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Risk Assessment and Risk Management for Transportation Research

Elizabeth Deakin, Karen Trapenberg Frick,
and Kathleen Phu
University of California, Berkeley
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Elizabeth Deakin, Karen Trapenberg Frick, and Kathleen Phu
University of California, Berkeley
Dept. of City and Regional Planning and
University of California Transportation Center
228 Wurster Hall
Berkeley, CA 94720-1850
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1 - Statement of the Problem

Transportation agencies have looked to research to improve both their internal business practices and the products and services they deliver. However, while the potential for benefits resulting from research is significant, there also is risk. Not all research projects are successful. Some projects produce results that are promising but require more development. Further development does not always produce results that are ready to implement. Implementation may fail. Competing products may capture the market.

This paper sets forth a preliminary methodology to assess and manage risk for transportation research. The California Dept. of Transportation (Caltrans) funds numerous transportation research projects that range from studies that aim to improve the understanding of travel behavior to field operations tests and deployment studies for new technologies. The risk assessment methodology is designed to help 1) identify needs for transportation research, 2) identify likely audiences for the anticipated research products, as well as potential applications; 3) identify potential barriers that could impede research or prevent its implementation; and based on the findings of the first three steps, 4) assess whether Caltrans is best suited to fund and oversee the research, should co-sponsor it with other agencies, should support it in less direct ways, or should refrain from engaging in research efforts on the topic and simply monitor developments in the field. The methodology is intended to allow Caltrans to develop a more effective and targeted research program.

Research and practice in the private sector has shown that it is possible to identify possible risks associated with research projects and to manage the research process so that risk is kept to acceptable levels. A major objective of this study is to build on the concepts and approaches developed by private firms and translate them into concepts and approaches applicable to the public sector and specifically to Caltrans. We set forth a typology of research types ranging from basic research to Caltrans-specific applications of products and processes that are already implemented elsewhere. The typology is intended to provide perspective about reasonable expectations for outcomes. We then identify and categorize risk elements against the typology of research types, and identify strategies for counteracting the identified risks.

2 - Research Approach

The work presented here is based on a detailed review of the literature and in-depth interviews with 15 Caltrans research leaders, 5 MPO officials, 5 university researchers, 5 consultants who are active in research, and 5 research leaders at the federal DOT and at other state Departments of Transportation. These 35 interviews covered the respondents' views on the most pressing issues facing transportation agencies, advances that had come from research projects, problems with the research process, barriers to implementation of research, and best practices for research management. The set of questions used to guide the interviews is presented as Attachment A.

3 - Previous Work on the Topic

Definitions

We use the Merriam-Webster definition of research: investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws. Successful research aims at innovation, the introduction of something new - a new fact, a new interpretation, a new theory, a new application. In this sense, research is part of the innovation process, and thus a review of work on innovation and the barriers to innovation is useful for this study.

Factors Affecting the Adoption of an Innovation

Everett Rogers, in his book *Diffusion of Innovations*, describes in the process by which a new idea is adopted (or may fail to be accepted.) One of the most important contributions of the book is its explicit recognition that diffusion of innovation depends both on the qualities of the proposed innovation itself and the broader cultural, psychological, sociological and economic factors that shape whether and how fast it is accepted.

Rogers discusses characteristics of an innovation that affect its rate of adoption: *relative advantage, compatibility, complexity, trialability, and observability*. He also discusses characteristics of users of the innovation that affect how fast they are willing to accept the innovation, i.e., whether they are themselves innovators or early adopters, are part of a larger majority that will require more information and less risk before adopting a new product or process, or are likely to be slow in accepting a new idea or product.

Relative advantage is the degree to which an innovation is perceived to be better than the product/process it replaces. Relative advantage can be measured in terms of economics or other factors such as social prestige, convenience and satisfaction. Rogers' research found that the greater the perceived relative advantage, the more rapid the rate of adoption.

Compatibility is defined as the perceived consistency with existing values, practices and needs of the potential adopters. Compatibility with values and beliefs is important because products that will not complement the values of the potential adopters will face resistance. Therefore, compatibility should be assessed at the beginning stages of innovation design in order to ensure that cultural barriers do not exist, or to develop strategies to change user attitudes and behavior.

Complexity is defined as the degree of difficulty involved in understanding an innovation and making use of it. New ideas that are simple or relatable to existing practices are adopted more rapidly than innovations that require adjustments and new skills. Complexity is strongly tied to an intrinsic resistance to change. Critical mass is unlikely to develop until the required skills are in place and resistance to change is overcome.

Trialability is the degree to which the innovation can be tested before release to the broader market. Innovations that can be gradually adopted are likely to be easier to implement than those that must be released to the market in its entirety. In addition, innovations that can be tested prior to broad public release can help sponsors determine the attractiveness of the innovation and make adjustments if needed.

Observability is defined as the degree of the innovation's *visible* effect to others. If an improvement is visible to outsiders, it increases awareness among other potential users and may increase the attractiveness of the product.

