CHAPTER 1

Building Industry Challenges and Opportunities

Until one is committed, there is hesitancy, the chance to draw back. . . .
Whatever you can do, or dream you can do, begin it.
Boldness has genius, power, and magic in it. Begin it now.

—Goethe

The building industry is facing a looming worldwide crisis, a spectacular convergence of gross inefficiency and inordinate consumption of energy and raw materials. While the spectre of global warming has become a catalyst for renewed interest in conserving energy and raw materials throughout the life cycle of buildings, the environmental challenge only adds greater urgency to a far more elemental problem: the utter failure of the building industry to keep pace with the technological advancements and productivity gains of nearly every other industry in the last fifty years. Even farming, the most ancient productive activity in human civilization, has managed to achieve productivity gains in the last hundred years that are unimaginable in the building industry.

Technological advancement is measured largely by increases in efficiency, whether in means and methods of production or the consumption of raw materials. Increased efficiency and productivity lower costs, increase profits, and help raise the standard of living by making goods and services affordable to greater numbers of people. By that measure, the worldwide building industry has accomplished very little in the way of technological advancement.

GLOBAL TRENDS IN SUPPLY AND DEMAND

An estimated 40 percent of global raw materials are consumed by building construction.[1] In the United States, when all other manmade, immovable structures are included—things such as bridges, roads, dams, and ports—the raw materials consumed by construction *exceeds 75 percent* of the total.[2] Or to put it another way, construction in the United States consumes three times more raw material than *all other economic and industrial activity combined.*

In 1900, each living American consumed two metric tons of raw materials per year. By 1995, the annual per capita figure had increased five-fold to 10 metric tons per person.[3] Global warming aside, simple economics dictate that we cannot sustain either our current standard of living or a growing U.S. population unless we reverse our steadily increasing rate of raw material consumption (see Figure 1.1). With construction accounting for three-quarters of the total, we cannot reverse the overall consumption trend unless we learn how to build more with less.

Both worldwide per capita consumption of raw materials and energy and the world's population are growing. These compounding trends will cause the worldwide demand for materials and energy to grow exponentially. Global population is expected to reach nine billion by 2050.[4] According to the United Nations, the world can sustain a population of only 1.8 billion at a high-income

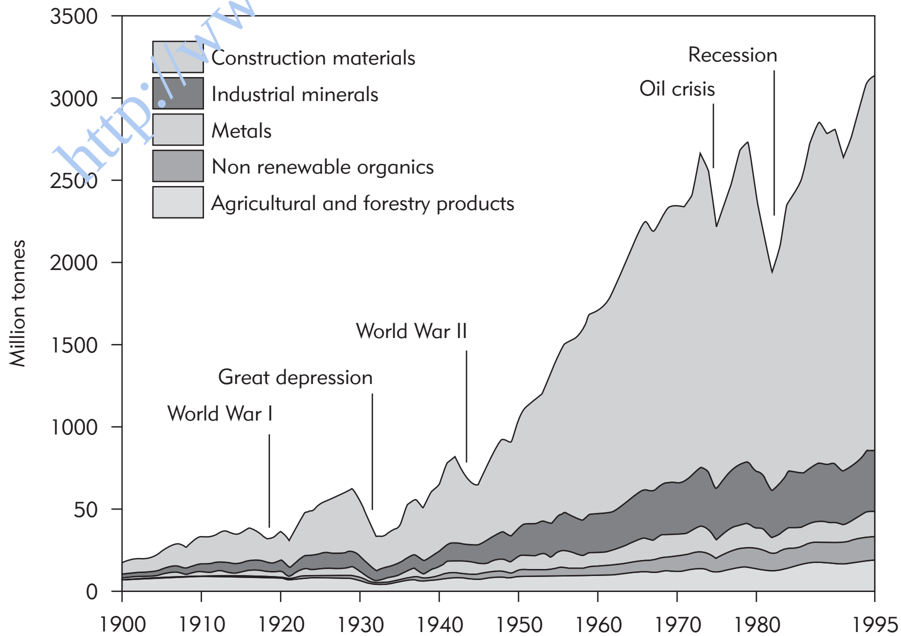

FIGURE 1.1 Raw Materials Consumption Chart. (Source: U.S. Geological Survey.)

consumption level, a number we exceeded in 1965, and a population of just under 6 billion at a middle-income consumption level, which we passed in the mid-1990s.[5] If the 9 billion people living in 2050 are to have any hope of enjoying a reasonably decent standard of living, we will need to find ways to house, clothe, and feed ourselves—and support all of the economic activity we generate—far more efficiently than we do now.

Concern about worldwide standards of living is not a matter of altruism. Whether we like it or not, our economy is global. It is not possible to isolate ourselves from the global supply chain or the global supply and demand equation. The growing global demand for raw materials and energy resources will affect every consumer of construction materials in the United States. Demand for steel, lumber, and gypsum in China will affect the price Americans pay at home. The fundamental question is not whether we will run out of the raw materials we need; it is whether we will be able to afford them and continue to sustain a growing and profitable building industry.

So what's the good news? Simply this: in terms of efficiency and productivity, the building industry has nowhere to go but up. And given the inexorable growth in global population, a lean and efficient construction industry can count on a virtually limitless worldwide demand for its products and services for the foreseeable future. Successfully meeting that demand, however, will depend on whether the industry as a whole can deliver buildings of higher quality at a lower cost; buildings that are constructed with less energy and fewer raw materials, and generate less waste for their construction; buildings that are more durable and consume less energy while occupied; and buildings that are easier to recycle or adapt to new uses when they can no longer serve their original purpose. A failure to do so will lead to supply shortages or cost increases that global markets will be unable to bear, which will lead to economic contraction and widespread business failure.

BENCHMARKING CONSTRUCTION PRODUCTIVITY

Comparing the construction industry to agriculture over the last 50 years dramatically illustrates the point. From 1948 to 1999, the U.S. population grew from 147 million to just under 263 million, an increase of 79 percent.[6] Had the land needed for cultivation grown at the same rate as our consumption of raw materials, the amount of land we would need to feed ourselves would have had to increase nine-fold, from 1.6 billion acres in 1949 to 12.4 billion acres in 1999.[7] There's only one problem with that: the entire land area of the United States is only 2.3 billion acres. Had our rate of land consumption for growing food matched our rate of raw material consumption, we would have run out of land long ago. Instead, the amount of land under cultivation in the United States actually declined slightly from 1948 to 2004.[8] With a population that is now over 300 million, we are able to feed nearly twice as many people using the same amount of land as we did in 1948, and this does not even take into account that the United States is a net food exporter, so the gain in productivity is still greater.

