Educating Tomorrow's Transportation Engineers

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Before discussing educational needs, it is appropriate to ask several obvious questions about transportation engineers. Can their work be characterized with such specificity and is there sufficient stability over time to permit defining a body of knowledge known as transportation engineering? Consider, for example, the aviation mode. The air transportation vehicle requires aeronautical engineers reinforced by others with expertise in power systems, electrical systems, computer systems, structural systems, and more. Electrical engineers, together with computer and communication specialists, build and maintain air navigation systems. To complete the picture, civil engineers and architects design the runways, terminals, and other appurtenances at the ground-air interface. And as for time stability, how many technical disciplines related to transportation have become obsolete in one professional lifetime?

So to refer to transportation engineering as a single discipline requiring a discrete body of knowledge is an unhelpful oversimplification. It is our intent, therefore, to discuss engineering for transportation in holistic terms. In particular, we will discuss some issues and trends in transportation and their implications for engineers and for engineering education remembering always that transportation touches everything we make, buy, or do. We will supplement this discussion with examples of what we have done at the Pennsylvania Department of Transportation (PennDOT) to enhance engineering education and training.

TRENDS IN TRANSPORTATION

John Naisbitt, in his best selling book Megatrends: Ten New Directions Transforming Our Lives (1), describes 10 super trends that emerge from the confusion of today's highly uncertain, rapidly changing world. Naisbitt writes about an information society, "high tech/high touch," networking, and multiple options, all of which have enormous implications for transportation and transportation engineering. Similarly, we can identify specific "megatrends" that will affect engineering education for transportation.

Systems Development to Systems Management

The first trend is the shift from transportation system development to transportation system management. This concept first emerged from the Urban Mass Transportation Administration in the early 1970s and created much confusion. It is uncertain even today whether the concept is well understood. From our own perspective, however, such a shift is conceptually sound and practically necessary for the survival of PennDOT.

The shift from systems development to systems management means many things. It means paying first attention to maintenance and performing maintenance work using a business-like approach. It means limited capital programs that are no longer "wish lists," but rather are grounded in fiscal reality. In an effort to become more efficient we have begun to pay more attention to "make-buy" issues and have contracted out a great deal of work to private firms.

Although PennDOT has existed for 80 years, we have spent a considerable amount of time trying to determine just what business we were in and decided that really we are in three businesses. We own and operate a significant segment of Pennsylvania's transportation system, we perform 26 million computer-based transactions each year in issuing driver's licenses and motor vehicle registrations, and we provide close to $.5 billion each year in technical and financial assistance grants for local and area transportation.

Needless to say, these businesses and the overlying fiscal, computer, and personnel systems require a rich mix of professional skills. With the well-established centers for fiscal and project control the department now enjoys, we are encouraging our 67 county maintenance managers to act as if they were in business themselves. Of course, they receive considerable direction from the central office and the district offices to which they report, but this year for the first time we have asked these county units to develop individual 4-year business plans for achieving previously developed major departmental objectives. The notion of being in the business of systems management within a larger public works agency is a new trend in transportation--at least in Pennsylvania.

Forced Technology to "High Tech/High Touch"

In the opening paragraphs of his chapter on Forced Technology to High Tech/High Touch (1), Naisbitt states

> High tech/high touch is a formula I use to describe the way we have responded to technology. What happens is that whenever new technology is introduced into society, there must be a counterbalancing human response--that is, high touch--or the technology is rejected. The more high tech, the more high touch. During both the 1950s and the 1960s, we mass-marketed the products of that industrial era--products whose regimented uniformities mirrored their industrial base. High tech was everywhere--in the factory, at the office, in our communication, transportation, and health care systems and, finally, even in our homes.

The urban expressway plans of the 1960s illustrate an obvious attempt to force a new technology beyond ready public acceptance. When we assumed office in 1979, eight major Pennsylvania Interstate urban expressway projects were locked in various controversies. Since 1979 we have withdrawn one from the Interstate system and downscoped and redesigned the remaining seven. Five are now well under construction and the other two will be under construction shortly. This represents some 65 miles of urban expressway and close to $1.5 billion worth of engineering design and construction. In each case, we were successful because we first insisted that there be a local consensus in the design and location and, secondly, because we remained totally committed to constructing facilities compatible with their respective environments and sensitive to the concerns of those citizens most directly and significantly affected.