Turning to the adopters or users of an innovation, Rogers identifies five categories of adopters, whom he calls *innovators*, *early adopters*, *early majority*, *late majority*, and *laggards*. To each category, he attributes characteristic attitudes toward change, which he relates to scientific knowledge concerning the proposed innovation as well as to the user's socioeconomic status, the number of social connections the individual has, and his or her access to financial resources, among other factors. Those with higher levels of knowledge, higher socioeconomic status, a broader social network and higher levels of financial capacity are more accepting of risk and are more likely to be innovators or early adopters than others, who are more likely to resist change. Rogers acknowledged that an individual may be an innovator or early adopter in some fields and a laggard in others, since the designation is a function of knowledge about a purported innovation as well as the socioeconomic and personality characteristics of the individual.

Researchers also have investigated barriers to the adoption of innovations. For example, Gourville (2006) investigates why there are high rates of failure with product innovations. He identifies a number of factors affecting the failure rate, including product-based causes (e.g., the product costs too much), consumer-based causes (e.g., the skills necessary to use the product require knowledge or training that many consumers do not have), and developer-based causes (e.g., developers overestimate the benefits of a product and underestimate problems with it.) Two psychological factors that affect consumer adoption are reference dependence and loss aversion. Reference dependence is when the consumer assesses the innovation in reference to (comparison to) existing conditions or practices. An innovation must provide a big improvement to overcome the inertia associated with

sticking with what is already in use . Loss aversion refers to the research finding that a loss is perceived to have a far greater impact than a positive gain of a similar magnitude. Therefore an innovation requires a high perception of gain in order to appear attractive enough for a target group to adopt it,

Importance of Organizational Structure and Culture

A growing body of research shows that not only individuals but the organizations of which they are members influence how an innovation is assessed and adopted. Hannan and Freeman (1984) investigate why certain organizations lean towards structural inertia, i.e., stasis. They find that higher inertia rates are positively related to *age, size* and *complexity* of the organization as well as to an organizational mission to achieve *high levels of reproducibility*. Damanpour and Schneider (2008) identify the following organizational characteristics that influence innovation adoption: leadership, degree of bureaucracy, learning orientation, risk management approach, availability of knowledge, work infrastructure, physical work environment and the organization's culture.

Organizational culture has been the focus of considerable attention. Greenburg et al. (2008) have defined organizational culture as the "cognitive framework of attitudes, values, behavioral norms, and expectations shared by organizational members or a set of basic assumptions shared by members of an organization" The authors further assert that a strong culture exhibits the following characteristics:

- a clear philosophy exists about how business to be conducted
- considerable time is spent communicating values and beliefs
- explicit statements are made that describe the organization's values
- a set of values and norms exist that are shared widely and rooted deeply
- new employees are screened carefully to ensure fit with culture.

Desouza et al. (2009) describe contrasting types of organization - "robust" and "brittle" (Table 1). They argue that innovation is facilitated by the "robust" organization. Robust organizations are more inclusionary, networked, systematic in their approach to change, and willing to learn from problems. Brittle organizations tend to be hierarchical, rigid, and risk-averse. Organizational design strategies can be used to reform organizations so that they can take on new challenges, but the efforts need to be systemic and persistent.

Bhatta (2003) finds that public sector organizations are generally more risk averse than private firms, in part because demonstrating careful stewardship of taxpayer-provided funds is a high priority. He argues that public agency leaders also have less latitude than their private sector counterparts to refocus their organizational missions, allocate funds to new uses, or hire and fire staff members based on their performance and fit with agency mission. In addition, government agencies typically face more severe consequences from failure than do their private sector counterparts. Public agencies face possible budgetary risks as well as reputational / political risk for managers and for the agency as a whole. However, Bhatta (2003) also notes that public agencies vary in their appetite or tolerance

for risk, in part as a function of the organizational structure and culture, including management style and top management' willingness to take risks.

Table 1: Properties of Robust and Brittle Organizations

(source: Desousa et al., 2009)

<i>Robust Organizations</i>	<i>Brittle Organizations</i>
Whole organization is targeted; existing initiatives are incorporated	Process is draconian and top-down with little regard for existing processes
Realistic objectives are established; knowledge broker role is acknowledged	Objectives may be arbitrary
Dialogue is emphasized with all stakeholders	Lack of dialogue exists
Older, duplicative processes are eliminated	Old processes persist and unlearning is slow and not encouraged
Unlearning is understood and prepared for	Minor failures threaten culture
Storytelling and metaphor is used to inspire and convey the need for and type of change; values and culture are emphasized	Existing culture and stories disregarded; change is not obviously in line with existing values or culture
Social networks are utilized; customer segmentation is established	External stakeholders are disregarded
Technology is used to communicate	Technology is not fully supported
Failures are evaluated and considered for further stages or processes	Failure is an end point

Implications

The literature shows that many factors can impede successful innovation and its implementation. Key factors include limitations of the innovation itself; weak performance; high costs; proponent overestimation of the benefits and underestimation of the costs of delivering the product; insufficient market / user interest in the product; competing approaches or products, both existing and new; organizational structure that is resistant to change and therefore to the consideration of new ways of doing business; and organizational culture that is risk-averse and low on the learning scale.

