A Framework for Developing a Future Transportation Research and Development Agenda

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"I know of no safe depository of the ultimate powers of society but the people themselves."
Thomas Jefferson

Now in its third century as a nation, United States citizens too often indulge in an excess of shallow, misleading, and unhelpful ways of thinking and talking about research, both in public and private contexts. As a result, research output often is of indifferent quality and quantity; consequently, so is research support.

Examining these traits we find the following: (*a*) shallowness as evidenced by unprincipled, fragmented, narrowly drawn, and incoherent research programs; and (*b*) misleading spoken and written words, especially to the degree that the highly tenuous link between research and innovative products, and thus the uncertain potential for real benefit, is not communicated with clarity and candor. Finally, for all research and development (R&D) flag-waving, there is no clear, principled, and helpful vision for advancing a national transportation research agenda to ameliorate these doleful circumstances or to integrate and accelerate the flow of innovation. (A January 19, 1995, report, *Special Report on Transportation R&D Priorities,* by the National Science and Technology Council's Committee on Transportation R&D, provides hope for stronger national direction in these matters.)

Despite all this, some say that the United States enjoys transportation systems that, with few exceptions and not withstanding considerable public grumbling, meet most of our social and economic needs and expectations. All this happens within increasingly severe fiscal and environmental constraints. The many defenders of the status quo will maintain, with brash immodesty, that the current U.S. transportation system excites nothing less than global envy! Indeed, they will say, the United States owes much of its present prosperity and well-being to the efficiency and effectiveness of its transportation system.

We must ask, therefore, Does all this breast-beating about transportation research really matter, or is it just another special pleading? To answer forthrightly: yes, it is a special pleading, and beyond any reasonable doubt, it matters. Clear thinking, speaking, and writing about the future transportation research agenda is essential because this agenda, both

basic and applied, along with a clear understanding of the processes linking it to successful application, must frame and facilitate new technological developments. These developments can, and must, make more effective the transportation systems on which the social, environmental, and economic dimensions of society increasingly depend.

However, before launching into the process of developing a future transportation research agenda in response to what we perceive as a clear public need for technology, our community of transportation interests would do well to inquire more broadly concerning other perceptions of these matters. In his new book, *Cleopatra's Nose—Essays on the Unexpected,* Daniel Boorstin considers "our conscience-wracked nation," saying, "We are a people haunted by past injustices and fears of future injustice. And against these evils we seem driven to find . . . panaceas" (*1*). We should be cautioned, then, that what we transportation professionals look back on as great progress, many citizens look back on as "haunted"—a past filled with transportation-related injustices. More at issue here is their fear of future injustice—even evil—from transportation research and its unknown offspring.

In 1988 Paul Gray, Former President of the Massachusetts Institute of Technology, addressed this matter during the 24th Annual Meeting of the National Academy of Engineering. In his paper *The Paradox of Technological Development,* Gray acknowledged the mixed blessing of almost every technological development, with examples from transportation, communication, food, and energy production (*2*). He listed how technological developments feed public fears:

- Major new technological developments produce changes that deeply affect society and often do so in ways that make it impossible to turn the clock back by rejecting the development.
- Because we live on a crowded planet, the consequences of technological development have a more immediate and far-reaching impact and are more readily apparent than they were in earlier times.

According to Gray, "The paradox of technological development is compounded by public perceptions about risk and by the fact that we lack an effective system for developing public policies to help guide technological development, particularly as we face these issues as a global society." He compares new ideas and technologies that stem from the efforts of engineers to the golem of the Rabbi of Prague—"an artificial creature, created to serve, the Golem exhibited a mind of its own, acting in mischievous ways, unanticipated by its maker." It is the many well-recognized golemlike attributes of transportation advances that make it appropriate to lay out this reality before discussing future transportation research agendas. Our suggested remedy is to broaden inputs, giving early, clear public voice to these concerns.

To gain public acceptance for necessary major changes in transportation (e.g., change toward greater sustainability), there is yet another context discussion that is necessary. This discussion is advanced by some with the question, How do we break out of what we know? In his book *The Day the Universe Changed,* James Burke posits that at any time in history there have been closely held views on how the universe works and that there are clearly defined moments in time when these views changed (*3*). "Like the people of the past," he says, "we disregard phenomena which do not fit our view because they are 'wrong' or outdated. Like our ancestors, we know the real truth."

