A Reliability Project Brief

Travel Time Reliability 2030

Innovations and Strategies for Today and Tomorrow

MAY 2013

What will the reliability of the transportation system be like in the year 2030? Over the next two decades, many factors that can impact roadway travel conditions, congestion, and reliability are expected to change—namely technology, climate, economy, and energy—but it is hard to predict exactly what the changes will be. With so many variables, how can we be ready for what may come?

Projects from the second Strategic Highway Research Program (SHRP 2) are exploring innovations and possible trends that can shape the future of travel time reliability. This brief provides an overview of two of those projects: SHRP 2 Project L11 (Evaluating Alternative Operations Strategies to Improve Travel Time Reliability), which identified and evaluated strategies and tactics for improving travel time reliability for users of the roadway network in urban and rural areas; and SHRP 2 Reliability IDEA Project L15B (Proximity Information Resources for Special Events), which developed technology for automatically measuring pedestrian crowd metrics, including the size, movement, directionality, and density of crowds.

Evaluating Alternative Operations Strategies to Improve Travel Time Reliability

Travel time reliability is reflected in the variation in travel time for the same trip from day to day. If the variability is not predictable, then travelers and shippers cannot count on arriving at their destination when planned or within some acceptable time window. They build in extra travel time to arrive on time, which has a real cost. Some variability occurs regularly, for example the weekday cycle between peak and off-peak traffic. But at least half the variability is due to unpredictable events such as traffic incidents, weather, work zones, special events, surges in demand, and traffic devices not working properly. Addressing these problems saves time, reduces frustration, and improves safety. Indeed, a consensus is building that motorists value improvements in reliability roughly the same as improvements in average travel time.

The final report for Project L11 (SHRP 2 Report S2-L11-RR-1, *Evaluating Alternative Operations Strategies to Improve Travel Time Reliability*) is useful for different types of planning—including corridor, long-range, and performance-based planning. This report has a strong user focus and at the outset seeks to characterize different reliability requirements. For person travel, key considerations are whether trips are daily or occasional and constrained or unconstrained. Reliability needs of freight movement stem from three factors: the level of schedule flexibility (flexible, inflexible), level of operational adaptability (complete, none), and cost of variability (high or low).

Project L11 identified and evaluated strategies and tactics for improving travel time reliability for users of the roadway network in urban and rural areas. The intent of this project was to

SHRP 2
STRATEGIC HIGHWAY RESEARCH PROGRAM
Accelerating solutions for highway safety, renewal, reliability, and capacity

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provide a short-term perspective regarding system operations and travel time reliability, and to produce a long-term view with innovative ideas that can be implemented in the future. The final report for this project presents a set of options regarding technological changes, operational solutions, and organizational actions that have the potential to improve travel time reliability both now and in the future (by the year 2030). SHRP 2 Report S2-L11-RR-1 is available at http://www.trb.org/Main/Blurbs/168142.aspx or by searching the report title at www.TRB.org.

Effectiveness of Agencies

The final report describes the current effectiveness of transportation agencies (state, local, toll authorities, and metropolitan planning organizations with operations responsibility), incident responders, and other stakeholders in meeting travel time reliability requirements. The report mentions existing measures used by agencies to assess travel time reliability or evaluate disruption events. It also documents the factors that influence the effectiveness of transportation agencies based on a comprehensive literature review. Lastly, transportation management infrastructure is analyzed to assess its influence on an agency's ability to achieve travel time reliability.

Goals and Performance Targets

Given the reliability needs of stakeholders and the ability to manage reliability by agencies, agency goals and performance measures were identified to improve travel time reliability. The final report describes existing data issues and the need for developing goals and performance measures to improve travel time reliability. The goals and performance measures are built on the previous findings and are presented in three parts:

1. Existing travel performance and disruption data,
2. Potential performance measures for agency use, and
3. Developing performance measures and setting goals.

Understanding how the reliability of roadway operations affects stakeholders, agencies can identify the statistics that track the attributes of roadway performance. However, those statistics are useful only if data can be collected to accurately populate the variables. The report describes the current practice in terms of data for roadway-performance travel time reliability and the factors that can adversely disrupt normal roadway operations and cause delay.

Based on the current needs of highway users and the availability of roadway-performance and disruption data, the report discusses the basic performance measures that roadway agencies could use. By combining the needs of individual travelers and freight movers, along with the needs and limitations of agencies, performance measures aimed at improving travel time reliability could be developed within the following three areas:

1. Roadway Performance—measures related to roadway performance (outcome measures);
2. Disruption Management—measures related to how an agency responds to disruptions in normal roadway operations (output measures); and
3. Information Dissemination—measures related to how well an agency informs highway users about current and expected travel conditions in order to improve the users' ability to manage their lives and businesses.

