20/20 Vision: The Engineering & Construction Industry in the 21st Century

While venturing to predict the future is a risky proposition, there are certain issues and trends developing now that will definitely have an impact on how the engineering and construction industry will do business in the next 20 years.

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Now that we are ending the second millennium by dragging the engineering and construction industry kicking and screaming into the twenty-first century, it is time to look at ourselves and decide what we want to be when we really grow up. The biggest change that we will confront is that we will have to provide "products" rather than projects and the product will have to be structured to meet performance requirements from the cradle to the grave. True life-cycle performance will have to encompass all "product" aspects from sustainable development to ultimate re-use or disposal — be it a building, a highway or a generator set. To do so will require a total delivery system that cuts across all disciplines within our industry and that also directly involves all other industries that contribute to the final product. This delivery system will include not only the traditional team members — such as designers, builders, lawyers and insurers — but also the manufacturers of the construction equipment as well as the entire range of construction materials manufacturers. We will also see the entry of a whole new range of non-conventional advanced materials that are self-assembling, self-growing and self-healing. These materials will be designed by teams working in cyberspace, built and assembled in highly automated environments, and linked together electronically from inception to ultimate disposal.

What changes will help us get there? Throughout history there has been no shortage of prognosticators. Here is a sample of what some of them have had to say about the "future":

- In 1899, Charles Duell, then head of the U.S. Patent Office, said, "Everything that can be invented, has been invented." He also recommended that the office be abolished.
- In 1943, Tom Watson, Chairman of IBM, said, "I think there is a world market for about five computers."
- In 1977, one year after Steve Jobs founded Apple Computer, Ken Olsen, the President of Digital Equipment, said, "There is no reason for any individual to have a computer in their home."
- And, in 1981, Bill Gates, then CEO of Microsoft, said, "640k [of RAM] ought to be enough for anybody."

So much for the science and art of forecasting future needs.

Everyone aspires to 20/20 vision, even if one may need a bit of correction to achieve it. Let us see what our 20/20 vision for the engineering and construction industry in the year 2020 might look like. What changes are occurring, and how will they impact our activities?

In order to identify the possible changes that we might see confronting our industry between now and the year 2020, we need to look at the industry from three perspectives:

- The significant changes that have impacted our industry over the last 20 years.
- The implications of those changes on our future, and the challenges they engender.
- The possible changes that might occur during the coming 20 years and what we should try to do to bring them about.

But whatever we do, we better get ready for a major restructuring of our industry — one that will be revolutionary rather than evolutionary.

Significant Changes

Let us list some significant changes that took place during the past 20 years that have influenced the engineering and construction industry:

- The continuing depletion of the world's natural resources and resultant awareness of the need to consider sustainable development.
- The transformation of the design profession from a labor-intensive to a capital-intensive sector of the industry through the application of computer and space technologies — in particular, computer-aided drafting and design (CADD), global positioning systems (GPSs) and geographic information systems (GISs).
- The introduction of new construction materials, plastics, composites, fiber optics, etc.
- The better understanding of the need for, and value of, applied research.
- The emergence of environmental and hazardous waste clean-up as a top national priority.
- The evolving changes in the packaging and delivering of projects: design-bid-build, design-build, turnkey, construction management, program management, etc.
- The growing importance of women and minorities in the workforce.
- The rise of the consumer movement and public activism and the need for community participation.
- The growth of a litigious climate.
- The shrinking of the globe due to communications and information advances.
- The emergence of a "global economy" with the introduction of global competitors.
- The renewed emphasis on trade barrier reductions — NAFTA, European Union, APEC, World Trade Organization.
- Increasing pressure on governmental budgets in the United States and worldwide causing reductions in public investments and a trend towards more privatization of public facilities.