The problem of gaining public support for change has been articulated in the transportation context by Thomas Deen, former Executive Director of the Transportation Research Board (TRB). A recent article by Deen and Skinner predicates, on two key assumptions, the paradigm or model of how transportation changes are made in times of normalcy and in times of crisis (*4*). "First, no technological breakthrough will occur that significantly alters the role transportation plays in environmental and energy problems. . . . Second, an array of modest, incremental changes to the transportation system currently under way . . . will be insufficient by themselves to achieve a sustainable transportation system."

Both references suggest that, apart from operational factors, real innovation is difficult to realize because it lacks an "enabling environment." According to Deen and Skinner, "A

substantial part of the debate about transportation policy today tends to focus on how to balance our desire for mobility (broadly defined) and our desire for sustainable development." Given the interminable discussion and the less helpful posturing on these vital matters, they see value in conducting research that seeks incremental improvements and in examining the conditions that could lead to crisis and thus force radical innovation. Although there is no magic to dispel this difficulty, we believe that aggressive interaction with the public is the best option.

There are many weaknesses in our research debate and practice. Despite these weaknesses, U.S. transportation, on the whole, has served us well. Still, and beyond reasonable doubt, an infusion of innovative technology and new ideas that reach out to the broad context of transportation is needed to maintain and improve services. This infusion may be interrupted by a conscience-racked and self-satisfied public, unless there is more effective and extensive involvement of the public in setting the research agenda.

So how are we to proceed? Can we do better? Can we reconnect with principles and posit a vision and processes to drive development of a transportation research agenda—an agenda that is (*a*) responsive to public concerns and expectations, (*b*) technically competent, and (*c*) future oriented and that produces innovative products? Finally, can we agree on performance assessment measures to enhance output from future transportation research? The following advances these complex and necessary elements and describes several research programs worthy of emulation.

Reconnecting with Principles

Remembering who and what we are as a nation—and taking note of Thomas Jefferson's injunction concerning the proper locus of power—is an essential first step in coping with current transportation issues. Reconnecting with principles provides the only platform strong enough to launch a new, empowering transportation research framework and vision.

To grasp the principles to which we must bind ourselves anew, we can do no better than to turn to our first national documents, the Declaration of Independence and the Constitution. The authors of America's charter documents sought to identify ways to unite a people as a nation and to serve that people. The Declaration of Independence established the nation on principles unbounded by a specific people or geography. It addresses laws of nature, respect for mankind, and inalienable rights. Common to these concepts is concern for all people. During the debate on the Constitution, James Madison articulated the importance of transportation in binding the states together as a republic and made a provision for this service under the general welfare clause (Article I, Section 8). From our beginning as a nation, therefore, there has been an understanding of the relationship between transportation, the unity of the republic, and the well-being of all people.

We focus here on the difficult notion of "all people." To be responsive to this charge, public involvement in transportation, and by logical extension in transportation research, must extend beyond current mechanisms. Principled research, which reflects root, national principles, is guided by exceptional efforts to listen and respond to the widest possible profile of issues from all citizens.

A Principle-Based Vision for Transportation Research

To bring clarity and power to future transportation research agendas, we offer the following vision statement:

> A principle-based, future-oriented national transportation research program for the United States will, by aggressive outreach to citizens, be shaped so that it nourishes, advances, and integrates—for greater effectiveness—transportation services. Such a program will provide for the welfare of all people, binding the nation together. The

future national transportation research agenda will reflect the critically important private-sector role, particularly as it can "pull" technology into practice. It will recognize, and in holistic ways be responsive to, broad social, economic, and environmental considerations within our nation and among the community of nations.

Getting the Processes Right

At the beginning, we labeled many research discussions as misleading because the processes linking research and profitable adoption of innovative products, which are not perfectly understood even by experts in the field, too often are treated as trivial—or are overlooked entirely. This allegation has obvious impact on the success of any research effort and therefore must be considered in building a research agenda. Two particular relationships within the linking processes must be understood. We also need a working definition of innovation.

Dealing first with definition, we define "effective innovation" as a process that results in new ways of doing things and new ways of using resources to produce better products and services, at reduced costs.

