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CONFERENCE PROCEEDINGS 49

Performance Measurement of Transportation Systems

Summary of the Fourth International Conference

KATHERINE TURNBULL, Texas A&M Transportation Institute
Rapporteur

May 18–20, 2011
Irvine, California

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This project was sponsored by the Federal Highway Administration, the Federal Transit Administration, and the Transportation Research Board.

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Preface

A Transportation Research Board (TRB) conference on U.S. and international approaches to performance measurement for transportation systems was conducted May 18 through 20, 2011, at the Arnold and Mabel Beckman Center of the National Academies in Irvine, California. The theme for the fourth in a series of international conferences, driving change and being driven by change, captured the changing environment in which transportation services are delivered as well as the role of performance measurement in delivering these services.

TRB assembled a committee appointed by the National Research Council (NRC) to organize and develop the conference program, which included five tracks:

- Driving forces for change;
- Performance-based decision making: the bucks start here;
- Data collection and analysis technologies;
- Drivers and applications; and
- Capturing system performance: new measures for difficult-to-measure topics.

Each track consisted of a plenary session followed by three concurrent breakout sessions.

These proceedings follow the conference format, with the plenary sessions and the breakout sessions for each of the five tracks presented in chronological order. The breakout sessions and the closing session gave participants the opportunity to provide ideas and suggestions on further research, technology transfer, and training. Research topics identified for potential consideration

are listed in the section on concluding remarks. The conference also featured an interactive poster session. Summaries provided by the poster authors are presented in Appendix A.

The conference attracted 130 participants from Canada, Germany, Japan, the Netherlands, South Africa, and the United States, and featured transportation specialists who offered real-world expertise on the application of performance metrics and case studies. This range of experiences provided attendees with a comprehensive overview of the techniques and approaches being applied to transportation systems both in the United States and abroad.

The speakers reflected on the significant evolution of performance measures since the first conference was held in 2000 as well as the increase in their use throughout the transportation industry. As a key tool for delivering results and establishing accountability for transportation systems worldwide, performance measurement is being applied to gauge and evaluate a wide range of transportation activities, from the efficacy of transit operations and congestion management to organizational excellence, program budgeting, and customer satisfaction.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the previous federal surface transportation spending bill, expired on September 30, 2009. In July 2012, after having renewed SAFETEA-LU's funding formulas 10 times, Congress passed the Moving Ahead for Progress in the 21st Century Act (MAP-21), the new funding and authorization bill. Before MAP-21's passage, however,

there had been a heightened interest in and awareness of the possibility of including performance measures in funding considerations.

This report was prepared by the conference rapporteur as a factual summary of what occurred at the conference. The planning committee's role was limited to planning and convening the conference. The views contained in the report are those of individual conference participants and do not necessarily represent the views of all conference participants, the planning committee, TRB, or NRC.

This conference summary was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published conference summary as sound as possible and to ensure that it meets institutional standards for objectivity, evidence, and responsiveness to the project charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

TRB thanks the following individuals for their review of this conference summary: Daniela Bremmer of the

Washington State Department of Transportation, Sue McNeil of the University of Delaware, Michael D. Meyer of Meyer Consulting, LLC, Brendan Nugent of Transport for New South Wales, Australia, and Lance A. Neumann of Cambridge Systematics. Although these reviewers provided many constructive comments and suggestions, they did not see the final draft of the summary before its release. The review of this summary was overseen by C. Michael Walton of the University of Texas at Austin. Appointed by NRC, he was responsible for ensuring that an independent examination of this summary was conducted in accordance with institutional procedures and that all review comments were carefully considered.

The conference planning committee thanks Katherine F. Turnbull for her work in preparing this conference summary and extends a special thanks to the Federal Highway Administration and the Federal Transit Administration for providing the funding support that made the conference possible. Thanks are also due to the members of the TRB Committee on Performance Measurement for their many contributions to planning this event.

