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16. ABSTRACT
 This white paper examines the literature on the status of research in the United States and examines the value of transportation research as viewed by seasoned transportation researchers and senior-level practitioners in universities, public agencies, nongovernmental organizations, and the private sector. The paper documents the changing research landscape (funding levels, decision processes, expected products, dissemination strategies) in general and for transportation research in particular, drawing upon a wide-ranging review of the literature and 50 interviews we conducted with producers and users of transportation research. The paper discusses changes in the research environment and current research challenges, as well as perspectives on the value and limitation of current research paradigms and products. It documents how research is used and notes the direct and indirect benefits that leaders in the field attribute to transportation research. The paper also identifies barriers to moving research results into practice.

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The Benefits of Transportation Research

**White Paper
prepared for the
California Department of Transportation**

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University of California, Berkeley

April 30, 2018

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Executive Summary

Transportation agencies provide substantial funding for research, but their budgets are constrained and research is only one of many programmatic needs competing for financial support. Transportation research is a vulnerable budget item because unlike, e.g., construction or maintenance projects, research rarely delivers a tangible product, or if it does, the product often requires further development to move into market or practice. Increasingly, funders are asked to demonstrate that the benefits of research justify its costs. This raises the question, what are the benefits of research and how and over what time frame can they be measured?

This white paper examines the literature on the status of research in the United States and examines the value of transportation research as viewed by seasoned transportation researchers and senior-level practitioners in universities, public agencies, nongovernmental organizations (NGOs), and the private sector. The paper documents the changing research landscape (funding levels, decision processes, expected products, dissemination strategies) in general and for transportation research in particular, drawing upon a wide-ranging review of the literature and 50 interviews we conducted with producers and users of transportation research. The paper discusses changes in the research environment and current research challenges, as well as perspectives on the value and limitations of current research paradigms and products. It documents how research is used and notes the direct and indirect benefits that leaders in the field attribute to transportation research. The paper also identifies barriers to moving research results into practice.

Previous studies on the benefits of research (e.g., OTA, 1986; OECD, 1996; Rosenberg, 1990; Pavitt, 1991; Mansfield, 1998; Salter and Martin, 2001; Schuller et al., 2001) point out that research can produce new conceptual frameworks and understandings for policy and planning, develop new products or processes that enhance wellbeing, increase economic productivity by reducing costs or increasing output, provide a better understanding of markets for products, uncover process strengths and weaknesses and ways to improve them, enhance decision tools and strategies, identify best practices for improved safety, environmental protection, and social equity in transportation systems, and more. In addition, research findings and hands-on research experience are incorporated into undergraduate and graduate education and training, which in turn leads to personnel who have both explicit and tacit state-of-the-art knowledge as well as mindsets and work habits that are beneficial to employers. However, research benefits do not necessarily materialize at the conclusion of a research project; in many cases research results require confirmation, further development, refinement, testing, or even simplification in order to be put into practice. A previous study on research and innovation in transportation (Deakin, Frick and Phu, 2014) noted the importance of assessing research in accordance with its objectives, since the types of benefits that can be expected and how fast they are realized differ with research type.

In terms of research products, our interviews revealed a difference in what university researchers value, and believe that they are evaluated on, versus what practitioners value

when seeking to learn from research. Researchers aim to publish in highly ranked peer reviewed journals and their performance assessments often depend on this. However, the top ranked journals in transportation and allied fields are rarely read by practitioners, who stay up-to-date through blogs, online newsletters, and other brief research summaries. Many transportation practitioners also make considerable use of professional networks as a way of gaining quick access to current thinking and innovative practices. Conferences that bring researchers and practitioners together are an important source of learning for practitioners, but budget restrictions sometimes limit practitioners from engaging in these events.

Both researchers and practitioners voiced concern about highly technical papers that stopped short of explaining their implications and significance for policy and practice. Case studies whose contribution to the previous body of research is unclear were also criticized by some of the researchers and practitioners interviewed. Practitioners noted that heavy workloads and the fast pace of change limited their ability to wade through lengthy reports. Still, many practitioners as well as researchers noted the value of research that opened up new pathways but might take years or decades to have a significant impact, citing work on pricing and environmental impacts as examples.

The study indicates the importance of new media approaches to research dissemination. It also confirms the importance of university – practitioner partnerships as a means of building networks for bringing research into practice and suggests the need for a more critical view of academic publication strategies. In addition to the publications that academics need for promotion, materials are needed that are accessible to those in practice – shorter, written in less technical language, and pointing out why the research findings or products matter. Production of the latter materials may require investment in communication specialists – editors, bloggers, and writers who are adept at translating complex research papers for a wider audience.

Key Words: transportation research, benefits of research, research dissemination strategies

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<p>30 Research Pays Off (RPO) articles appear in most issues of TRB's bimonthly magazine, TR News. RPO articles highlight research results that provide innovative, cost-effective solutions to important transportation-related problems. The range of these solutions is multimodal and broad.</p>	
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1. Background and Study Objectives

The value of research is a recurrent issue in many fields, ranging from theoretical physics and astronomy to the more applied fields of medicine, business management, public health, and transportation. This paper documents a study designed to provide Caltrans with an assessment of the benefits of research for its own programs, as well as broader benefits to the state and nation. The findings are intended to assist Caltrans to guide investment in research in a rapidly evolving transportation context, and to help Caltrans explain why research is a sound investment with significant positive returns, addressing questions posed by both internal and external decision makers, including the Legislature.

Transportation agencies provide substantial funding for research, but their overall funding is limited, and research is only one of many programmatic needs competing for funding. Consequently, transportation agency staffers devote considerable time and resources aiming to show decision-makers in their own agencies and in legislative oversight committees that their expenditures are cost-effective.

Research is a vulnerable budget item because unlike, e.g., construction or maintenance projects, its cost to sponsor(s) are apparent, but its benefits are more elusive. While research aims to add value, it does not always pay off; for example, a theory may not pan out, a product may be too expensive to be practical, a process may turn out to have unintended consequences. While researchers are increasingly proposing that even these failures are valuable and may open the way to new insights and eventually to positive results in subsequent research efforts, a lack of positive results may lead some researchers to be reluctant to publish and some sponsors to react with dismay (Goodchild van Hilten, 2015). Furthermore, even research that is seen to be successful upon completion may not deliver a tangible product, or if it does, the product often requires substantial development to move from the research setting into market or practice. Thus, there is a need to demonstrate that research expenditures produce sufficient benefits to justify the cost.

A recent study by the National Research Council (NRC, 2012) noted that several challenges are putting the United States' research capabilities at risk. First, federal funding for university research has been unstable, and declining in real terms. Second, state funding for higher education, another important source of research funding, has been declining in real terms for several decades; many universities are under pressure to increase teaching loads without expanding regular faculty positions and this also reduces research capacity. Third, business and industry have shuttered or reduced the size of a number of the private research centers that previously provided research leadership, such as the Bell Labs, but have not fully offset these moves by funding research elsewhere. Meanwhile, other countries have stepped up their research investments. Under these circumstances it is more important than ever to document the benefits as well as the costs of research. Documenting the benefits of research can help transportation agency decision-makers as well as legislators and other high-level executives understand why research is a sound investment even when transportation dollars are scarce.

The objective of this white paper is to provide an assessment of the benefits of research in general and transportation research in particular, drawing upon a wide-ranging review of the literature and

interviews with seasoned researchers and practitioners in the transportation field. In the paper, we inquire about and document direct and indirect benefits that accrue to individuals, organizations and societies as a result of transportation agencies' substantial funding for research. We also identify barriers to moving research results into practice and suggest strategies for overcoming the barriers. The focus is on research sponsored by the California Department of Transportation, but recognizing that research results often have far-reaching implications, the white paper also takes note of benefits that accrue to other agencies and users of research findings and products at the federal, state and local levels in the US and beyond, and in the private sector.

2. Literature Review

Previous studies on the benefits of research provide a foundation on which this study can build. Earlier works (e.g., OTA, 1986; OECD, 1996; Rosenberg 1990; Pavitt, 1991; Mansfield, 1998; Salter and Martin, 2001; Schuller et al., 2001) have documented direct and indirect benefits from both basic and applied research. For example, in addition to providing new products and processes, research can increase economic productivity by reducing costs or increasing output, provide a better understanding of markets for products so that they can be “right-sized”, improve the understanding of product and process strengths and weaknesses and generate ideas on ways to improve them, and develop improved strategies on how to make decisions, deliver products, or change direction. In addition, research is reflected in undergraduate and graduate education and training, which in turn leads to personnel who have both explicit and tacit state-of-the-art knowledge as well as mindsets and work habits that are beneficial. In this way, research can provide both individuals and organizations access to knowledge and skills that are both cutting edge and accumulated through months or years of effort and experience. Studies of the impact of research have also found that there is a local effect, that is, networks of researchers and the development of new capabilities benefit firms close to major research centers and those located close to such centers have a major advantage over those located at a distance.