All of these factors affect the sponsorship, conduct, and use of research in transportation organizations. Research is not always successful; it may not fit well with established ways of doing things; its benefits may be too modest to justify a change; the change may be seen as a threat to the expertise and practices, and authority of established units, and so resisted. Research and implementation of its results can be risky and fear of failure and its consequences may be more important than the prospect of successes.

State highway departments were established in an earlier era to quickly deliver standard highway designs "by the book", and although the organizations became DOTs in the 1970s, they retained many of the same organizational characteristics that they originally exhibited (strong hierarchies, e.g., and an emphasis on rule-driven decision-making). As useful as these organizational characteristics may have been when they were established, today they sometimes get in the way. The tasks DOTs must carry out today - managing a mostly-built system, solving environmental problems such as poor air quality or damaging runoff, coordinating multimodal transportation investments with local governments' land use plans, addressing social justice, reducing carbon emissions - take new skills and, importantly, greater flexibility and linkages to other organizations and levels of government than has been traditional.

In figuring out how to improve DOT organizational capacity to innovate, and in particular to do so through research and development it sponsors, it is necessary to recognize the organization's capacities and limitations, and to distinguish changes that can be done rather easily from those that might take a longer-term strategy for organizational change - since some changes likely would require the consent and support of higher authorities. For this study, we have focused on changes that could be carried out, while recognizing that other changes may be possible only if instituted at a higher level as part of a larger overhaul of organizational structure and behavior.

4 - Types of Research

Research in transportation, like research in general, is investigation or experimentation aimed at the discovery and interpretation of facts, or ways to practically apply facts. This two-part definition covers the two basic types of research that most researchers recognize: *basic research and applied research*.

The Lawrence Berkeley Laboratory (2011) provides the following definitions of these two research types:

"Basic (aka fundamental or pure) research is driven by a scientist's curiosity or interest in a scientific question. The main motivation is to expand man's knowledge, not to create or invent something. There is no obvious commercial value to the discoveries that result from basic research.... basic research lays down the *foundation* for the applied science that follows. If basic work is done first, then applied spin-offs often eventually result from this research. As Dr. George Smoot [Nobel Laureate, physics] of LBNL says, "People cannot foresee the future well enough to predict what's going to develop from basic research. If we *only* did applied research, we would still be making better spears."

Applied research is designed to solve *practical problems* of the modern world, rather than to acquire knowledge for knowledge's sake. One might say that the goal of the applied scientist is to *improve the human condition*."

Noting that the distinction between basic and applied research isn't always clear, Dr. Ashok Gadgil of LBNL asks the following question and uses the categorization that follows to classify the work:

"How long will it be before some practical application results from the research?"

- If a practical use is only **a few years** away, then the work can be defined as strictly **applied** research.
- If a practical use is still 20-50 years away, then the work is somewhat applied and somewhat basic in nature.
- If a practical use **cannot be envisioned** in the foreseeable future, then the work can be described as purely **basic** research."

While the LBL definitions emphasize science as the field of research, the basic concepts also apply to work in the social sciences and humanities. Social science research also can be thought of as basic (e.g., psychology and sociology research aiming to understand individual and group behavior) or applied (e.g., marketing studies, organizational change strategies), and much would fall in the mixed category (e.g., studies of voting behavior, studies of decision-making in bureaucracies.) Research also can use a variety of methods, from laboratory tests, field observations, surveys, interviews, text analysis.

In the field of transportation, much of the research is applied, and in some cases is intended to be applied immediately. For example, the National Cooperative Highway Research Program, funded by state DOTs who also select the research topics, aims to produce "practical, implementable, and timely solutions to problems facing transportation agencies and organizations" (NCHRP, 2011.) Each NCHRP research project requires a research dissemination plan which is intended to help put the research findings into practice. This focus also ensures that most NCHRP projects have a short-term emphasis (although NCHRP is currently conducting a series of longer term studies in recognition that an emphasis on projects that can have immediate application may not be sufficient to address the challenges of this century.)

The university transportation centers (UTC) program established in the late 1980s was intended to offer a modest counterbalance to this emphasis on the short term, providing federal funding for universities to explore a variety of transportation research topics. Some universities, especially those in California, where Caltrans provided matching funds with few "strings attached", were able to establish mixed portfolios of research using the UTC funds; they were able to investigate new ideas in exploratory research (e.g., developing algorithms for more efficient freight movement, finding out more about how lifestyle and lifecycle affect travel choices) as well as to develop and implement practical applications of research findings (e.g., applying integrated land use - transportation models in partnership with a major metropolitan planning organization, developing new policy initiatives on parking.) Not all UTCs fared as well, however; finding the 50% matching funds required for UTCs meant that some UTCs had to focus their work on the highly applied problems that state DOTs or other organizations with matching funds proposed.

