Improving the Effectiveness of Highway Research

Reflections from the SHRP Experience

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Highway research improves the construction, maintenance, and operation of highways. But such research in the United States is often not as effective as it could be. Too many individual research projects operate without reference to each other and are disconnected from any practical application. Basic research provides many benefits, but applied research is also needed.

Effective highway research improves how highways are built, maintained, and managed. Such research draws talent to the transportation field, thus building its overall base of human resources. It also enhances the credibility of transportation professionals in budgetary and policy matters that are far removed from research.

Three features of effective highway research should be stressed. First, effectiveness depends on change. Second, change must be for the better; it must improve durability, cost-effectiveness, quality, or safety, or it must benefit the environment. Third, change must be evident in the end product or end service—that is, in how highways are built, managed, and maintained. Whether research meets the test of effectiveness depends partly on how the research is conducted but heavily on other stages of the delivery process.

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The Research Delivery Chain

A long chain of events—sometimes spanning decades—separates the birth of a research idea from the beneficial application of its products. Research decisions are made at the front end of that chain, when subsequent links are hidden from view. Envisioning what the whole chain looks like involves speculation about the outcome of research, the extent to which it will alter technology, the extent to which the modified technology will be adopted, and the benefits that will emerge. Granted, these are all highly uncertain matters. But at every stage, steps can be taken to improve the odds that research will be highly effective.

The chain of events from the birth of a research idea to the beneficial application of its products can be thought of as having seven links. The first two links are typically designated as research, the second two links as development, and the fifth and sixth links as implementation. The effectiveness of the whole enterprise ultimately depends on the benefits that accrue once the research product is used—the final link.

Typically, one to four years elapse between links 1 and 2, the creation of a research idea and the initiation of some sort of field or laboratory work to validate the idea. If the experiment requires financial support from some other organization, the process of programming, contracting, and completing the work usually takes several years.

When an idea has been verified through experimentation, it is usually necessary to apply the new knowledge in the context of some revised prototype procedure or device. The more revolutionary the idea, the more radically different the new application is apt to be. Therefore the most significant new developments may take the longest to develop into working prototypes. Prototype development (link 3) generally takes two to five years, but in many cases it takes far longer. Researchers often do not have sufficient incentive to get involved in this phase, which requires financial support and the participation of prospective product users. The result is often a long delay between experimentation and prototype development.

Refining the prototype into a finished product (link 4) requires a serious commitment from the producer, which could be a private manufacturer, a quasi-public standards-setting body, or a public highway agency. Each production process is unique, but all require that the product be redesigned to address user needs, which in turn requires time-consuming pilot testing and user evaluation.

Marketing a new product to highway agencies (link 5) is rarely managed as a deliberate part of the production process. Highway agencies do not usually devote as much thought and money to product marketing as do private companies. The generic nature of many highway products and the

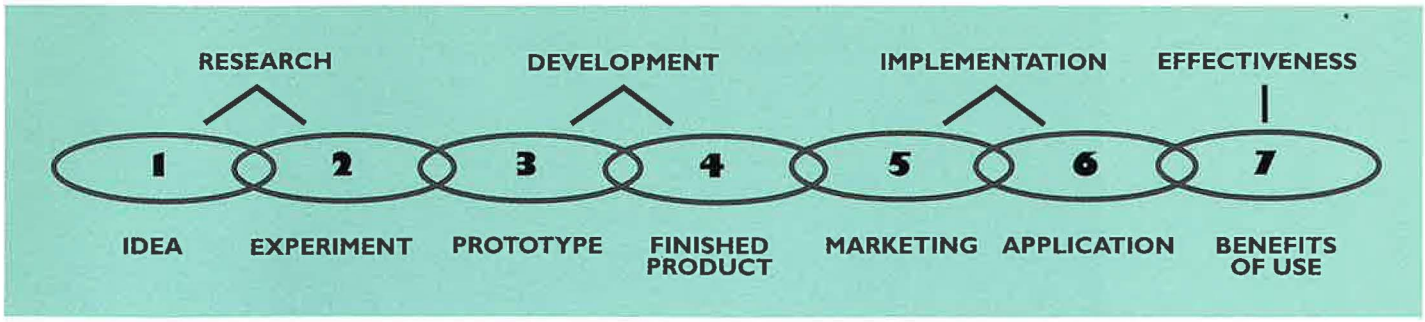

FIGURE 1 The path from the birth of a research idea to the successful application of its products resembles a chain with seven links.

inability of most public procurement systems to reward greater-than-minimum performance undermine the usual profit incentives.