Future Implications

What are the implications for the future and can we meet those challenges? Here are some issues we might face:

- The entry of defense contractors and accounting firms into our industry as part of their diversification strategies.
- The introduction of performance-based procurement, requiring delivery systems that are faster and more finance-driven (such as design-build-operate-maintain, build-operate-transfer, partnering, etc.),

which continues the trend to more privatization, or "contracting-out."
- The introduction of new building materials and systems, as well as greater use of recyclable materials.
- The greater use of automation and pre-manufacturing that is more capital intensive, leading to further industry consolidation into fewer but larger and more diversified companies.
- The transformation of the construction industry through computer-enhanced construction methods as in architect Frank Gehry's "experience music project" in Seattle that integrate three-dimensional computer-aided design (first developed to design airplanes) into the construction process.
- The use of digital design-build techniques (sometimes called 4dcad), where three-dimensional computer-aided designs are joined by the fourth dimension of time.
- The ability to tap distant low-cost markets. For example, the use of third world labor for design as well as for pre-manufacturing building components.
- The need for new skills, including a broader ability to address not only technical but also economic, environmental, societal, political, legal and aesthetic concerns.
- The globalization of the industry and the need to recognize barriers such as language, cultures, standards and certification.
- The advent of a truly balanced environmental ethic resulting in multinational cooperation to deal with global ecosystems, pollution reduction, resource conservation and sustainable development.
- The need to create new scientific breakthroughs to deal with hazardous and non-hazardous waste management (to recognize that waste is an out-of-place resource).
- The need to restore mutual trust in our society and introduce serious tort reform.
- The need to bring back the credibility of engineers and constructors. (For example, we need a television show like *LA Engineer*.)

Future Changes

What are some of the possible changes that might occur during the coming 20 years and how will we meet those challenges? The greatest single change is one that started more than 30 years ago: the growth in the global construction market versus the U.S. domestic market. Thirty years ago, the U.S. market represented about half the world's total. In 1999, it had shrunk to 18 percent. Now 18 percent of a $3.6 trillion market is still a huge workload. However, our domestic market is static and the global market is expected to grow at an annual rate of 5 percent. Therefore, five years from now the U.S. share will be down to 15 percent of the total. The implications are clear: with more than 80 percent of the market elsewhere, many of the major breakthroughs are likely to occur outside of the United States. And we had better shed our parochialism and learn from those "foreigners."

Not surprising, the world's entire population growth, estimated at 100 million per year over the next 20 years by the World Health Organization, will mostly occur outside the United States. In fact, this development will occur outside of all the developed nations of the world. If you cannot get your arms around 100 million people, think of building a new San Francisco every 3.5 days for the next 20 years — and that does not include all the many unmet needs of less developed nations.

Those changes and growing needs present an immense challenge to our industry and, in fact, to our whole society. A total of $3.6 trillion in construction per year means a lot of natural resources, a lot of money and a lot of talent.

Natural resources have to be converted into the building materials and equipment that make up a completed facility. We will need literally hundreds of millions of tons of building materials and from where will those materials come? Every year the U.S. construction industry deposits over 100 million tons of construction debris in landfills; probably another 100 million tons or more are dumped elsewhere. How long can we continue to throw away those materials? Many European countries — as well as Japan, Korea and Taiwan — have established target dates by which they will eliminate construction debris disposal by employing re-use and recycling technologies and by finding new uses for those materials. Their target dates for 100 percent material recovery range from the years 2002 to 2010.

In addition, the European Union has instituted regulations — now voluntary, but ulti-

mately mandatory — that relate to source control, where the manufacturer or producer becomes responsible for the cost, or the act, of product disposal at the end of its useful life. Initially, those regulations have been directed at the automobile industry but they will eventually apply to all manufacturing industries including construction. Here is one example of what would happen with those regulations in force:

> You buy a Mercedes Benz, drive it for a couple of years, and then give it to your kid to take to college. A year later it is totaled on the way home for winter vacation. At that point it once again becomes the property of Mercedes Benz, which is responsible for disposing of the wreck. You paid for that disposal cost because it had been included in your original purchase price, but now it is the manufacturer's responsibility to dispose of the wreck and the manufacturer will want to keep dismantling and disposal costs to a minimum. This burden will create a huge wave of innovation in materials — many non-conventional, combining chemical, biological, biomolecular and other cross-fertilized sciences to create components that can be transformed into other substances during the recycling and reformatting process. BMW has a demonstration car that can be disassembled in 23 minutes, reducing the disposal labor cost significantly.

