



## **EXECUTIVE SUMMARY**

### **ICIS Workshop on Civil Infrastructure Systems Education**

**June 11 – 12, 1999**

**Held at the Polytechnic University of New York**

Prepared by Professor Roy Sparrow, Director of Educational Programs at ICIS and  
Stephen James, ICIS Research Assistant

With the assistance of Nate Gilbertson, Meloney McGuire, Lisa Bellini (ICIS Research Assistants),  
and Annie Raven (Ph.D. candidate at the Polytechnic University of New York.)

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Any opinions, findings, and conclusions or recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

## **INTRODUCTION**

The Institute for Civil Infrastructure Systems (ICIS) was established in 1998 by the National Science Foundation. Its primary goal is to promote activities that enhance the value of civil infrastructure to the users and to the communities that experience its impacts. Critical to that effort is establishing and promoting a broader context for infrastructure planning and management. Many individuals in academia and industry now recognize that the engineers (and other civil infrastructure systems (CIS) professionals) who are responsible for developing and designing our infrastructure lack the interactive and integrated skills needed to support socially responsive civil infrastructure systems. Since education at all levels is one of the principal instruments for developing and maintaining the knowledge and competence of general citizens as well as professionals, ICIS has developed programs to assess the objectives, content, the methods and impact of the educational programs, including those that train future CIS professionals.

In order to better understand the state of development of higher education programs, ICIS conducted a conference on June 10 and 11, 1999 addressing the higher educational needs of CIS professionals and the success of civil engineering and related programs in meeting these needs. A broad and diverse gathering of educators, industry and agency managers convened to discuss, debate, and deliberate the issues and problems that they perceive as the failures, the needs, and the successes of civil infrastructure systems higher education. The conference was produced under the leadership of Professor Roy Sparrow of New York University, Co-principal investigator of ICIS, and Professor Ilan Juran of Polytechnic University.

The purpose of the workshop was to create a university-industry dialogue on the relationship between the nature of CIS practice and the performance of professional education programs. In other words the workshop asked how well civil engineering programs are doing to address the rapidly changing needs of government and industry. More specifically this workshop had three main goals. First, it provided a venue for a broad-based discussion of the core competencies and skills engineers will need in the future to be effective developers and managers of civil infrastructure systems. Second, the conference brought to light the challenges to innovation and change in the educational system. This was done by examining existing practices in higher education as well as reviewing some alternative and innovative methods that may provide a foundation for future educational approaches. And third, ICIS will use the results of the conference as important input in developing model curricula designed to prepare infrastructure developers and managers who can meet the role and performance demands of modern civil infrastructure systems. The knowledge gained through the workshop will also inform the choice of activities in other ICIS programs as they relate to higher education.

## **CONFERENCE STRUCTURE**

Prior to the conference, ICIS commissioned thirteen papers that were presented during the conference. These papers were written along the three main conference themes and were authored by a diverse group of academic and industry professionals. In commissioning the papers the aim was to have a number of specialists bring diverse perspectives to the question of how to improve the quality and

impact of CIS professional education. The papers also served to broaden the context of the discussion and introduce non-traditional perspectives of engineering education to the conference participants. They served to focus the discussions that followed.

To maximize interaction among participants, the choice was made to have the conference facilitated by Kathy Stein and Arnold Bloch of Howard Stein Hudson Associates. After presentation of each group of papers, open discussions were held in the form of a "Samoan Circle." People rotated in and out of the circle to allow new people to enter the discussion as others left after finishing their comments. This restricted the number of people to eight, allowing for meaningful exchange of ideas and enabling the group to change in composition. After all presentations, the facilitators created a long list of topics selected by the participants. This list was then filtered down to three broad theme areas and these became the focus of discussion for three breakout groups the following day. After reporting their comments, each group retired to their space to create their list of core competencies and skills for future CIS professionals. The conference concluded with final observations and suggestions from the organizers and participants on future directions for the ICIS higher education program.

## PAPER THEMES AND DISCUSSIONS

Papers and discussions were organized around three themes, each focusing on different perspectives or aspects of CIS education. (See Appendix 1 for the full agenda and list of attendees.) These themes were Industry Perspectives on CIS Education, CIS Educational Strategies, and Alternative Perspectives and Innovative Approaches.

