Computers and Construction—Midcareer Reflections

By Boyd C. Paulson Jr.,[1] Member, ASCE

Abstract: Midcareer reflections based on work combining computers and construction leave an appreciation for the rapid progress that has taken place in both fields in recent decades. Computers have brought many benefits in helping the industry to meet increasingly complex challenges, but as automation becomes pervasive, greater attention must be focused on the social and economic impacts on construction people. Construction education and research have also become much more computer-oriented, but it may be time to take stock of evolving curriculums and more systematically consider what should be done to meet future industry needs. In general, construction has a strong cadre of young researchers who have become well-grounded in advanced computer technologies and are in a position to continue bringing its benefits to construction practice in the future, but they must stay attuned to the needs of industry.

INTRODUCTION

Unlike most entering college freshmen, there was no doubt regarding my career plans; I had grown up knowing little about anything but heavy construction. It was but a twist of fate that made my subsequent venue academia rather than industry. Similarly, since I first got into my father's tools, I have enjoyed building things—a personality trait that has made me something of a nuisance in my neighborhood because I keep knocking down parts of my house to make additions and "improvements." The main thing that changed my plans in college was that I became interested in computers and merged them into my construction career. That diversion began when I first figured out how to work an IBM card punch and then fed my slim deck of cards to a high-speed reader. After hours of effort, my little program probably caused the multimillion-dollar machine behind glass walls to do no more than a little arithmetic and print five or six pages of paper to give a single answer, but the feeling of control over such advanced technology became addictive.

In 25 years since graduation, I have continued this somewhat schizoid pattern, with one part of me well rooted in the traditional materials, methods, and people of construction, and the other focused on our neighbors in Silicon Valley. My research has ranged from methods for tunnel construction and improving labor relations to applications of computer-based interactive graphics and robotics.

It is not clear to me what in my background merited the Peurifoy Construction Research Award. Perhaps, after all these years, I have simply accumulated enough friends who have decided to give me their kind and generous consideration. I am very grateful to all of you for this privilege. But I have struggled with the other half of the honor, that of giving what the rules call the "Construction Advancement Address." The nature of the honor seems to have tilted past recipients toward a retrospective vein, even a philosophical one, and I will be no exception.

PEURIFOY ADDRESS

1993 was the eighth year of the Peurifoy Address. It seems such a short time ago when, in 1986, Richard Tucker became the first recipient, and Mr. Peurifoy himself attended a reception that the Construction Research Council (CRC) sponsored to honor the pioneering construction educator for whom the award is named. In preparing my own address, I reviewed each of the first seven papers, and thought it would be worth digressing for a moment to summarize the wide range of views that have been presented in this series.

Richard Tucker began appropriately with a broad 6,000-year sweep through the history of technology to show where construction fits in (Tucker 1988). He inevitably mentioned what has been a recurring theme in subsequent talks: construction lags other industries, and does so partly for its comparative lack of effort devoted to research and development. The Construction Industry Institute (CII) has been a recent and successful effort to begin redressing that imbalance. As director of CII, Tucker has done much to get universities into collaboration with industry to address real problems.

The second recipient, Richard Shaffer, was himself a pioneer, having joined the Construction Engineering and Management Program at the University of Illinois in the 1950s a few years after it was started by David Day. In 1971 Shaffer moved to take a long-term leadership position in the U.S. Army's Construction Engineering and Management Laboratory (CERL). In his Peurifoy lecture, he particularly emphasized the need for research to address the nation's massive infrastructure-rehabilitation demands, and took a positive view in presenting case studies of technologies developed at CERL that have moved quickly and effectively into practical applications to solve some of the Army's own infrastructure problems (L. R. Shaffer, award address, 1987).

In 1988 Clarkson Oglesby became the third recipient. A contemporary of Peurifoy and a leader in pioneering construction education and research at the graduate level, Oglesby first examined the needs of the construction industry for education focused on its unique characteristics (Oglesby 1990). He then traced the evolution of construction-management training from its craft-based historical background to the present focus on college education at the four-year undergraduate and graduate levels. Having participated internationally throughout the 40-year evolution of modern construction education, he provided personal insights into both engineering-based and construction speciality programs. He also emphasized the importance of increased industry support for education and research to make construction more competitive in the world market.