Another type of research that has become relatively popular in the last 10-15 years is the research synthesis, that is, research that pulls together findings from many basic and applied research studies and interprets them as a body of work. Research syntheses have become popular in the transportation field because of the initiatives of the Transit Cooperative Research Program. They at very least provide a sort of "one stop shopping" for research findings, and at their best may also add new insights and thus provide original contributions to the research field.

DOTs also use research funds to pay for work that many researchers do not in fact consider to be research - for example, developing user guides or public information materials. These products are useful to the agencies that commission them, and in some cases university and consulting firms may be well positioned to produce these products. However, they do not offer the possibility of finding out something new that is the mark of a research project, and are better classified as tech transfer products. Also, while such products do run some risks, these are for the most part limited to contracting problems (delays, cost overruns, poor performance) or the possibility that a product will be duplicative of efforts elsewhere.

Why does the type of research matter, when considering risk? The chief reason is that it is important to match expectations to the objectives of the research. Basic research cannot reasonably be expected to produce usable products in the short term; tech transfer products are highly unlikely to produce new ideas. The large grey area of applied research is the most challenging in terms of setting reasonable expectations, but careful consideration of the time frame in which marketable products are likely to appear can help research managers establish appropriate standards of performance review.

5 - Findings from Interviews

To better understand how research is viewed by Caltrans, and how both research administrators and researchers themselves view the risks of research, we conducted a series of interviews as described in the methodology section of this paper. The objectives of the interviews were to determine how risk is assessed and managed in research projects. In addition, interviewees were asked about common barriers that can prevent research products from achieving their intended results.

A preliminary round of interviews was held with senior Caltrans leadership, university research leaders, and research leaders at US DOT and at other state DOTs. These interviews identified a set of issues that the interview participants felt were responsible for risk in transportation research projects. In addition to what might be called the "normal" risks of research, i.e., that the experiment would fail or the findings would be insignificant, the respondents identified five other sources of research risk: contracting problems, unrealistic expectations for research, lack of organizational capacity to manage research, lack of organizational capacity to implement research, and insufficient attention to the need for partner participation in research design and implementation. These themes were used to structure the questions posed to research administrators.

The next round of interviews was conducted with Caltrans office chiefs and staff. The following are the main findings from these interviews.

- 1. Staff is concerned with the decline of capacity within Caltrans to conduct research and actively manage research projects.** Several noted that in previous years Caltrans staff could carry out some research projects in house and could be active participants in research conducted at universities and consulting firms. Today, however, staff cutbacks and increased workloads mean that most research managers can only review the products delivered to determine whether the contract terms are met (due dates, deliverables as specified) and that there is little ability to contribute substantively to the research projects. Some project managers reported that they do not have time to read the journals or attend seminars to keep up with the latest work in their fields. Caltrans has tried to make up for this by establishing project advisory committees that include experts from outside the agency, but these are volunteers and their time is also limited. One adverse effect has been the occasional duplication of effort, e.g. conducting a research study that mirrors one funded by others. To address this problem Caltrans is now asking for a literature review to back up research requests and put them into context.
- 2. Contracting problems frustrated many of the research managers.** Delays in processing contracts (often several months, sometimes longer) can result in missed start dates and higher costs. For some contracts, where data collection can only occur during specified periods, contracting delays can result in missing the windows of opportunity. Contract delays also sometimes lead to having to renegotiate a contract altogether, for example because the Principal Investigator is no longer available. A number of specific contract problems including patent and copyright issues, use of state property, and permitted profit margins also have been barriers to partnerships with universities and especially in the case of profit margins, with some private companies.
- 3. Interpretation of what constitutes "success" for a research project varies widely.** Some individuals working as project managers responded that a project is successful if completed in accord with contract requirements, on time and within budget. Others looked for products from the research that could be put into practice and were frustrated with researchers who considered published papers to be the ultimate goal of the research; as one put it, "We need to change the way we do business, not just publish things." Still others argued for multiple definitions of success matched to the objectives of different types of research; they felt that research into new approaches that could have a big payoff in the future but might not be immediately relevant was under-valued by measures of success that focused on changing the state of the practice. At the same time, these managers worried that basic research projects were not valued by practically-oriented managers and decision-makers (including the Legislature) even if new results were being

produced, and that this basic or early-development research projects risky investments because they could be attacked as a waste of money.

4. Understanding stakeholder perspectives and getting their buy-in early in development stages of a project was recognized as crucial in preventing future roadblocks. Internal stakeholders and external partners in other agencies and in the private sector were seen as potential allies or potential opponents when it comes to implementing a research project's findings. Making sure key stakeholders are on board at the outset was seen as a way of improving the chances that a research project would be considered a success. Managers noted that Caltrans, like many other DOTs, is a large, complex agency; Caltrans also has decentralized many functions to district offices and has given considerable discretion in decision-making to the districts. As a result it is not easy to change directions from Headquarters. This is one reason that internal buy-in is important. In addition, both federal and state law assign many decisions to other state agencies (e.g., the air quality agency and other natural resources departments) and to metropolitan planning organizations, and California law gives considerable authority to city and county organizations. Thus for many projects, getting broad interagency buy-in is also a necessity if implementation is to occur.