Definitions of Research

It is useful to begin with a discussion of the many definitions of research, since expectations are shaped by the way research is understood. In its broadest terms, research is any activity that advances knowledge or understanding (OECD, 2015). A variety of types of research have been identified, ranging from basic (or exploratory) to applied (or utilitarian.) Virtually every discipline and every sector of the economy conducts research, from science to the arts, from agriculture to astrophysics, and the research methods used vary widely. Research may be based on systematic reasoning, assembly and analysis of empirical evidence, or on the experiential, and may use quantitative or qualitative methods or a combination.

The objectives of research likewise vary. Research can aim to develop new theories, discover and document facts, replicate or test the validity of previous work, develop new data, methods, and processes, or discuss the issues surrounding a particular issue. While education is usually a secondary objective, research also serves the purpose of training students so that they will be able to carry out

future jobs effectively, creatively approaching the problems before them and systematically applying state-of-the-art methods to their work assignments.

Applied research is distinguished from practice by its generalizability. Activities that apply existing knowledge to a particular case or application are generally not considered research, even though such activities may involve recently developed and creative approaches, unless the analysis and interpretation adds to the understanding of conditions, methods, or other phenomena of interest. Research is thus defined as a systematic activity that contributes to generalizable knowledge.

The Benefits of Research in General

Measurement of the benefits of research has been the subject of numerous undertakings in the research community. Among universities, peer-reviewed publications, patents, and citations continue to dominate as metrics for research value, but there is a growing movement to acknowledge research contributions in other formats, including audio and visual recordings, works of art, computer software and databases, technical designs or working models, major works in exhibition, innovative legal or policy developments, and the translation of research into practical applications that improve people's lives. In addition, there has been movement toward measuring research impact as well as research output, though impact often requires new and less quantitative forms of assessment. Where societal benefit is seen as an important measure of research value, both peer assessment and broader end-user or stakeholder esteem become important measures of research contribution (Hazelkorn, 2012; Bornmann, 2013).

The weight given to practical benefits and therefore to the types of research that are considered valuable varies with the discipline. Not surprisingly, applied and professional fields value practical outcomes more than theoretical disciplines. In business management, research has social value if it generates benefits for society or has actionable or teachable content (Pearce & Huang, n.d.). Similarly, in bioethics, research output of a trial that would not alter any upcoming policy decision affecting a community is deemed not worth conducting in that population (Wenner, 2017). In other words, for these fields research is valuable only if it impacts decision-making or benefits society; as one observer noted, research evaluation is clearly embedded in the sociology of science (Bornmann, op. cit.)

Some research will not produce the anticipated results, and this often presents a dilemma for both the researcher and the sponsor. For the researcher, a project that did not work out as anticipated may mean that no publication will emerge from the work. While journals publishing failed research are beginning to appear, especially in the medical sciences (e.g., *Journal of Pharmaceutical Negative Results*, *Journal of Negative Results in Biomedicine*), in many disciplines there remains a reluctance to publish the findings of studies or experiments that did not pan out. From the sponsor's perspective, failed research may pose a risk, especially if higher-level decision-makers assume that failed research was not conducted carefully or adequately supervised. Yet there is evidence from a number of fields that research failures often lead to considerable learning and in turn result in more robust research methodologies, more detailed data collection, and eventual successes- so that even a research failure can make an important contribution.

Some commentators have posited that research that does not have an immediate product or actionable items is hard to understand and therefore is valued less than more practical research (Petit, 2004; Nightingale & Scott, 2007; Smith, 2001.) Also, if benefits from research do not reach the investors in the research or their immediate customers and clients, this can pose difficulties even if benefits to others are measurable (Neta et al., 2014; Shackleton & Young, 2010). Thus, it can be difficult to assign value to research without actionable content because benefits are less direct and obvious; it also can be difficult for sponsors to see the benefits if they accrue to parties outside their immediate circle.

Communicating benefits of research that does not have an immediate product is also difficult. In the transportation field, one example is the advances in understanding of travel behavior that occurred in the 1970s but took decades to be widely implemented because they did not easily fit into standard four-step modeling processes. A major challenge for practitioners and policy makers is that most research or evidence-based interventions are not ready for dissemination because it takes a long time to translate research into practice (Neta et al., 2014). In several fields, efforts have been made to remedy or at least alleviate this problem. In public health, for example, researchers have developed a framework for dissemination of research findings that emphasizes more contextualized and transparent planning and communication of results (Neta et al., 2014). Public health researchers also have created reporting systems to keep track of the implementation of research. An example is the Robert Wood Johnson Foundation's database on health impact assessments in various fields. In ecological sciences, two large projects have developed a knowledge platform aimed at providing access to a wide range of resources on natural capital and ecological services, designed to make ecological knowledge available and usable to communities of science, policy and practice. The knowledge platform was developed with the understanding that progress toward sustainable development depended on both policy makers and practitioners making decisions with a sound, shared understanding of ecological services (Pérez-Soba et al., 2017). In the field of transportation, publications emphasizing research payoffs are widely disseminated, as, for example, in the Transportation Research Board (TRB) series "Research Pays Off" (TRB, n.d.) Articles appear in most issues of TRB's bimonthly magazine, *TR News*, and highlight research results that provide innovative, cost-effective solutions to important transportation-related problems. In addition, university publications such as the University of California's *Access* magazine aim to publish brief, readable articles on transportation research findings to make complex topics accessible to non-experts. Increasingly, researchers are using blogs to discuss their research in a compact and nontechnical format and are using other social media such as Twitter to send out even briefer summaries of new findings along with links to the full paper or report presenting the work.

The application and uptake of research, sometimes described as the diffusion of innovation, depends not only on the qualities of the innovation itself but also on broader cultural factors that shape how fast it is accepted. The innovation's complexity and its compatibility and relative advantage over existing practices can affect how the research is applied (Rogers, 2010). Research that challenges existing practices, and products and processes that disrupt existing ways of doing something, may offer significant advantages but nevertheless may be resisted by incumbents. Change has costs, and these costs can be considerable even if new policies, practices, or products emerging from research would be beneficial if implemented.

In general, researchers across all fields acknowledge the challenge of translating research into practice, and many have identified better communication of research findings as a key way to make the connections clearer – but how to do this itself remains a topic that is both context-specific and contentious. Investors in research can be expected to have difficulty seeing the returns on their investments when the research output is not a product or otherwise actionable, or when it poses a threat to practices that they are not ready or able to change. The extent that the research lines up with the user’s values and priorities affects how the research is valued and applied. Thus, research funding may depend on selling a value proposition to those who fund research (Shackleton & Young, 2010) -- but this also may result in research that is incremental or marginal in its impact rather than research that challenges and possibly transforms existing practices. The other alternative is to try to create more flexible institutions and organizations so that research that challenges the status quo, or that delivers benefits that don’t happen to be shared by the sponsors, can nevertheless be seen as valuable.

The Benefits of Transportation Research

For a transportation agency, funding research may be considered risky when constrained by a tight budget and competing priorities. Sources of risk internal to the agency include contracting problems, unrealistic expectations for research, lack of organizational capacity to manage or implement research, and insufficient attention to the need for third party participation in research design and implementation. External sources of risk include changes in cost, as well as changes in technology, the economy, governance and institutions, or public policy. Overcoming these barriers may require large institutional changes, such as changes in law or restructuring of an organization (Deakin et al., 2014). Given the risks, agencies may be hesitant to invest in research when there are funding concerns, internal organizational constraints, or great uncertainty about the future directions for the agency.

Despite the presence of risks, federal, state, and local transportation agencies fund billions of dollars of research each year. Research led by the Federal Highway Administration has introduced new technology and design practices that have produced cost savings, reduced congestion, improved safety, maintained infrastructure integrity, and helped plan for future uncertainties, such as extreme weather impacts (FHWA, 2009). Ongoing stakeholder support for research from both the public and private sectors helps keep research funding flowing. Organizations such as the Transportation Research Board (TRB), the American Association of State Highway and Transportation Officials (AASHTO), the American Road and Builders Association (ARTBA), the American Public Transportation Association, (APTA) the American Society of Civil Engineers (ASCE), the American Planning Association (APA), and many others produce statements on research needs and urge Congress and the states to support government spending on research in transportation. Awards for excellence from these organizations are designed in large part to underscore the importance of continued support for research.

