

Enhancing Infrastructure Management Education through Collaboration

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Introduction

Efficient and well-maintained infrastructure systems are essential for societal stability, economic growth, and sustainable competitiveness. Although the United States is served by some of the best civil infrastructure systems in the world (valued at more than 20 trillion dollars)¹, many of the current systems are reaching the end of their service lives. For example, the United States infrastructure earned only a D+ in a recent American Society of Civil Engineers' (ASCE) survey². This ASCE report also estimates that the investment needs to bring the condition of these deteriorated systems to an "acceptable level" is estimated at more than 1.6 trillion dollars. Consequently, we must emphasize the maintenance and renewal of our infrastructure by using sound infrastructure management principles.

The term "infrastructure management" has been used since the 1980s to describe the activities involved in maintaining and rehabilitating civil infrastructure systems, such as transportation, water, and wastewater. Transportation infrastructure management has typically focused on systems of bridges or pavements. More recently, the term "asset management" has been used to describe the high-level planning and implementation of good stewardship of these facilities. While there is no standard definition for the term "infrastructure management," "asset management" has been defined as "... a systematic process of maintaining, upgrading, and operating physical assets cost-effectively"³. Although in its broadest sense the term asset management also includes the management of non-physical assets, in practice the terms have been used interchangeably. For consistency, the term "infrastructure management" is used throughout this paper.

Technological advances in the last decade have resulted in significant growth in the infrastructure management field. For example, improved sensing technologies provide better information about facility condition. Advanced materials and more sophisticated equipment have increased facility life-spans. However, probably the most revolutionary advances have resulted from increases in computing power. Today's computers can store and analyze large quantities of data, allowing the evaluation of different maintenance and rehabilitation options in terms of timing, location, and actions. Nevertheless, even with these technological advances, additional improvement is needed in areas such as information management and data integration, condition assessment, performance prediction, life-cycle analysis, and resource allocation optimization.

Some of the components necessary to facilitate these developments include:

1. A strategic agenda for infrastructure management that guides the efforts, provides direction, and sets short, intermediate, and long-term goals and priorities.
2. Academic research programs focused on infrastructure management that are capable of conducting high-quality intermediate and long-term interdisciplinary research efforts.
3. A significant number of qualified graduate and undergraduate students interested in infrastructure management.
4. Funding organizations that are committed to the advancement of infrastructure management and that are willing to fund medium and high-risk initiatives.
5. A strong network of infrastructure management scientists, practitioners, and educators who are willing to cooperate for the advancement of the infrastructure management field.
6. A community of infrastructure management practitioners that is aware of the importance of preserving our infrastructure assets and is willing to implement the results from research efforts.
7. Good dissemination and training mechanisms to communicate research findings to practitioners and to facilitate implementation of these findings.

However, there are several potentially serious impediments to the successful development of this important field. These potential obstacles include the following:

1. Lack of interest in infrastructure preservation and management among civil engineering students. Students often choose to specialize in more traditional areas within civil engineering. This has resulted in low enrollments in civil engineering infrastructure programs throughout the country, leaving limited qualified professionals to address infrastructure management and renewal.
2. Lack of succession planning, which is creating a significant generation gap in infrastructure preservation and management academics.
3. Lack of significant investment by federal agencies and industry in high to medium-risk, and intermediate to long-term strategic research on infrastructure preservation and management.
4. Resistance to change and reluctance to embrace technological advances among decision-makers. These attitudes sometimes discourage young professionals.

Academics have been interested in civil infrastructure systems education for several decades. Amekudzi et al.⁴ describe some of the history of the development of infrastructure management as an academic discipline. Several texts have been published, including Haas and Hudson's first edition of *Pavement Management Systems* in 1978⁵, Grigg's *Infrastructure Engineering and Management* in 1988⁶, and, most recently, Hudson, Haas, and Uddin's *Infrastructure Management* in 1997⁷.