5. Lack of expertise or high turnover in key departments can be a barrier to the implementation of some kinds of R&D products. Research managers noted that there is a big difference between being able to appreciate the value of a new technology, method or product and being able to use it; they have found that in some areas such as IT, having the staff who can effectively implement research results has been a problem. This is true not only for Caltrans but also for its partners, e.g., many cities, especially the smaller ones, have limited staff and/or high turnover in the field of traffic operations and signal systems. More generally, job turnover can lead to stalled implementation of new ideas from research because new staff have to be familiarized with the project and trained in how to use its results.

6. Internal and external resistance to change prevents many good ideas from being implemented. Although efforts are made to get buy-in from the relevant managers, lower level staff do not necessarily feel bound to agree with the results of a new project and even management directives are sometimes resisted or re-interpreted in a way that allows previous practices to continue. Internal differences in perspective between e.g., transit planners and traffic managers over such issues as the potential use of shoulder lanes for transit priority and the amount of flexibility to give local jurisdictions over transit-prioritizing street designs were mentioned as examples. Differences in willingness to try new products or approaches also crop up between the state and local agencies. Here too, efforts to get buy-in early in the process are seen as only partially effective because they can only reach some of the responsible staff.

At this point the researchers raised questions about whether other channels for getting research done might be effective alternatives to state DOT-led research. Two such channels were proposed: providing more research funds to universities to develop and carry out transportation research agendas, with the advice of transportation agencies but not necessarily under individual project contracts; and greater use of partnerships with the private sector and other agencies / levels of government who might be able to manage research with fewer complications. Responses to these suggestions were as follows.

7. As a strategy to increase research effectiveness, independent university research received mixed reviews. Research managers were appreciative of the university's role in creating new ideas and its role in translating research findings into practical products and collaborating with Caltrans, expressed strong satisfaction with University-Caltrans research projects, and believed that the universities were often the most persuasive speakers when e.g., legislative changes are needed, because of the university's role as an independent seeker of knowledge. However, the managers also noted that a favorable view of university research was not universally held in the agency, specifically because some in the agency thought too much money was being spent on university research that did not have practical products. Because of this perspective, when asked about the possibility of funding more research at universities and in particular allowing faculty members to have more discretion in selecting research topics, there were doubts that this would be acceptable to the agency. As one put it, "If we're funding it, we are responsible for it and we ought to be more involved... We ought to fix it [fix our processes and improve our capacities] so that we are better partners." Others noted that consulting firms and nonprofits also conduct transportation research and that sole source funding to universities is not appropriate for work that a variety of entities could carry out.

8. As a strategy to increase research effectiveness, public-private partnerships and interagency or intergovernmental partnerships were seen as attractive but difficult. Research managers noted that partnerships for research are nominally appealing, especially in areas such as new technology where developments in the private sector could potentially be harnessed for use on public roads and transit systems. However, they felt the appeal was tarnished because the contracting arrangements are so difficult. They cited rules on ownership of state-funded research, disclosure requirements, the amount of time it takes for the state to develop, negotiate and approve a contract, and slow payment processing as some of the key barriers to public-private partnerships. As with university research, the research managers felt that it was necessary to improve agency processes and capacities so that they could be better partners with the private sector. They noted, however, that some of the improvements that private sector partners would like to see might take changes in legislation.

These eight points map reasonably well to the those raised in the initial round of interviews and confirm that in addition to the normal risk of failure of a research activity,

other key sources of risk are contracting problems, expectations for research, staffing problems, organizational capacity, and partnership relations.

After these interviews were analyzed, a third round of interviews was carried out with researchers, experts from university, private sector, and nonprofit research groups, as well as with Caltrans leaders. These follow-up interviews were designed to elicit comments on the initial findings. Based on this third round of interviews, two additional topics were added:

- *being clear about the audience for the research*
- *being clear on the next steps that are needed to make use of the results.*

6 - Managing The Risks That Research Presents

In this section we review the key risks that were identified in our first two rounds interviews, plus two others that we have added to the list based on the third round of interviews. We suggest ways of managing the risks.

The Risk of Failure

The possibility that the research will fail, even if it has been carried out on time, within budget, and in satisfactory ways, is a normal risk of research. Failure of a research product to be implementable is also a normal risk of research. Failure can be technological, economic, institutional, market-based, or a combination of any or all of these factors; products also can fail to have the expected utility if policy shifts in a different direction. A research product may turn out not to work as anticipated, may be too costly, may require a change in law or a restructuring of organizational assignments of responsibility to be fully implemented, or may not generate enough consumer demand to be worth continued investment.

A common occurrence is that other products are introduced that duplicate or compete with the research product, either capturing the market for it or dividing the market so that returns are lower than sponsors had anticipated. Agencies can reduce this risk by researching the topic ahead of time and flagging similar projects reported in the literature or ongoing in some other venue (for public agencies, these are increasingly listed on the web.) But there are limits to this approach, especially when there is the potential for profit from the research; the research in these cases is probably confidential and proprietary and due diligence may not uncover it.