Is the comparison fair? The per capita drop in land under cultivation would not have been possible without improvements in mechanized equipment and intensified use of pesticides, fertilizers, and other "inputs." If the total cost of all these inputs, including land and labor, had risen dramatically over the same period, then the per capita reduction in land use would not be an indicator of increased agricultural productivity. But according to the U.S. Department of Agriculture (USDA), while "the use of some inputs such as fertilizer and machinery has increased [between 1948 and 2004], these increases were more than offset by reductions in cropland and especially the amount of labor employed in agriculture."[9] In fact, the "total inputs" for agriculture (land, labor, capital, equipment, fertilizer, feed, and seed) have remained flat since 1948, while total output has increased 270 percent.[10] If the construction industry had achieved a comparable increase in productivity, a building constructed in 1948 at a cost of $1 million could have been built in 2004 (in constant 1948 dollars, before adjusting for inflation) for just $370,000.

Comparing the building industry to other industries—and looking for lessons from those industries that might be applied to our own—has become a popular pastime of late. We look at design automation and design-to-fabrication technologies in the automobile and aircraft industries and ask ourselves why we can't do the same thing. But there are two significant differences between construction and these other industries that make any comparison imperfect and any "lessons learned" difficult to apply. First, Boeing and Airbus are the only two commercial customers in the aircraft industry. They can dictate what they want from their suppliers, including exactly how goods and services should be delivered. They can effectively control their entire supply chain without the capital required to own it. The auto industry, while not as concentrated, is still dominated by a few global players who can define the "rules of engagement" with their suppliers. Second, both industries benefit from being able to assemble their products under factory conditions, giving them a great deal of control over the quality of the manufacturing process, the technology and capital that can be applied to it, and the supply and skill of labor.

The building industry, by comparison, is highly fragmented—there are millions of customers, end users, service providers, and product manufacturers.

No single entity commands sufficient market share to demand greater efficiency and productivity throughout the supply chain. Also, markets for many building industry goods and services tend to be local or regional, leaving consumers—building owners and facility managers—with a very limited range of product/service options. Though up to one-third of building components are manufactured under factory conditions, most construction remains a field activity. The supply and quality of labor is more difficult to control. The weather affects working conditions and schedules. And despite an increase in the number, type, and variety of mechanized tools in the last fifty years, construction remains largely a craft process. A stone mason who worked on the Parthenon over 2,500 years ago could walk onto a job site today and, with little difficulty, recognize his tools and get to work. In this environment, the most that individual business enterprises can do is optimize their own operations, often to the detriment of overall efficiency and productivity.

Fair enough. But does the oft-repeated lament of industry fragmentation fully explain why the construction industry has failed to evolve technologically? The weakness of the argument becomes apparent when construction is compared to agriculture in greater depth. Though construction differs from the airline and automotive industries in important respects, the construction and agricultural industries of 1948 had many characteristics in common: a high degree of industry and market fragmentation; a diverse, poorly educated, and irregular supply of labor; limited access to sources of capital; little technology or automation; and very similar "field" working conditions. None of these characteristics impeded a rapid increase in productivity in agriculture. So how did agriculture manage to leap so far ahead of construction?

A lack of reliable statistical productivity data about the construction industry is a factor. Though the U.S. Department of Labor's Bureau of Labor Statistics (BLS) compiles productivity and unit labor cost data for most industries, "Productivity and Costs data are not published for any industries in construction."[11] We have nothing like the measure of total inputs and total outputs that the USDA uses to measure agricultural productivity.

The lack of such broad-based statistical data puts the construction industry at a significant disadvantage. If something as fundamental as productivity cannot be measured, then it is impossible to assess the effect on productivity—good or bad—that results from changes or improvements in technology, skill, business practices, or production methods. Nor is it possible to measure reliably whether productivity is going up or down over time.

When the impact of innovation cannot be measured, innovation is less likely to occur, and the risk of implementing change is much higher. It is often said that the building industry is conservative and resistant to change. One might argue, however, that the "resistance" actually reflects sound business judgment. The slow pace of innovation in the building industry is more likely the result of the lack of reliable business information. Among our highest priorities, then, should be to demand that the federal government compile the same detailed economic data that it compiles for every other industry in the economy and that all other industries take for granted.

CONSTRUCTION PRODUCTIVITY METRICS

Paul Teicholz, professor emeritus in the Department of Civil and Environmental Engineering and founding director of the Center for Integrated Facility Engineering at Stanford University, has advanced the idea of a "construction labor productivity index" that compares BLS data for fieldwork hours to U.S. Department of Commerce data for contract dollars of new construction (see Figure 1.2).[12] Teicholz does not measure productivity directly; he infers a measurement of productivity by comparing two unrelated macroeconomic data points compiled by two different U.S. Cabinet departments. But in the absence of more precise data, it may be the best available barometer of construction industry productivity.