OPENING PLENARY SESSION

Winning Performance Management Strategies for the Change Game

Lance A. Neumann, *Cambridge Systematics* (Moderator)
 Daniela Bremmer, *Washington Department of Transportation*
 Sue McNeil, *University of Delaware*
 Steve Heminger, *Metropolitan Transportation Commission*
 Carlos M. Bracerias, *Utah Department of Transportation*
 Lawrence D. Burns, *University of Michigan*

CONFERENCE WELCOME

Lance A. Neumann served as the moderator of the conference's opening session and welcomed all participants. He provided an overview of the morning session to include welcome remarks from the conference cochairs Daniela Bremmer and Sue McNeil, followed by presentations by Steve Heminger, Executive Director of the Metropolitan Transportation Commission; Carlos M. Bracerias, Deputy Secretary of the Utah Department of Transportation (DOT); and Lawrence D. Burns of the University of Michigan. He then welcomed Daniela Bremmer to the podium to deliver her opening remarks.

Daniela Bremmer welcomed attendees to the Transportation Research Board's (TRB's) Fourth International Transportation Performance Measurement Conference and thanked her conference planning committee cochair, Sue McNeil, and team members for their excellent work in organizing an interesting, informative, and interactive program. Bremmer expressed her appreciation to the conference cosponsors, the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA), and to Martine A. Micozzi and Matthew A. Miller of TRB for bringing the conference to fruition.

Bremmer drew attention to the international nature of the conference, noting that the participation of representatives from Canada, Germany, Japan, the Netherlands, and South Africa reflected the universal challenges faced by transportation stakeholders worldwide. The economic slowdown, she said, had rendered performance measurement and analysis all the more timely and critical.

She observed that performance measurement in transportation was still relatively new when the first conference was held in 2000. The first three conferences provided information on methods, techniques, and data needs, and now performance measurement had become a well-established practice at many transportation agencies. Several agencies, however, had yet to embrace performance measures. Since the third conference in 2007, there had been a heightened need for accountability and transparency at transportation agencies, and this conference was a response to the increasing salience of performance-based investments.

Sue McNeil provided an overview of the format and structure of the conference program, which was organized around the following five tracks:

- Driving forces for change;
- Performance-based decision making: the bucks start here;
- Data collection and analysis technologies;
- Drivers and applications; and
- Capturing system performance: new measures for difficult-to-measure topics.

She stated that the conference's primary objective was to share information on the current use of performance measurement by public transportation agencies at all levels and the private sector. The secondary objective was to give attendees the opportunity to identify topics and areas for additional research and technology transfer. McNeil noted that the closing session would focus on follow-up activities, including the development

of research problem statements, sessions for the 2012 TRB annual meeting, and ideas for future conferences. She encouraged active participation during breakout sessions and urged participants to discuss ideas and exchange information with the poster session authors at the evening reception.

MAKING PERFORMANCE COUNT

Steve Heminger acquainted conference attendees with his background in performance measurement, which was heightened by his participation as a member of the National Surface Transportation Policy and Revenue Study Commission (NSTPRSC). At the regional level, his insights have been informed by his tenure as Executive Director of the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area, California.

Heminger reviewed the NSTPRSC's recommendations regarding the reauthorization of the Surface Transportation Act, focusing on performance-driven approaches. The commission recommended that the federal surface transportation program not be reauthorized in its current form. Instead, it recommended a new beginning with a federal program that is performance driven, outcome based, generally mode neutral, and refocused to pursue objectives of genuine national interest.

Acknowledging the difficulty in predicting the outcome of the reauthorization process, Heminger noted that performance measurement was likely to be a factor. He noted the difficulty in defining the objectives of national interest in the post-Interstate era, observing that one challenge in implementing performance measures relates to the saying "the perfect is the enemy of the good." For example, he used transportation safety to illustrate how performance measures could be initiated at the federal level by building upon a preexisting program that rewards states for taking the necessary steps to reduce traffic fatalities.

Asset conditions could be a second logical national focus area, in view of the wealth of data on assets and asset conditions. According to Heminger, agreements could be reached on standard approaches for different modes and types of assets, including roads, bridges, transit, and other components.

He noted the difficulty in determining appropriate performance measures, benchmarks, and targets for metropolitan areas, given their diversity. Metropolitan areas with populations greater than 1 million capture a large share of the market and are key economic engines for the country. Approximately 58 percent of the country's population lives in these areas, which capture approximately 61 percent of gross domestic product (GDP). These metropolitan areas also account for 97 percent of the country's traffic congestion, 92 percent of transit

ridership, and 88 percent of the population exposed to criteria pollutants. Significant movement of freight and goods also occurs in these areas.