By setting goals and performance targets that fit the context of the current situation, agencies can report on the effectiveness of their programs (capacity increases, operational improvements, incident response programs) for improving roadway performance without being held to a performance standard that assumes a volume/capacity ratio that is not attainable. Where publically acceptable and realistic performance targets can be identified, they may be adopted. Good examples of these exist for managed lanes (for example high-occupancy toll lanes that need to operate in free flow conditions 95% of the time during peak periods) where the public has accepted the volume control measures (pricing) and the operating agencies have devoted the incident management resources necessary to allow the goals to be met.

The Cost Effectiveness and Economic Value of Reliability Improvements

The report includes considerable information on the effectiveness and benefits of strategies or actions that can improve travel time reliability. Such information comes from the US Department of Transportation Research and Innovative Technology Administration (RITA) Intelligent Transportation Systems (ITS) Database, the Benefits Desk Reference, the ITS Deployment Analysis System, and other literature and sources. The benefit data was combined with information on costs to provide some insight regarding the relative cost-effectiveness of different approaches to improving travel time reliability.

The research also sought to develop a way to impute to the dollar economic value of improvements in reliability. The customary approach is to make inferences based on actual or stated behavior. In this research an analytic method was developed that could be easily applied to a specific segment or trip. The approach is based on determining the certainty equivalent of the variability of speed. The analytic procedure—Black-Scholes—is widely used in the financial sector and those who devised it won the Nobel Prize. However, numerous experts could not agree on the validity of applying this economic analysis method to valuing travel time reliability. This innovative approach to valuing travel time reliability, even with the disagreements about validity, is likely to stimulate future research. Appendices describe in detail the method that was used along with examples.

Trends Affecting Travel Time Reliability

The final report provides an overview of the trends that are anticipated to shape future roadway travel conditions, congestion, and reliability. Particular attention was paid to research documents and other literature related to these topics:

1. Demographics, land use, and urbanization;
2. Environment and climate change;
3. Energy costs and availability;
4. Technological innovation;
5. Freight; and
6. Finance, road pricing, and privatization.

Emerging and Future Technology

Technological change, especially innovations that are likely to become reality by 2030, received considerable attention in this research. Among the technological developments identified were wireless mesh networks (e.g., connected vehicles), active traffic management, automation of passenger transport, many types of freight operations, robotic deployment of incident screens to reduce rubber necking, big data and real time analytics in a shared data and decision making environment, wearable computers and augmented reality, telepresence and holographic 3D imagery to support telecommuting, optimal routing and matching of supply and demand, real-time pricing, and resilient infrastructure that preserves functionality when perturbed.

Using Alternative Futures to Identify Trends

Alternative futures were crafted to group the current and potential range of trends and scenarios in order to identify the following:

- A range of cumulative impacts on the operation of the transportation system and the demands placed on it;
- The frequency of nonrecurring congestion;
- The priorities likely to be placed on mitigating such congestion;
- The technologies that may exacerbate the problem or facilitate effective responses to it; and
- The broader social, environmental, and contexts within which the future transportation system is managed.

These alternative futures are not forecasts but rather are a mechanism for bounding the trends that might impact congestion and reliability. To capture the range of possible impacts, these trends were combined to produce a set of three possible future scenarios:

- Alternative Future 1: The Optimistic Scenario
- Alternative Future 2: The Mediocre Scenario
- Alternative Future 3: The Pessimistic Scenario

Global climate change, economy, and energy were considered to be the defining variables within each alternative scenario. Likely influences on the other known trends and on the operation of the transportation system and travel behavior are described for each of the alternative scenarios. In addition, the potential effects of these trends on the sources of congestion are noted.

As the future gets closer, the attributes of the highway system naturally become clearer and strategies can be adapted to meet more specific challenges and needs. The immediate task is to develop strategies and treatments that can be used to assure the satisfactory performance of the transportation system under any and all of these possible outcomes.

Alternative Future 1: The Optimistic Scenario

The optimistic scenario assumes a positive outlook on the future as it relates to climate change, economy, and energy. A key assumption of this scenario is that technological advances in energy will provide alternative sources of energy at an expense comparable to today's levels. New technology will also dramatically reduce the contribution of transportation to greenhouse gas emissions, achieving a 75% reduction in greenhouse gas emissions relative to year 2000 levels by 2030. The impacts from climate change will also be less severe than expected. In addition to new technology providing a solution to anticipated

Source: Richard Kelly

Electric Vehicles Charging

escalating energy prices and climate change, economic growth will be stimulated with a steady increase in employment and population within the United States. The demand for reliable transportation will increase because of both (1) increased travel demand as a result of strong economic, population, and employment growth, and (2) new technology making more-reliable transportation systems feasible.