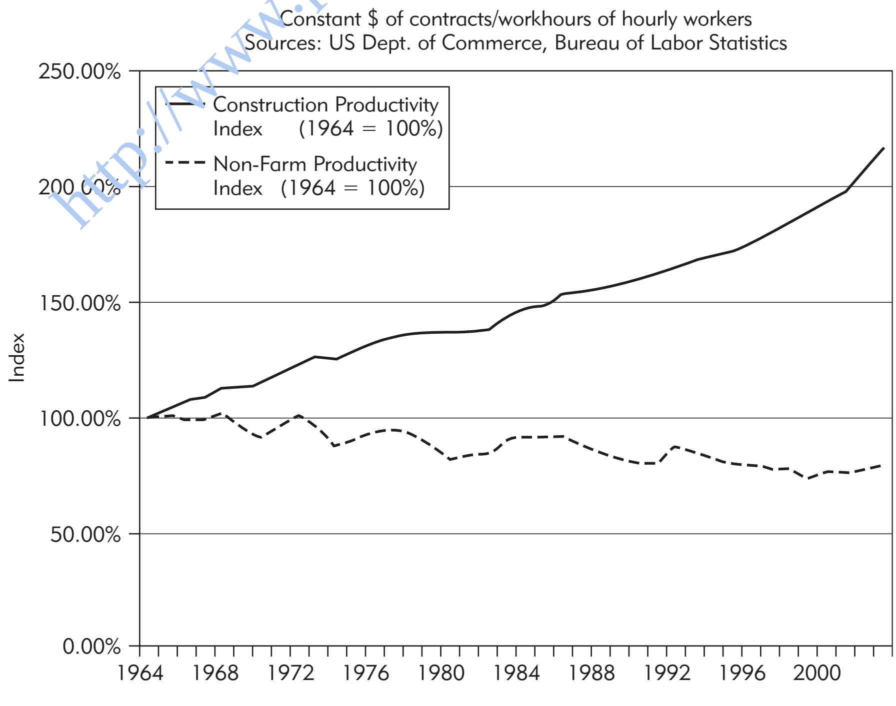

FIGURE 1.2 Teicholz Construction Productivity Index Graph. Indexes of labor productivity for construction and non-farm industries, 1964–2004. Adapted from research by Paul Teicholz at the Center for Integrated Facility Engineering (CIFE) at Stanford University.

According to Teicholz, measuring constant contract dollars of new construction work per work hour reveals that productivity in the construction industry has *declined* by an average compound rate of 0.59 percent annually between 1964 and 2003, while labor productivity in all non-farm industries *increased* by 1.77 percent per year over the same period. Teicholz's index shows a cumulative drop in construction productivity of approximately 20 percent over 40 years.

Others in the construction industry have publicly challenged Teicholz's findings, but none of the dissenting opinions is based on the type of broad-based statistical economic data that makes similar measurements of productivity in other industries so reliable. Preston Haskell, chairman of the Haskell Company of Jacksonville, Florida, analyzed data of building construction projects completed by his company from 1966 to 2003 and concluded that real construction costs per square foot for four building types (warehouse, retail, office, and multifamily residential) had dropped by 12.3 percent over that period, while productivity had increased a total of 33 percent, or 0.78 percent per year.[13] Haskell's methodology is rigorous and well documented but is based on the data of a single company, which is no substitute for data gathered across an entire economic sector.

The core dilemma facing the building industry today is that the best data available—Teicholz's and Haskell's—varies so widely (more than 100 percent, from an estimated annual decline in productivity of 0.59 percent to an estimated increase of 0.78 percent) as to be of little or no value. We are left with inconclusive competing arguments rather than actionable statistical data.

Even if we could extrapolate Haskell's results to the industry as a whole, the annual increase in productivity that he claims his company has achieved is still considerably less than half that of all non-farm industries. Haskell attributes the difference—as does everyone else—to the fragmentation of the construction industry, where "research is nearly nonexistent because architects and engineers have neither the resources nor the incentive to fund research, and constructors have little ability to influence innovation in architectural, engineering, or product design."[14]

The key insight of Haskell's paper is not that the construction industry is fragmented, but that research plays a significant role in driving productivity. The agricultural and construction industries of 1948 were equally fragmented. Farmers had no greater financial resources than builders did and no greater incentives to fund research individually. The exponential and differential growth in agricultural productivity can be attributed almost entirely to the vast amounts of state and federal funding for agricultural research over the past sixty years, which has supported and continues to support a nationwide network of agricultural research stations managed by schools of agriculture at land-grant colleges and universities. Had the government funded research into construction at a comparable level over the same period, there can be little question that the industry could have achieved similar gains in productivity.

The growth in agricultural productivity is a worldwide phenomenon, at least in the developed world. This can be attributed, in part, to comparable investments in research by many national governments but also to the fact that the knowledge gained from government-supported research in agriculture is in the public domain and is widely published in academic and agricultural industry journals, which makes the knowledge available to anyone who wishes to apply it. As a result, innovation spreads rapidly.

The building industry is poised to move ahead with or without government support. However, the lack of research funding from private or public sources is acute, and if left unchanged will continue to hamper the pace of innovation. Industry organizations committed to change in the industry would do well to include advocacy of increased government funding for building performance research among their strategic planning goals.

In the absence of government funding, the importance of a global culture of innovation that includes knowledge sharing, open standards development processes, and full interoperability of digital building industry data cannot be overestimated. With such limited public investment in building industry research, private investment must be leveraged to achieve the greatest possible aggregate returns. Whenever a corporate enterprise, a software company, or an industry organization asserts proprietary control—as opposed to stewardship—of intellectual property in the realm of information exchange, the entire industry suffers, including the entity that originally seeks to protect its turf. The critical role of the culture of innovation in the building industry will be examined in greater depth in Chapter 3.

BENCHMARKING BUILDING PERFORMANCE

While productivity metrics are useful for assessing industry performance during the construction phase of buildings, energy efficiency is one of many metrics, and among the most easily quantifiable, for assessing the performance of buildings while they are in use. Energy efficiency statistics are as sobering as the productivity statistics and, according to at least one government agency, are not expected to improve.

In 2005, nonindustrial buildings accounted for 39.6 percent of all energy consumed in the U.S. and 71.8 percent of total U.S. electricity production.[15] (Industrial buildings are excluded from these figures due to the fact that the energy consumed by industrial buildings for building operations is indistinguishable from the energy consumed for the industrial operations that occur within them.) In its *Annual Energy Outlook 2007,* the U.S. Department of Energy (DOE) forecast that total U.S. energy consumption will increase 31 percent by 2030, from 100.2 to 131.2 quadrillion BTUs per year. Despite the many promising efforts underway to improve the energy efficiency of buildings, DOE forecasts that buildings will actually consume a marginally *greater* share of that higher total: 40.5 percent of total energy consumption by 2030.[16] One way to interpret this forecast is that DOE expects no meaningful improvement in the total energy efficiency of buildings over the next twenty years.