This process requires considerable interaction with both local officials and private citizens. It also requires creative, imaginative, and innovative designs to address local issues and still provide the basic service for which the facility is primarily intended. For example, in some cases we found that by limiting the number of interchanges we could reduce the number of lanes required--thus, the needed right-of-way was reduced considerably. In another case, high-occupancy vehicle lanes were incorporated into the design. In general, we were able to substitute higher technology but only through extremely sensitive interaction (high touch) with the various constituencies involved. To again quote Naisbitt, "We must learn to balance the material wonders of technology with the spiritual demands of our human nature" (1).

Pocket Calculators to Personal Computers

Another obvious area where high technology has been forced is computer technology. Because of an early awe for electronic brains and artificial intelligence, many people became intimidated by what is a relatively simple machine. There is no need to discuss the dramatic shift that has taken place since the advent of computer games and such user friendly systems as the Apple and the Peanut. But we will point out some of the implications for engineering agencies, again drawing mostly from our own experience.

First of all, the personal computer finally put the computer in its place simply through the creative device of calling it personal. Even though today's personal computer has more storage capacity and operates much faster than the world's largest and fastest computers of just a few years ago, they have now been put on a scale where the individual believes that he or she actually is in control rather than being manipulated by electronic wizardry.

The personal computer can facilitate the entrepreneurial approach to running a large public works agency by aiding in the establishment of adequate control systems for overall monitoring and management. But large central processors and massive data banks are also necessary. We have committed almost $30 million over a 4-year period to enhance our various electronic data processing, or information systems. Major efforts include upgrading the driver's license and vehicle registration system, integration of the various systems related to fiscal management, and integration of the various systems related to roadway management. In addition, we have made a major commitment to computer-assisted design and drafting and office automation. In all cases, because users have terminals at their finger tips, whether it be a time-sharing terminal or a self-contained personal computer, they have more of a sense of being in control.

It might be helpful to provide some examples of how personal computers are now being used. At the district level, all districts will soon be putting their annual county maintenance programs on personal computers. These programs include county-by-county routine maintenance activities such as shoulder cutting, pipe replacing, crack sealing, and so forth--tasks occupying 8,000 employees and consuming $600 million per year. In addition, we expect that most of the districts will soon have their 4-year business plans on personal computers. At the statewide level, we recently developed a pavement management system called Systematic

Techniques for Analyzing and Managing Pennsylvania Pavements (STAMPP). The computer system that supports STAMPP was developed by a pavement engineer in the department. He developed most of it on his own time with his personal computer (PC). Now each district has a computer zealot and a PC to support the STAMPP system and its application to pavement management.

Although not personal in the same sense as PCs, our computer-assisted design and drafting system gives our designers and drafters a greater sense of being in charge. As this system becomes more fully operational, we expect a three- to five-fold increase in productivity. More important, designers and drafters will be free from most of the tedious monotony of their work so that their creative abilities can be applied to innovative design and development. For decision makers, it means that instead of choosing from "either-or" situations, a more sensitive selection can be made from a full array of options.

Big Federal Government to Smaller Local Private Enterprise

The trend in the 1960s and 1970s was toward a larger and more centralized federal government. That trend has now reversed; the federal government is delegating more responsibility to state government and state government is delegating more responsibility to local government. President Reagan made an issue of New Federalism some years ago. Although the formal package never developed, defacto "new federalism" has been in effect for at least a decade. As inflation has decreased the purchasing power of the federal dollar, state and local governments have had to fill the gaps. In Pennsylvania, for example, we recently embarked on a 6-year, $1.4 billion bridge replacement and rehabilitation program. Although the federal bridge program provides for a participation rate of 80 percent overall, Pennsylvania's program is only counting on 50 percent federal aid. Our local problems were so bad that we simply could not wait on more federal support.

At the state level we are returning highways to local governments. Pennsylvania's 44,000-mile state system contains some 11,000 miles, which, by any measure, are local in function. We have recently launched a program to repair these roads and return them to local management. Currently, more than 1,400 miles of such roads will receive attention from more citizen-responsive local managers rather than from the more centrally directed state managers.