Alternative Future 2: The Mediocre Scenario

The driving variables—climate change, the economy, and energy—will be in a range that supports moderate economic growth as well as the deployment of advanced technologies for transportation systems and operations. Energy prices will continue to increase, but supply, in the form of traditional and alternative fuel sources, will be fairly reliable. The demand for reliable transportation will increase because of (1) a stronger economy and increased employment, (2) pressure for efficiency coming from climate change and energy constraints and regulations, and (3) emerging technologies making more-reliable transportation systems feasible.

Alternative Future 3: The Pessimistic Scenario

The driving variables—climate change, the economy, and energy—will be in a range that does not support economic growth due to, among other influences, frequent extreme weather events and increasing energy prices. In particular, it is assumed that the drivers of change will result in worst-case outcomes, such as an increasing rate of climate change, a worsening of economic conditions, and increasing energy prices. This scenario focuses on the effect of exogenous variables on travel costs and provides the basis for an overall assessment. The demand for reliable transportation will increase because of policies and goals focused on (1) reducing fuel consumption, (2) decreasing greenhouse gas emissions, and (3) supporting economic growth. With the high value of travel cost, delays will become a much stronger economic constraint. Strategies aimed at reducing delays and travel variability will become an important component of state and regional transportation strategies to improve system performance. Large-scale applications of technology, financial tools, and institutional arrangements will be needed to support this focus on system reliability.

Gas Pumps

Summary of Alternative Futures

These three different scenarios help to define the possible range of impacts. They span the set of reasonable predictions that are taken from a variety of studies. They provide a basis for developing a robust set of reliability-improving strategies for the future. These future scenarios also highlight the significant changes that may unfold to help transportation agencies and members of the transportation industry ensure that our infrastructure, both physical and institutional, is prepared to address the transportation needs during the next twenty years. In response to the scenario drivers and responding trends, agencies and the private sector have an opportunity to begin implementing strategies and treatments that can help mitigate a reduction in travel time variability.

Operations Strategies and Treatments to Improve Travel Time Reliability

The final report identifies a list of key strategies and their strengths, weaknesses, threats, and opportunities for improving travel time reliability under the baseline and three future scenarios developed. In order to identify the strategies and treatments that are most likely to have the greatest impact, a literature review focusing on previous and current work of other SHRP 2 Reliability and Capacity projects was conducted, including L03 (Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies), L06 (Institutional Architectures to Advance Operational Strategies), L07 (Evaluation of Cost-Effectiveness of Highway Design Features), and C05 (Understanding the Contribution of Operations, Technology, and Design to Meeting Highway Capacity Needs). In addition to these projects, information from the Federal Highway Administration, state transportation agencies, universities, and other countries were reviewed to ensure a broad assessment of strategies and treatments. Innovative technologies that may impact travel time reliability in the future were also reviewed and included in the report.

Based on their general focus area, the strategies are grouped into six major categories as follows:

Flooded Road

1. Agency management, organization, and resource allocation;
2. Information collection and dissemination;
3. Vehicle technologies;
4. Incident and special event management;
5. Infrastructure improvements and demand optimization; and
6. Technology innovations.

A Concept of Operations

According to the US Department of Transportation, a concept of operations describes the roles and responsibilities of stakeholders with regard to systems and transportation operations within a region. Because of the complexity of the transportation system, as well as the roles and responsibilities of the stakeholders, a typical concept of operations is intended to be a high-level document. In fact, the depth of information of a concept of operations will likely rely heavily on the quantity and variety of systems and likely scenarios within a region. To that end, many regional intelligent transportation systems architectures use high-level operational scenarios to engage stakeholders and to better define their roles and responsibilities. For example, these scenarios may describe what happens during a major weather incident, hazardous material spill, or long-term construction project. As stakeholders assess these scenarios and document their concept of operations, the significance of their roles and responsibilities is readily apparent, which gives stakeholders time to prepare for gaps or challenges in regional operations. The resulting documentation can be a series of statements an agency or group of entities may wish to adopt that are binding, simply stated facts, or that establish a goal or direction.