The first theme, *Industry Perspectives on CIS Education*, brought "real world" insight into the roles that infrastructure engineers and managers must perform in order to deal effectively with the problems and issues that they now confront and the skills and competencies that are required to meet the evolving role demands. Presenters also identified and examined the performance problems (for both organizations and individual managers or professionals) that have emerged for CIS agencies and the ways in which educational preparation contributes to the problems as well as the ways in which new educational approaches might improve both agency and individual performance. Included were the perspectives both of young and experienced engineers. The principal focus was on the effectiveness of existing educational approaches and methods and the ways in which new approaches could lead to better outcomes for the design, implementation, maintenance and use of civil infrastructure systems.

The presenters under this theme were civil engineers. Importantly they were all in agreement that the context in which civil engineering is now practiced has changed substantially during the past two decades. They also agreed that social, economic and political context for infrastructure decision-making has shifted in ways that compel engineering professionals and managers to incorporate knowledge from these important areas. At the same time the presenters agreed that the level of technical skills imparted to civil engineering students continues to be primary. A key issue for educators concerns development of curricula and instructional methods that maintain high technical competence while preparing engineers to work within and understand the broader social context that will inevitably impact their work. Representatives from the civil infrastructure industry advanced the notion that a disjunction has developed between the industry and the academic institutions responsible for preparing students for careers in infrastructure. This disjunction, they suggest, may have originated

because of the changes in the industry and the environment in which infrastructure is developed with little change in the way we educate those who are mostly responsible for its creation and maintenance.

The papers and discussion under the theme, *Current CIS Educational Strategies*, focused on current non-traditional and innovative education programs in civil engineering. More specifically this session was concerned with examining educational programs that were attempting to provide students with an enhanced knowledge base and broader skills set. Faculty from several engineering schools offered a description of their programs and assessment of their achievements. This examination covered program goals, curriculum components, innovative methods, and the observed results. Importantly, each of these programs, in varying degrees, planned and coordinated with industry partners. The programs discussed were civil engineering programs at the Urban Engineering School of Paris, Tulane University, Colorado School of Mines, and Harvey Mudd College. Elements of the engineering program at the University of Southern California were also examined. All of these universities have initiated innovative programs, some over a decade old, which aim to broaden the values and competencies of civil engineering students. Among the non-traditional goals of these programs are enhanced skills for communicating with external stakeholders, development of a service orientation toward customers and users, appreciation for the values of other disciplines, critical thinking, creative problem solving, developing team skills, and valuing diversity. Several of these programs used well-designed internship and project experiences to help students develop an understanding of the contexts in which their broader skills would be used.

Participants were in general agreement that the constraints to developing and enhancing non-traditional programs are numerous and difficult. These constraints should serve as reminders that the development and increased use of such approaches must be undertaken with considerable care in planning and implementation. For one thing the importance of technical competence is as important as ever. The addition to educational goals of contextual values cannot come at the expense of sound engineering. This will likely mean that innovations in educational methodologies will have to be developed or improved. For another thing the normal resistance to change found in any major strategic shift is compounded in the case of professional education because it is imbedded in long-standing practice, professional codes, and reward systems. Educational institutions have developed missions and programs that focus on a highly technical and theoretical approach to engineering education. Breaking with this practice is difficult.

Finally, any new program is also constrained by the market. When changes are instituted, programs will still be judged by the success of students finding initial jobs often in fairly traditional venues. Though academics may have a vision of the CIS professional they would like to create, ultimately the graduates must be employable or the program will fail. This constraint will place a premium on close coordination with governmental agencies and industry.

Papers and discussion under the topic, *Alternative Perspectives and Innovative Approaches*, introduced views of CIS education from individuals outside of engineering. All of the presenters in this session brought many years of experience in dealing with issues of civil infrastructure. They also approached the topic from diverse perspectives (researchers, planners, social scientists, and administrators). They focused the discussion on several critical issues most of which pertained directly to the issues raised in the previous session. Presenters and discussants agreed that the current state of infrastructure practice presents enormous problems. They also expressed the view that these problems

seem to be less technical than social and political. They agreed that the human side of infrastructure systems— the politics, the social impacts, the economic impacts, etc.— are often more complex and problematical. Nevertheless, few engineers are exposed to alternative views of infrastructure or of society during their education or careers. Most agreed that certain aspects of infrastructure, including aesthetics, history, community context, and customer service are little understood or valued.

Presenters also raised the important issue of who is missing from the civil engineering table. Among major professions, civil engineering remains among the least diverse in terms of gender and ethnicity. The consequences, it was argued, are felt not just in the realm of equality, but also in the absence of new perspectives and approaches. Experimental programs at Cornell and MIT were discussed as offering insight into how to address this critical problem.