It is well within the ability of the building industry to defy this forecast. According to *The 2030 Blueprint* published by Architecture 2030,[17] 5 billion square feet of new buildings are built in the U.S. each year, 5 billion square feet of existing buildings are renovated, and about 1.75 billion square feet of existing buildings are demolished. Over the next 30 years, 75 percent of our building stock will be built new or renovated. How those buildings are built or renovated will determine whether the energy consumed by buildings can be meaningfully reduced. If we fail to do so, "fragmentation" of the industry will be no excuse; as noted in the *Blueprint,* significant reductions can be achieved with existing technologies in the existing building industry culture, "through proper design, i.e., building shape and orientation, natural heating and cooling, daylighting and ventilation strategies, proper shading, and straightforward, off-the-shelf building energy efficiency measures." These strategies do not require the development of new technology, the implementation of alternative technologies, or additional capital investments. Instead, they require an alignment of the building design with the surrounding physical environment, both natural and man-made.

Most commercial building owners pass on the cost of operating their buildings to their tenants and therefore have no direct incentive to increase the energy efficiency of their buildings. But commercial building lessees are becoming more and more sophisticated with respect to their total leasing costs and are increasingly demanding—as a matter of corporate policy—that the space they occupy have the least possible deleterious effects on the environment. The total operating cost, energy efficiency, and "greenness" of leased space are becoming increasingly significant factors in leasing rates. For building owners, minimizing their own costs at the expense of their tenants' operating costs is becoming less and less of a viable option.

CONVERTING INEFFICIENCY AND WASTE INTO PROFIT

In 2004, the Construction Industry Institute (CII) estimated that up to 57 percent of construction spending in our current business model is non-value-added effort or waste (see Figure 1.3).[18] With a U.S. market estimated at $1.288 trillion for 2008, over $600 billion in waste annually—if the CII estimate is accurate—is waiting to be recovered as profit by enterprising companies.

In any business enterprise, every dollar of unnecessary expense is a dollar of lost profit. Inefficiency and waste are unnecessary expenses that every business enterprise should ruthlessly eliminate. The historical fragmentation of the building industry is no longer the reasonable excuse for inefficiency and poor productivity that it has been for the last sixty years. Opportunities for improved efficiency and productivity are available now across the board and throughout the life cycle of buildings. Inefficiency and waste in any process are prime targets for greater profit. Achieving meaningful improvements in efficiency and productivity on every project and in every organization will depend upon access to reliable building information that can be created, exchanged, analyzed, modified, and updated throughout the useful lives of buildings. The obstacles to improved efficiency in the building industry are no longer primarily technical. Instead, it is the lack of reliable, timely information that makes efficient behavior and strategic decision-making difficult.

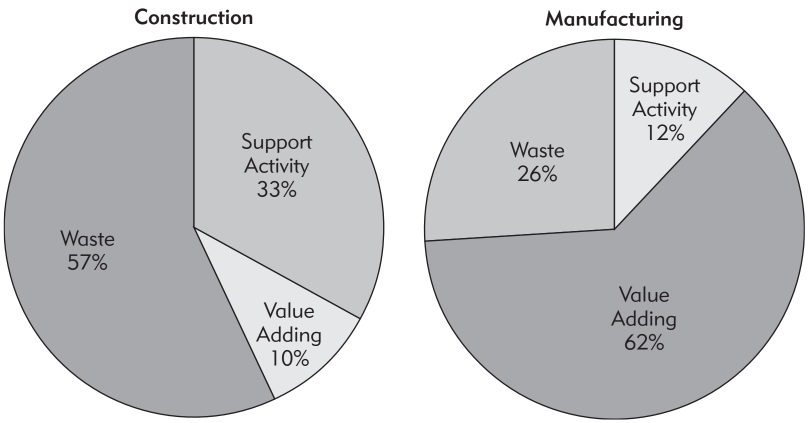

FIGURE 1.3 Construction/Manufacturing Waste Comparison Pie Chart. (Source: Eastman et al., *BIM Handbook.* © 2008 by John Wiley and Sons, Hoboken, NJ. Reprinted with permission.)

The potential for recycling of building materials is just one example of how accurate, readily available building information can foster strategic decision making, improve efficiency, and boost productivity. Currently, construction waste accounts for nearly 40 percent of the volume of material disposed in landfills.[19] Construction waste is material generated in both the putting up and the tearing down of buildings. A lot of those materials are reusable, either in their original or some altered form. The problem is that they are typically disposed in a heterogeneous pile that is then incorporated into a heterogeneous waste stream, from which it becomes uneconomical to extract them for recycling or reuse. In their original incarnation, however, they exist in a highly structured form; in a building, no one has any difficulty distinguishing ceiling tile from drywall from carpeting from cast-in-place concrete. During construction, neither is it difficult to distinguish building materials from the packaging in which they are delivered. These materials—for both construction and demolition, become “waste” only when they are mixed together, degraded, contaminated, or otherwise rendered unsuitable for their original purpose.

If the quantity and location of materials and packaging could be tracked efficiently and accurately in a building information model, or BIM, it would be much easier to plan strategically for their eventual reuse or disposal. Buildings scheduled for demolition or renovation in which the types and quantities of materials to be removed are known could be “deconstructed” instead of demolished, because the value of their embodied “raw materials” could be quantified. The market for these materials, and the cost and sequence of removing them, could be determined in advance. The potential exists not only for reducing the waste stream, but for dramatically reducing or even eliminating demolition costs, depending on the value of the raw materials that could be “mined” from a building. Spot markets have developed for copper pipe reclaimed from buildings scheduled for demolition, and the reclamation of antique heart pine and heavy timber hardwood from nineteenth-century industrial buildings (and river bottoms) is a mature industry. Both are strong indicators that large-scale material reclamation is a potentially viable business model for purely economic reasons, regardless of its environmental benefits. An entirely new segment of the building industry—deconstruction—is just waiting to be born, and the midwife is building information.

BENCHMARKING WASTE

The United States is home to one of the world’s most effective and prosperous vehicle recycling industries. Today, 95 percent of cars retired from active use each year are processed for recycling, with about 75 percent of a car's material content (steel, aluminum, copper, and so on) eventually being recycled for raw materials use, including material that goes back into the manufacturing of new parts for new automobiles.[20] Putting these materials back into the supply chain increases raw material supply and lowers raw material costs across the board, to say nothing of the environmental benefits that accrue from not having to harvest and process additional raw material in the first place. This feedback loop occurs despite the fact that the original product has to be retrieved from the end user. Buildings, by virtue of being immobile, are much easier resource-recovery targets. It is only the lack of reliable information about their material contents that impedes the effective reuse of those materials and diminishes their value.