The impact of transportation research is often discussed in terms of cost savings to transportation agencies (Shackleton & Young, 2010). For example, the US Forest Service and Colorado DOT pioneered development of geosynthetic reinforcement soil for abutments, which led to a 25 percent cost savings and a two-week time savings (FHWA 2009). As in this example, cost savings to the public agency are often the focus of the assessment.

In addition to cost savings, the number of lives saved is often discussed a major benefit of transportation research. Road safety research ranges from evaluations of various road designs to investigation of the effects of alcohol and narcotics on driver performance, and these studies help agencies assess the efficacy of various interventions. Research results thus inform and improve decision making (Hauer, Bonneson, Council, Srinivasan, & Bahar, 2012). Researchers have also developed models to estimate the dollar value of different safety research projects to help agencies determine which safety research projects to fund (Hauer et al., 2012).

Research also can help agencies better understand their own priorities and preferences and how they compare with views of other groups. For instance, a survey conducted in Australia found that road agency executives gave the highest ratings to research that improved infrastructure and network operations outcomes and reduced costs to the agency, whereas other funders of research were more interested in benefits in terms of lives saved and reduced harm to others (Shackleton & Young, 2010).

Research is also likely to be supported when there is strong relationship between the user community and the research institution. In rural Africa, the Africa Community Access Programme (AFCAP) provides a participatory approach to introducing innovative road technology, which has fostered buy-in from many African countries. By successfully demonstrating research on alternative road surfacing, AFCAP has created an efficient route from research into practice. The AFCAP theory of change is based on a virtuous cycle of research that demonstrates best practice, which leads to capacity development to undertake further research (Leta & Geddes, 2015).

The TRB's "Research Pays Off" series highlights benefits of research in the United States; brief (750-1000 word) summaries written for a broad audience. Topics covered are multimodal and wide-ranging. Over the past several years the topics covered have included runway safety, the impacts of traveler information systems, use of recycled materials in pavements, bridge management, intercity bus services, and subway ventilation, among many others.

The National Cooperative Highway Research Program (NCHRP) has acknowledged that overcoming communication barriers is key to convincing practitioners and policymakers to fund transportation research. NCHRP projects include a strategy for communicating research results to target audiences. Also, NCHRP published a guidebook with tips and recommendations for researchers to help them improve communications on the value of their research (Zmud et al., 2009). The report recommends that agencies develop a communication strategy matched to the context and audience, tailor the content to the audience and channels of communication used, and pay attention to presentation style; however, the authors of the report also suggest that hiring a communications specialist may be an important step – tacitly acknowledging that excellent researchers may not be the best people to communicate the value of their work to others.

In terms of content, the benefits of transportation research that are often discussed are economic benefits, such cost savings and time savings. Other research benefits are more challenging to communicate.

Financial Support for Transportation Research and the Implications for Measuring Benefits

In thinking about how transportation research is evaluated, it is important to consider who is funding it and what their missions are, since this may well affect expectations for outcomes and therefore the evaluation of research benefits.

Research on transportation is funded by a variety of public and private organizations. The US Department of Transportation and its operating agencies (Federal Highway Administration, Federal Transit Administration, Federal Aviation Administration, and others) have been major sponsors for transportation research. For example, current law authorizes FHWA to use funds from the Highway Trust Fund in fiscal year (FY) 2016 through FY 2020 to conduct the Highway Research and Development Program (HRD), the Technology and Innovation Deployment Program (TIDP), and the Intelligent Transportation Systems (ITS) Program. USDOT also provides research funding through other modal agencies and is the lead agency for the nationwide University Transportation Centers (UTC) program. Other than the UTC program, federal funding for research goes not only to universities but also to think tanks and other non-governmental organizations (NGOs) and to consulting firms and other private entities.

In addition, federal law establishes the State Planning and Research (SP&R) Program, which is funded by a two percent set-aside from each state's apportionments of five programs: The National Highway Performance Program, the Surface Transportation Block Grant Program, the Highway Safety Improvement Program, the Congestion Mitigation Air Quality Improvement Program, and the National Highway Freight Program. At least 25 percent of these funds must be used for research, development, and technology purposes. States use these funds to conduct research aimed at solving specific transportation issues at the State level or can apply them toward Transportation Pooled Fund projects. (<https://www.fhwa.dot.gov/research/about/funding.cfm>)

While most transportation research funding from the federal government has been provided through USDOT, other federal agencies have on occasion sponsored research on transportation issues of interest to their missions. Department of Energy funding on transportation energy issues and Environmental Protection Agency funding on transportation and air quality are two examples. The Defense Advanced Research Projects Agency (DARPA) has funded research on automated vehicles and alternative fuels for transportation. Recent years have seen funding from the Centers for Disease Control and Prevention (CDC) and other health organizations on such topics as the health effects of active transportation. In addition, the National Science Foundation has supported transportation research, often with an emphasis on methodological development.

Transportation research is also conducted by and funded by industry. Auto manufacturers, fuel producers, and operator associations are among those that have funded both extramural and internal research programs and projects. As a recent example of industry-sponsored transportation research, automakers have funded market studies and demonstration projects on various types of electric vehicles at several California universities. In addition, a large body of research on transportation safety

has been supported by the insurance industry. One limitation of industrial research is that only some of it is public.

In the US, state funding for transportation research varies considerably, based on the amount of federal pass-through funding received as well as on state legislative priorities. California has been a leader in providing state support for transportation research despite shortfalls of transportation funding. It has matched funds for several university transportation centers and has supported additional research on topics ranging from pavement design to airport planning.

Regional and local transportation agencies and special districts also have funded a considerable amount of applied research. Topics have included improved travel forecasting methods, design of policies for transit-oriented development, evaluation of traveler responses to parking policies, multimodal transportation facility designs, investigation of the causes for decline in transit ridership, and proposals for innovative financing mechanisms, among others.

Sponsorship by operating agencies tends to tip funding toward applied research with short-term implementation possibilities, though some longer-term and more exploratory research has been conducted on new technologies, new data sources, and emerging methods. National Science Foundation (NSF)-sponsored research and a portion of the research funded through the University Transportation Centers program have been more likely to include research that aims to develop new theory or methods.

Research Uptake: Putting Research into Practice

Research uptake is the process of becoming aware of and making use of research products. It involves a broad range of activities including the establishment of partnerships and the development of effective communications strategies and networks of collaboration for identifying research needs and transmitting and discussing research findings. Research uptake also depends on the development of individual and organizational capacity and willingness to access and use the products of research. Strategies for encouraging research uptake must be cognizant of the broader framework of institutions and policies that may support or deter the process.

Studies on research uptake have been done in applied professional fields such as education, public health, and business, as well as in the transportation field. Work on the topic has considered the efficacy of various channels of communication, the impact of social influence and leadership, the value of incentives, “nudges”, and penalties, and the characteristics of a learning vs. a tradition-bound environment. In the transportation field, for example, studies have found that while some organizations are in contact with researchers and learn directly from them, much learning occurs through peer-to-peer exchanges (Marsden et al., 2011). Studies have also identified barriers to implementation of research results; common issues are resource constraints, limited staff capabilities and confidence in their skillsets, the need for further refinements to research products to make them ready to use, as well as internal and external controls that restrict changes in practice (Glasgow and Evans, 2007; Deakin et al, op. cit.).

One insight from the work on research uptake is that researchers, policymakers, and practitioners typically work in separate spheres with differing incentives, goals, language, demands, and time frames, and most have limited engagement with each other (Neal et al., 2013). An emphasis on research dissemination may focus such interactions as do occur at the end of the research project when results are available, overlooking the importance of interaction during study designs so that the results will address decision-makers' information needs and match their capacity to absorb the results. Opportunities for ongoing contact through research partnerships or even through indirect channels such as periodic professional meetings may provide researchers with a better understanding of the problems agencies are contending with as well as the constraints they face in responding to new research results, especially ones that challenge current practices. Other strategies for closing the gap between research and practice include identifying and making use of various types of information "brokers" within the organization (Gould and Fernandez, 1989, Tseng and Nutley, 2014) to communicate research findings and help them take root, as well as the development of explicit strategies that allow agencies to graft new approaches onto existing ones, allowing for more gradual change.