Marketing a new highway product means accelerating its acceptance among users. Field personnel make many of the key acceptance decisions. These decisions are influenced by many factors, including familiarity with the new product and its features; cost and performance data that favor the product's application; national or local standards that apply to the product; steps taken by the agency's management, product evaluation team, or procurement department to encourage use of the product; and the availability of local distributors. Any one of these factors can delay a product's introduction.

There is no commercial interest in accelerating the user-acceptance process for products of most research. The necessary familiarity, evaluations, and standards depend on chance, word-of-mouth referrals, and volunteer efforts to encourage improved practice. Results are highly uneven. Whereas responsibility for conducting highway research is clear, responsibility for marketing the research tends to be poorly defined and typically depends on voluntary champions in other organizations.

At some point, successful products become sufficiently known and proven to be used in standard applications throughout an agency (link 6). The benefits of using a new product may be immediate, as in the case of some labor-saving device, or they may be far removed in time, as in the case of a more durable pavement mix design. The real effects of research cannot be known until the end of link 7. Because of the durable nature of many highway products, 1 to 20 years may elapse between the application of a new product and the emergence of its benefits.

The time span from the creation of a research idea to the beneficial application of its products is a long one. A research idea can get bogged down at any stage in its deployment if the person or organization responsible for one stage does not have responsibility for the next stage. Therefore research projects should be evaluated at each successive stage, but any weeding out has to be based on the ultimate benefits expected, not on unfounded presumptions about later links in the delivery chain. The feedback between earlier links and later links is crucial not just in recruiting champions for a product but also in making sure that the product successfully passes the weeding-out processes that occur as it moves along the delivery chain. If each link of this chain is viewed as an independent step, the work done in one link will not be designed to complement that done in other links.

The intrinsic problem in evaluating the effectiveness of research is that research is only the first link in a chain of links spanning many years. Furthermore, the chain is only as strong as its weakest link. In the case of highway research, some links are traditionally weak and poorly connected, making a focus on the effectiveness of the research link almost meaningless. Instead, one must begin by examining the strength of the overall delivery chain. The research link is not some independent, established structure whose shape and function are perfectly well defined and around which the other links simply have to fall into place. The research link may be described as an interactive mesh in which each part overlaps with each other part. The shape and function of each part are not well defined because its role can only be judged by the effectiveness of the whole.

The process by which the beneficial application of the products of a research idea emerge could be sketched in many ways: links might be added to or deleted from the seven-link chain described earlier, somewhat different milestones might be chosen to define each link, or different guesses might be made about the length of each step. Even so, three aspects of this process would remain constant. First, the process is extraordinarily long—often as long as an individual's career—so the length of the process may lure one into viewing individual links as one-of-a-kind events, not as

FIGURE 2 The period between the birth of a research idea and the successful application of its products can span decades.

parts of a manageable system. Second, the process is fragmented, with different individuals and different organizations in most cases responsible for different links. Third, the process is uneven; the weeding out of research projects hinges on chance as much as merit.

Streamlining this process is difficult. Because the research delivery chain is so lengthy, few people ever have the opportunity to observe every link in it. Because the chain is fragmented, different people look at the same phenomenon from different perspectives. And because each link receives uneven treatment, those who survive to tell tales are able to tell only one side of the story. All these realities make balanced, knowledgeable, constructive examination of this process very difficult.