In private businesses, risks of this sort are considered normal costs of doing business, and the vast majority of research projects are expected to fail in one way or another. Researchers manage expectations, and often celebrate not only great new innovations but findings that a particular direction is a dud and should be refocused or even discontinued. Furthermore, everyone is involved in research, from product developers to brand

managers to the "skunk works" that looks at far-out ideas, so everyone is on the line for research productivity in one way or another.

Government has been less willing to argue the proposition that research will sometimes fail and that many ideas that originally looked promising will fail. However, the pressure to show a practical result from all research products may well be having negative results, including a tendency to focus only on short term, sure things and a tendency for researchers to overstate the potential of their work and to claim short term relevancy when the research would more fairly be described as exploratory. Possible antidotes would be to enlist the private sector's support in advocating government-sponsored basic and longer-term applied research, i.e. to help convince decisionmakers that this is not a waste of taxpayers' money, and to encourage university researchers to more explicitly engage in public education on the value of research.

Risks Introduced by Contracting Difficulties

Contracting risks include the risk that the contractor will not perform the work or will not perform in a cost-effective, timely, and substantively satisfactory manner. Standard contracting procedures offer the principal means of limiting these risks. They include competitive bidding; peer review and evaluation of proposals, with awards only to those deemed qualified; and contractual requirements for interim and final work products that are peer reviewed, together with contract provisions allowing partial withholding of funds until work is completed or cancellation of the contract if work is not performed satisfactorily.

However, as the interviews noted, contracting risks also can come from the sponsor's contracting processes and capacities. Common problems include an inability to process contracts, amendments, payments, etc. in a timely manner, leading to delays in work; insufficient staff time available for proposal and work product reviews and other contract monitoring tasks, and insufficient staff expertise (in the legal department, among the technical staff, or both) to handle particular contracting issues.

Risks that arise because of cumbersome contracting processes are a big part of the problem that many public agencies face, not only with their research programs but with procurement and other functions. For example, delays in contracting that lead to a project starting late can result in higher costs or less value for money because costs have increased. Key personnel may no longer be available or may have limited time for the project. Schedules may have to be renegotiated because certain tasks must be carried out at particular times of year (e.g., surveys are generally not done over the holiday period from just before Thanksgiving until the middle of January.) Opportunities for data collection may have been lost altogether (e.g., a late start may make collection of "before" data impossible or may limit its scope.)

Strategies that have been widely used by public agencies to manage agency contracting problems include omnibus contracts (designed to reduce the number of contracts processed, and allowing quicker response to requests for support), use of outside experts

on peer review panels for proposals and work products (alleviating the work load for staff and obtaining higher levels of expertise than might be feasible internally), and use of outside counsel and expert consultants to develop specialized contracts and specifications. Outside counsel is widely used when complex or specialized financial instruments must be developed (bond issuances, e.g.); increasingly, outside counsel and technical consultants are also used by many agencies for procurement of advanced technology. Large agencies may also seek to create their own staff positions and expertise to carry out these functions, but because experts in these specialized fields are typically in high demand, the agency may not be able to meet the salary requirements to hire or retain top experts - hence contracting as an alternative approach.

Agencies might also consider the use of outside legal staff to handle routine contracting matters that are backlogged, if it is not possible to increase staff positions to do the work in a timely fashion. The agency would keep control over the policy decisions but would use outside staff to speed processing times. Such a strategy might require legislative action, however.

Risks Created by Unrealistic Expectations for Research

Government agencies such as Caltrans spend research budgets on a variety of activities, some of which researchers would consider research (mostly applied, a small amount basic) and some of which researchers would call "tech transfer" because the activities do not involve the creation of new knowledge and in most cases are not the first practical applications of new or revised understandings. Despite the diversity of enterprises, it is common to hear government research managers say that they need to get practical results from all of their research investments - results they can put to use quickly in improving a process or product. In part this emphasis on existing processes is because higher-level decision-makers have been focused on delivery of existing products rather than improvements and innovations. In part it is because government agencies are particularly vulnerable to being characterized in the press or in government hearings as "wasteful" of the public's funds if they take chances on new approaches.

Yet expecting basic research to produce practical products is unrealistic. Demanding practical products from basic research leads to researchers "stretching" to try to make their work seem practical. This was clearly a problem with many ITS projects, which were long term applications at best, but were "sold" as offering prospects for congestion relief, and ended up disappointing decision-makers because they were a long way away from being able to do that (Deakin, 2004.)

To protect both the research project and the project sponsors from unrealistic expectations that may make a project look as if it has fallen short of its targets, it is important to have clear and realistic targets in the first place. Classifying research as basic, near-term applied, longer-term applied, synthesis, and tech transfer would be a step forward in making sure that reasonable expectations are applied in evaluating the results. However, it is also important to communicate these distinctions clearly to other parties, including potential

users of the work, elected officials and other decision-makers, and the press, so that expectations for the results are appropriate.

