VIEWPOINT

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INFRASTRUCTURE: INTEGRATED ISSUE OR TOWER OF BABEL?

By Neil S. Grigg

INTRODUCTION

Although the term ''infrastructure'' is used to describe policy issues, it has not been well accepted as a description of technical and management work in the diverse sectors of the infrastructure arena. This nomenclatural problem, which might seem unimportant, actually inhibits dialogue and cooperation and raises questions about the very notion of infrastructure as an integrated issue. This is a very important problem for civil engineers who, while seeking to take the lead role in infrastructure, are not always able to explain clearly what this key role is about and, consequently, may fail to grasp its full significance.

TECHNICAL, MANAGEMENT, AND POLICY WORK IN INFRASTRUCTURE

How did this problem arise? To begin with, infrastructure has a complex definition, which keeps changing. Then, too, infrastructure is actually a high-level issue and seems distant from the conceptual worlds most of us inhabit. Work on it takes place at several levels—by construction workers and road crews, by engineers and planners, by public works managers, and in congressional committees—but most of these would use terms other than ''infrastructure'' to describe their work. The term ''infrastructure'' would be at best a second- or third-order identifier, sort of like, ''I live in Philadelphia, and, yes, I am a citizen of the world, now that I think of it.''

For civil engineers, this is especially important because the public has a narrow image of our work, and to remedy that, the American Society of Civil Engineers (ASCE) has adopted the term infrastructure to broaden our image beyond the dictionary definition: ''engineers who design and construct public works'' (*Webster's II* 1984; ASCE 1999). However, if we place our bet on a term that people do not accept, we send a confusing message.

Gordon (1999) recently explained how this message is increasing in importance and how requirements on engineers who manage infrastructure have changed. Such engineers must be jacks of multiple trades; they must understand complexity and system impacts; they must manage the old as well as build the new; they must know more about governance and politics; they must know more about economics and finance; and they must know what is happening outside their disciplines. Gordon's points are not new, but they underline again for us how civil engineers are looked to for solutions to increasingly complex problems.

Many signs show that, when infrastructure problems are discussed in public forums, the main spotlight is not on technical issues but on problems such as finance, public acceptance, and environmental impacts. These problems, which deal with systemic effects rather than component parts, are the front lines of the infrastructure issue arena and explain why a panel of the National Science Foundation (*Civil* 1993) wrote: ''infrastructure problems are 95% social, economic, and political, and only 5% technical.''

These facts explain why infrastructure management problems, which require broad skills and experience, compel civil engineers to compete with others for positions such as public works director. The point is—once you leave the technical arena, the advantages that civil engineers have by virtue of education and aptitude diminish.

This presents a dual problem to the civil engineering profession. On the one hand, infrastructure problems badly need solutions; on the other, civil engineers seek leading roles in solving them but face significant barriers due to competing and confusing roles. To solve these problems, we need to clarify infrastructure as an organizing concept for work and articulate a broader view of the work of civil engineers.

CLARIFYING INFRASTRUCTURE AS AN INTEGRATED ISSUE

At its root, the problem begins with definitions of ''infrastructure'' (Grigg 1988). These vary, but they converge on defining infrastructure as ''physical assets arrayed in systems that provide essential public services.'' This is a very general concept, and if a civil engineer explained, ''I design assets arrayed in systems, which provide essential public services,'' the listener's eyes would glaze over quickly.

Actually, the problem has even deeper roots, which arise

from the very complexity of infrastructure systems. ''Infrastructure'' is actually several conceptual levels from the spheres where most engineers work. At the highest level is the ''civil infrastructure system (CIS),'' a framework used by the National Science Foundation (1995) for research. Next is the ''industry level,'' which includes transportation, communications, water, energy, waste, and build areas as systems. These have subindustries, e.g., highway transportation, air transportation, and water transportation, which have their own government agencies, regulatory laws, and trade associations. These involve ''engineered systems,'' such as source, treatment, and distribution systems for water. These, then, break into components, which are the ''assets'' of infrastructure, such as pavement, bridges, and individual buildings and which themselves can be subdivided further.

In spite of its shortcomings, we will probably not find a better word than infrastructure, and, given its complex, multilevel nature, the way to clarify it is to give meaningful examples; otherwise, dialogue will be ineffective. A good place to begin is with our technical publications.

These publications reveal the communication problem in several ways. Years ago, the cover of *Civil Engineering* magazine had terms such as ''design and construction.'' Then, it added ''environmental design,'' then ''engineered design and construction.'' Today, the terms are gone and it only says ''civil engineering.'' *ENR* magazine is ''The Construction Weekly.'' None display ''infrastructure'' on the cover, probably proving that publication experts understand the ambiguity of the term.

Journals are not read by large numbers of people, but they provide a forum to work out ideas about integrating the complex and multilevel nature of infrastructure work. Both ASCE's *Journal of Infrastructure Systems* (JIS) and the American Public Works Association's (APWA) *Journal of Public Works Management and Policy* (JPWMP) cover all infrastructure systems. JIS was first published in 1995 and by the end of 1998 had published 97 papers, with the largest number about ''hard'' management and maintenance topics such as condition assessment, computerized management systems, and nondestructive evaluation. Examples in these papers refer mostly to single categories, such as bridges, pavement, or water systems, and little ''cross-talk'' among the categories is evident. It is actually an ''interindustry'' version of the ''interdisciplinary'' communications problem.