The research delivery chain is not working well in the case of highway technology because all too often management of the chain is neglected. Institutions are often confined to reinforcing, rather than alleviating, gaps in the delivery chain or no organized support is provided for the later stages of the delivery chain. Pointing to these flaws may seem strangely out of season now that highway research in the United States has attained new heights of respectability and financial support. But recent gains in these areas should not be interpreted as proof that structural problems have been solved. Rather, the gains indicate that some ways to overcome the problems have been found. Continued success in improving the health of the nation's highway research depends on continued success in overcoming these problems.

The Experience of SHRP

The experience of the Strategic Highway Research Program certainly underscores the length and fragmentation of the research delivery chain. The program was initiated more than 15 years ago; another 5 years or so are likely to pass before most of its products are in widespread use—despite unusually focused and accelerated implementation.

SHRP's leadership discovered the need to build many ad hoc coordination structures to reduce the organizational fragmentation that existed. We approached this task with no special foresight but rather with a myopia that today appears astounding. This is a good time to look back at some of the things that made us stumble and to ask if there are ways that others can avoid being tripped up by them.

A product-oriented program, SHRP was to produce dollar-saving benefits, not just reports, in a short time. With more money and visibility than any other single highway research program in history, many worried that the image of highway research overall would be negatively colored if SHRP were to fail. Would the program's benefits to the nation exceed the $150 million invested in the program?

This visibility drove us to find ways to make research effective. In retrospect, it also showed us four areas where we needed to take corrective steps: giving implementation sufficient attention and support, involving management-oriented end users early in the research management process, estimating the extent to which product-oriented research clashed with the prevailing basic-research institutions and culture, and recognizing the necessity for vertical integration of SHRP's coordination structures. Fortunately, many perceptive, public-spirited individuals who were involved in SHRP helped us recognize and correct these mistakes before they became permanent flaws. SHRP's Executive Committee; advisory committees; expert task groups; state, provincial, and international coordinators; loaned staff; and other friends sounded the alarm and assisted in the development of solutions.

Taking Responsibility for Implementation

When SHRP was proposed to the highway community in 1984, highway research was underfunded, and its relevance was being challenged. Some argued that increasing and improving training was a higher priority; others argued that implementation of existing innovative technology should take precedence. Nonetheless the proposal for SHRP called for a tightly focused, large-scale, accelerated research program. It contained virtually no mention of education or of implementation. About the strongest statement to that effect in the initial proposal appears in the preface of Special Report 202, *America's Highways: Accelerating the Search for Innovation,* published by the Transportation Research Board in 1984.

> In the end the success of the STRS [Strategic Transportation Research Study] program will depend on the extent to which innovation is transferred into practice. In this context, the Committee recognizes that its proposals are only one part of successful implementation. It seems certain that the widespread and effective application of innovative materials and techniques will also require changes in training, procurement practices, and other phases of implementation that cannot be thoroughly addressed until the findings of the proposed research are known.

This statement reflects recognition that the effectiveness of research depends on later links in the research delivery chain. But it also reflects two common misconceptions: that implementation is somebody else's job and that the time to worry about implementation has not yet arrived.

About halfway through the program's five-year life, SHRP's Executive Committee became aware of these misconceptions and set out to remedy them. Implementation was already overdue, so SHRP staff, contractors, and advisors pitched in to perform the chore. It was becoming evident that when the research ended, business-as-usual implementation would be too slow and cumbersome. The Executive Committee and its advisory committees created subcommittees to chart an implementation strategy. Everyone involved in the program came to view implementation as their job, not somebody else's. The American Association of State Highway and Transportation Officials, the Federal Highway Administration, the Transportation Research Board, and the SHRP staff took on this same sense of responsibility and created special structures to speed implementation. What resulted was a vigorous implementation effort under the Strategic Highway Research Program and a more permanent implementation program, authorized by the Intermodal Surface Transportation Efficiency Act of 1991, under the Federal Highway Administration.

At one of their final meetings, members of the SHRP Executive Committee expressed surprise at how inadequately implementation had been provided for at the outset. It seems astounding, in light of the attention given to SHRP implementation in the past six or seven years, that this link of the delivery chain could have been so ignored at the same instant that historic actions were being taken to restore the health and relevance of highway research.