Conrail is another example of a large agency shedding itself of burdensome local branches in an effort to regain profitability. Where a more cost-effective local operation could be established, such lines, and the rail freight service they support, have been preserved through local management with state assistance. The Reagan Administration's efforts to back out of providing transit operating assistance offer yet another example. Although the proposal has not yet become a reality, Pennsylvania has been working with its local governments toward enabling legislation that would allow local governments to develop taxation for transit operating expenses.

Another aspect of this trend toward smaller government is manifested by increasingly large shares of government work being contracted out. Over the past 6 years, PennDOT's work with private contractors has been increased almost five-fold from $180.2 million in fiscal year 1978-1979 to an estimated $850 million in the current fiscal year (1983-1984). The belief is that the competitive bidding process will result in more cost-effective work. The exercise of going through make-buy evaluations also puts our own people in a competitive mode so that our force account work becomes more productive and more cost effective. In either case, whether by private contractor or by in-house effort, the result is a more entrepreneurial approach to public enterprise.

From Research to Innovation

During the 1960s and 1970s we got carried away with the Buck Rogers type of transportation research. Probably the zenith of these efforts was the Transpo Exposition held at Dulles Airport in Washington, D.C. during 1972. At that time we were talking about automated highway systems, flying trains, and kneeling buses. Clearly, the problem was not a lack of ideas, but rather one of ideas whose time had not yet come. Although the public may have been receptive to some of these ideas, the economics for putting this technology in place simply did not exist. As a result disappointment turned to disenchantment, which in turn almost led to a complete dismantling of the transportation research effort. Belatedly, we realized that research consumes resources and only innovations in operation hold the promise for savings.

Recently this disenfranchisement of transportation research has been turned around. The efforts of the Transportation Research Board's Strategic Transportation Research study (2) provides one positive example. A proposal has been developed for a $150 million 5-year effort to accelerate the search for highway and bridge innovation. For example, the study recognizes the strategic importance of the fact that as the nation begins to rebuild its highway infrastructure, enormous quantities of asphalt cement will be required. Asphalt was once derived from a few well-known sources that produced asphalt with predictable properties; now new asphalts may come from any place in the world and behave in an unpredictable fashion. The result is that in too many cases asphalt pavements, instead of providing a smooth surface for 10 to 15 years, are coming unravelled in only 2 or 3 years. The importance of this issue is emphasized by the numbers. America will place about $100 billion worth of asphalt pavement in the next decade. A savings of 1 percent would yield $1 billion a year for other purposes.

What are the implications of these trends in transportation and how will they affect education for engineers? We will discuss the implications for education as well as the implications for the transportation industry, but first, let us try to describe the ideal transportation engineer in today's world.

TRANSPORTATION'S IDEAL ENGINEER

The ideal engineer for the 1980s is well grounded in basics and is capable of solving unique problems in creative, imaginative, and "high-tech" ways. The ideal engineer is completely comfortable with modern information systems and is equally at home either working individually or working on multidisciplinary teams. He or she is sensitive and skillful in basic social interactions and possesses good communication skills. The ideal engineer has an understanding of both entrepreneurial reality and the broad social and economic aspects of local, state, national, and even international political structures. Above all, he or she has high moral standards, good leadership qualities, and the ability to manage both herself or himself and others in the pursuit of transportation's social, economic, and environmental objectives.

Perhaps an ideal engineer can be represented by the famous father-son team that engineered the Brooklyn Bridge--John and Washington Roebling. In a recent article in Professional Engineer (3), Florman reports that John Roebling, in addition to architecture, bridge construction, and hydraulics, "studied philosophy under the great Hegel." Washington Roebling in addition to his technical courses, "studied logical and rhetorical criticism, French composition and literature, and intellectual and ethical philosophy." Florman concluded that the Roeblings' "ability to persuade, enlighten, and inspire their fellow citizens contributed as much" to the success of the Brooklyn Bridge "as did their considerable technical talent."

IMPLICATIONS FOR EDUCATION

The implications for the educational system striving to produce the ideal engineer are enormous. All levels of education are affected, and there are ramifications beyond the traditional boundaries of formal education.

At the primary education level, it is important that children with aptitudes for growth in technological sophistication be identified at an early age. These young people should be encouraged to experiment and develop their natural curiosity--to learn on their own. Education should be focused on the individual, and every opportunity should be taken to expose the individual to both nature and science as well as man and society (4).