In the 1989 Peurifoy address, Ben C. Gerwick Jr., who had a distinguished industry career before returning to academia, used his experience to show that innovation has indeed been abundant in the construction industry, and that much of it comes from the industry itself (Gerwick 1990). He provided excellent examples in materials, equipment, construction technology, and management to show how concepts can evolve to problem solutions even on specific projects, and then go on to change industry practice. He described the

[1]Charles H. Leavell Prof., Dept. of Civ. Engrg., Stanford Univ., Stanford, CA 94305-4020.

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J. Constr. Eng. Manage., 1995, 121(2): 197-200

interplay among materials and equipment manufacturers, contractors, and designers that contributes to the industry's progress. But even though innovations continue to abound at the basic research stage, short-term economic thinking in the United States has been causing development—and the resulting rewards—to move overseas.

Over 30 years ago, the fifth recipient, John Fondahl, codeveloped precedence critical path method (CPM) networking, one of today's most successful and widely used project-management techniques. Looking back over a successful career, he used a small scheduling example to illustrate four problem areas still facing graduate education and research and the industry (Fondahl 1991). These include gaps in understanding that slow implementation of useful ideas; wasteful postproject litigation that results largely because of deficiencies in planning and construction; adversarial contractual relationships in which the parties seem more likely to use modern management tools as weapons against each rather than as aids toward mutual goals; and lack of trust and team cooperation in professional relationships. These problems point to a need for a better system for planning, design, and construction.

In the 1991 address, Robert Harris also began by briefly tracing the history of construction education (Harris 1992). But he particularly focused on a perceived divergence in the needs of industry relative to recent trends in university education and research for construction. As construction has become more accepted in academia, its teachers and researchers have become more academically isolated and ignorant of industry terminology and practice; there is a growing communication gap between industry and its academic counterparts. As evidence, he cites trends in the *Journal of Construction Engineering and Management*, in which papers on management and computers by academics have all but displaced those on construction engineering, field processes, and other topics that could be of more interest to practitioners. To remedy this problem, Harris advocates much stronger industry involvement in university education, particularly in research.

The first six Peurifoy awards went to first-generation construction academics. All were educated in more traditional civil-engineering subjects, and then, based on industry experience and self-driven scholarship in construction, they became pioneers and leaders in this field. Last year the seventh award went to a second-generation academic—a person whose graduate education took place in an established construction program—and so it is again this year. I am not sure about the significance of that observation, but it is tough to live up to the reputation of the pioneers.

In 1992, Daniel Halpin, the seventh recipient who was widely recognized as both an educator and a scholar, presented an address that was based on both his research success and his international interests (Halpin 1993). He said that if construction is a discipline subject to research and development, then it ought to have a fundamental theoretical framework to which it can relate its results and build its progress. In chemistry the framework is the periodic table, and in music it is the notation. For construction, a process-oriented industry, he recommends simulation modeling as such a framework.

Taken as a whole, these Peurifoy-award recipients have already said a great deal about the history of and the need for construction education, and the paradox of industry's real need but lack of support for research and development. They have addressed persistent problems in both of these areas, and have offered a variety of thoughtful solutions. Each presentation offered the recipient's own unique and personal views, with a surprising lack of repetition given the recurring themes. Their ideas are worth rereading.

I will try to avoid repeating the well-covered histories of construction education, and the admonitions for more extensive and better focused research and development, except to say that I support almost all that has been said by my predecessors. I will follow up on some of the concerns I share with Harris, and will also base what I say on personal experience. But I will also focus more specifically on one topic: computer applications in construction.

COMPUTER'S IMPACT ON CONSTRUCTION INDUSTRY

During 1969 to 1971, when I did my doctoral research and wrote a thesis called "Man-Computer Concepts for Project Management," interactive computers were at an early stage of development (Paulson 1972, 1973). The human interface typically consisted of a Teletype or IBM 2250 hard-copy terminal that worked at 10–15 characters per second. Graphical-display devices had not evolved much beyond large analog oscilloscopes. While programming an interactive CPM/cost/resource-allocation system with that primitive type of equipment, I had in mind and described with words and pictures—but could hardly implement—a way of interacting with computers that has become commonplace with today's powerful microcomputers and project-managment software. There is some satisfaction in seeing one's predictions come to reality through the efforts of many other people, whether or not one can take any credit for the actual course of events.

Two decades ago, the impact of computers on construction was negligible. The machines did crank out the payroll and some cost reports for larger companies, and some firms even struggled with centralized CPM scheduling systems that produced reams of tabular reports that were largely ignored in the field. The focus of construction professionals remained on the field work itself, and on directly managing the resources to get the work done.

