, thereby reducing constructing financing charges. It permits the use of more sophisticated assembly equipment. And it permits the kind of design flexibility described earlier. Of course, not all, or even most, of the opportunities are exploited in existing fabrication facilities.

The new technology is, of course, not without some drawbacks. Movement to factory construction could undermine the position of some small businesses, eliminating jobs or replacing skilled jobs with relatively unskilled ones, and weakening the role played by local regulatory authorities. The next section will return to this issue.

Field erection techniques are also in the process of rapid change, particularly for commercial structures. A variety of computer-assisted equipment has been introduced in the past few years. It ranges from earth-handling equipment to erection cranes and fully robotic equipment. Computer-assisted equipment is being introduced for two primary purposes: replacing people in hazardous circumstances, and improving precision. A significant fraction of construction accidents, for example, result from crane operations. It is apparently rare for a crane operator to complete a career without being involved in a fatal accident. Control equipment can automatically 'remember' critical lift heights and swing restrictions. Earth-loading equipment can be programmed to dump only after sensing a truck in a proper orientation.

One of the major barriers to increased construction productivity has been the difficulty of making joints. Accumulated field errors often result in joints that fall far short of specified tolerances. It is difficult to introduce precisely engineered components in a project where overall standards of precision are lax. Productivity gains require all components to be erected with roughly the same standards. Precisely engineered components, such as the computer-constructed, space-frame structures, for example, must frequently be adjusted to fit imprecise structures. Errors of as much as a foot are apparently common in structures of ten stories or more. Improved grading equipment, guided by laser leveling and positioning equipment, is an early example of devices designed to improve the accuracy of field work. In the near future, computer-assisted equipment with active location controls can further improve the precision of field work.

A final field that defied the analysis of the assembled experts had to do with the technologies of renovation and retrofit. Statistics on the size of these enterprises are particularly poor. But it is reasonable to argue that rapid improvements in building technology will increase demands for building renovations to improve the large stock of existing structures. While some new technologies are available for diagnosing and repairing problems identified in older structures, the field remains a very murky one. Most of the new techniques identified were designed to pinpoint sources of heat leaks so that the energy efficiency of the structure could be improved.

4. Impacts

a. Employment. Taken together, how will new technologies change the construction industry, the quality of the products it delivers, and the nature of the jobs it offers? There is little question that the technologies described have the potential to affect both the number of jobs generated by the construction industry during the next decade, and the nature of these jobs, in dramatic ways. On the whole, it seems likely that the net labor productivity of the system can be increased, though experts disagree about the quality of the jobs that will remain. No one has a satisfactory explanation for the mysterious fall in the productivity of the construction industry measured using standard statistical series. Some of the workshop participants claimed that the decline was an artifact of flawed measurement. The productivity gains created by modular-home factories, for example, do not contribute to the measured productivity of the construction industry since factories are classified as manufacturing firms and not construction companies.

Design firms are likely to see routine drafting and cost estimating become much more productive as modern equipment assumes a greater portion of routine chores. There will be fewer people as well as fewer steps between the designer, the engineer, and the customer. The opportunity to keep refining and revising designs, and the opportunity to try relatively imaginative designs at modest cost, may keep overall levels of employment relatively high even though the productivity of each individual analysis may have increased. Certainly this has happened in other 'office-automation' settings where the demand for new information and data has outstripped growth in the productivity of generating data.

Factory construction can also reshape construction trades. The technology can be used to replace skilled field labor with relatively unskilled, routinized jobs in assembly lines. Flexibility in these settings has too often been achieved the easy way — by laying people off when business slows. But technology can also be used to create for production workers relatively attractive, indoor jobs which are less sub ject to the vagaries of weather. Workers in the construction industry could then be treated more like employees of an automobile fabrication facility than day laborers, with greater opportunity to acquire new skills as new technologies are introduced, more continuity of employment, and better identification with a firm.

b. Education. There is little doubt that the new building technologies place new burdens on the educational system. At first the demands seem contradictory. There will be a need for individuals with highly specialized skills and a need for individuals with a broad perspective on many aspects of the design and construction process. In fact, the underlying demand is for individuals with basic skills in architecture, engineering and analysis who can quickly acquire specialized skills when needed. Lighting design provides a particularly vivid example of the need for unique combinations of skills. Good lighting design requires knowledge of such diverse areas as fixture technology, control systems, and daylighting strategies.