Workshops and conferences have also been held. For example, in 1992, the Federal Highway Administration sponsored a conference, titled "Transportation Management Systems Conference for Colleges and Universities," that focused on education related to transportation management systems. In 1999 and 2000, *Public Works Management and Policy*, the journal of the American

Public Works Association (APWA), published a series of articles focused on infrastructure management education⁸⁻¹¹. These articles prompted the APWA to hold a “Summit Meeting” at the organizations’ annual meeting in 2000. The summit was called “Creating a New Curriculum to Prepare Public Administrators and Engineers to Effectively Manage Public Works Programs” and featured a series of short presentations followed by substantial discussion. The summit was attended by a mix of engineering and public administration faculty and highlighted the ambiguity of what should be required for a field that relies heavily on more than one discipline. Revised versions of papers from the summit were published in a special issue of *Public Works Management and Policy* in April, 2001¹²⁻¹⁸. Also, in September, 2001, the 4th National Transportation Asset Management Workshop featured an Education Reception with a series of short talks followed by discussion (<http://www.mrutc.org/outreach/workshop/program/>).

In addition, the National Science Foundation has sponsored the following workshops:

- *Workshop on Integrated Research for Civil Infrastructure* (July 1996; Washington, DC) focused on identifying multidisciplinary research needs for improving civil infrastructure.
- *Bringing Information Technology to Infrastructure* (June 2001; Arlington, VA) defined a research agenda connecting information technology and infrastructure.
- *Mitigating the Vulnerability of Critical Infrastructures to Catastrophic Failures* (Sept. 2001; Alexandria, VA) focused on identifying research topics related to the vulnerability of critical infrastructure networks, such as power systems, telecommunications, and computer networks.
- *Construction Engineering Professional 2020* defined the requirements for construction professionals in 2020 and a roadmap to achieve the required changes in construction engineering education.

The objective of the *Infrastructure Management Research and Education* workshop was to develop a plan to strengthen infrastructure management research and education by focusing on the issue of recruiting qualified graduate and undergraduate students who are interested in infrastructure management. In addition, the workshop identified some of the problems leading to the recent decline of interest in infrastructure management among North American students. Participants also discussed potential remedies for these problems and strategies to increase the number of undergraduate and graduate students interested in the field. In addition, workshop participants identified present and future problems and issues within the infrastructure management field and to prioritize research areas. The workshop was attended by 15 infrastructure management educators, researchers, and government representatives, from 12 different organizations.

This paper describes the problems and solutions identified, focusing on student enrollment, succession planning, and institutional roles, including support for research.

Student Enrollment

The first portion of the workshop concentrated on identifying the main reason for the recent decline in the number of North American students interested in pursuing careers in infrastructure management. There was some disagreement about the real magnitude of the problem; however,

there was consensus that the universities with the largest graduate programs in the field have experienced great difficulties in attracting domestic students. Two important points were raised:

- There has been an overall decline in Civil Engineering enrollment, with students choosing more “technology-oriented” careers in the computer, electronics, and information technologies fields. However, it was also noted that the trend appears to be reverting, following the slow-down in the technology industry. The general public is becoming more interested in infrastructure and is placing pressure on public organizations. For example, the Ministry of Transportation of Ontario has recently hired many civil engineers, including five who are working in pavement management, three in bridge management, and two in asset management.
- Thanks to more public awareness about the importance of maintaining our infrastructure, there are more academic programs that focus on infrastructure management; thus, the pool of prospective applicants is distributed over a larger number of institutions than in the past⁴.

The main reasons for the lack of undergraduate and graduate student interest in infrastructure management were identified as follows:

- Students are not adequately exposed to infrastructure management in the early phases of civil engineering curricula.
- The term infrastructure management lacks a standardized definition.
- The field is not high-profile. In particular, it was noted that the field is usually perceived as *low tech* and that there are not *large-scale* initiatives that attract students. For example, a recent large infrastructure initiative in Canada has created great interest among students.
- Few clearly defined job opportunities for graduates with a concentration in infrastructure management exist. While there is clearly a strong market for B.S. Civil Engineering graduates, the opportunities may not be as well known for M.S. and Ph.D. students graduating with a focus on infrastructure management.
- Students perceive that high-paying jobs are not available and that professionals who specialize in infrastructure management lack opportunities for career advancement.