Today things are changing. Many if not most jobsite trailers on medium- and large-size projects have computers, and increasing numbers of construction engineers and managers use them and their powerful software as routine construction tools. Knowledge of software for scheduling, estimating, and using spreadsheets and even computer-aided design (CAD) shows up in both want ads and résumés for entry-level construction engineers. Having taught computer applications in construction off and on since 1970, I also feed pretty good about that kind of change. I'm afraid that most of my earlier students couldn't do much with such knowledge, but now they can.

On balance, the impacts of computers on construction appear to be positive. Projects have become more complex both technically and administratively, and computers have helped construction professionals not only to cope with the resulting challenges, but to manage projects better than ever. Computer-based positioning and measurement devices are improving the accuracy and quality of construction work while reducing costs. CAD and visualization software helps clients better participate in the planning and design process and reduces errors that used to cause problems in the field. Today computers are improving communications among the diverse parties involved in designing and building projects to help reduce fragmentation and coordination problems. These and other technical accomplishments are generally well-publicized, so I will not belabor them here.

Throughout the years that I have worked with computers and other advanced technologies, I have tried to keep in mind their potential usefulness and possible consequences for the construction people under whom I grew up. Thus far there have been few large-scale displacments in construction resulting from automation, but there have been some. Design-

J. Constr. Eng. Manage., 1995, 121(2): 197-200

ers working in traditional ways were laid off by the thousands in the 1980s, and as the large engineering constructors again began to expand by the end of that decade, many of these people were not rehired. The process of doing more with less that is euphemistically called "downsizing" has largely been made possible by the proliferation of microcomputers. Computer-controlled robots thus far have had little impact in construction, but already in Japan there are claims that automated construction of high-rise buildings requires 80% fewer workers. They claim that existing labor shortages minimize the social impacts, but what would be the situation in the United States and other countries? The social and economic impacts of computers on construction need much more attention than they are getting. This could be a suitable topic for the joint industry-university efforts of the Construction Industry Institute or the ASCE Civil Engineering Research Foundation (CERF).

COMPUTERS IN CONSTRUCTION EDUCATION

At this stage I have mixed feelings about the role of computers in construction education. In reviewing past papers, I found that Robert Harris shares some of my concerns. In the first half of my career, courses on computer applications were more of an elective than a core-curriculum necessity in construction. To provide background for applications in construction, most schools were content simply to have their students take introductory programming. Now I wonder if we might be overdoing it. Computers are increasingly important tools in construction, but they are not an end in themselves. But many of our young facility and students have more experience with computers than they have with field construction, and it is much easier for them to gain access to computers than to construction jobsites for research and educational activities. Thus it is not surprising that computer applications have proliferated throughout many curriculums. This in itself is not bad. My concern relates more to what may have been jettisoned to shape a curriculum to fit the limits of a four-year undergraduate degree or a one-year masters degree.

For years it has been recognized by leading construction professionals that direct hands-on experience in one or more construction crafts provides excellent background for field engineering and supervisory jobs in construction. Presidents and other senior executives of some of the largest companies did just that. Educators also often had such experience to complement their advanced engineering degrees, and many had progressed at least to field-management positions in industry before crossing over to academia. Academic career-development paths are usually different today; they have become more conventionally academic and even inbred. My impression is that there is also much less construction engineering taught today than before (courses such as equipment and methods, marine construction, concrete construction, heavy construction estimating, construction materials, etc.) in order to make room for computers as well as other new courses in various management and administrative topics. We can only teach so much in a finite time, of course, and when industry needs people who can work programs for CAD, estimating, scheduling, and cost-control something has to give. But are these changes happening in a well-planned manner, or are they happening more as a result of the accumulating momentum of advancing computer technologies, increasingly complex legal and regulatory demands, and the desires of research-oriented faculty?

No doubt the industry has changed and universities must be responsive to changing industry needs. When I started work in the industry back in the 1960s, there was little regulation related to environmental impacts—noise, turbid water, and dust were simply taken for granted as by-products of progress. Safety was important but was not significantly regulated until the Occupational Safety and Health Administration (OSHA) came along. Changes, changed conditions, and other contractual problems were resolved mostly by owner and contractor professionals working together, and seldom involved lawyers and claims consultants. Things are much more complex today, and students must be prepared for modern realities. But with all the emphasis on complex administrative procedures and the application of advanced technology to cope with them, have we lost our focus on the basic pleasures and rewards of building?