At the secondary level, greater emphasis must be placed on math and science (5). There should be emphasis on research and experimentation with attention to problem solving. Students should be encouraged to get involved both in their school and in their communities. They should develop an early appreciation for entrepreneurship and gain a sense that they as individuals can make a difference in their community. They should also realize that by working with others the difference can be even greater. They should be encouraged to compete--not only with those around them but with themselves for greater personal achievement.

In higher education the concept of the individual, the notion of ownership, and an appreciation for entrepreneurship should be developed to a fine edge. In addition to a strong grounding in basic scientific and engineering skills, students should be given specific real world projects, both basic and applied. The skills in communications, problem solving, and decision making should be thoroughly developed and applied at every opportunity.

Of particular concern is the need to communicate to young people that they can make a difference. We have a good example from our department of how much difference an aggressive, young entrepreneur can make. We inherited a department with thousands of projects being managed from many different program centers. There was no systematic way of controlling these projects or of monitoring progress toward their completion; so there was little progress. We knew a young civil engineer at Pennsylvania State University who had become interested in computer technology and had made substantial progress on his own in this field. He was willing to leave his graduate program in civil engineering and come to the department to help us straighten out our electronic data processing activities. We talked about the need for a project management system. This young man, Scott Kutz, took this as a personal assignment and by force of incredible individual effort (100-hr weeks) and creative interaction with dozens of people throughout the department, he created a project management system in approximately 6 months.

And by motivating and stimulating people throughout the agency, we built the data base, and quite literally created an electronic file cabinet that now allows us to control projects, control cash flow, arrange our letting schedules, communicate with legislators, and perform a variety of highly effective tasks. Again, all of this was because of one man's zeal and dedication during a very short time period. We need to tell young people throughout their education that great inventions and notable strides toward improvement are usually the result of one committed person or of a person leading a team in our modern society.

With respect to educators, it is critical that they become "facilitators of learning" as opposed to instructors. The traditional textbook-lecture approach must be merged with programmed learning whereby individual students move according to their own skills and at their own pace. At the primary and secondary school levels, some teachers should be encouraged to seek summer jobs in technical environments. In institutions of higher learning, educators should be encouraged to consult and to enter public service.

IMPLICATIONS FOR INDUSTRY

The implications for industry of "new" education in areas of concern to transportation can be discussed in terms of the experienced engineer, the engineer-in-training, the engineering profession, and finally, the involvement of industry itself in education.

For the experienced engineer who has become comfortable in a stable bureaucratic environment over a 10- to 15-year period, perhaps the first step to consider is job rotation. Such engineers should be encouraged to take risks and to develop an entrepreneurial attitude toward their jobs. They should become more involved in their profession by developing and delivering technical papers. They should become more involved in their community's education system. For the experienced engineer whose skills have become stale or obsolete, "restart" training should be provided. For those uncomfortable with the computer, they should be assisted, possibly through a computer loan program. Where necessary, management training should also be provided. In general, the experienced engineer should be encouraged and given wide latitude for personal development (6).

At PennDOT, we have used the rotation technique extensively. Particularly while engineers are in their developmental years, they need to be rotated around the agency so that they can observe the various contributions needed to make the whole agency function. There is nothing more distressing than to see a young man or woman who believes that traffic engineering, for example, is the extent of transportation.

We try to use targeted training for experienced transportation engineers. Each year we perform an extensive evaluation, and as part of that evaluation we outline a program that includes both in-house and external training. Sometimes the training is general short courses, sometimes skills area improvement, but the notion is to make the worker more satisfied with his own abilities and more productive for the department.

For engineers-in-training, it is important to identify the star performers and to do everything possible to put them on a career fast track. Again the entrepreneurial approach is appropriate. People should be given the feeling that they, in a business sense, own and operate the resources assigned to them and have full responsibility for their applications to the problem at hand as well as for the performance that results. Young engineers must learn through experience by taking risks and even by being allowed to make some mistakes. They should be challenged early and brought along as rapidly as their personal development potential will allow.

For the whole engineering profession, it is important to promote engineering and the education required to excel at engineering. A major achievement this year has been the so-called "engineering amendment" to the National Science Foundation Act passed by the House in late April (7). This legislation, recommended by the Engineering Education Task Force (comprised of representatives of the National Society of Professional Engineers, the American Society for Engineering Education, and the National Association of State Universities and Land-Grant Colleges), added an engineering mission to the National Science Foundation's charter.