It is alarming that even a program like SHRP—with all its pragmatic aims, product orientation, management involvement, and resources—could start out so blind to the demands of implementation. Most of us who participated in the program held broadly shared but unrealistic presumptions about how big the implementation job is and who would do it. We assumed that somebody else would take responsibility for that job in due time. We learned that implementation is a huge job, integrally intertwined with research. It requires money and thought, and the planning must begin with the research itself. Nevertheless, throughout the field of highway research, implementation is still not getting the resources and attention it deserves.

Including Management-Oriented End Users

Research is a highly specialized, small-scale activity of public highway agencies. It accounts for only a fraction of 1 percent of spending by all highway agencies. Most agencies' funds go to construction and maintenance, and most agency employees work in those areas. And most engineers and technicians have their hands full doing their day-to-day jobs; they have neither the time nor the money to spend on research. The agency employees who deeply care about highway research are perhaps the agency's own research staff and a few managers from construction or maintenance divisions who have developed an appreciation for research.

When it comes time to select agency engineers to help guide a national research program, the names that naturally come to mind are those of the atypical few who are already identified with research or innovation. They may be an underappreciated minority in their respective agencies. The experience of being surrounded by skeptics and people too busy to be bothered about research may have accentuated their advocacy. They are apt to show unquestioning confidence that the

research they are overseeing will somehow overcome all barriers.

This confidence and advocacy are valuable in building the research enterprise, but when it comes to management of the research operation, hard-nosed assessments must be made of the likelihood of success, the potential to improve practice, and other key possibilities. The technical expertise of persons already familiar with research is vital to this assessment, but even more important are the challenges of engineers who are skeptical of research and its value. The views of engineers are a good barometer of how most prospective users feel.

We who participated in SHRP did not at first recognize the importance of working with engineers early on, while there is time to address their concerns and develop products that will win their confidence. As the program approached its midpoint, however, it became apparent that more had been started than could be finished. With time running short, energy was focused on the projects that could be completed. Committee memberships were reassessed with an eye toward identifying those committees best suited to accomplish this weeding out. By and large, committees with more skepticism and more impatience seemed, with their supporting contractors, to move forward more effectively. Deep levels of technical skill and a little more managerial leavening proved to be a good blend. With benefit of hindsight, it is clear that there were some areas in which an earlier injection of managerial disbelief might have been valuable in redirecting research toward more productive ends.

Although the advisor selection process with which the program started appears to be logical and representative, it had the effect of focusing too little on the later links of the research delivery chain. Surrounding oneself with innovators who offer great technical skill and application insight can create a false sense of security about the challenges of application. In the future the advisor selection process can be improved by consciously selecting some representatives of those later links, specifically management-oriented end users who are not predisposed to trust in research.

Creating a Product-Oriented Culture

The Strategic Highway Research Program was appealing to users, managers, and researchers alike because of its strong emphasis on products. But we who participated in SHRP did not realize the extent to which highway research *operates* as a basic-research activity.

Everyone involved knows that highway research is applied research, and considerable time and effort are expended between research contracts to design the next research step to meet the concerns raised by users and developers. Surprisingly, however, less stress is placed on creating this applications-oriented culture during the *execution* of research. Once a research contract is let, the prevailing culture resembles that of basic research in three key respects. First, the principal investigator has designed the statement of work. Second, the research manager judges the performance of the principal investigator on the basis of adherence to the statement of work. And third, experts and prospective users who serve as advisors review the progress of the work in terms of its clarity, factual foundations, and accuracy. This is a basic research model in that the work is envisioned as an agreed-upon experiment, and everyone involved in the process defines their roles in terms of producing objectively valid results.

Product-oriented research, by contrast, begins with a vision of an end product, even though the work path that leads to that product may not be fully charted at the outset. The work statement becomes increasingly detailed as interim developments occur. Researchers mark their progress by the impact that they have on changing the shape of the final product. Research managers are concerned with discovering some path that connects the ongoing work with the end product envisioned. Experts and prospective users help weed out results that will not work in the final product and suggest new avenues for achieving desired features.