Heminger stated that reaching agreement on how to value, measure, and monitor these items is not an easy process and that taking a phased approach makes sense. Initial efforts could focus on one or two items on which there is consensus, and then work could be continued in the other areas.

Heminger described MTC's long-range plan, *Change in Motion*, and mentioned that MTC is developing a new plan, *Plan Bay Area*, that features the following 10 performance targets:

- Reducing per capita carbon dioxide emissions from cars and light-duty trucks by 15 percent by 2035 (a California statutory requirement);
- Ensuring housing for 100 percent of the region's projected 25-year growth by income level without displacing current low-income residents;
- Reducing premature deaths from exposure to particulate emissions by 10 percent for fine particulates and 20 percent for coarse particulates (giving areas high in particulates priority treatment);
- Decreasing collision injuries and fatalities by half;
- Increasing the average daily time spent walking or biking for transportation by 60 percent (an average of 15 minutes per person per day);
- Limiting all nonagricultural development within the urban footprint (existing urban development and urban growth boundaries);
- Decreasing the share of low-income and lower-middle-income residents' household income consumed by transportation and housing by 10 percent;
- Increasing gross regional product (GRP) by 90 percent, an average annual growth rate of approximately 2 percent in current U.S. dollars;
- Decreasing vehicle miles traveled per capita and average per trip travel time for nonautomobile modes by 10 percent; and
- Maintaining the transportation system in a state of good repair.

As Heminger noted, most of these targets do not specifically address transportation; however, transportation infrastructure plans are becoming broader documents for achieving a broader array of social objectives, which he believes is a healthy trend. Although transportation is too often considered an end, rather than a means to other ends, orienting transportation toward broader socioeconomic objectives is a step in the right direction, the problem being that most of these targets are difficult to measure.

MTC analyzed the 10 targets on the basis of the current plan and of an initial vision scenario that includes

significantly dense development patterns and new transit capacity to respond to the legislative mandate. There was little difference in the results from the current plan and those from the initial scenario. The results reflect the large base that exists in the region. They also reflect the progressiveness of the current plan, which allocates 80 percent of available funding to maintenance of the existing system and the remaining 20 percent to new transit capacity or priced roadways.

MTC's current plan accommodates approximately 73 percent of the projected regional housing growth. The remaining 27 percent is expected to occur in the Central Valley. The initial vision scenario assumes that 100 percent of the projected housing growth will be accommodated in the region. A test of the new plan will be how much housing growth can actually be accommodated. The preliminary analysis indicated that the initial vision scenario would reduce the costs of housing plus transportation as a share of low-income households, assuming that affordable housing is constructed in the region.

Determining how to examine GRP has been challenging, and MTC is working on a defensible way of expressing how a transportation plan influences GDP and GRP. Although the plan makes intuitive sense, developing a methodology that is defensible and easy to understand is difficult. MTC is continuing to analyze more traditional transportation targets that depend on the level of investment.

Heminger said that in addition to the discussion about determining appropriate performance measures, there was also a lot of discussion regarding the projects to which the measures should be applied. There has been agreement in the region that once a project is committed, it will not be reevaluated in the plan every 4 years. Two approaches to defining committed projects were considered: one used the existence of completed records of decision in the environmental impact statements to determine committed status, and the other used the beginning of construction. The latter option was considered because many projects, especially transit projects, experienced significant cost increases between the record of decision and the beginning of construction. Ultimately, the environmental record of decision was chosen as the gauge for considering a project to be committed.

The value placed on different elements is also an important part of performance measures and project assessment outcomes. To put projects on an equal footing, MTC used a rigorous benefit-cost analysis (Figure 1).

Reaching agreement on the benefits to be monetized is not easy. Although MTC used a transparent process, there was still some disagreement on the values associated with some measures, such as travel time delay.