Material recycling is just one example of the business opportunities available—at the very end of the building lifecycle—to those with access to reliable building information. Similar opportunities for greater efficiency, productivity, and profitability are available to everyone—architects, engineers, constructors, and building owners—at every stage of the building lifecycle, especially in the very early stages of design.

IDENTIFYING BUSINESS OPPORTUNITIES

The core attribute of building information modeling that distinguishes it from the design technologies that preceded it is not three dimensional geometric modeling, but structured information—information that is organized, defined, and exchangeable. Unstructured information, by comparison, is difficult to identify, manage, or exchange. If you have to search for a needle in a haystack before you can sell the needle to a customer, the search for the needle might cost more than the needle's resale price; the needle becomes a cost center instead of a profit center. The lack of information about where the needle is stored renders the needle worthless; it is cheaper to go out and buy another needle from another, more efficient supplier, even if that means a reduction in mark-up and profit.

This scenario is repeated over and over again in the building industry throughout the lifecycle of buildings. The cost of gathering information about the actual equipment, materials, and components that make up a building can be so great as to render the physical artifacts worthless—or *worth less* than the cost of replacing them or subjecting them to thorough cost/benefit analysis.

In the design process, for example, it is often said that 80 percent of the cost of a building is determined in the first 20 percent of the design process.

This is another of those axioms that is insufficiently supported by statistical data, but industry professionals generally accept it as true. Once the major decisions are made about a structural system, a mechanical system, a cladding system, and so forth, the ability of the design team to control the cost of these components diminishes.

Design professionals—architects and engineers—rely on their experience and seasoned judgment to make critical decisions about the design and selection of major building components, materials, and systems in the early stages of design. Decisions are commonly made by applying rules-of-thumb or tried-and-true formulas that have not been rigorously tested against the specific requirements of the specific project. This is the best that can be hoped for in the current business climate. In the absence of reliable building information and the ability to share it easily among team members, the research needed to test different design scenarios and conduct rigorous comparative analyses of every plausible design option for every project would be cost prohibitive.

Substantially missing from the conventional building design process is the body of knowledge that has been delegated to constructors about the means and methods of construction. Without this knowledge, even the best design decisions by the most knowledgeable designers are made in a partial vacuum. In warfare, battlefield success up to the era of the Civil War often depended on the ability of a field commander to guess correctly the position of the enemy, based on the commander's knowledge and intuition of the opposing commander's judgment. Subsequent advances in aerial (and later, satellite) reconnaissance eliminated the guesswork. But for the design of buildings today, we still rely a great deal on this sort of intuitive judgment.

A second and even larger factor in building design is time. Time is money, and during the building design and construction process time has two parallel units of measurement: the total amount of "chargeable" time spent by design professionals to design and constructors to build the building (labor cost), and the "calendar time" between inception of a project and final occupancy of the facility. Chargeable time is easily quantified. The cost of calendar time, which can exceed chargeable time by a wide margin, is much harder to determine. It includes the cost of inflation, the nonperformance of physical and capital assets during the design and construction period, the cost of financing, and other "soft" costs such as legal and accounting fees, permits, and so forth.

With the clock (and money meter) continually ticking, design teams are under enormous pressure to make decisions quickly, even if the decisions are suboptimal. It does not take long before time-related costs exceed the potential savings of more-intensive design analyses. The challenge for designers and constructors is to reduce the cycle time and increase the value of conceptual design by leveraging richer sources of reliable information in the early stages of the design process. Building information modeling creates opportunities for scenario planning and rapid prototyping to determine optimum design solutions while potentially shortening the design and construction schedule.

The pattern of inefficiency repeats itself throughout the building life cycle, beginning with the warranty period and extending through operation and maintenance of the building until the end of its useful life. Information about components, materials, and systems is continually lost, and the cost of regathering that information quickly becomes cost-prohibitive. Facility managers, like design professionals, have no choice but to rely on their own experience and seasoned judgment, and their own rules-of-thumb or tried-and-true formulas. Staff changes within an organization result in further loss of specific, reliable knowledge about the facility. Inadequate maintenance—because reliable information about proper maintenance is not systematically available—leads to suboptimal equipment performance and premature equipment or system failure. The lack of documented maintenance history may itself compel premature replacement. If you don't know the exact age of a piece of equipment, its maintenance history, and its estimated useful life, its continued operation can become a gamble with life safety implications. Before long, the safe and prudent decision is to replace it. Worst of all, the loss of the original performance specifications may result in replacement with new components that do not meet those specifications. This scenario repeats itself again, and again, and again, to the frustration of all concerned. Expediency rules at every turn, simply because good information is not available for making better decisions.

By contrast, a database of structured information is a tangible asset that can enhance the value of a building. A true database of structured information—a building information model—also enables different parties to view the data from their own point of view. Computer-aided design (CAD) had little impact beyond the design and construction phase of buildings, because the data output—two dimensional, diagrammatic, pictorial representations of buildings—were of little value to facility managers, who view building information primarily in alphanumeric form. Most of the information created during the design and construction process that is of value to facility managers can only be found elsewhere and in scattered sources: in written construction specifications, warranty certificates, and operations and maintenance manuals. Any information contained in construction documents—CAD drawings and written specifications—that might be relevant to facility managers has to be extracted, yet another arduous, inefficient, needle-in-a-haystack task.

The core attribute of BIM—structured information—opens the door to easier and more effective *building information* transfer at every critical juncture of *building stewardship* transfer. The full potential of this is yet to be realized. The compilation of building information during the design and construction process, and the necessary electronic information exchange protocols, need to reach a certain level of maturity before useful facility management information can be conveyed routinely and easily to facility managers. But the structured nature of building information models provides the necessary infrastructure to facilitate this technological and business process development.

EMERGING BUSINESS STRATEGIES

The construction industry today is not unlike the sailing industry of a century ago. Skilled, seasoned mariners relied primarily on a method known as "dead reckoning" for coastal navigation. Complex calculations based on the inputs of wind speed, water current speed, and compass settings would produce—at best—a rough guess of the correct course to navigate. Dead reckoning was a poor substitute for the preferred method of coastal navigation: sighting prominent physical landmarks such as lighthouses, and either navigating toward them or away from them based on knowledge of coastal conditions as shown on nautical charts. The crude metrics of dead reckoning became most evident—and deadly—when they were most needed: when landmarks could not be seen due to weather conditions.