The report includes a concept of operations document to define the roles and responsibilities that participating agencies play in applying strategies and treatments for improving travel time reliability. The agencies that can contribute to improving travel time reliability include those responsible for transportation systems (at the federal, state, and local levels), law enforcement, freight movement, emergency response, and vehicle manufacturers. If agencies are to achieve the vision of improving travel time reliability, they will have to work individually and in collaboration to implement those strategies most relevant to their region and be able to measure the performance of each strategy. This document has the following purposes:

- Establishing a baseline set of existing conditions describing the strategies that are employed today; and
- Describing the strategies that could be implemented over the next 20 years to enhance travel time reliability for both passenger and freight vehicles.

Cherry Blossom Festival, Washington D.C. | Eric T. Gunther

Strategies were developed to address the three alternative future scenarios spanning the range of future possibilities that could develop by the year 2030.

By anticipating changes in transportation services and travel characteristics, transportation agencies will be positioned to maintain or improve reliability and mobility in the context of increasing levels of demand. The report provides an overview of the organizational, business practices, and funding strategies that are needed to improve travel time reliability by 2030.

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PRoximity Information System for Mobility

Travel time reliability—which is increasingly important to highways, arterials, transit, and air travel—is also important to pedestrians. When managing large crowds, performance measures relating to volume, density, and trajectory of pedestrians (crowd metrics) are essential. PRISM (PRoximity Information System for Mobility), which was developed in SHRP 2 Reliability IDEA Project L15B (Proximity Information Resources for Special Events), gives event organizers the ability to automatically measure crowd metrics. PRISM uses detectors that sense Bluetooth devices, such as cell phones, to identify the location of pedestrians. Software is then used to aggregate this data with data from Twitter and FlickR, and display the size, movement, directionality, and density of crowds in near-real time. The potential uses for these crowd metrics include emergency management and deployment of event staff.

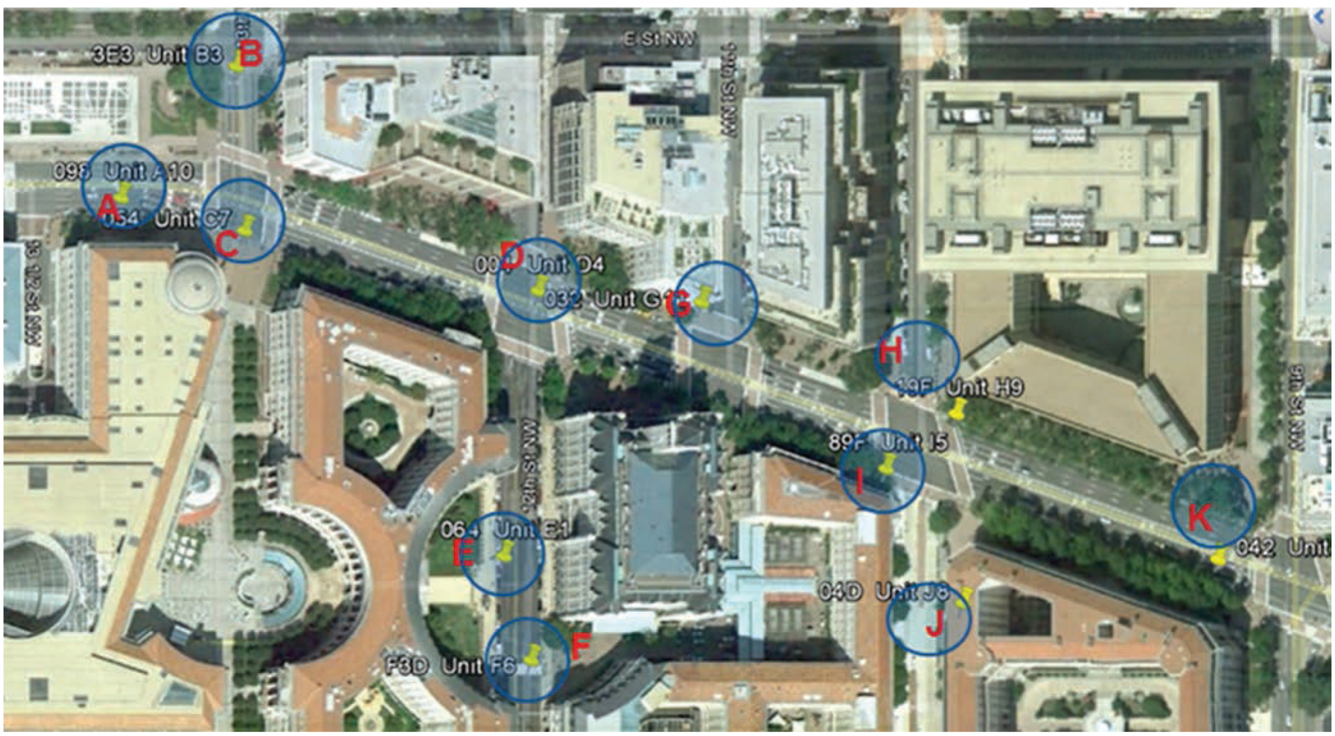
The PRISM team was unified through common experiences while attending special events in the Washington, D.C., area. At these events, critical information related either to health, sanitation (restrooms), first aid, guidance, or mobility (parking, shuttles, and recommended driving routes) were frustratingly difficult to obtain. Many times event specific information such as the program, timetables and navigation of booths and stages were also inconveniently conveyed by event organizers. Stage I of the project consisted of sharing the PRISM concept, and its motivations to a number of potential stakeholders and experts. Through collaboration with this group, the PRISM concept was refined, and revealed that event organizers were similarly frustrated by the lack of objective information about the size and disposition of the crowd attending the event, and by lack of means to communicate with them, particularly in emergency situations. By the completion of Stage I, a number of smartphone applications had emerged to service conference venues, delivering a portion of the event specific information envisioned by the original PRISM concept.