The first of the two relationships in need of clarification is the relationship between research and innovation. One may observe that research costs money and innovation saves money; however, there is much more here. Common wisdom says that the strategy to follow for increased innovation is increased research investment. But Stanford University professors Stephen J. Kline and Nathan Rosenberg have noted, "Contrary to popular wisdom, innovation is not a linear process leading directly from research to development, production and marketing. It is (rather) inherently uncertain, somewhat disorderly, involves some of the most complex systems known, and may consist of changes of many sorts at many different places within the innovating organization." They add that, although research sometimes makes major innovation possible, research more frequently is used to solve problems along the chain of innovation, from initial design to finished production processes.

Again, contrary to common wisdom, research often is not the initiating step in innovation. Instead, the initiating step can be a design—a new combination of existing products and components, rearrangements of processes, and new equipment within, but extending beyond, the existing state of the art. The elements of successful research generally are known; the actions required to strengthen the flow from research to innovative products are more free form. The actions include the following:

- Providing numerous means for feedback that link research to production and marketing, visualizing as the end product a catalog of research/innovative products;
- Developing specific research efforts to nourish a process for major change (e.g., design change);
- Establishing research intended to produce innovative products alongside powerful streams of basic research; and
- Being alert for the by-products of the mainstream effort, which may lead more rapidly to innovative products than the main effort.

The second process to be clarified links innovative products to application. Good ideas and products bound up in reports or patents do no good. Holding out reports as products justifying research expenditures, and counting on conventional technology transfer processes to bring new technology to application, must be replaced by something more effective. The answer, we believe, lies in finding forces that will pull innovative products and new technology into service.

Robert Malpas, in the spring 1994 issue of *The Bridge,* says, "Technology supply is potentially plentiful. We need to learn how to increase demand pull, which is very much an issue of attitude and process within industrial companies, and how companies link to the technology supply sources, both internal and external (*5*). For the private sector, says Malpas, the clear motivation to pull technology into application is the enhancement of products

in order to increase sales and customer satisfaction. Malpas says, "To create and harness technology one must travel to and fro along a route. At one end is the domain of science, in the middle is the domain of technology, and at the other end is the domain of business." He recommends strongly that small- and medium-size enterprises be tutored in specific methods for understanding and traveling from one end of the route to the other, to improve their profitability and earnings (i.e., the technology pull).

But there is the different and more difficult matter of getting innovative products into public service, where there is no explicit profit or earnings to provide pull. What then? Clearly, there remains the vital, and too often overlooked in the public sector, matter of customer satisfaction. Public servants are increasingly being called to account on this score and therefore will become more receptive to innovation. But this process will be slow and uncertain. More is needed to increase pull. Under the broad and often misused concept of privatization—turning all or portions of activities now in the public domain over to business—profit and customer satisfaction are linked, and technology pull, therefore, is enhanced. Increasingly, private industry experience with nontraditional teams indicates their potential to bring new strengths to research design, emphasizing real-world testing and evaluation.

Another option is the development of public-private partnerships that can keep research efforts focused on technology with a high probability of application. ITS America is a highly relevant, contemporary example of this option. The organization connects government and industry in a goal of providing improved customer services. This experiment deserves support and careful watching.

The critically important matter of technology pull in the public sector may be the pivotal issue in justifying things such as government-backed (to some carefully defined limit) infrastructure banks, which serve to encourage a larger private role in transportation. Within and beyond these options, much more needs to be done to create forces for pulling technology into service for the public.

Getting back to the question of devising successful frameworks for future research agendas, does all this discussion of process matter? Yes, because it is at the agenda-setting stage when outcomes must be considered, when the persons who must walk the route from research to product application and profit, however defined, must be involved, and when the cost of all this must be carefully considered.

Shaping Transportation Research Agendas

Before suggesting any new frameworks for building future transportation research agendas, it is useful to examine several frameworks that have helped shape some of the more successful research programs in the past.