Presenters in this session also raised the often heard question, why aren't more engineers in leadership roles in this country? This led into a discussion of the important values and competencies that need to be introduced in educational programs. Among the most important were these: conceptual breadth and systems thinking; appreciation of the value of aesthetics in engineering projects (not simply as adornment, but as an inherent feature of design and context); trade-off thinking in the use of resources (including financial); creative problem-solving; a positive and proactive attitude toward increasing the diversity of people and perspectives in engineering; and the development or enhancement of non-cognitive competencies such as communication, adaptability, negotiation, conflict resolution, and effectiveness in teams. There was agreement that, while all engineers do need to develop strength in these areas, a systematic effort to develop a sizeable group who do have considerable capacity in these non-technical subjects would have a significant professional and societal impact.

## **CRITICAL ISSUES**

During the conference, several issues emerged from the presentations and discussions as the most significant in addressing future CIS educational strategies.

### ***Integration of social skills into engineering education***

The topic that received the greatest attention from most participants was the need to implement a much broader approach to engineering education. There was broad agreement that beyond the range of technical skills taught to engineering students, CIS education must integrate a wide-ranging set of social skills into the required curriculum. The current focus on technical skills that dominates civil engineering education is producing students, and therefore future engineers, who are technically well prepared, but have an exceedingly narrow frame of reference for their work and are often ill-prepared to work effectively within the social context of civil infrastructure systems. Given the multi-stakeholder, multi-disciplinary nature of civil infrastructure work, preparation must impart an understanding of regulatory and institutional frameworks, stakeholder perspectives, finance and economics, team building and many other of the so-called "soft" skills. The ability to communicate effectively with (and to listen to) a diverse group of stakeholders was considered by many as the primary skill that engineers currently lack and that future CIS professionals must possess.

### ***Engineering faculty - industry disconnect***

The performance criteria for faculty at engineering schools place primary emphasis on research. The careers of most faculty develop with this motivational emphasis clearly in mind. But the research orientation, leading to a strongly theoretical course load for undergraduates, is creating a disjunction between engineering faculty and the industry that generally employs those engineering graduates. Industry continues to change in response to infrastructure's changing social, political, economic and technical environment, yet because of this disjunction, academia is not accomplishing a corresponding change. Establishing a partnership type arrangement between academia and industry was suggested as one possible solution to maintaining a connection and ensuring that engineering graduates are better prepared for the realities of their future careers in infrastructure. An additional consequence of the predominant emphasis on research and theory is that the educational process itself maintains its traditional orientation toward a lecture-based, technically narrow pedagogy. The creative energy needed for curriculum change and innovation is largely absent from the teaching and learning process.

### ***Engineer or non-engineer?***

A contentious issue that prompted more questions than solutions was the debate over whether future infrastructure managers and developers need an engineering education as the foundation for their careers. Framed in a broader context, the question can be posed this way: is it desirable to focus on the development of a new type of professional – an infrastructure systems professional – or are incremental changes to existing civil engineering programs adequate? There is also the question of professional certification and whether it should be required or if it is even necessary at all. This very fundamental issue has significant bearing on the structure and content of any educational strategy aimed at creating better infrastructure managers and developers.

### ***Engineering leadership***

Many participants expressed a concern about the gradual loss of leadership roles for engineers in the infrastructure area. Important decisions in infrastructure are no longer the province of the engineer and many young engineers, as a survey report indicated, interpret that as lack of recognition and influence among other professionals. The diminished influence and visibility of the engineer has weakened the attractiveness of civil engineering both among potential students and the public at large. This important perceptual change leaves the future role of engineers in question. As noted above there remains the important question of how best to prepare engineers and other civil infrastructure professionals for leadership roles.

### ***Continuing education***

Underscoring the need for a better connection between academia and the industry is the demand for continuing education. Participants from industry all articulated the need to properly consider the coordination of continuing education goals into any new CIS program that may be developed. Some participants expressed their concern that the continuing education that industry now provides is mostly to fill in the gaps left by the undergraduate institution. But the dynamic nature of infrastructure systems requires a dynamic skill set maintained and continually improved through an enduring learning process. Successfully developing a CIS professional requires an integrated program of lifelong

learning, a careful collaboration between academics and industry professionals. What was left unresolved, however, was the debate over the degree of involvement by academics in a continuing education program, control of the content of the program, and the use of alternative teaching methods such as team teaching and distance learning.