Sakura Matsuri Demonstration Project

Stage II activities consisted of a number of small data collection experiments and prototype software development that led up to a major demonstration in cooperation with Sakura Matsuri, a cultural festival held annually in Washington, D.C., in conjunction with the Cherry Blossom Festival. Sakura Matsuri provided a compact venue with crowd densities similar to that of large National Mall events. Typical attendance at the one-day festival is estimated at 30,000 to 60,000; large enough to adequately exercise the pedestrian monitoring equipment. The Japan American Society of Washington DC (JASW) collaborated with the PRISM team, sharing many of the same needs identified by Stage I collaborators, particularly identifying the need for an objective source of real-time crowd metrics without having to rely on subjective crowd observations and estimates. With the cooperation of the JASW, the team was able to deploy its prototype PRISM system during the one day event and demonstrate many of the key features of the re-focused concept.

The JASW demonstration illustrated a number of capabilities and provided insight into a number of issues. Crowd monitoring was demonstrated using a deployment of 11 portable sensors at strategic locations—such as entrances, crossroads, and stages. Data from the sensors was delivered in real time to a monitoring station and was post-processed for in-depth analysis. Additional data streams from social media (Twitter and Flickr), simulated data streams reflecting the availability of space in nearby parking garages, and the location of a roving medic were integrated into the real-time monitor display. Key findings of the demo included:

- PRISM core monitoring technology was able to capture relative volume of pedestrians at entrances as well as at various locations and attractions within the festival. Although sensor range and placement need to be further optimized, the basic sensing capability was affirmed.
- Integrating social media sources, such as Twitter and Flickr, provided further dimension and color to the real-time monitoring system.



PRISM Sensor Deployment at Sakura Matsuri Festival

- Simulated data feeds for parking capacity and key personnel locations demonstrated extensibility of the system to provide a broad-based event monitoring platform.
- The data architecture relied on a cloud-based information publishing and subscription model that abstracts data integration. This approach minimized application complexity, eased the development of a custom display, and has the potential to greatly enhance reliability.

In depth post-processed data analysis of sensor data provided detailed information on the size, location, and movement patterns of festival attendees. Key accomplishments and findings included:

- The distribution of attendees determined by sensor data agreed favorably with the portions inferred from same-day ticket sales data provided by JASW.
- The estimated sampling rate of attendees was 1.5% to 2.0%. Uncertainty of actual festival attendance, discriminating attendees from passersby, and varying antenna detection characteristics limited the precision of this estimate.
- Detailed trip patterns from the sensor data revealed the time and sequence of visits to various locations and attractions at the festival. Based on this data, the relative attractiveness of various festival locations and attractions was analyzed.
- Attendance patterns (such as time of entry, time of exit, and length of stay) were extracted from the trip pattern analysis. The data sample was of sufficient density to create an animated simulation of the sampled trips, which provided a visual representation of the level of activity at the festival.

Final Report and Video

The final report for this SHRP 2 Reliability IDEA Project L15B is available at http://www.trb.org/main/blurbs/168235.aspx or by searching the Proximity Information Resources for Special Events at www.TRB.org. A video, which documents the demonstration at the Sakura Matsuri Festival, is available on the National Academies' Vimeo site at http://vimeo.com/57636858.

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