The thrust of recycling of paper and of beverage containers with which we are familiar will be followed by that assault on the automobile and other manufacturing industries and, in the end, on all industries, even the conservative, non-conservationist, construction industry. Doing so will give real meaning to the concept of sustainable development.

Paying the Piper

What about money? How do you pay for works that will require $3.6 trillion, or more, every year? The global construction market breaks down into major categories:

- 36 percent residential;
- 36 percent non-residential; and,
- 28 percent civil works, or physical infrastructure.

Traditionally, residential construction has been partly funded from public sources and mostly from private sources. Non-residential construction, with the exception of government offices and secondary educational facilities, is mostly funded by the private sector. Civil works have generally been provided by taxpayer funds or user funds (which is another form of taxation levied by governments).

With limitations on the availability of taxpayer dollars, a growing proportion of the world's construction bills will have to be paid by non-government sources — by the private sector. That brings on the golden rule: whomever has the gold, will make the rules. One result is to move to value-based delivery systems, with whole-life or life-cycle cost as the driver. The time value of money and the operating and maintenance costs will generally outweigh the initial design and construction costs by factors of 20 to 30. Early completion to achieve early investment recovery, coupled with ease of maintenance and controllable costs of operation will drive project considerations. The value-added delivery systems will have to incorporate all those factors. The client of the future will no longer be the chief engineer but will be the chief financial officer.

Private-sourced funding has traditionally been project oriented. But, in addition to funding discrete projects as we do today, in the future we will also see more project bundling — "mutual funds" of projects, not of companies or of industries. They will be either captive funds created by insurers, pension trust fund managers, retirement fund managers, privatized social security programs, etc., or they will be open to individual investors (in other words, open to the public). There are huge pools of money looking for reliable returns on the investment. This bundling of projects also will help to balance the risks. E-links will simplify the process and also help generate other forms of innovative financing.

Getting It Done

Where we are going to find the talent to do it all? The western world's population is aging. Fewer people are entering our industry than

are leaving. More of our technically educated people are moving into other careers. With growing needs to produce more and better constructed facilities, we will have to do things differently. One important aspect is that we better realize that all industries — including ours — now have to perform in a truly borderless environment: with no physical boundaries, no political borders and no cross-industry barriers. No ways exist to constrain unlimited flow of information, not only within a project but also within an industry, across industry sectors and literally beyond this planet to extraterrestrial bodies. The detailed mapping of the planet earth by a NASA space shuttle last February is a good, but probably primitive, example of things to come. A better example of things is the development of the "E-Era," the electronic communications that have made it possible to create an automated 24/7 design office, located wherever talent is available and affordable. For example, Indian and Philippino engineers, architects and planners will design international projects in their home countries that are checked, monitored and managed by supervisors in Boston. The Worldwide Web, Internet, intranets and other electronic communications and control systems will radically change the pre-construction as well as the construction and operation and maintenance phases as we know them today.

For the construction part, the solutions will be different. A shrinking work force in certain countries cannot be offset by farming out everything to another country. But replacing some of your traditional workforce with pre-manufacturing, with automation, robotics, electronic and e-commerce, etc., cannot only reduce your dependence on that shrinking labor market, it can also increase your productivity and competitiveness. Pre-manufacturing reduces on-site labor and can also tap low-cost labor in other parts of the world. Automation, such as satellite-controlled construction equipment, eliminates the need for equipment operators. Robotics can be used to build entire buildings with a minimum of manpower (a modular 12-story reinforced concrete structure was built recently in Japan using only robots and computer controlled construction equipment). New technologies permit a paperless project all the way from conceptual design to a good set of as-built drawings, with the concomitant reduction of office and field staff. E-commerce will simplify and expedite the whole procurement cycle by providing access to the entire world for the best subcontractors, to the most reliable and least costly materials delivery, to readily available construction machinery, etc. In other words, e-commerce enables you to leverage your resources and will help you deliver projects with less manpower and at a lower price.

So let us get ready for an electronically straddled borderless marketplace where only the fittest will survive. And the fittest are those who are willing and able to embrace change.

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