Case in Point: The Benefits of Transportation Research in California

Transportation research in California is carried out by private companies, universities, foundations, nonprofits, and state and local agencies. A considerable body of research has been funded under contract to the California Department of Transportation (Caltrans), which has a long history of sponsoring studies addressing the full spectrum of topics for which it has responsibilities. Research projects have addressed policy, planning, travel forecasting, facilities design, materials, geotechnical engineering, construction management, environmental protection, social impact assessment, safety, mobility, new technologies, operations, maintenance, and recycling of materials. Caltrans also funds and supports research by University Transportation Centers, whose work ranges from exploratory to highly applied. Furthermore, Caltrans works in partnership with other agencies with an interest in transportation research, for example by participating in AASHTO pool-funded research and, in state, by including other agencies on relevant research advisory committees. From time to time other agencies in California sponsor research that is relevant to Caltrans (e.g., the California Air Resources Board, the California Energy Commission) and Caltrans often participates in the oversight and review of those projects.

Examples of transportation research in the State of California highlight the some of the ways that research has been of benefit to Caltrans and its partners:

--Acknowledging that gaps exist between research and practice, Caltrans has funded research to review the issue of induced vehicle travel. The research was intended to inform the development of guidance on transportation analysis in response to Senate Bill 743, a state law that (among other provisions) revised environmental review processes and congestion management plan provisions. The research provided an assessment of the applicability of various research findings on induced demand, discussed the limitations in sensitivity of travel forecasting models, and made recommendations on the appropriate use of induced vehicle travel elasticities (Milam, Birnbaum, Ganson, Handy, & Walters, 2017). The results will inform

future analyses of potential highway expansions, which can have significant impacts on land use and the environment.

--Questions have been raised regarding the effectiveness of HOV lanes in curbing emissions. Caltrans funded a case study of the HOV lanes on I-710 in Southern California. The researchers found that the HOV lanes do reduce emissions, but not when the HOV lanes are underutilized or when their addition allows for very high speeds on the facility overall. The study also accounted for the effects of different vehicle fleet compositions (Boriboonsomsin & Barth, 2007). The results are helpful in assessing HOV lane effectiveness under different operating conditions and with different fleet mixes.

--A long-time investor in intelligent transportation system (ITS) technologies, Caltrans sponsored research on why ITS implementation had been slow even when useful technologies appear to be implementation-ready. From interviews with practitioners across the state, the study found that barriers to implementation included ITS literature that contained too much jargon, lack of good information on ITS benefits and costs, ITS evaluations were not objective enough, lack of clear guidance on legal issues such as liability, lack of staff trained to handle the new technologies, and lack of partnerships across local and state agencies. The study also found that there was a need for clearer next steps to move emerging technologies into appropriate applications (Deakin, 2004). These findings acknowledged that existing research was insufficient to guide practitioners on how to implement ITS and identified specific areas that subsequent research addressed in greater detail. The research was presented to the House Science Committee at their request and influenced federal legislation.

-- Research on light rail proximity in Santa Clara County found that properties within 0.5 miles of a light rail station command higher lease rates. The purpose of this research, conducted with partial support from Caltrans via the UC Transportation Center, was to understand the effect of proximity to light rail on property values. The results in the short term allowed local government to fend off lawsuits claiming LRT had lowered property values and in the longer run has been cited in support of higher densities around transit stations (Weinberger, 2001).

--A series of research projects on parking, funded by the University of California Transportation Center, led to regulatory reforms that made parking management more efficient and rational in cities not only in California but across the US (Shoup, 2017.)

--Freight transportation is critical to the economy but has been under-studied since its deregulation in the 1970s and 80s. A series of projects on freight transport, funded through METTRANS, a Caltrans-supported UTC, produced important advances in the understanding of freight transportation issues and opportunities. A report funded by TRB's NCHRP synthesis program documents many of these studies (Giuliano, 2013.)

--Transit has long been considered an important element in urban mobility, livability, and environmental quality, but transit ridership has not kept pace with metropolitan growth and in recent years has stagnated or lost market share. Research on the factors causing a decline in

transit ridership has begun to unpack the relationships among fuel prices, auto ownership and use, the rise of new ride-matching services, and transit level of service (Manville, Taylor, and Blumenberg, 2018). This work is important to state, metropolitan, and local policy makers in California and other states.

These examples only touch on the impact of transportation research in California. Nevertheless, they illustrate that research can help fill specific knowledge gaps, provide defensible policies, and better position agencies for future planning and decision-making.

Summary of Findings from the Literature

Previous studies have identified both direct and indirect benefits from research. Potential benefits include the broad social value of increased knowledge as well as specific, utilitarian benefits such as new, valuable products and processes; increased economic productivity resulting from reduced costs or increased output; a better understanding of markets for products and of product strengths and weaknesses; improved methods and processes for decision-making, production and operation; better understanding of social, economic, and environmental processes, and much more. In addition, research strengthens education and thus contributes to a more effective workforce. There also are economic, social and cultural advantages accruing to locations in which major research centers are located. Which benefits are valued most highly depends on the context and the missions and needs of the sponsors and users; the evaluation metrics often are not the same as those used in the research community. However, even when there is no question about the benefits, putting research into practice can be problematic. Research implementation faces a variety of barriers ranging from resource constraints to staff capacity to internal and external institutional opposition. There is a growing body of research on how to overcome these barriers, generally emphasizing earlier collaboration between researchers and the potential users of research. In the field of transportation, both national and State of California examples of research that has delivered benefits are available.

3. Interviews: Objectives and Procedures

To further elaborate on the findings from the literature and to garner additional ideas on how to assess the benefits of research, we conducted a series of interviews with transportation researchers, research sponsors, and practitioner-users of transportation research. The interviews were designed to elicit the respondents' views on the benefits of research, its cost-effectiveness, barriers to achieving the benefits of research, and ways to overcome the barriers, recognizing that the different groups included in the interviews would be likely to hold differing views. Respondents also were asked to offer examples of research that has had significant benefits from their perspective.

We first assembled a list of potential candidates for interview. We identified individuals who were seasoned professionals, with at least a decade of experience and typically significantly more. We included senior faculty members specializing in transportation, sponsors or directors of transportation research, and prominent practitioners in senior positions of responsibility (executive directors, planning

and policy department heads, division chiefs) in transportation agencies, consulting firms, and nongovernmental organizations (think tanks, special interest groups.) We also included several elected officials who were in positions of responsibility with regard to transportation policy and investments. Since our study was focused on the California experience with research, most of the candidate respondents we placed on our list were located in California. However, we also included a dozen thought leaders from the transportation profession elsewhere in the United States. Seventy individuals were included on the list, including 14 individuals identified as alternates.

We prepared an interview guide that included questions on the respondent's experience and views of challenges and changes in the field, their ways of staying up to date on developments in their field, expectations regarding research benefits and costs, and personal and organizational strategies for putting research into practice. We also asked respondents to discuss research that they found particularly valuable as well as research that they found to be less useful. The questions were designed to structure the interview, assuring that major topics of concern were covered, but the overall aim was to have a wide-ranging discussion of the issues. Slightly different questions were asked of researchers than were asked of practitioners. The questions covered in the interview are presented in Table 1.

For each candidate respondent, we located a telephone number and email address from public sources, such as their organization's website or published reports and papers. We then prepared a letter of invitation and a brief description of the purpose of the interview, along with a consent form. Candidate respondents then were contacted and invited to participate in the interviews. We first sent email invitations to the 56 individuals on our primary contact list. Most responded within a day or two; for those who did not, we followed up with a second email and then with a telephone call if we still had not received a response.

We received positive responses to our invitation from 47 of the 56 individuals on our primary list. Three of those we contacted declined to be interviewed, one stating that permission would be needed from upper management and was unlikely to be granted, and two others stating that they did not engage with researchers sufficiently to be helpful to the study. We did not receive a response from six individuals after three attempts to make contact. One person who consented to do an interview was unable to schedule it during the study period. We proceeded to contact five additional individuals from our list of alternates to make sure that the respondents represented a broad range of interests and were successful in recruiting four of them; one could not be reached. The resulting 50 interview respondents included current and former elected officials from the California Legislature and California cities, counties, and transit boards, senior officials from the California Department of Transportation and other state agencies dealing with transportation issues, metropolitan transportation organizations, transit operators, city and county transportation departments, federal transportation agencies, private sector transportation providers, consultants, and nongovernmental organizations. Of the 50 who were interviewed, 42 were from California and eight were from other parts of the US.