In conclusion, Heminger shared a few lessons learned from MTC's experience with performance measurement. First, performance-based results are more helpful for strong projects than harmful to weak ones. Second, resolving the

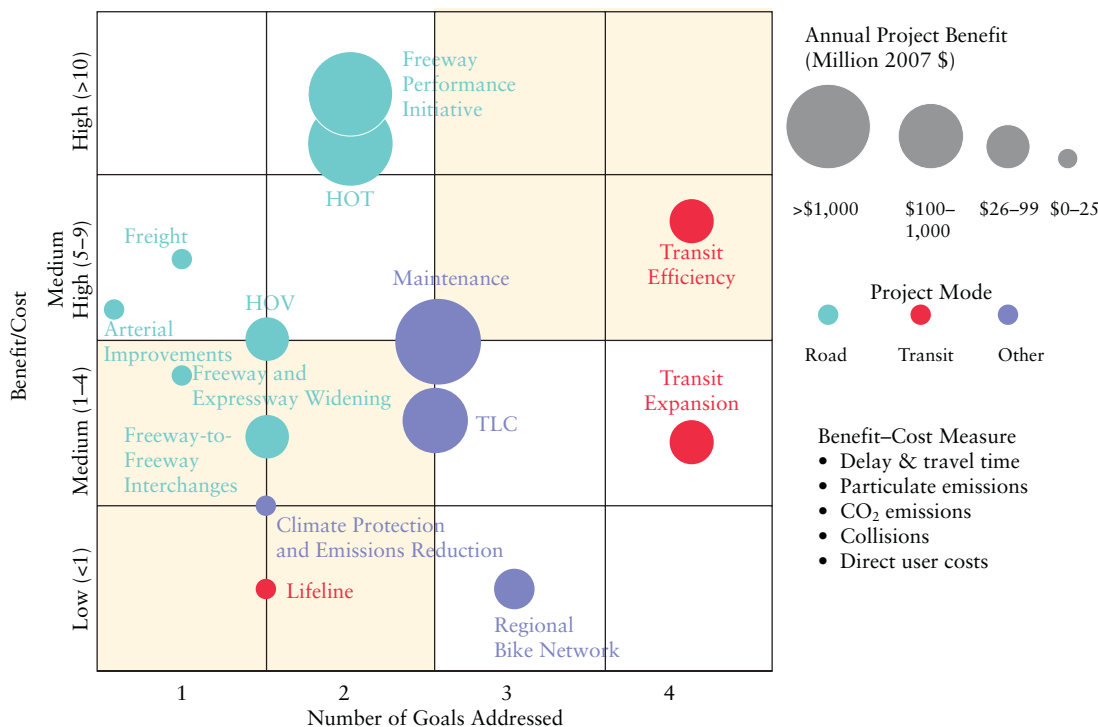


FIGURE 1 San Francisco Bay Area MTC benefit-cost analysis: project assessment outcomes.

question of which projects will be assessed is important. Third, MTC is straining travel models to analyze wide-ranging targets, such as affordable housing and greenhouse gases. Finally, he encouraged conference participants not to eschew aggressive performance goals nor be too risk averse during the transportation planning process.

LINKING TRANSPORTATION PERFORMANCE AND ACCOUNTABILITY

Carlos M. Braceras, Deputy Director and Chief Engineer of the Utah DOT, recounted his experience as cochair of an international scanning study on transportation performance and accountability sponsored by FHWA's Office of International Programs, the American Association of State Highway and Transportation Officials (AASHTO), and TRB's National Cooperative Highway Research Program (NCHRP). In August 2009, a 12-member scan team visited six transportation agencies in Australia, England, New Zealand, and Sweden to benchmark how these countries practice performance management and demonstrate accountability by linking their organizational performance to their budgets. The scan team included representatives from state DOTs, FHWA, FTA, local agencies, metropolitan planning organizations (MPOs), AASHTO, and the private sector, some of whom were in attendance at the conference. The scanning tour was especially timely because of three U.S. transportation issues that needed to be resolved: the reauthorization of the national transportation programs, the stabilization of a financially depleted Highway Trust Fund responsible for both highway and transit programs, and the pressure to demand greater accountability from state, regional, and local recipients of federal transportation aid.