The workshop participants agreed that improving the image of infrastructure management is particularly important. One critical component of this effort is to increase the “visibility” of infrastructure management. The following specific steps were identified by the workshop participants to accomplish this goal:

- Include infrastructure management content in core undergraduate courses so that students are introduced to the topic early in the curriculum. These courses can be used to recruit high quality students.
- Define and communicate the principles of infrastructure management. Participants emphasized the importance of reaching the design and construction community.
- Obtain funding to increase the visibility of the field and to support graduate and undergraduate students.

- Market the systems perspective and “high-tech” facet of infrastructure management to undergraduate and graduate students as well as to the general public and elected officials.
- Profile and promote specific success stories of infrastructure management graduates.
- Develop *multidisciplinary* infrastructure or asset management M.S. programs modeled on the professional M.B.A. programs.
- Network with other professionals and organizations.

Succession Planning

Workshop participants perceived a gap between those faculty in the infrastructure management field who are well-established and those in the early stages of their careers; there are few in the field who are at “mid-career.” At most institutions, there is no more than one faculty member working in the area. As a result, the continuity of a program is fragile.

Responding to these concerns, Dr. Ralph Haas presented a keynote presentation on succession planning in infrastructure management. Succession planning is a process for ensuring the orderly renewal, upgrading, and continuity of an organization’s resources, including people, technology and information/ data. Succession planning is good business because it contributes to organizational stability, helps preserve a large investment, reassures the “marketplace,” helps with public relations, and saves costs. Some of the major requirements for successful succession planning include a top level commitment from high level decision-makers who recognize the need for this orderly transfer of knowledge and experience and who are willing to undertake the necessary investments. It is also important to develop a plan that includes timing replacements, training, contingencies provision, and mentoring; the plan must also be updated periodically to assess its effectiveness.

Despite all the advantages of succession planning, obstacles exist, such as rapid turnover of administrators, financial exigencies, short-term political decisions, frequent resignations and/or “poaching” by competitors, and lack of data, resources, documentation (technology, methods, equipment, procedures, etc.), and/or training programs. Philosophies such as “we can buy people, technologies and information,” or “we can always rely on immigration for any shortfalls” are also detrimental.

Dr. Haas charged the group to meet the challenge of creating a “culture” of succession planning in the infrastructure management field in the public and private sectors and in academia.

Specific actions include:

- Establish transportation and infrastructure education foundations and endowed professorships;
- Form organized alliances of transportation and infrastructure professors;
- Develop a succession planning primer;
- Showcase / profile achievements and success stories; and
- Create "Bob the Builder" equivalents for transportation and infrastructure.

Institutional Roles

The third part of the workshop identified the roles that different interested parties can or should play in the development and promotion of infrastructure management. The main responsibilities of academia, government, professional organizations, and the private sector include the following:

- The role of Academia is to train engineers who are knowledgeable in various infrastructure management areas, such as deterioration modeling, life cycle economic analysis, management tools, statistics, planning, design, construction, maintenance, and in-service evaluation and monitoring. It should also conduct state-of-the art research and provide courses that encourage inquiry-based learning and are up-to-date, interesting, and relevant to the industry.
- The Government can provide support to universities in the form of research contracts and grants; support for teaching programs, including guest lecturers and government publications and literature for possible use on assignments or projects; encouragement of relationships and cooperative efforts among the private sector and universities; and emphasis on “engineer-in-training” programs so that succession planning can occur.
- Professional organizations can support universities by offering research grants, collaborating with teaching programs by providing guest lecturers and case studies for possible use on assignments or projects, and facilitating cooperative ventures between the private sector and universities. Professional organizations could also take the lead in the development of standardization of definitions for infrastructure management and related terminology.
- The private sector can partner with universities to conduct research. It can also provide co-op or summer jobs that are interesting and challenging, provide research funds and scholarship opportunities for students interested in this area, and support teaching programs through guest lectures and adjunct faculty.

Three specific areas for collaborations that may help the development of the infrastructure management field were identified. For each of these areas, the group identified a series of actions.