- The first framework for our past research success might be called the "no-framework" framework. Somewhere, at some time, we are using every approach, every process, and every type of institution in pursuit of successful research and innovation. Although much success has been achieved, it has been prohibitively expensive. In addition, this no-framework framework often has been unprincipled (i.e., disassociated from our national values and transportation realities).
- The Strategic Highway Research Program agenda was shaped by an interactive process among a large number of "owners." Agenda setting involved discussion of process, players, and budgets. The program has produced a catalog of innovative products and aggressive processes for application.
- Private companies—3M, for example—invest human and financial resources to stay close to lots of customers. Each year 3M expects 25 percent of sales to come from new products. Customers drive the agenda. From its customers, 3M gleans new ideas and target markets in which to achieve this remarkable goal.

- The search for greater transportation safety has been a major framework for setting a massive research agenda in all modes. This has been, in our terminology, a "principled process" in that it responds to a need of all people at the most fundamental level of government responsibility.
- The Federal Highway Administration (FHWA), locus of a venerable research program, has established, with the assistance of TRB, the Research and Technology Coordinating Council. This council is charged with providing a framework for shaping FHWA's research agenda. In the search for more holistic, principled transportation research, we suggest that the effort be broadened from highway research to surface transportation research.
- Selection of transportation centers of excellence and National Science Foundation centers provides a framework for agenda setting. Each center is assigned a research scope developed by an advisory body. The tendency for these centers to be made up of special interests limits the degree to which they achieve success by measures suggested here.
- The National Cooperative Highway and Transit Research Programs, administered by TRB, have a process, a framework, for setting agendas. The programs depend on committees of technical experts and therefore meet an expert's assessment of criteria, although they might not fully meet our citizen input criteria.
- TRB and its remarkably extensive committee structure, extensive in both scope and numbers, provides a powerful framework for research agenda setting. Because the work of the committees inevitably shapes particular agendas, holistic program development may be constrained. The TRB Executive Committee produces, on an intermittent basis, a listing of critical issues in transportation. This listing, which is based on wide outreach, is processed through an increasingly diverse committee membership.

This sampling of agenda-setting frameworks helps define the elements to be considered when looking to the future.

Recommended Framework for Future Transportation Research Agendas

We have touched on the elements essential for building a successful national transportation research agenda and provided several examples of frameworks. We now will summarize these elements and suggest a generalized framework likely to be successful in delivering them. It should be clear, however, that the ability to deliver the elements is, by definition, the key summary performance measure for any agenda-setting framework. Elements of an effective framework include the following:

- An unambiguous, visible connection and responsiveness to the basic principles of our society. Transportation, and hence transportation research, must focus on maintaining strong ties for binding the republic together and on providing every individual safe access to work, health care, recreation, and other basics of living. Transportation research must focus on enhancing economic competitiveness by providing a timely response to market opportunity. Transportation research must focus on supporting security through the capability of quick response to threats within and beyond our borders. Transportation research can help link our nation with other nations in a global marketplace of shared opportunity and shared environmental responsibility.
- Responsiveness to citizen customers, which demands listening to them. Virtually all citizens have transportation expertise in some area, and this expertise must be integrated into the research agenda–building process.
- Continual updating of the vision for transportation, which must drive the effort. This is important because America is a land beneficially tied to principle and vision.
- Execution of transportation research that yields and applies innovative technology and ideas, which can improve effectiveness, build public support, and provide needed resources.
- Technical competence, broadly defined, and uncompromised integrity. Competence and integrity must invite challenge—and so be strengthened.

- Emphasis on "search," looking toward the horizon so that the inevitable lead time required to produce innovative products is minimized and so that research appears credible to our increasingly sophisticated citizen customers.
- Private-sector involvement in setting the transportation research agenda and in carrying out the work. This is important because technology will flow best to transportation if it is pulled to that purpose.
- Encompassment of the larger, economic, ecological, and social systems affected by the transportation system.

Getting down to the bottom line is, in this instance, quite easy. We believe that the ingredients for rounding out and making acceptable many existing frameworks for research agenda setting are more intensive interaction with and more careful listening to all citizen customers. We believe that this is in keeping with Mr. Jefferson's advice. Although easy to say, it is a demanding and expensive requirement. We have learned a lot about public outreach, but we need to learn more and practice what we have learned. This is the only sure route to principled research agenda setting.