Risks Related to Staff Capabilities

Obvious responses to risks related to staff who are not sufficiently expert to manage research projects or implement research products would be to hire more qualified staff and to increase staff training. To the extent that staff capabilities are weaker than desired because of frequent staff turnover, agencies may need to review their compensation packages in comparison to the competition and make adjustments. However, public agencies may not be able to implement such changes, at least not fast enough to make a dent in the problem. Other options would be to increase the use of outside experts to help assess research projects and oversee their conduct, and to contract out for the implementation of new ideas that the agency not able to implement well in-house. Contracting out could be used for a variety of services ranging from pavement designs using advanced materials to transportation-land use modeling.

Risks Related to Organizational Structure and Culture

Research and the changes its implementation can bring about can create institutional upsets; it can challenge long-accepted ways of doing things, and (directly or indirectly) their practitioners and proponents; it upsets social relations and changes power structures; it can lead to new priorities and resource allocations. Because of this, research managers need to be assess the potential effects of a proposed research project on the organization and need to be clear on what changes the anticipated results might suggest. Then the research managers need to be painfully honest in assessing whether the agency is able to adopt the research findings and change practices, or is likely to resist. This is clearly related to whether there is buy-in for the research in the first place - whether the affected parties see the need for research and the change it may propel, but it also is affected by the willingness of leadership not only to endorse the research but be willing to spend the time, money and political capital necessary to change practices within the organization. Without a clear strategy for implementation, which may in turn require certain organizational change strategies, many research projects are likely to languish on the shelf or to fail during the implementation process.

Changing an organization's structure and culture is not something one unit within an organization can be expected to tackle, at Caltrans or elsewhere; obviously this is a serious matter that requires the commitment of top leadership. However, one unit can certainly bring issues such as this to the attention of leadership and make recommendations on how to develop strategies for effective change. Research on organizational structure and culture is important in its own right and would be a good move for most agencies as a step toward strategic implementation planning.

Audience for the Research

In reviewing the list of research implementation issues, several of our interviewees noted that the audience for the research is sometimes unclear. An example given by several of those interviewed was advanced travel models. Several of those interested felt that advanced travel models had a rather specialized audience but had been "sold" to planning agencies as a broad-based need. As a result, they felt, the research was not as clearly targeted to the audience as it might have been, with resources wasted on promoting advanced models to agencies that had little need for them. The interview respondents felt that this sort of misreading of the audience occurred rather frequently, and could be easily avoided by asking at the outset who the market for the research would be - and exploring that presumed interest by talking directly to those who are intended users.

While there also was some caution given that research can lead the market, i.e., that people may not know they want a product until they see it, the interview respondents felt that it was risky for research administrators to simply assume that research would have an audience, or that the research proponents would have accurately assessed what the market would be.

Identifying Next Steps

Interviewees also noted that it is important to ask researchers, and also potential users, to identify next steps for their research, even before it is implemented. This need not be an implementation plan in the sense of putting research into practice but might be, for example, a discussion of the next research steps that would be appropriate if this one pans out.

7 - A Methodology for Assessing and Managing the Risk in Research

Based on the findings from the interviews as well as our own assessments, we have developed a preliminary methodology for assessing and managing the risk inherent in research endeavors. The methodology consists of a set of questions about the research itself, the audience for it, the next steps that would be needed to implement it, and the steps that would be needed to implement it. Research managers could use these questions to evaluate whether to invest in a proposed project, who else might be involved, and what criteria would be useful in measuring its success.

1) What type of project is it? Is it basic or applied research, and what is the time frame in which it might deliver practical results?

- Is it a product, process or service innovation?
- What are the expected products of the research? For example, is it new knowledge about something we don't understand? A new method for doing a task that we need to accomplish? A new activity that will make us better off? A new material or device?

- What is the extent of the innovation in the project being proposed? Is it a stand-alone project or does it build on other prior projects and add to their results? Is this project likely to produce incremental change or radical or transformational change?
- What are the anticipated attributes - relative advantage, compatibility, complexity, trialability, and observability - of the innovation?

2) Research initiation / supporters of the project: Where did the proposal originate? For example, was it developed by researchers? By potential users?

- Whose needs does it address?
- Are any of the supporters in position to help fund the research, or to help in later stages of development and testing?

3) Markets for the research: Who is the product ultimately for? Is it for the general public, employees of the research sponsor, other agencies? Or is it largely a research product that adds to knowledge and will be of interest primarily to other researchers? To what extent is the research case-specific, generalizable and/or transferable?

- How big is the market for the products of the research? What do users see as the strengths and weaknesses of current approaches and how does this research fit in?
- Are there certain user groups who may not have access to the research results, and if so, why?
- What are the potential tangible outcomes of the research products for that audience or audiences? Outcomes could include new knowledge or improvements to safety, service quality, system performance and operations, mode split, traveler information, quality of life, the economy, energy (fuel savings), and the environment (better, cheaper, faster...)
- How can these outcomes be measured? Are sufficient data and tools available for such analysis?

4) Costs of the research: What is the budget for the research? How certain is it that the proposed research will produce the projects on budget?