As part of the effort to schedule the interviews, each respondent was provided with a consent form for their review and was offered a copy of the questionnaire we planned to use in the interview. Each interview was scheduled for 45 minutes to one hour at the respondent's preferred date and time. All

interviews took place in winter and spring of 2018. Five interviews were conducted in person and the rest were conducted by telephone. Respondents were informed that their identities would not be made public and no comments that would allow them to be identified would be reported; rather, their comments and viewpoints would be reported without specific attribution. The interviews were not video or audiotaped but the interviewer kept detailed notes of each discussion, and at the conclusion of each interview the interviewer reviewed the notes for clarity and underscored key points.

After completion of the 50 interviews, we analyzed the interview notes to identify key themes, areas of agreement, and areas in contention. These are reported as findings from the interviews. As a shorthand, we sometimes refer to those with university positions as academics and everyone else as practitioners, although some academics engage in practice (consulting, government service, etc.) and some staff members have taught at the university level.

4. Findings from the Interviews

The interviews identified a number of salient changes in the research environment, discussed the issues raised by current funding levels and program designs, and offered a variety of perspectives on the value and limitations of current research paradigms and products. Respondents discussed what they saw as the key benefits of research as well as concerns they had about research costs and how research is funded, how research is selected and produced, and how its results are communicated. They also discussed the ways they and their organizations make use of research, identified several barriers to moving research results into practice, and offered suggestions for increasing research uptake.

The Changing Research Environment

All of the respondents had at least a decade of experience in the transportation field and most had been the field for at least two decades. Respondents observed that the research landscape has changed in recent years in several ways: in the funding levels available, the decision processes for funding research, the expected products and time frame for production, and the dissemination strategies expected, as well as the topics receiving the most attention. Almost all of the respondents commented that funding constraints had become a significant issue. Beyond funding, academics focused primarily on process issues whereas senior officials and practitioners were more likely to comment on changes in the topics that research is addressing.

Academics commented that transportation research is better funded than in the past, but there is also more competition for available funds, as well as less funding for the more basic, speculative types of research and for projects that evaluate or propose changes in direction for current organizational relationships. In particular, funding for research in from the National Science Foundation (NSF) was pointed out to be very limited and difficult to secure. Several

researchers noted that increasingly, extramural funding is tied to specific products that are expected to be put into practice or to inform a policy decision on a short time frame – a year or less – with multi-year projects less commonly supported. Research on new technologies was called out as an exception by some, who commented on agency and private sector willingness to invest for the long haul, but others argued that the fast pace of change in new technologies and services made the necessary pace for research even faster.

Asked about how the topics addressed in their work had changed, everyone commented that increased prospects for the implementation of automated vehicles would likely transform the transportation industry in numerous ways and commented that the emergence of shared services (carsharing, bikesharing, scooters for rent, as well as Uber, Lyft and other transportation network companies) were already having a large impact, although it was mostly being felt in central cities and not so much in the suburbs or in intercity travel. Practitioners also commented that social and environmental factors were a bigger part of their concerns than they had been in previous decades. Several made the point that compared to, say, 20 or 30 years ago, considerable work is being funded on transportation and social equity, transit issues, nonmotorized modes, and environmental concerns, especially with regard to strategies to reduce greenhouse gas emissions. They saw less emphasis (although not necessarily less need) in the areas of highway design, materials, and construction processes. Some commented that there needed to be renewed emphasis on new ways to finance transportation, especially given the changes in the vehicle fleet and the controversies over gas taxes. A few commented that work on design, materials, and processes remained critically important, given aging infrastructure and limited funds; innovations that allowed faster and less costly construction and renewal were seen as urgent. Several also pointed out that automation research would need to broaden out from vehicle technologies to their implications for street and highway design and control, parking management, curb management, and the institutions necessary to manage the new options being offered, but they also noted that at this point such research is likely to take the form of speculation because the technologies are still emerging.

Practitioners and elected and appointed officials agreed with academics that considerable emphasis was being put on research that could produce short term payoffs. As discussed in more detail below, the academics tended to see this as creating problems whereas practitioners saw the short-term focus as producing more predictable and measurable benefits and added that in a tight and uncertain fiscal environment and changing technological framework, a short-term focus seemed unavoidable.

The Importance of Research Funding

While most university faculty members are paid in part to carry out research, the faculty members interviewed as part of this study universally looked to extramural funding as urgently

needed, both to help support their own research and to allow students, particularly graduate students, to participate in the research process. Some in the consulting field also seek research contracts and grants from federal and state agencies and see this as an important part of their work. For agency leaders and elected officials, research benefits are often measured against the funding that they provide for research. In this context, nearly all of the participants in the interviews talked about the importance of funding for transportation research, noted that it had increased over the last couple of decades even though transportation budgets had in general not kept pace with costs, and underscored the importance of explaining how the research funding was paying off.

The increase in funding for transportation research cited by many of those interviewed was attributed largely to the creation of US DOT's University Transportation Centers (UTC) program in 1987 and its expansion in the 1990s. UTCs are consortia of two or more universities and they periodically compete for multi-year federal funding. Currently the UTC program has federal funding for five years, 2016-2020, at approximately \$2.8 million a year for national UTCs, \$2.6 million a year for regional UTCs, and \$1.4 million a year for Tier 1 UTCs. Each center is required to obtain matching funds from non-Federal sources; national and regional UTCs must obtain dollar-for-dollar matching funds and Tier 1 UTCs must find matching funds for 50 percent of the amount of the UTC grant.

Some of the funding at UTCs goes to support conferences, publications, and administrative activities, but most of the funds are directed to faculty-led projects that provide graduate students with paid research opportunities. As several faculty members interviewed for the study noted, the UTC program has enabled university transportation programs, especially in engineering and planning, to increase graduate student enrollments and transportation course offerings and thus to increase the number of trained transportation professionals entering the workforce. The graduate student fellowships and research positions funded by the UTC program were credited with attracting students to transportation who might otherwise have gone into other fields, and in turn, the higher student enrollments in transportation programs were seen as having enabled universities to expand the number of faculty positions in transportation. While the faculty members who participated in this study were extremely grateful for this, they also noted that a side effect is that there also are substantially more faculty members and students in competition for extramural transportation research funding than in previous generations.

Outside the university, the UTC program is viewed positively, with many interview respondents commenting that it had produced a number of useful studies and had led to new policies and programs in some instances. At the same time, several state officials did raise a concern about its impact on agency funding. This is because the UTC program requires matching funds, and in

many cases state DOTs have provided it, or at least a substantial part of it. For example, for many years Caltrans provided a full match for the UTCs in the state, although with increasingly tight budgets and a large UTC presence, Caltrans has now reduced its contribution to a 25% match for the first year and 50% in later years. (Other DOTs follow different practices; for some state DOTs, the match has been provided on a project-by-project basis and the UTCs have also sought private sector grants or other non-state funds as their match.)

California researchers commented that they feel extremely fortunate that Caltrans has provided so much of the match for the UTCs in the state, has allowed projects to be proposed by faculty- and PhD students rather than by the agency, and has supported a project selection process that is based on external peer reviews as well as reviews by Caltrans staff. However, several researchers also voiced concerns about the stability of UTC funding, mostly because of uncertainties over federal funding for transportation. They commented on the frequent changes in federal priorities for the program since its inauguration and on past difficulties in renewing the federal transportation legislation in a timely fashion. (In past years, federal surface transportation acts were repeatedly extended for short periods rather than renewed.) The current legislation, dubbed Fixing America's Surface Transportation Act (FAST Act), was enacted in December 2015 and funds surface transportation programs through 2020, providing the longest-term federal surface transportation authorization enacted in a decade. Proposals for renewing the legislation thereafter are not yet solidified, however.

UTC projects are usually funded on an annual basis, though the principal investigator can structure the work so that applications for second and third years of funding are possible. A typical project budget includes a graduate student at half time (a direct cost, including tuition benefits, of \$45-\$60 thousand dollars a year – more at private universities with high tuition) plus a faculty member for one or two summer months. The resulting total project cost is on the order of \$80-\$120 thousand, though amounts vary considerably depending on the individual faculty member's salary, direct costs associated with the project (for, e.g., data collection or lab supplies), and the campus' indirect cost rates. While this program structure tends to maximize the number of faculty members and students who receive funding, several faculty members commented that it also leads to a focus on topics for which results can be produced relatively quickly rather than ones that are riskier, where the researcher might be puzzled about both the nature of the problem and the best approach to it and spend a period exploring alternative directions. Yet the latter sorts of projects were seen as having potential for breakthroughs that the near-term, incremental projects are unlikely to produce.