### ***Community awareness of infrastructure and the role of engineers***

While there was much concern about the engineer's lack of appreciation of the concerns of the communities in which infrastructure is located, and their need to develop skills in dealing with community issues, there was also a concern that low public awareness of the value and importance of infrastructure remains a significant barrier to coordinated renewal of urban infrastructure. This issue also impacts the development of viable CIS educational programs. Participants expressed the belief that increasing the public's awareness of and interest in infrastructure will aid in attracting future students to a CIS program. Further, under more positive circumstances new students could enter programs with a sense of the community perspective of infrastructure. To change this situation a better understanding of its causes is essential. While there was not complete agreement on the causes, a number of possible explanations were advanced. Some participants expressed the view that the absence of mutual appreciation between engineers and the public can be attributed to the very narrow and highly technical training that engineers receive. Some expressed the view that another important perceptual barrier that militates against the profession's ability to attract a larger and more diverse group of young people, namely the continuing perception of the engineer as nerd or loner.

Whatever the causes, there was complete agreement that an essential facet of the future education of CIS professionals must be community awareness. Strong support was also expressed for the need for raising the awareness of the public about infrastructure and engineering, and while this view was acknowledged, it was not developed since it was outside the scope of the workshop.

### ***Academic program stakeholders***

Like infrastructure systems themselves, to be effective and meet the complex and changing requirements placed on them, the redesign of educational programs must take into account the stakeholders of the larger systems that form their contexts. While all of the important end users of innovative CIS educational programs are difficult to identify, many of the key stakeholders are known. They include the students themselves in civil engineering programs, alumni, employers in government and industry, the users of civil infrastructure systems, related infrastructure disciplines, professional societies and governmental funders, authorizers, and regulators. While no one expects educational programs to take into account the diverse and often conflicting perspectives of all stakeholders, it is clear that most programs take into account relatively little outside information. Effective change happens, however, only when organizations invite performance assessment from outsiders. In the case of most higher education programs this would mean a sea change in the normal way of doing business. In view of the decline of the civil engineering profession in recent decades, some workshop participants believe that this is an important avenue for exploration.

## CORE COMPETENCIES

A list of Core Competencies for Infrastructure Systems Professionals was developed as a foundation for a new curriculum. A collective effort involving all participants, creation of the list was one result of the second day of the conference. Following is a summary list of the competencies and skills that the conference participants regard as necessary for future CIS professionals.

*Communication skills* – The ability to listen to stakeholders and to skillfully communicate the importance of infrastructure to politicians, stakeholders, taxpayers, etc.; the ability to make themselves understood.

*Recognition and Inclusion of the Perspective and Values of Stakeholders*– An open mind sensitive to alternative viewpoints, trying new methods, listening to stakeholders instead of just selling projects to them, understanding the abilities and contributions of other disciplines (e.g. architects and artists), and understanding the needs and preferences of diverse and multi-cultural communities.

*Integration Skills* – The ability to integrate knowledge in wide range of areas –technical, political, economics, community skills, to integrate multidisciplinary teams, to integrate and manage conflicting interests and goals; an understanding of strategic change in the infrastructure area and the need for improved organizational processes and structures to implement strategic change.

*Economics/Finance/Accounting* – The ability to understand and create capital budgets, long-term financing, asset management, life-cycle costing.

*Law and Policy* – An understanding of the regulatory and institutional frameworks; an understanding of policy rationales, objectives and frameworks

## NEXT STEPS

Participants agreed that a great deal of research needs to be done to better understand the evolving roles required for effective performance in the renewal, maintenance, and use of civil infrastructure systems. They also recognized the difficulty of educating students who are both technically competent and socially aware. At a minimum an extensive experimentation in the CIS educational arena is in order.

ICIS is committed to furthering both the experimentation and dialogue. Educational units at the University of Southern California, Polytechnic University, and New York University are currently planning or implementing innovative programs that aim to deal with some of the challenges described above. The nature of these experimental and model programs will be reported at future conferences and on the ICIS website.