JPWMP started publication about the same time as JIS and published 82 papers in the same period. Its largest category, with 27 papers, was economics and finance (which also attracted 11 papers in JIS). The other main category of overlap was planning and policy, where JPWMP published 18 papers and JIS published 27. These papers address infrastructure as a unified system and include topics such as economic development, urban and regional planning, policy analysis, and risk analysis.

According to ASCE, circulation of JIS is about 1,200, as compared with 4,000 for their *Journal of Structural Engineering* and 1,000 for *Cold Regions Engineering*. JPWMP is still establishing its circulation, after a period of free distribution to American Public Works Association members, but a circulation of 2,000 would be considered good. Given that many of the subscriptions are to libraries and agencies, one might conclude that not many people read these journals, and it is widely believed that the journals are a method for researchers to talk to each other.

On the other hand, journals in separate infrastructure categories, such as the *Journal of the American Water Works Association* (AWWA), cover topics within a single industry and have greater circulations, being targeted at multiple levels. For example, AWWA's membership of 50,000 in the drinking water community includes treatment plant operators and managers, scientists, environmentalists, manufacturers, academicians, regulators, and others who hold genuine interest in water supply and public health (''AWWA'' 1999).

This limited evidence suggests that the number of readers interested in the ''big picture'' of infrastructure is quite limited and that scholarly activities take place more at the detailed levels of infrastructure. Also, cross-talk between categories, or ''technology transfer,'' to use a fancier term, does not appear to be operating very vigorously, at least for technical issues. The most serious problem is that not much dialogue about infrastructure as an integrated issue is apparent.

WORK OF CIVIL ENGINEERS

In articulating a broader role for civil engineers, we must begin by affirming the critical importance of our technical work—design, construction, and care of civil facilities. However, as infrastructure systems become more complex (as measured by urbanization, advancing technology, and shear magnitude), the management and regulatory roles of civil engineers must expand or others will fill the vacuum. In other words, we have to work harder—and smarter—just to stay even.

Looking at where the nation's some 185,000 civil engineers work, we see that most are in the engineering services (44%), followed by state and local government (32%). These are followed distantly by federal government (7%), construction (6%), manufacturers (4%), and electric, gas, and communication utilities (2%) (Ellis 1997). It is difficult to separate the technical work from the management work of these civil engineers, but clearly, this work force has a major impact on the nation's infrastructure. It can be argued that no other group of workers has nearly as much influence.

The other point that is evident from employment statistics is that the role of the civil engineer in local infrastructure—where the shootouts occur—has become more critical, as measured by the large number of engineers working in consulting and in local government. Look at any local infrastructure situation and you will find abundant opportunities for engineers to take lead roles in defining issues, creating solutions, explaining these solutions to the public, and leading the process to implementation.

So, if infrastructure work is more nontechnical than technical, and if civil engineers dominate the infrastructure sector, then improvements in it will depend on civil engineers gaining more skill in nontechnical arenas such as public acceptance, finance, impact assessment, and systems integration. This was outlined by Gordon (1999) in his suggested new curriculum, which would include a focus on infrastructure as an integrated whole, including provision of key contextual information about society, politics, and economics; finance and accounting; and recognizing the larger world.

INTEGRATING THE INFRASTRUCTURE ISSUE

To sum up, I have argued that, while the term ''infrastructure'' is used to describe policy issues, it has not been accepted for technical and management work in the trenches because of its complex definition and multiple levels and sectors. For civil engineers, this is especially important, because when we try to use the work to overcome our narrow public image, we imply that we have the lead in infrastructure—but others see the field as primarily social, economic, and political, not technical.

To make progress on this problem, we need to articulate a broader view of the role of civil engineers in the infrastructure arena, beginning with clarification of the nature of infrastruc-

ture work. A good place to begin is with our technical publications, such as this journal. While readership of these publications is quite limited, they at least enable us to establish a common base of understanding.

Clearly, no other group of workers has as much influence on the nation's infrastructure as the civil engineering workforce does. The future will require civil engineers to adapt to complex, confusing, and exciting new opportunities in infrastructure. The problems that civil engineers will face are not simple, and any course of action directed at them must be comprehensive. We should start cutting the ''fog factor'' of the term infrastructure by giving examples, moving away from philosophical discussions to explain clearly how infrastructure problems in different categories face common cross-cutting issues such as operations management, maintenance, economic and environmental impact, financing policy, and public involvement techniques. Finally, taking leadership in solving integrated problems is required. This sequence—understanding problems, clarifying the integrated nature of infrastructure, and setting roles and responsibilities for engineers—should lead to better policy, improved cooperation, and programs of research, education, and action to solve the nation's infrastructure problems. Let's get a clear view of civil infrastructure systems and help society work better.

APPENDIX. REFERENCES

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