There is an obvious need for architects and engineers familiar with the capabilities of computer-assisted design and analysis techniques. Architects will need to know more about engineering, and engineers will need to learn more about design. There are growing demands for individuals who understand how to analyze heat-flows in buildings, optimal dispatch of electrical equipment, and the capabilities and limitations of the variety of new materials. And there is an interest in individuals able to work as effective members of a multidisciplinary team.

c. **Industry Structure.** What will the technology do to the structure of the industry? Will we see engineering firms displacing architects? Will smaller design firms be edged out by large firms capable of mastering expensive new computer technology? Will factory construction change the role of the small, independent homebuilder who has been the mainstay of the industry for centuries? Will the small builder's role be largely one of site preparation and assembly of components manufactured by larger companies?

Several of the participants argued that engineers will play an increasing role in the design of buildings, citing examples of architecture and engineering firms that had become engineering and architecture firms. There is no reason why the engineers should run away with the show. To maintain control, however, architects must master the art of gracefully integrating engineering analysis into their designs. Computer-based systems may provide a good opportunity for doing this.

The cost of powerful design equipment is falling so rapidly that most small firms will be able to purchase quite sophisticated computer-assisted design and analytical systems within a few years. Thus, most members of the workshop felt that small design firms would not be threatened. If nothing else, the dynamic nature of the industry is conducive to small, relatively specialized firms that can be combined for specific projects.

The role of the small builder, on the other hand, may well change if factory construction captures a growing share of the market. Growing use of factory-made structural elements has already made the small builder more of an assembler than a craftsman, a trend that is likely to continue. Will the small builder's role be limited to pouring a foundation and assembling a set of modules or panels? Will he become a captive of major production houses? The experts disagreed on this point.

d. The Dynamic Performance of the Industry. Will all of this new technology and the pressures of foreign competition lead to a permanent shift in the way the construction industry conducts research and adopts innovations? At present, the evidence is somewhat ambiguous.

While there was one strong dissent, most members of the workshop were concerned by the shortage of research money in construction. Virtually all research is conducted by component suppliers and not by the building industry itself. Chemical companies, for example, have developed new materials for sheathing, roofing, piping, and adhesives. But research on compnents is not an adequate substitute for research designed to improve the way the building performs as an integrated system or the way the construction process operates as a whole.

The largest U.S. home builder apparently has no research budget. The professional associations of builders and architects have research budgets that are tiny in proportion to the industry they support. The National Institute for Building Science has an extremely small research budget. Direct government support for building-related research funded through HUD, the Department of Energy, and the Bureau of Standards was never very large and has been drastically reduced in recent years.

Failure of construction firms to conduct significant amounts of in-house research can lead directly to a relatively slow rate of growth in construction productivity. It can also have strong indirect effects. Studies of manufacturing firms show that firms with significant amounts of in-house research are in a much better position to monitor research conducted by other firms and are much better able to exploit new discoveries and innovations.

Two other major American industries share the problems of the construction industry. The health industry and the agricultural industry consist of relatively large numbers of relatively small establishments and firms — few of which have the resources to conduct their own research. In both cases, the government has chosen to support such research. For reasons of history, construction is treated quite differently.

5. Where Do We Go From Here?

It is clearly possible to use new technology to provide interior spaces that are more productive and more comfortable, without significant increases in cost. New technologies allow the construction of structures that are more flexible, more free from defects, and less expensive to operate. Unfortunately, it is also possible that foreign construction firms will move more rapidly to exploit these opportunities in U.S. markets than will domestic firms.

The technologies of ‘smart buildings,’ computer-assisted design, and factory-construction techniques open a range of promising business opportunities. One of the most fascinating is the possibility of managing buildings as business-service companies capable of providing everything from comfortable and flexible office space to advanced communication networks and ‘value-added’ computer systems. The industry is clearly capable of delivering superior products where they are needed. But institutional problems, and an antiquated set of federal, state and local policies, may make it difficult for innovators in the industry or their potential customers to exploit the possibilities.