Despite the lack of reliable information, seasoned and experienced navigators managed to reach their intended destinations by the most expedient possible route most of the time. Long-range, low-frequency radio navigation (LORAN) systems eventually replaced dead reckoning in the mid-twentieth century, greatly increasing the accuracy of coastal navigation and dramatically reducing the risks of ocean shipping. In the late twentieth century, satellite-based global positioning systems (GPS) enabled mariners to determine their precise location anywhere on the globe with pinpoint accuracy. Mariners today are no more—and no less—skilled than their predecessors of a century ago. Like modern army field commanders, they simply have access to better information. Meanwhile, the life-or-death "data points" they formerly relied upon—lighthouses—have become artifacts of nostalgia with no useful function.

The real value of BIM to any organization—whether it is a design firm, construction firm, or building owner—lies in leveraging the structured information contained in a building information model to create value. The first step is a critical evaluation of the organization's core competencies and business objectives, followed by strategic deployment of appropriate technology to take the guesswork out of business decisions and shift the organization's output from routine, low-value-added tasks and services toward high-value-added tasks and services.

Moving from an unstructured to a structured information environment is neither cheap nor easy. Mariners skilled in dead reckoning were loath to trust the newfangled LORAN technology when it first appeared on the market after World War II. Many building industry professionals initially will be reluctant to substitute trust in the accuracy of structured information for their tried-and-true, rule-of-thumb methods for building design, construction, and operations. Confidence in the reliability of building information is a necessary prerequisite.

In order to make meaningful progress on this score, the industry needs to reach the level of information assurance that now prevails in the eBanking and eCommerce industries. The public overwhelmingly accepts that financial transactions executed at any ATM in the world, or purchase transactions executed online, will be executed properly. The occasional system failures, transaction errors, or outright thefts are regarded as aberrations, not fundamental defects. The building industry needs to develop the same level of confidence in building information and needs to provide its customers with the same level of information assurance. The only way to do so is to develop a profound understanding of the digital building information by engaging it, interacting with it, and exploiting it.

CHOOSING THE RIGHT TOOLS, DEPLOYING THE RIGHT TOOL SUITES

The selection of the most appropriate software solutions for individual firms is extremely important. Software should be selected for one reason and one reason only: to enhance the revenue-generating potential of the company. For a design firm, the selected software should enhance its ability to design; for a specialty consulting firm, its ability to perform iterative analyses; for a construction firm, its ability to build; for a building owner, its ability to manage and maintain its real property. In every case, software should enable every firm to do more with less. In all cases, software should enhance the ability of individual firms to communicate with other firms and exchange information reliably. If an investment in software does not increase productivity, streamline workflow, increase the quality of goods and services produced, reduce operating costs, and increase profits, then it does not meet the definition of a technological advancement and should not be deployed.

Business leaders have a tendency to evaluate technology on the basis of its acquisition cost rather than its full implementation cost and full revenue-generating potential. There is a great deal more to a strategic technology plan than software licensing and training, which are often viewed and managed as overhead expenses to be controlled, rather than as components of a larger strategic investment that should produce a measurable financial return. The larger, often hidden investment is in the education (as opposed to mere training) that will enable an entire organization to change its business culture, and in the resulting reform of core business processes to achieve greater productivity than can be achieved by simply automating existing processes(see Figure 1.4).

The result of the cost-based view of technology is that most software is grossly underutilized, either because the software is poorly matched to the firm's business needs or the firm fails to fully exploit the technical capabilities of the software it already has. This is so common because so few firms conduct the rigorous, critical assessments of their software applications' functional capabilities that would determine how well those capabilities align with their business goals.

BIM authoring tools—the large, robust applications that are used to create and compile most of the information contained in a building information model—are often perceived as costly to purchase and deploy. The failure to perceive BIM software as an investment is compounded by the failure to recognize that the cost of the software is only a small fraction of the total investment in BIM. The problem is particularly acute in design firms, which tend to make

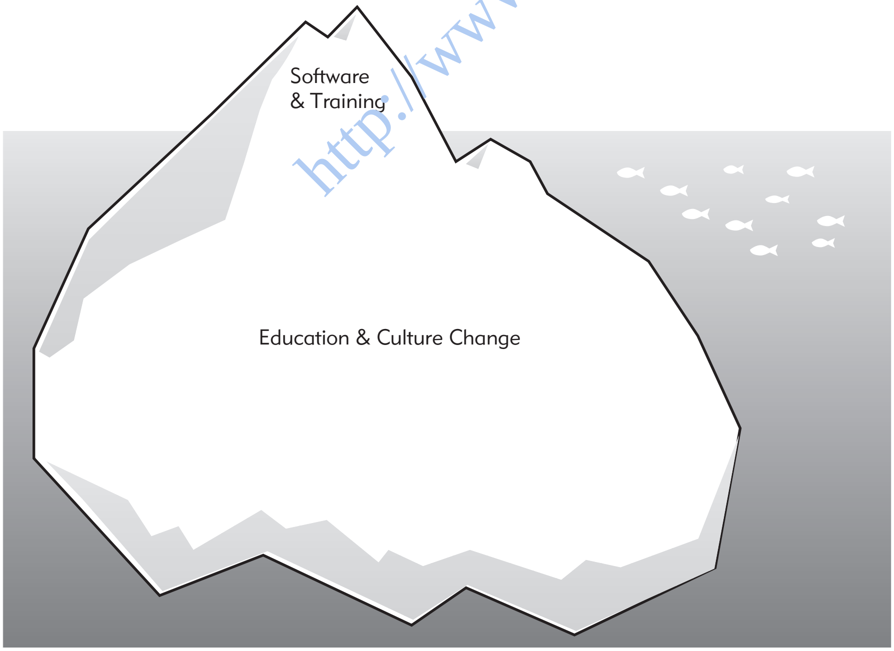

FIGURE 1.4
The Hidden Costs and Benefits of BIM

little effort to measure the return on their investment in BIM. As a result, design firm leaders' perception of the impact of BIM on their firms is often grossly inaccurate, which makes it impossible for them to make the correct strategic decisions.