The product-oriented model places unfamiliar burdens on researchers, staff, and advisors. First, the principal investigator's work plan is largely shaped by user evaluation of prospective product features. Second, research managers are responsible for reshaping work programs to fit product expectations. And third, the experts and prospective users who act as advisors throughout the process help redefine product expectations, not just assist in maintaining research quality.

The Strategic Highway Research Program could have moved faster and more productively if these cultural differences between basic and product-oriented research had been immediately understood. Because they were not, the familiar basic research model prevailed for some time. In the future, if selected areas of research are targeted for intensive, fast-track treatment, special product-feature reviews should be structured early in the process. These reviews will help advisors, staff, and contractors shed some presumptions that would otherwise hinder the work.

Ensuring Sufficient Vertical Coordination

Each of the major groups involved in highway research in the United States places coordination high among its responsibilities. They do so primarily to avoid duplication of efforts and to build on the experiences of others.

Most coordination within the highway research community is horizontal coordination, in which researchers exchange information with researchers, and users trade experiences with other users. Existing structures are not as strong in providing vertical coordination—that is, coordination among the different groups that are responsible for different links of the research delivery chain. The groups involved in research, development, implementation, and impact assessment normally operate sequentially, with little interaction. Indeed, because the time involved in each link of the research delivery chain is long and variable, sustaining continuous vertical coordination can be difficult.

By contrast, a research department in a private company must occasionally meet with the production and marketing units to make key product development decisions and to coordinate the schedule of activities related to these decisions so that the units can arrange their plans accordingly. This vertical integration helps generate product development decisions that are responsive to market demands, and it helps coordinate development, production, and marketing activities to mutual advantage.

The members of SHRP's advisory committees and expert task groups were selected for their ability to integrate research with downstream development and implementation activities. Some people, for example, were asked to serve on SHRP committees because of their involvement in standard setting, technology transfer, or other deployment activities. By itself, this tactic could not bring about vertical integration because the downstream activities, with which upstream activities were being coordinated, were lacking the necessary resources.

By and large, institutional support for vertical coordination of highway research is insufficient. When highway research projects are completed, results are reported at professional meetings in the hope that users will apply them. In stark contrast to a company's vertical coordination, however, no product development decisions are made and no timetables are set up to develop, produce, and market products. As a consequence, the results that are presented represent a diverse mixture of developed, prototype, and conceptual ideas. They have different degrees of applicability, and they may or may not have the commitments needed to develop them further.

When the idea for SHRP was first being advanced, Thomas Moreland, then head of the Georgia Department of Transportation, astutely observed that "management had abdicated its responsibility for research." Many agreed. In hindsight, this was only the tip of the iceberg: management had abdicated its responsibility not just for research but for the whole research delivery chain. As SHRP's activities moved link by link along this chain, we found that each new link required new institutional mechanisms for coordination. Out of this realization emerged many ad hoc organizations for vertical coordination, among these the TRB-SHRP Committee, American Association of State Highway and Transportation Official's Task Force on SHRP Implementation, the Federal Highway Administration's technical working groups, and the regional asphalt user-producer groups. These entities will not only vertically coordinate product development, production, and marketing for SHRP products but also speed up their use. Similar attention to vertical coordination of other new technologies could also speed up their application.

Corrective Actions

The research delivery chain is a long, fragmented, and uneven one. The Strategic Highway Research Program's product-oriented goals and its accelerated schedule forced us to attempt to manage this chain. Although the job is far from finished, some of our early steps and missteps suggest corrective actions that may apply elsewhere:

- Implementation is not somebody else's job to do at some later date. It is deeply interrelated with research and should be funded and planned in tandem with research.
- Management-oriented advisors are needed to bring more healthy skepticism to research management in its earliest stages.
- Traditional structures for managing contract research are geared to basic research, and a significant cultural change is needed to exploit them effectively for product-oriented research.
- Existing coordination structures work well across each stage of product development, but new institutional responsibilities must be established to ensure the necessary vertical coordination throughout the entire research delivery chain.