An example of promoting education required to excel at engineering is the program called MATHCOUNTS sponsored by the national Society of Professional Engineers (NSPE) in addition to the CNA Insurance Companies, the National Council of Teachers of Mathematics, the National Aeronautics and Space Administration, and the National Science Foundation. Only 1 year old, the program, with the assistance of thousands of NSPE members, has already involved 400,000 students from 47 states. Each of the 4,000 participating schools selected "mathletes" who worked their way through state level contests for an opportunity to compete in Washington, D.C. Winners were awarded a trip to Cape Canaveral to watch a space shuttle launch. We, as professional engineers, should encourage and become involved in more such efforts.

For industry, there are numerous ways to support better engineering education. At the primary and secondary school levels, employees should be encouraged to run for local school offices. A speaker's bureau for local schools should be developed so that engineers have the opportunity to describe their profession to budding students. At a recent conference sponsored by the U.S. Department of Education, Pennsylvania Governor Richard Thornburgh noted that partnerships "make the difference" (8). A way to accomplish this is for agencies and businesses to become involved in adopt-a-school type programs in which they form a partnership with a particular school or schools and make special efforts to support each other through exchanges.

In the past few months, PennDOT adopted the Harrisburg Area Middle School. This is a school of about 2,300 young people; most of them live in the city core area where the work ethic and work experiences are lost or at least badly blurred. We have used a variety of techniques, including providing speakers to the school. But more important, we have brought small groups of students (20 to 30) into the department to share experiences in our computer centers, airports, equipment fleet, and in our driver training, giving them exposure that we hope will enrich their total educational experience. The results so far are promising, but certainly preliminary.

Perhaps most important, the engineering-related industries should make special efforts to employ students in summer jobs and through internships. We have brought students into the department in some special ways. At the secondary level, we are developing litter cleanup crews that work under the auspices of the school system to patrol Pennsylvania's highways and help to make them clean and attractive. We borrowed the idea from Oregon, and although it is just beginning, we believe it offers real promise. Perhaps more important for our engineering students is our summer programs for construction inspection and road condition assessment. We have found that we can take students with 2 years of engineering training, give them a 1-week course, and make them into effective construction inspectors. During the past summer we had 248 such students at work. What they lack in knowledge they make up in dedication. Certainly, the idea of developing highly motivated construction inspectors is a problem that has plagued the industry for years. We believe that this approach is helping to stimulate young careers and is providing us talented short-term inspectors as well. Similarly, we train and use summer students to assess pavement condition for our pavement management system.

At the higher education level, industry can make more resources available through cash and equipment contributions as well as through employee involvement. Practicing engineers should be encouraged to become involved in advisory committees for curriculum review and course development (9). They should be encouraged to teach part time at local universities. On the other side, university consultants should be hired and challenged to field test their ideas. The concept of the visiting scientist to industry should be developed for field testing ideas from university research laboratories.

Three years ago, we established a position of visiting scientist with the intent that a university scholar in a transportation-related area would come to the department for no less than 6 months nor more than 1 year to work with us in a program that would be developed in a cooperative fashion. The first visiting scientist stayed 1 year and elected to stay a second year as director of research. The second visiting scientist has been identified, an individual with a strong structural research interest. We are looking forward to a continuation of this positive experience, and indeed, are considering expanding it. The benefits so far are clear on both sides.

SUMMARY AND CONCLUSIONS

In summary, let us repeat our assertion that transportation is too broad and involves too many elements of the environment, the economy, and society to be treated as a single discipline. We must recognize that this function exists in a rapidly changing, highly uncertain world that requires creative solutions to emerging issues and innovative application of advancing technology.

If our country is to remain competitive in the world economy, then there must be a national commitment to excellence in education; in particular, a recommitment to science and technology. Education for transportation can only benefit from such an effort. Such a commitment, however, carries responsibilities: as parents to our children, as engineers to the institutions that educate us, as employers to our employees, and as citizens to our communities--education is everybody's business.

Our objective is to educate creative individuals who are not afraid to take on a problem and solve it, individuals who develop entrepreneurial ownership for their ideas and pursue them even though the risk of failure may be great, individuals who interact with others so as to remain sensitive to both the individual and collective needs of society, individuals who welcome new challenges in a world of change.

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