Though BIM is relatively new technology, distinct categories of BIM software have emerged. Authoring tools—which include Autodesk Revit, Bentley Architecture, Graphisoft ArchiCAD and Nemetschek Vectorworks, among others—are optimized for building design. Each has distinct characteristics or attributes that make it suitable for particular types of design firms serving particular markets. Constructors need to look beyond these tools to other software applications—such as dProfiler by Beck Technology and Constructor by VICO Software—that have specific functionality for construction cost estimating, constructability analysis, and construction sequencing. Building owners and facility managers need to look even further for tools that are suitable for facility management, operations, maintenance, and real asset management, such as Archibus, ArchiFM, Drawbase, Facilivue by Omegavue, FM:Interact and FM:Space by FM:Systems, NETFacilities, and the MARS Facility Cost Forecast System by Whitestone Research.

For design firms, BIM authoring tools are merely the first and most powerful weapon in the design arsenal. Audit and analysis tools, typically far less expensive than authoring tools, have a far greater direct payback. They are easier to learn because they typically are designed to do one thing very well. Design firms are now using such tools for clash detection, energy analysis, sustainable design analysis, code compliance, and construction cost estimating. Applications in this category include Autodesk Navisworks for clash detection; Ecotect and IES VE-Ware for energy analysis; and Solibri Model Checker for rules-based (including code compliance) model checking. These tools enable teams of experienced and knowledgeable design professionals to leverage databases of statistical, technical, or financial information and complex algorithms to conduct detailed analyses of specific designs at a marginal cost. The real benefit of audit and analysis tools, however, is that they enable design professionals to enhance and leverage the value of the very thing that clients pay them for: their professional judgment. For design firms, tools in this category are essential to increasing efficiency, productivity, profit, and value.

BIM audit and analysis tools continue to proliferate because the volume of building information available for analysis is continually growing, and with it, the market for analysis tools. Integrated Environmental Solutions, Ltd. (IES), for example, in addition to releasing VE-WARE, has released a Sustainability Toolkit for sustainable design analysis and a LEED toolkit for LEED credit compliance analysis, among others. These toolkits can only be used to analyze building information models created in other applications: BIM authoring tools. So the market for specialized audit and analysis tools depends entirely on the growth of the BIM authoring software market. Many more such specialized applications will emerge as the volume of structured building information grows and software developers capitalize on the market opportunities for software that facilitates the analysis of structured building information. Continually surveying the BIM software market and evaluating these specialized tools is an essential component of a design firm's strategic business plan.

For the very early stages of projects, architects, planners, developers, and government agencies should consider predesign tools that can be exploited to accelerate, automate, or streamline tedious and expensive information-gathering or decision-making processes. Tools in this category include the Onuma Planning System by Onuma, Inc., and Affinity by Trelligence, Inc., both of which are specifically designed for the scenario planning, master planning, and programming stages of projects. While these tools can be deployed by anyone, they are a natural fit for design firms that have developed core competencies in planning and programming services, and for any government agency engaged in land planning and the related consensus decision-making processes.

Firms throughout the industry should look beyond BIM for technologies that can further enhance the benefits of BIM. A building owner or a design firm specializing in historic preservation or the adaptive reuse of existing buildings, for example, should consider deploying the laser-scanning technology of companies such as Quantapoint or Intelisum to document existing conditions. These technologies can dramatically reduce documentation time and cost while significantly improving the quality and detail of the information gathered. The integration of these applications with BIM applications is continually improving.

THE BIM VALUE PROPOSITION

As part of their "due diligence" in assessing the deployment of BIM in their businesses, design firm leaders often ask how they can pass on the added cost of developing robust BIM models to their clients. Construction firm leaders, on the other hand, ask how they can exploit the technology to reduce their own project-related expenses and increase their profits. Several early BIM adopters in the construction industry are reporting astounding results from their BIM implementations. Design firm leaders would do well to view the technology through the same lens. The key to leveraging BIM technology to increase profitability is not raising fees but rather reducing cycle time and increasing value. Clients will only pay more for something if they perceive that it has greater value, and the value of BIM models to clients, for now, can be difficult to demonstrate as a hypothetical future benefit. Asking clients to pay more without delivering more is a dead end. The value of BIM must first be proven. By focusing on increasing the efficiency of their own internal operations and the productivity of their own design teams, design firms can demonstrate the value of BIM to their clients while increasing their own profitability. By shifting their own perception of their services from cost-based to value-based, design professionals also may succeed in shifting their clients' perceptions as well, enabling them to earn higher profits while reducing their clients' costs.

PROCESS ENGINEERING

To some extent, building industry business leaders will need to recognize the seemingly perverse effect of efficiency and productivity on revenue. Improvements in efficiency and productivity resulting from BIM will cause the unit cost of design and construction services to go down while the quality, value, and profitability of those services will go up, because lower costs will increase total market size. This is an axiom of economics that is taken for granted in other industries such as automotive or computers, but is more difficult for building industry professionals to embrace. The unit cost of computing power of personal computers is only a fraction of the cost of the first computers introduced in the early 1980s, but the computer industry remains highly profitable. Toyota sells cars today of much higher quality and value but at a lower relative price point (after adjusting for inflation) than it did thirty years ago, but continues to enjoy record profits. Henry Ford did the same thing a century ago when he introduced the Model T. (Ford went so far as to pay his workers a substantial premium over then-prevailing wages, simply to increase the market size for his product.)

The same inverse relationship between unit price and profit has always been and will continue to be the hallmark of innovation. An entire professional discipline—process engineering—is devoted to it. Whenever the amount of time—or the unit of labor—needed to complete a task can be reduced, the efficiency and profitability for completing that task increases. Whether the additional profit accrues to the producer or is passed on to customers is partly a business decision and partly a matter of market dynamics. Individual businesses may not be able to control the market forces that determine the market value of their services, but every business is fully in control of how well it maximizes the value of its core competencies and how efficiently it delivers those services. That is why Toyota has been able to exploit innovation to earn record profits while U.S. automakers lose money in the same market.

Some increased efficiency can be achieved through incremental improvements in workflow, but the greater gains will come from transformational changes in business processes. If you're a wholesaler of sewing needles, you might increase your profit by 10 percent by finding a cheaper supplier, but you could increase your profit 400 percent by not storing your needle inventory in haystacks—and the building industry is full of haystacks.