First, those in the field can form alliances for teaching and research at both institutional and personal levels. Alliances between universities and public or private organizations may facilitate student exchange programs and provide opportunities for students and researchers to work with “real life” tools such as pavement, bridge, and hardware management systems. In addition, these alliances allow professionals to mentor students, work on research projects, and teach infrastructure management courses. They may also provide opportunities for sharing resources, such as syllabi and course materials, and promote the use of available resources. The group highlighted the importance of government organizations’ willingness to support these alliances and proposed the addition of an education link to the American Association of State Highway and Transportation Officials’ (AASHTO)-sponsored Asset Management “Community of Practice” website.

Second, we can form exchange programs, where students can spend a term or summer away from their home university, taking courses in other universities, working at a public agency or private company, or conducting research in a national laboratory. These programs can be modeled upon successful existing programs in government agencies, many of which have systems in place that can actually pay for this type of programs. Students can also work in practical field projects that are useful to agencies, use available data for projects, and/or participate in internship programs (e.g., some universities have one term or one year internships for Ph.D. students). Continuing education courses, such as those offered by the National Highway Institute (NHI), are excellent sources for teaching aids and case studies. It was also noted that the National Science Foundation (NSF) has at least four programs that may facilitate and fund these activities: Grant Opportunities for Academic Liaison with Industry (GOALI), Integrative Graduate Education and Research Traineeship (IGERT), Industry University Collaborative Research Centers, and Research Experiences for Undergraduates (REU).

Third, we can promote the profession among colleagues, decision-makers, and the general public. This goal can be achieved through collaborations on research and teaching, interaction with the private sector (conducting research and marketing this research), establishment of funded chairs and professorships specifically at the associate professor level, and aggressive pursuit and securing of research funding. Other means of promoting infrastructure management include pro-actively participating in professional organizations, getting students involved in these organizations, giving invited lectures and inviting speakers to give lectures, and involving undergraduate students in your own research. Participants also highlighted the importance of large-scale projects such as the long-term pavement performance project (LTPP), paper contests, and national scholarship programs.

Research Needs

In the fourth workshop segment, the group conducted a brainstorming session to identify infrastructure areas in need of research. Research needs were discussed from two perspectives. First, a strong research program is necessary for sustainable education programs, as students work on projects and research informs course development. Second, research into how to best educate students in the area is also needed. Twenty-nine research topics in five broad areas, data collection and integration, condition assessment, performance prediction, analysis, and “big picture issues, were identified.

Conclusions

The decline in the number of students interested in infrastructure management that has occurred in the last decade was identified as one potential impediment for the development of this important sector. The *Infrastructure Management Education and Research Workshop* identified causes for this decline in student enrollment, potential solutions for the impediments identified, the role of the different interested parties involved, and significant areas of research focus. The main conclusions of the workshop include the following:

- Careful succession planning and long-term cooperative efforts are critical for advancing infrastructure management.

- The primary reasons for the shortage in undergraduate and graduate students interested in infrastructure management include a lack of understanding about the field, low visibility of the field, and a perceived lack of career advancement opportunities.
- Specific steps to improve the understanding and visibility of infrastructure management include developing standard definitions, communicating the principles of infrastructure management, finding a higher level of research funding, marketing infrastructure management as a “high-tech” field, networking, and promoting success stories.
- The academy, government, professional organizations, and the private sector can facilitate this process by forming alliances for teaching and research, developing and implementing exchange programs, and collaborating to promote the profession among colleagues and the general public.

As a result of the productive interactions among faculty, industry, and government at the workshop, participants undertook several efforts.

- At our request, AASHTO added an education component to the *Transportation Asset Management Today* “Community of Practice” website (<http://assetmanagement.transportation.org>); the area is facilitated by a workshop participant.
- The organizers developed and are maintaining an infrastructure management research and education website (http://128.173.204.63/IMRE_Workshop/homepage.htm).
- Several participants are investigating possibilities for student exchange programs.
- A follow-up meeting, in which several industry representatives participated, was held in January 2004.

We expect this effort to continue; possibilities for future efforts include a technical symposium for faculty and students, developing a list of desired outcomes for infrastructure management education at the undergraduate and graduate levels, and strengthening professional ties through collaborative research and continued workshops.

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