- What are the potential sources of funding and financing packages? To what extent would other agencies and/or the private sector participate, and how could this be arranged?
- Are there additional costs likely to be needed for next steps and if so what are those steps and likely costs, or is it too early to tell?
- Is the research itself likely to risk other nonmonetary costs, e.g. to human subjects or to the environment? What are those costs and how significant are they likely to be?
- Are there alternative business models for implementing the research if it is successful?

5) Other efforts underway: Is there other, similar research underway? If so, how will the research products be compared to the products of the similar work?

- Are other research efforts in competition with the proposed research or are there opportunities for collaboration?
- In either case, will funding this research lead to a stronger case for change and a better overall outcome, whichever product is most successful? Or is there a risk that a competing product will render this research obsolete?

6) Other stakeholder perspectives and institutional coordination: Who are the key stakeholders who would have an interest in the research and what are their key concerns and interests? What other governmental agencies would have an interest in the research? To what extent is the private sector interested? Nonprofits? The general public?

- What processes and information are needed to facilitate coordination with other stakeholders? Will the project be more effective if stakeholders are included from the beginning or at some other decision point?
- If multiple organizations are involved in the project, is there consistency in the priorities given to the work among the organizations? Are there agreed standards for allocating costs and other risks? Are there explicit incentives for partners to manage risks effectively?

7) Legal/regulatory/process issues: Are there existing legal/regulatory requirements that impact this research or could impact the implementation of its products? Are changes needed or are new legal instruments needed? What are the challenges associated with existing measures or seeking new measures?

- Is the agency able to contract for the work in a timely manner? If not, what will the consequences of delay be on the relevance, costs, competitiveness and productivity of the research project?
- Are there alternative contracting procedures that could be used to facilitate research progress, e.g., partnerships with other agencies that may have faster / less cumbersome agreements?

8) Organizational behavior and culture issues: What is the culture of the group that would be expected to make use of the research findings? If it is an organization, does the organization have the characteristics that facilitate the adoption of innovations (e.g., rewards for staff taking risks in innovation, senior-level engagement, inter-department communication, flexibility in management)? Or does the organizational structure and culture tend to hinder innovation (e.g. exhibiting risk aversion, punishing failed attempts, lack of identified team for risk management, etc.)?

- What are feasible recommendations to improve the organizational environment if needed?
- Have leaders been identified who will sponsor change in the organization is needed and see it through? How deep is the sponsorship?

9) Monitoring and evaluation: What methods and processes are needed to monitor and evaluate the project's tangible outcomes?

- What will be the consequences if a project fails or the performs poorly? What can be learned from the experience?

- Can peer reviews of proposals, advisory committees to oversee research progress, and a strategic plan for "next steps" be effective strategies for managing the research project as proposed?

10) Benefit / cost analysis: Given the assessment of steps 1-8, do benefits outweigh costs? If not, are there possible revisions to the research plan that would make it net beneficial?

8- Conclusions

Research is an enterprise that is full of promise but also entails risk. Problems with research and its implementation not only reflect back on the researchers but also on the sponsoring organization. Research problems may affect the sponsoring organization's credibility with leadership, rapport with peers and stakeholders, and future funding prospects. Thus managing research risk is an important activity.

Not all research can be expected to produce short-term implementable or deployable results or products. For instance, exploratory research may open up new areas of R&D rather than produce products itself; evaluation research may identify policies or programs that are not working well and lead to termination or revamping or even termination of the policies or programs rather than further implementation. Setting realistic expectations for research projects of different types is a key step in reducing risks.

Organizational issues can sharply affect the ability of an agency to manage research effectively. Issues include staffing availability and competencies, the agency's contracting procedures, its ability to manage internal processes of change, and its relations with other stakeholders and potential partners. Part of the process of risk management for research is to assess the capacities and limitations of the participating and affected organizations and either select strategies that are consonant with the conditions noted or institute a process for reforming the organizational structure and culture.

This paper has identified a number of factors that can affect an agency's ability to get research done efficiently, assess research performance accurately, and promote appropriate and effective use of research results. Consideration of these factors in a systematic way should allow for more effective management of risk.

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Attachment A: Interview Outline (for Semi-Structured Interviews with Transportation Research Managers and Research Leaders)

- 1 - What do you see as the main issues that arise in developing a strong transportation research program?
- 2- What are the most important issues that need to be researched? What types of research are needed to address these issues?
- 3- Who should be involved in designing transportation research program? (probe: federal/state/regional/local govt., transport operators, private enterprise / consumers, public, universities...)
- 4 - Who should be involved in funding a transportation research program? Does this depend on the type of research and if so how so?
- 5- What do you see as the main barriers to effective research? (probe: funding for research, agency priorities, staffing for research administration, research quality, researcher knowhow....)
- 6 - Does research pose risks? If so, what are the most important risks? (probe: outright failure of project; results that are not very significant; lack of money, staff skills, organizational culture to make use of results, resistance from partners, ...)
- 7 - How would you suggest overcoming or managing the risks?