Recently University of California transportation faculty members have further benefitted from research funding from Senate Bill 1, The Road Repair and Accountability Act of 2017 (SB 1). While most of SB 1 funds are for transportation projects such as road repair, bridge

replacement, and transit, SB 1 also includes a \$5 million annual allocation for UC transportation research, with most of the funds flowing to the four campuses that have an Institute of Transportation Studies (ITS). A portion of the research funding is reserved for projects specifically requested by the Legislature, and another portion supports ITS system-wide activities, including a small set-aside for transportation research at UC campuses without an ITS. About 15% of the funds are kept available for “rapid response” activities addressing questions raised by local, regional, and state governments in California. Faculty members can compete for the remainder of the funds by applying for a small grant (\$25,000) for a white paper, exploratory research, or a translational project (e.g., field test, policy briefs.) Research grants of up to \$80,000 are also available on a competitive basis; they require a letter of support from a California government sponsor. Like most UTC grants, the SB 1 funds are for one year only. Currently, however, SB 1 is being challenged and a vote on its repeal has been placed on the ballot for November 2018.

The UTC and, where available, SB 1 funds are welcome sources of support for transportation research, especially because the researcher can propose the topic to be studied. However, these funding sources are not enough to support a large graduate program. For one thing, UTCs are consortia of campuses and the amount that any one campus receives from a center is only a portion of the total granted. With some campuses having dozens of graduate students specializing in transportation in several programs – as one example, UC Berkeley had over 100 master’s and PhD students specializing in transportation in 2017-18 - student support costs run into the multiple millions. Some students are self-funded; university and external fellowships cover part of the costs; but substantial funding for transportation students is sought from extramural contracts and grants. In addition, several research programs in transportation depend heavily on full-time research staff in addition to faculty and students; typically, all or nearly all of such staff costs must be funded on contracts, grants, or gift funds. Thus, to support a large transportation research enterprise, campuses must actively pursue extramural funding from a wide variety of sources.

Many academic researchers commented that they consider NSF the “gold standard” for funding. However, they also acknowledged that NSF funds are hard to get for projects relevant to transportation. As a result, many researchers seek extramural funding primarily from federal, state, and private sector sources, in addition to the UTC and (where available) SB 1 funds. California-based researchers reported that they received substantial state funding from Caltrans in addition to the UTC program match; some also reported receiving substantial funding for transportation-related projects from other state agencies, including the California Air Resources Board, the California Energy Commission, and the California Growth Council. Other important sources of funding mentioned by researchers include the National Cooperative Highway Research Program and the National Cooperative Transit Research Program; US DOT

and its agencies, especially the Federal Highway Administration and Federal Transit Administration; the Centers for Disease Control and Protection; auto manufacturers; other transportation companies, including shippers and freight handlers; and a variety of foundations. Some of these organizations allow researchers to propose the topics for the research but in many other cases the topic is specified by the organization and the researcher responds to a request for proposal (RFP).

Faculty members commented that programs that allow researchers to propose the topic rather than respond to an RFP are extremely important because this opens the way for pathbreaking ideas and critical evaluations in addition to the incremental improvements to existing programs and processes that typically come from RFP-driven research. The programs that accept researcher-generated topics also provide an opportunity for funding PhD dissertations, for which the challenge is for the student to identify a research need, propose a methodology for addressing that need, and then to carry out the research. The ability to propose the research as opposed to simply responding to an RFP is why NSF funds are rated so highly and also why the UTC and SB1 programs are so highly valued by faculty members. Several faculty members commented that RFPs often ask for products that, in the words of one interviewee, are “not really research – there is no new question or uncertainty about the outcome – they’re asking for a summary of what’s known about a topic, or for an application of well-established knowledge to a specific case, technical assistance but not research.” Other faculty members felt this was an issue but also noted that such projects were nonetheless useful in providing training opportunities for undergraduate and masters students.

The other side of the coin is that at least some research sponsors are unclear about the utility of some of the research designed by faculty members and PhD students and are concerned about a substantial portion of transportation research dollars being spent this way. Several transportation agency leaders pointed out that they had specific issues that needed to be addressed and a limited research budget; they argued that at least some of the work done at UTCs should respond to the agency’s research agenda. But a large part of the problem is that the research sponsors found it hard to explain what the benefits of the more abstract, technical, or theoretical work was for their agencies or the broader public. As one put it, “With very little money to put into research, we have to make sure we get what we need from it, and we need to be able to say what was accomplished by each project we fund. We may have to explain our expenditures to [elected officials] who won’t be happy with us if we can’t explain the relevance of the work to our mission.” The respondent emphasized that the concern was one that researchers should be able to address successfully, by documenting the value of their work in a way that policy-makers will understand the benefits, even if the work is, e.g., correcting a statistical bias in a model estimation procedure or deepening the understanding of how travel by young adults or the elderly may be changing. Several respondents also

commented that in their view, it is important for researchers to have links to practice so that they understand the issues that agencies are facing and reflect upon those issues in their work.

To sum up, funding for transportation research has grown, and with this growth in funding more universities have transportation programs and many programs have expanded their transportation faculty and student enrollments. With more researchers and programs in the field, the research environment has become more competitive. At the same time, transportation agency funding has not kept pace with growth, inflation, or travel demand, and so it is even more important for researchers to clearly explain the value of their research to the sponsoring agency and the broader public.

Learning about Current Research

Asked how they kept up with current research, academics tended to list two or three journals that they regularly read or skim, as well as another three to five journals that they read selectively (when looking for research on a particular topic, for example). The journals listed varied with the specialty of the researcher. In addition, several academics noted that they because they update their course reading lists each year, they use that process as an opportunity to catch up with the literature. Pulling together the literature review for research projects and reviews of manuscripts submitted to journals and book publishers are other ways that academics keep up with the literature.

In contrast, most practitioners reported that they did not have a lot of time for keeping up with the journals or wading through lengthy reports. Some read one or two journals or trade magazines on a regular basis, especially if they are otherwise involved in the organization producing the journal. Senior officials and elected officials acknowledged that they do not themselves read journals very often but are more likely to ask their staff to keep track of current research on particular topics and bring it to their attention. However, senior officials often keep track of blogs on transportation and read news articles on the topic. Blogs, newsletters, and short news and magazine articles also were identified by other practitioners as a frequently used source of information on current events in the transportation field and to some extent on research, although several practitioners also noted that many of the blogs are “selective” in what they report, i.e., report on findings that favor their positions but not on findings that are critical or raise questions about their positions.

Both researchers and practitioners commented that conference attendance was a way that they learned about current research. At conferences, they attend sessions selectively to hear particular speakers or to learn about the work on a particular topic of interest. They also network with others in their specialty and learn about current research and changes in the field in that way.

Some agency leaders encourage their staff to write papers and attend conferences each year as part of ongoing professional development which they budget each year. Other agency leaders reported that they are constrained in offering this opportunity to their staff because of limitations on out-of-state travel. Instead, these latter agencies rely on in-house training as well as occasional seminars, luncheon talks, and webinars as key ways to keep up staff up to date on the latest research findings. Consistent with findings in the literature, practitioners also contact their network of colleagues in other agencies or at universities and consulting firms to find out about specific issues that arise from time to time.

Relevance of Particular Research Topics and Continuing Research Needs

We asked interview respondents to comment on transportation research that they found particularly relevant as well as on research that they found less relevant. Practitioners were not particularly comfortable in criticizing current research; a typical comment was, “I don’t know enough about most of it to judge.” Several practitioners commented that they had occasionally observed that work that had initially struck them as excessively abstract or far removed from practice later on turned out to be useful -- two topics given as examples were transportation pricing and work on Vision Zero, i.e., strategies to achieve the goal of zero deaths in transportation. Both of these policy proposals were initially viewed as impractical and of dubious relevance to the US but came to be seen as plausible and desirable. Practitioners and researchers also noted the value of research that opened up new pathways but might take years or decades to have a significant impact, as appears to be the case with work on automation or on ways to prevent environmental damage.