The building industry did not invent such business concepts as invoicing, which accelerated business transactions by separating the delivery of goods and services from the related financial transaction, or just-in-time delivery, which dramatically reduced inventory costs in manufacturing, wholesaling, and even retailing. When these business practices were adopted by the building industry, they did not inaugurate much introspection and analysis. It appears that BIM, however, is causing the building industry to cast a critical eye on other business processes and ask how these can be reorganized in a structured way, whether the process is design, construction, marketing, communication, project management, professional development, or financial management. How much time does your highly paid staff spend managing e-mail? Processing submittals and RFIs? How frequently does your accounting department deliver project financial information to your project managers? Are your project managers able to act on the information provided? How effectively are you able to assess staff performance? How much do these nonchargeable (and therefore no-value) tasks cost your firm?

These are questions that are directly related to the availability of structured *transactional* information that is beyond the immediate realm of any individual project and, for the most part, beyond the realm of BIM technology. These are enterprise-wide issues of business information flow that can only be addressed by applying a strategic approach to enterprise workflow. Firms that focus solely on BIM may realize gains in project delivery only to be undermined by rising operating costs in other areas.

The disciplines of process engineering and supply chain management are largely absent from the building industry, but this will inevitably change. The most enterprising firms in the industry can be expected to recognize the void and begin acquiring this expertise and applying it to their own enterprise workflows, linking suites of specialized tools in customized end-to-end solutions that will significantly increase the value of their services. Organizations that fail to innovate or lag behind will find themselves at a significant disadvantage in the marketplace. As the Toyota and Ford example shows, innovation can come from any quarter and disrupt what seem like safe and secure markets.

THINKING LIKE AN OWNER

Design and construction industry professionals are often caught looking through the wrong end of the telescope, focusing on improvements in the design and construction of buildings rather than on the impact that design and construction has on the total life cycle costs and operations of a building, or the total environmental impact of design and construction decisions.

Buildings are built to serve a purpose. The true value of a building to an owner is the product or service produced by the people who occupy it, or the fulfillment of the mission that the building is intended to shelter. The cost of the facility itself is typically a small fraction of the cost of the operations or the value of the activities that it houses. Over the typical twenty-year life of a commercial building, for example, 90 percent of its total facility cost can be attributed to the payroll cost of the people who occupy it—a 9:1 ratio. The remaining 10 percent is evenly divided between the original construction cost and twenty years of operations and maintenance (including energy consumption).[21] In manufacturing, the ratio of total production cost to facility cost can be 100:1 or greater. It is easy to understand, then, why the owners of commercial or manufacturing facilities devote scant attention to their buildings, regarding them as little more than containers for the revenue-generating operations that take place within them. Though the metrics may vary, the same principles apply whether the building is a factory, office building, hotel, apartment building, convention center, dormitory, shopping mall, airport terminal, hospital, research laboratory, sports stadium, theater, church, or single-family home.

From an owner's perspective, however, anything that interferes with or diminishes the revenue-generating potential of the operations within a building is detrimental to the owner's business interests. If a $10 million business operation cannot take place because a $250,000 building is not ready for occupancy or is unavailable because $100,000 was spent on a roof that chronically leaks, the relatively small facility-cost investment suddenly takes on outsized importance. NASA spends so much money on every component of its habitable nonplanetary assets not because it wants to build best-of-class habitable environments, but because the consequences of component failure are so high.

Other pressures can compel short-term thinking. At the project inception stage, building owners face acute cash-flow challenges. Because a building cannot generate revenue until it is occupied, construction financing can be difficult and expensive to obtain. The only assurance that the lender has of recovering its investment is for the building to be completed and begin generating revenue or serve its intended purpose; a building that is 95 percent complete is a liability, not an asset. So before a building is built, the fact that design and construction costs are such a small fraction of total life cycle cost doesn't matter very much. The dollar amount that needs to be financed and the amount of time it will take to complete the building are the owner's and the lender's paramount concerns. It is little wonder, then, that owners strive to limit both construction cost and construction time regardless of the long-term consequences.

Building industry professionals often overlook these mission-critical financial considerations. It may come as a shock to design and construction professionals, but from an owner's point of view, the entire time between the moment a decision is made to erect a building and the moment the building is ready for occupancy is an obstacle to achieving the owner's business mission. For design and construction firms that are truly client-focused, the primary goal should be to complete the building and get it into service as quickly as possible. For long-term consequences to be given greater consideration, design and construction time cannot be lengthened.

BUILDING PERFORMANCE METRICS

While the building owner's focus on minimizing initial construction costs is understandable, it is grossly shortsighted. The cost of operating and maintaining a building—and the efficiency and productivity of the activities that take place within it—are all directly related to the quality of its original design and construction. The quality of the physical environment has a direct effect on the health and well-being of the people who occupy it, which in turn directly affects their productivity, as numerous studies on workplace productivity have shown.

Just as structured building information allows architects and engineers to incorporate environmental considerations and life cycle operating and maintenance costs into the design process cost-effectively, building information modeling will enable workplace productivity factors to be taken into account in equally methodical ways based on reliable statistical workplace performance data. This will dramatically alter the value proposition of buildings and the business environment with respect to cost/benefit analyses of design alternatives.

NEW METRICS FOR REAL PROPERTY VALUATION

Reliable, accurate life cycle building information will change the metrics for real property valuation. Currently, buildings are valued largely on the basis of their physical attributes such as square footage, location, and rough measures of "quality" such as Class A, B, or C office space, "affordable" versus "luxury" housing, and three, four, or five-star hotels. While the latter three metrics bear a relationship to a building's revenue-generating potential, they are loosely based on physical attributes grounded in the original design and construction quality and cost. When the true life cycle costs and benefits of buildings can be reliably quantified, these factors will be monetized and reflected in the value of buildings alongside physical factors, which will then account for a proportionally smaller fraction of a building's total value.

Historically, it has been all but impossible for building owners to measure the relative life cycle costs and benefits of design and construction decisions because, once again, the cost of the research and analysis needed to develop reliable forecasts has been prohibitive. Building information modeling provides an information infrastructure that will allow architects, engineers, constructors, and owners to assess multiple life cycle factors in the early stages of design collaboratively, including energy consumption, total life cycle cost of materials, equipment and systems, and workplace productivity. Project teams will also be able to assess the total environmental impact of material, product, and equipment selections, and not just their impact on energy consumption during building operations or their effect on the environmental health of the building's occupants.

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