Performance Measures

How are managers, sponsors, and citizens to know when the transportation research agenda and research programs are the right ones? Ultimately, transportation research will be judged by the quality of transportation services, which in turn are judged by larger social, environmental, and economic outcomes. Performance assessment, in any context, involves inputs of all types and outputs—products and outcomes. The latter depend on "doing the right thing" for the advancement of human purposes in a global context, which is why principled research must become the norm. Future transportation research can be guided toward doing the right thing only by obtaining as wide a range of inputs as possible and can be measured against the resulting benchmark of expectations only when set in the context of our national values. Unfortunately, the complexity inherent in what we have just described has made it convenient to ignore performance measures in research. Too often research is justified only on the basis of being a good thing. This is no longer good enough.

As noted previously, incorporating key ingredients in the process provides some assurance that there will be responsive performance. In particular, there must be a careful examination of the outreach guiding the agenda.

Programs Illustrative of Concepts

To provide specificity to the concepts advanced in this discussion, we will examine briefly two transportation research programs that illustrate key points. The first of these—Partnership for a New Generation of Vehicles (PNGV)—is under way. Launched September 29, 1993, PNGV could affect virtually every person—for the good. This collaborative effort of the government and the Big Three automakers intends to triple auto fuel efficiency in the next decade. This is a leapfrog initiative to produce safe, affordable family cars that get hundreds of clean miles per gallon. Principles guiding this initiative include partnering, safety, and sustainability—energy conservation and environmental protection—with positive social and economic impacts.

In assessing impacts, it is important to remember that auto production is the world's number 1 industry, that autos are the largest users of petroleum and the source of approximately 50 percent of all air pollution (26 percent of volatile organic compounds), and that approximately 90 percent of all person-trips in the United States are made in cars. Although PNGV has much to recommend it, the great leap intended brings out difficulties such as those noted previously, and more. For example, what happens to competition and therefore pricing? What will these new fuel-efficient cars mean in terms of land use and congestion?

What will happen to conventional supplier industries (e.g., steel and aluminum)? Can our so-often-irresponsible national government be a good partner in any such venture? Finally, because all this is clothed in the public interest, will there be adequate public input? These questions deserve, and are getting, thoughtful discussion. The January 1995 *Atlantic Monthly,* for example, includes two excellent articles on this subject (6,7).

A second program, under development by a consortium of national laboratories and universities, is titled Enhanced Mobility of Older Drivers and Other Special User Groups. Turning first to the principles of impact and involvement, there has been input thus far from the American Association of Retired Persons (with 32 million members), from the $113.5 billion private and commercial insurance industry, and from the $700 billion trucking industry, which carries some 75 percent (by value) of our freight. As noted previously, about 90 percent of all trips are made by automobile—a percentage that may well increase as the population ages. (By the next century 23 percent of the U.S. population will be 55 or older.) As another matter of principle, this work will draw heavily on research "assets" paid by previous taxpayer investments—both at national laboratories and at universities. Finally, improved safety, a nonnegotiable, nontransferable government responsibility, is the focus of this effort.

Concluding Thoughts

In a previous section we spoke about the wisdom of building product-oriented research alongside streams of basic research. Basic research, as has been demonstrated in many contexts, frequently provides a fertile platform on which applied research can grow and prosper. But this applied work, we have argued, should increasingly become the province of for-profit businesses with the means and motivation for technology pull. Two questions follow: (*a*) Is there a government role in applied transportation research? and (*b*) With businesses now focused on short-term profitability, who will support these necessary basic research streams?

As to the first question, the government is a major owner of infrastructure and thus must be active in research. But the more immediate need is for greater business involvement. On the second question, support for basic research is a matter of transcending importance. Further, it seems that the constitutionally mandated general welfare of the people must, in this generation, mandate national government support for basic research.

Perhaps at no other time has the discussion of our national budget been more intense. In this environment, what will happen to research—basic and applied? To the highest extent possible, and as a highest priority, principled transportation research must be independent of budget debate, reorganization, and administration changes. The principle-based framework suggested here enables the appropriate, effective use of available resources; integrates diverse organizational capabilities and efforts; and identifies the common ground transcending administrations.

Our earliest national documents are the foundation to which we return, periodically, for direction and focus. We believe that this is such a time for transportation research and that from such a return will come principled research agendas; that is, agendas focused on the transportation needs of the nation and its people, as articulated by the people.

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