It seems to me that we ought to take stock of where we are, and look at the evolving balance and content in the construction curriculum. That is not an easy task, and might only begin with a well-supported workshop or like mechanism. ASCE's Construction Research Council and the Associated Schools of Construction (ASC) could take the initiative here, but it would also require much more industry involvement—involvement from working professionals who can take a longer view than simply finding solutions to today's problems—than we have had in recent years.

THE FUTURE

As I began preparing for this talk, I planned to express concerns about whether some of our computer-oriented research might be getting too far ahead of realistic industry needs. To their credit, some construction researchers have become credible even in basic computer science, and have enhanced the image of the construction discipline within academic circles. But some topics of research within advanced technologies such as artificial intelligence, robotics, object-oriented programming, and others have left many working professionals incredulous. Perhaps it is typical of those who have moved on to middle age and beyond, but I was at first inclined to be skeptical and even critical; the tendency is hard to resist at this age. But as I thought about it, I became more ambivalent regarding the work of today's younger researchers, and then increasingly supportive.

Yes, the traditional part of me says that there is too much emphasis on computers and related technologies, and that we academics may be straying further and further from the needs of industry. Robert Harris had a lot to say on this theme, and I will not belabor it here. But I concede that my reservations may be true more of the needs of industry as I knew it 20 or more years ago than is the case today. Industry's needs themselves are a moving target, and we need to aim in advance of the trajectory to have an impact.

My reflections were also tempered by my own experience. As I think back on it, industry folks were surprisingly polite and deferential when I presented my visions for "man-computer systems for project management." In reality, they had no way to implement my ideas with the technology then available, even it were affordable. They pretty much had to take on faith that such predictions might come to something; none of us could then foresee the subsequent development and rapid proliferation of microcomputers that made today's interactive construction software possible. Much the same could well become true of today's research on applications involving even more advanced technologies. Without the people developing the prototypes, theories, and technologies of the future, and without students taking classes in topics that may not be readily applicable today, we will be poorly prepared as an industry to take advantage of the inevitable progress that will continue in other fields. Undoubtedly many of the bright ideas of today's cutting-edge researchers will fall by the wayside, but some may evolve to become routine tools for future construction professionals—tools reflected in the

J. Constr. Eng. Manage., 1995, 121(2): 197-200

want ads and résumés of the 21st century. Today's graduates will be in practice for around 40 more years; given the pace of technology just in the last decade, it would be foolhardy to predict what they will see. But it would be equally foolhardy to discourage the visionaries today from pushing their ideas as far as they can.

But again I return to Harris and his presentation two years ago. As editor of the *Journal of Construction Engineering and Management* he sees the bulk of papers submitted by U.S. construction researchers today—those rejected as well as those that survive peer review to appear in print. If, as seems evident, there are academics who canot tell the Associated General Contractors (AGC) from a government agency, and who clearly do not understand the basic construction processes and terminology upon which their computer programs and research papers are based, then we certainly do have a real credibility problem. Our research must be based on a fundamental understanding of the construction industry. To the extent that our faculties and students lack sufficient industry experience, they must work all the harder to seek active and effective involvement from industry professionals in university research and educational activities.

CONCLUSION

The reflection stimulated by this occasion did leave me with a few concerns, but also with the optimistic view that our field is stronger than ever. Construction has entered the mainstream of university education and scholarship. The programs have become attractive to bright students in large numbers, and more and more graduates have prepared themselves to meet the increasingly complex challenges of construction. There is an active cadre of researchers systematically working on advanced concepts and technologies from many fields, yet doing so with an appreciation for the special needs of our unique industry.

The main concerns I raised are: (1) To more explicitly address the social and economic impacts of new technologies and methods on the industry and its people; and (2) to take stock of the recent changes in construction curriculums and to more systematically consider just what changes are likely to be most needed for the years ahead. The first might be a good topic for industry-university groups such as CII or CERF. The ASCE CRC together with the ASC could initiate the second with a workshop, but should also see strong input from progressive leaders in industry.

Regarding today's academic research on computer applications in construction, initial skepticism led me to considerable optimism. Many young faculty and student researchers have become well-grounded in key areas of science and technology, and are taking a long view and some risks in attempting to bring the benefits of their work to construction. The world of construction will inevitably become more complex in the future, but we are preparing now the people who will offer knowledge and leadership to meet its challenges. But we must keep these efforts well attuned to the present and future needs of the construction industry.

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J. Constr. Eng. Manage., 1995, 121(2): 197-200