However, practitioners did express concern about highly technical papers that stopped short of explaining their implications and significance for policy and practice, and both researchers and practitioners expressed frustration with a growing tendency of faculty members to publish very similar papers in several outlets. As one practitioner stated, “If we are funding it, it’s very good that the work is worthy of a highly ranked journal, but it would be helpful if the author would also write a version for us – {the} audience of practitioners -- to make the work accessible to us.” Another practitioner said, “Researchers ought to be able to say what difference their findings will make for policy or practice and a lot of times they don’t do this.” The practitioner went on to say that this shortcoming might more a failing of the research presentation than of the research itself, and something that researchers could correct. For example, the researcher could specifically tie the findings to the policies or practices of a sponsoring agency and show how the findings confirm them or point to the desirability of modifications – additions or changes.

The concern about the need for more accessible publications stemmed in large part from a reaction that staff have a heavy work load and limited time for keeping up with research; they

need to be able to quickly identify relevant research and get the gist of it, after which they can determine whether the need to go into it more deeply (which they can only do selectively.)

While the literature has reported that a barrier to research uptake is agency rules that mandate particular practices, those we interviewed – both academics and practitioners, felt that this was only a moderate concern in California, where procedures for modifying rules of practice are well established (though those who commented added that for some issues the wheels of change move slowly.)

Academics were somewhat more willing than practitioners to criticize certain research topics as “mined out” or “over-done.” Some argued that research into traffic operations is mature and the issues are how to fund, implement and maintain robust traffic operations plans rather than what to do. Some felt that work on transportation land use interactions and on pedestrian and bicycle planning had hit a point of diminishing returns. Several commented that too frequently, case studies are carried out whose contribution is primarily to add another example to an already well-established body of knowledge. They argued that for a case study to be useful there needs to be some form of generalizable knowledge produced – a methodological innovation, an insight into how a policy might operate under conditions not previously studied, etc. Thus, while it is valuable to have multiple cases that represent the range of conditions when evaluating a policy or a design or a material, at some point there is a diminishing return from yet another case. As one researcher put it, “Researchers should be expected to justify why the case study is needed and what new information it will generate, if the topic has already been fairly well explored.” In addition, like their practitioner counterparts, a number of academics were critical of some of the analytical work that they had seen being done. For example, one commented that refinements to methods sometimes greatly increase their complexity but do not make a large difference in the statistical reliability of analysis results.

Several practitioners and a few academics felt that while in previous decades, too little work had been done on transportation’s social and environmental impacts and its overall sustainability, today topics such as ways to improve project delivery or lower costs of construction through management or engineering innovations might well be the ones that are under-studied. Nevertheless, the interviewees brought up a number of topics related to environmental and social concerns that they felt deserved continuing research attention. Specific topics that interview participants identified as needing research were as follows:

Finance

- Process (work flow) management techniques for reducing delays in project delivery, which increase costs

- Infrastructure banks, bonds, and other capital sources of funding: best practices and areas of potential difficulty
- Best practices for asset inventoring and management
- Public-private partnerships – pros and cons of various arrangements, applicability of international experience to US
- Asset recycling – leasing of public infrastructure to a private party with revenues used for infrastructure investment
- Criteria for project inclusion, performance metrics and oversight practices for infrastructure leases, partnerships, etc.
- Organizational structure and staffing needed to effectively arrange for and manage new financing mechanisms

Innovation

- Dealing with infrastructure obsolescence; strategies for introducing new technologies in a cost-effective and user-supportive fashion
- Risk management in tests of new designs and materials
- Risk management for cyberattacks against smart infrastructure
- Greenway design for ecosystem restoration; pros and cons of multipurpose greenways
- How to manage the effects of new services such as Uber, Lyft, bikesharing, etc. on dense urban areas and their streets, sidewalks, and bikeways
- Scenarios on street use and space allocation with automated vehicles
- How to extend new technologies and services to low volume roads
- Timing of changes such as electrification and implications for emissions, finance needs, etc.
- Organizational structure and staffing needed to effectively arrange for and manage innovative designs, materials, delivery systems, services

Multimodal Coordination

- Strategies for connecting ports to land transport that minimize community and environmental damage
- Intercity and regional rail interrelationships in growing regions, especially megaregions; the changing nature of intercity rail as regions expand into their former hinterlands
- Potential effects of high speed rail on demand for air travel at small airports; effects of automated vehicles on demand for short haul air travel and intercity rail travel
- Strategies for coordinating new services such as Uber, Lyft, etc. with public transit services

Public Attitudes

- Factors affecting public acceptance of or opposition to the gas tax and other financing mechanisms
- Better understanding of why large swaths of the public do not accept that revenues for transportation are insufficient to recapitalize systems and expand them as needed
- Longevity of “nudges” – whether behavioral change strategies last more than a few months
- Risk assessment methods for identifying projects that are likely to garner opposition (e.g., probability of litigation causing delays)

Interagency Cooperation and Coordination

- Ecosystem-based approaches to transportation facility design and renewal
- Research on unintended consequences of transit-oriented development, infill strategies, etc. and how to improve outcomes
- Ways to improve information on environmental impacts of transportation projects (interagency cost sharing, mapping, etc.)
- Strategies for managing megaregion issues effectively.

Benefits and Costs of Transportation Research

Asked what they looked for as benefits of research, nearly all those interviewed listed outputs of research: new products or processes and improved methods, decision tools and strategies. Agency staffers added that identification of best practices for meeting various objectives such as safety, environmental protection, and social equity are particularly relevant research products at present because they help them answer important policy questions and improve project designs and performance. Academic researchers and consultants added fact-based evaluations of how well various programs and policies are working to the list of benefits, along with foresight about likely issues and needs with changing conditions and technologies.

Practitioners at the state and local levels frequently mentioned the need for practical tools for project evaluation, scoring, and ranking, especially in light of California emissions rules, cap and trade policies, and financial concerns. But they also noted that the larger benefits of research would be better transportation systems – systems that are compatible with and contribute to healthy communities and a healthy natural environment, serve diverse populations equitably and well, and support commerce and trade for a healthy economy. In this context several suggested that one thing researchers could do was to help benchmark performance along these larger dimensions of benefit.

Faculty members listed training of the next generation of researchers and practitioners as an important benefit of research, but this was initially identified as a benefit by only two agency staffers and one former legislator. Since workforce development is identified in the literature as one of the major benefits of research, we followed up with an explicit question on whether workforce training should be counted as a benefit of university research projects. All but one of those interviewed responded that this was indeed a benefit to their organizations and to the broader field. One agency unit head put it, "...when we are looking for new hires, we do look for [recent graduates] who have had some work experience, either as interns or as research assistants while they were in school, because this gives them some hands-on skills that we can put to work. It also gives them useful perspective on what working in the transportation field is like, which is always helpful."

Publication itself was noted as a benefit of research by faculty members, many of whom noted that without extramural funding their ability to gather vital data, carry out surveys, conduct experiments, etc. would be limited or would take much longer to produce. Several faculty members further noted that they are evaluated in large part on their publication record, so research sponsorship increases their productivity. But while faculty members aim to place their work in highly ranked peer-reviewed journals, their practitioner's counterparts hardly read these journals, and several commented that many journal publications are of benefit to a relatively small research community rather than to the broader community of transportation agencies and users. While researchers would dispute this, arguing that such research finds its way into practice through further research and citation, inclusion in courses and training sessions, and through their own professional activities, they acknowledged that reporting findings in social media outlets, blogs, and brief research summaries would be a useful way to share the benefits faster and more widely.

The interviews revealed an increasing separation in what university researchers value vs. what practitioners value in terms of publications. Researchers aim to publish in highly ranked peer reviewed journals but these are rarely read by practitioners, who stay up-to-date through blogs, online newsletters, and other brief research summaries. Practitioners also make considerable use of professional networks, including associations with professors and graduate student interns, as a way of gaining quick access to current thinking. Conferences that bring researchers and practitioners together are an important source of learning for practitioners.

In terms of costs of research, in addition to the monetary costs, a few respondents mentioned costs of failure. It can be awkward for an agency to sponsor a research project whose results don't pan out for some reason, or one that turns out to have unintended negative consequences, or that generates substantial opposition from affected interests— especially if top management sees it as an embarrassment or members of the legislature see it as a waste of money. Examples listed (not necessarily from California) include pedestrian mall experiments, efforts to establish remote work telecommute centers, biofuels that in some cases did not actually lower emissions as anticipated and/or diverted land needed for food production to fuels production, and trip reduction ordinances requiring employers to establish commute

alternatives programs. While each of these projects has had some successes, each also was found to have some negative effects as well, and some ran into highly visible opposition. On the other hand, as one expert pointed out, a project concluding that a particular policy, methodology, technology, etc. does not work as anticipated or has adverse impacts that outweigh the benefits should not be considered a failure, as such findings could result in avoided costs.