## AGENDA

### FRIDAY – JUNE 11, 1999

- 8:00 am - 9:00 am      Breakfast/Check-in
- 9:00 am - 9:15 am      Welcome  
                               *Rae Zimmerman*, Director of ICIS  
                               *Ilan Juran & Dipak Roy*, Conference Organizers, *Roy Sparrow*, Director of  
                               Education Programs, ICIS
- 9:15 am - 9:45 am      Participant Introductions  
                               Facilitators: *Kathy Stein & Arnold Bloch*, Howard/Stein-Hudson Associates
- 9:45 am - 11:15 am     Session I: Industry Perspectives of CIS Education  
                               Introduction, *Ilan Juran*  
                               Presentations:  
                               *Lisa Bellini*, Study of Young Professionals' Experience in the Workplace  
                               *James Matteson*, The Engineer's Dilemma – The Educator's Opportunity  
                               *Annie Raven*, Summary of Industry Perspectives: The Executive's Point of View  
                               Other Perspectives: *Gene Fasullo*, *Robert Gaffoglio*, *Arthur Kressner*  
                               Response and Discussion
- 11:15 am - 11:30 am    Break
- 11:30 am - 1:00 pm     Session II: CIS Educational Strategies  
                               Introduction, *Dipak Roy*  
                               Presentations:  
                               *Sophie Banette*, The Paris Urban Engineers School  
                               *Cameron Gordon*, Educational Requirements for CIS Managers: What Should  
                               They Know and When Should They Know It?  
                               *Jack Grubbs*, CIS Engineering Education: A Target of Opportunity  
                               *Barbara Olds*, Integrated Engineering Education at the Colorado School of  
                               Mines  
                               *J. Richard Phillips*, The Harvey Mudd Way  
                               Response and Discussion
- 1:00 pm - 2:00 pm      Lunch  
                               *George Bugliarello*, Chancellor, Polytechnic University of New York

2:00 pm - 3:30 pm	<p>Session III: Alternative Perspectives and Innovative Approaches</p> <p>Introduction, <i>Roy Sparrow</i></p> <p>Presentations:</p> <p><i>Nancy Rutledge Connery</i>, Shaping an Ecological and Aesthetic Perspective in Civil Engineering Education and Practice</p> <p><i>Ezra Ehrenkrantz</i>, Planning in a Period of Discontinuity</p> <p><i>Judy Jackson</i>, Theory and Practice: Confirming Students' Interest and Holding Their Attention</p> <p><i>Richard Little</i>, Educating the Infrastructure Professional: A New Curriculum for a New Discipline</p> <p><i>Richard Wener</i>, Integrating Aspects of the Humanities and Social Sciences into Engineering Design: A Multi-Disciplinary, Team Taught, Project Class</p> <p>Response and Discussion</p>
3:30 pm - 3:45 pm	Break
3:45 pm - 5:30 pm	Reporting Session: Framing the Issues
6:30 pm	Dinner at Gage & Tollner Restaurant

**SATURDAY – JUNE 12, 1999**

9:00 am - 9:45 am	Breakfast/Check-in/Review of Day 1 and Revision of Issues and Direction for Day 2
9:45 am - 11:00 am	Working Group I: Issues and Key Questions from Day 1
11:00 am - 11:20 am	Brief Reports and Adjustments
11:20 am - 11:30 am	Break
11:30 am - 12:45 pm	Working Group II: Consensus Points, Major Topics and Questions that Require Attention, Specific Pilot Program Ideas, Other Contributions
12:45 pm - 2:00 pm	Lunch and Reporting Plenary Session
2:00 pm - 2:15 pm	Closing Remarks

## LIST OF PARTICIPANTS

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## **ICIS EXECUTIVE COMMITTEE, PARTNERS AND STAFF ATTENDEES**

### *Conference Program Coordinators:*

- Roy Sparrow, Co-Principal Investigator of ICIS, and Professor of Public Administration, New York University
- Ilan Juran, Professor of Civil and Environmental Engineering, Polytechnic University of New York

### *Conference Facilitators:*

- Kathleen E. Stein, ICIS Management Advisory Board, and Principal, Howard/Stein-Hudson Associates, Inc.
- Arnold Bloch, Principal, Howard/Stein-Hudson Associates, Inc.

### *Executive Committee Members:*

- Rae Zimmerman, Director and Principal Investigator of ICIS, and Professor of Planning and Public Administration, New York University
- Nancy Rutledge Connery, Infrastructure Specialist
- John Falcocchio, Professor of Transportation, Polytechnic University of New York
- James Moore, Associate Professor of Civil Engineering and Public Policy and Management, University of Southern California

### *Other ICIS Partners in Attendance:*

- Dipak Roy, Professor of Civil and Environmental Engineering, Polytechnic University of New York
- Richard Wright, ICIS Technical Advisory Board, and Former Director, Building and Fire Research Laboratory, NIST
- Patrick Killackey, ICIS Project Manager
- Courtney O'Reilly, ICIS Administrative Aide

### *Research Assistants (NYU and Partnering Institutions):*

- Lisa Bellini
- Nathan Gilbertson
- Stephen James
- Meloney McGuire
- Annie Raven (Polytechnic University)