Barriers to Moving Research Results into Practice

Asked about barriers to moving research into practice, most practitioners commented that the biggest barrier is the sheer amount of time that it takes. Changing policies and practices or introducing new ones can be especially time-consuming if the change requires the establishment of new regulations and guidance documents or revisions of policy and procedure memoranda, even more so if the change requires legislation or raises questions about legislative authority. In addition, implementation of some kinds of research findings may require that the agency find new funding, not an easy task, or require that the agency expand its skill sets, which may in turn require significant changes in hiring and promotion policies as well as in training. While in some cases staff resist new approaches, overtly or covertly, in many other cases the cumulative impact of budgetary restrictions, formal rules, staffing challenges, and traditions of practice combine to slow change. Several agencies reported that they have sometimes found it more expedient to form partnerships with other agencies or rely on a long-term consulting contract or a continuing series of consulting arrangements as a way of implementing new technologies or practices, rather than try to change their organization.

The other major issue that acts as an impediment to putting research results into practice is that much research is just not ready to be implemented. Some research is promising but needs follow-up research and development. Some transportation research is not aimed at implementation but rather at opening up new insights – for example, better understanding “irrationalities” in travel behavior and their potential implications for forecasting. As one researcher put it, “The apparent assumption that all research needs or is suitable for an implementation plan is just plain wrong. Research that opens up new ways of thinking about transportation in its many dimensions and varieties ought to be valued for its own sake even if there is not a tangible product or a change in practice that follows.” In addition, implementation opportunities can vary – as one expert pointed out, implementation is not just a yes or no decision; it may be possible to partly implement research results, and/or to implement them in particular situations or in particular locations.

5. Conclusions and Recommendations

Our findings support a conclusion that transportation research is producing a wide range of benefits ranging from new insights into travel behavior and the functioning of transportation systems, to new conceptual frameworks for policy and planning, to new products and services. These outputs in turn have wide-ranging benefits that enhance social and environmental wellbeing, increase economic productivity, and support more robust, equitable, and fact-based decision-making. Research findings and hands-on research experience are incorporated into undergraduate and graduate education and training, which in turn leads to personnel who have both explicit and tacit state-of-the-art knowledge as well as mindsets and work habits that are beneficial to employers. Findings from research are adopted by practitioners as they learn about them from sources ranging from traditional publications to blogs to networks of associates.

However, research benefits do not necessarily materialize at the conclusion of a research project; in many cases research results require confirmation, further development, refinement, testing, or even simplification in order to be put into practice. Many practitioners as well as researchers noted the value of research that opened up new pathways but might take years or decades to have a significant impact, citing work on automation, pricing, and environmental impacts as examples.

In terms of research products, our interviews revealed a difference in what university researchers value, and believe that they are evaluated on, versus what practitioners value when seeking to learn from research. Researchers aim to publish in highly ranked peer-reviewed journals, and their performance assessments often depend on this. However, the professionals we interviewed rarely read the top-ranked journals in transportation and allied fields, and instead stay up-to-date through blogs, online newsletters, and other brief research summaries as well as occasional seminars and training sessions. Many transportation practitioners also make considerable use of professional networks as a way of gaining quick access to current thinking and innovative practices. Conferences that bring researchers and practitioners together are an important source of learning for practitioners, but budget restrictions sometimes limit practitioners from engaging in these events.

The study indicates the importance of new media approaches to research dissemination. It also confirms the importance of university – practitioner partnerships as a means of building networks for bringing research into practice and suggests the need for a more critical view of academic publication strategies. In addition to the publications that academics need for promotion, materials are needed that are accessible to those in practice – shorter, written in less technical language, and pointing out why the research findings or products matter. Production of the latter materials may require investment in communication specialists – editors, bloggers, and writers who are adept at translating complex research papers for a wider audience.

Two major recommendations emerge from the investigation. One is that it is important for all concerned to find a balance between exploratory research and highly applied research. Both are needed, the latter to help transportation agencies move forward with their current workload and the latter to open up new directions and creative new approaches to the transportation of people and goods.

The second recommendation is that researchers need to do a much better job at communicating their research findings to practitioners. Researchers need to publish in the top journals and will be evaluated by their universities based in in large part on their success in doing so. Practitioners will only occasionally turn to these publications for information about new research findings and innovative practices but instead will use blogs, news and magazine articles, abstracts, and their networks of colleagues to learn about recent advances. This indicates the importance of new media approaches to research dissemination. It also confirms the importance of university – practitioner partnerships as a means of building networks for bringing research into practice and suggests the need for a broader set of publications emerging from extramurally funded research. Making sure that in addition to the publications that academics need for promotion are produced may require investment in communication specialists – editors, bloggers, and writers who are adept at translating complex research papers for a wider audience.

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Appendix: Interview Guide

1. Confirm consent.

2. Experience and Observed Changes in the Transportation Field

2.1. How long have you been working in (or interested in) the field of transportation?

2.2. In what ways, if any, have you seen the field change in the past 5, 10, 15 years?

(Open ended – let respondent speak and categorize / check off responses; probe if necessary)

changes in the way transportation is financed / financial difficulties

greater emphasis on sustainability / greenhouse gas reduction

some problems solved – air pollution, energy? (NOTE WHICH ONES)

emergence of new fuels / EVs / automation

new materials and processes for construction

greater emphasis on transit

greater emphasis on nonmotorized transit

new street designs, e.g., complete streets, urban boulevards

Other? _____

2.3. How, if at all, has your work on transportation (or transportation-related issues) changed over the last five years?

(IF CHANGES MENTIONED: What factors led to those changes?

2.4. In your opinion, what are the biggest challenges the transport field will face in the next decade or two, to 2030 or 2040?

3. Relevance of Research

3.1. Do you try to keep up with research findings in your field?

No, not really / don't have time

YES: In what ways? _____

Read journals/ professional magazines - Which ones? _____

Go to conferences - Which ones?

Participate in transportation organizations and attend their meetings: Which ones?

Attend professional development or continuing education classes or seminars

Other: _____

3.2 Is there any particular research product or body of research in transportation that you view as particularly important or influential in your field? If so, what is it?

3.3 What about the opposite: are there particular kinds of research that you don't find useful?

What are they and why are they not useful?

3.4 What are the biggest challenges being faced these days in your area of specialization in transportation?

3.5 Is research helping to address those challenges? Why or why not? (Discuss concerns or frustrations.)

4. Benefits and Costs of Research

4.1. What are your thoughts about the level of research funding in the transportation field? Do you think current spending levels are too low, too high, or just about right? (probe on benefits vs. costs)

4.2. Are there topics where you believe more research is needed?

4.3. In your view, are the various types of research currently receiving an appropriate share of available funding in the transportation field? (probe: basic research, development, applications, case studies) Are there areas where you think the funding needs to be raised? Areas where it could be cut?

4.4. To whom, in your view, do benefits of research accrue? (probe: sponsor, other orgs., broader network of individuals and orgs., general public, economy...) IF BROADER BENEFITS NOTED: What are your thoughts on how to account for those broader benefits? Does that affect your assessment of what public agencies should fund?

4.5 In your view, does having students work on research projects help with research training, or not so much? Why or why not? Has it been important to your organization?

4.6. Do you feel that your organization has the staff time and staff training to make use of current research in the field? Why or why not?

4.7. Does your organization seek out research partnerships with other organizations that have complementary skills, or to share costs? If so, please elaborate.

4.8. Do you see impediments to your organization's being able to capture the full benefits of research? If yes, what problems do you see?

___ staff are too busy

___ some of the research is too complex / too technical for the staff

___ field has changed and requires knowledge of topics not taught 5-10-15 years ago

___ agency rules require that things be done "by the book" even if research suggests other approaches

___ rules set by other organizations determine what can be done or who can do it

___ other:

5. Examples

5.1. Can you identify specific research products or findings that have been important to your work – where in your view research has paid off significantly?

5.2. Can you think of cases in which research was NOT helpful to you? (get specifics)

6. Other Comments

6.1. Are there additional thoughts in this topic that you would like to share with us?

Thank you. ((END INTERVIEW.))