Braceras elaborated on the scan's three main purposes. The first purpose was to find examples of national, state, or provincial strategic goals translated into meaningful performance measures for the transportation agency. The second was to identify ways to establish effective and achievable performance levels on the basis of input from the public, elected officials, and the business community. The third purpose was to examine examples of tying performance and transparency to national, state, provincial, and metropolitan budgets. The final purposes were to identify ways transportation agencies can demonstrate good governance and accountability in meeting or exceeding performance expectations and to obtain input on what works and what does not when performance measures are applied to federal or multiregional transportation programs. The final report on the scan tour, *Setting Safety Performance Measures in Australia and New Zealand: Lessons for the United States*, is available at <http://international.fhwa.dot.gov/pubs/pl11018/pl11018.pdf>.

The scan team met with transportation agency personnel and toured transportation facilities in Sweden, Great Britain, Australia, and New Zealand. The agencies visited included the Swedish Road Administration; the British Department for Transport; the New Zealand Transport Agency; and, in Australia, the New South Wales Road and Traffic Administration in Sydney, the Victoria Department of Transport in Melbourne, and the Queensland Department of Transport and Main Roads in Brisbane.

Braceras noted that a direct linkage between what society expects from its transportation agencies and what they achieve appears to be more evident in the six case study agencies than is commonly found in the United States. Despite the greater linkage of national goals to agency efforts found in the performance management systems, few specific national transportation targets were stipulated for the transportation agencies except in the areas of safety and climate change.

The combination of national goals cascading into state or regional performance management systems appeared to create a fundamentally different approach to managing transportation programs than in the United States, where the performance of state and regional transportation agencies is sometimes gauged by their adherence to federal processes rather than outcomes. Braceras noted that in most of the agencies visited, outcomes seemed to be more important than processes. Budget appropriations were not, for the most part, driven by the goals and resources required to reach their targets. The performance management systems seemed to be largely divorced from the central government's budget decisions. These performance management systems demonstrated how funds were spent and to what end, but lacked, for example, a feedback loop that triggered changes in legislative appropriations. Ambitious, new national visions and broad goals, rather than specific performance targets, tended to generate new investment. When the governments articulated a new transportation vision, adopted new transportation goals, or sought to use transportation investment to achieve other ends, such as an economic stimulus, the likelihood of new investment increased.

Braceras expressed his belief that the transparency and accountability displayed in the six agencies visited rivaled those of the best-in-class U.S. transportation agencies. He stated that the agencies clearly embraced performance management as the system for delivering results, documenting accountability, and producing detailed and ongoing metrics that illustrate the achievement of agency goals and the management of public resources.

On the basis of their meetings, the scan team identified considerations for linking transportation performance and accountability. He said that one consideration appeared to be the use of a few, clearly articulated, high-level transportation policy goals, measures, and targets.

Collaboration with transportation agencies, including the negotiation of local targets that implement national goals and measures, was also identified as important. Other considerations included clearly tracking, measuring, and reporting performance; emphasizing incentives rather than penalties; and understanding that the true benefit of performance management is achieving long-term improvements in decision making and investment.

Braceras said that the scan team found remarkable similarity in the major goals of all the agencies that were visited. These goals focused on safety, system preservation, economic growth, environmental sustainability, and reliability or systems operation. Asset management was also strongly emphasized at all the agencies that were visited. He said that the scan team found that, in general, central governments have steadily reduced the number of measures and targets required of transportation agencies and moved toward fewer, broader, and more policy-oriented goals. The most dramatic example was in Great Britain: the number of government-imposed measures on the Department for Transport had decreased from 600 in 1998 to 30 in 2009.

In 1998, local governments in Great Britain were required to report more than 2,000 performance measures covering all aspects of local governance, including transportation. That large number has been rescinded in the face of broad criticism and replaced with 188 measures. Local governments are required to set targets for only 35 of those measures. The local governments can select the measure on the basis of their local priorities. The remaining measures are reported as long-term indicators for trendline analysis. Performance standards for local governments in Great Britain are separate from those for the central Department for Transport or its Highways Agency.

Transportation officials emphasized the importance of doing it “with people, not to them.” They also advised that incentives and dialogue were preferable to penalties and dictates for intergovernmental performance management.

In most of the agencies examined, officials at one level of government were requiring performance reporting from those at lower levels of government. However, Braceras observed that, universally, state and federal officials said they did not impose penalties on local or state agencies that failed to meet performance targets. It appeared that few actual targets had to be achieved. Goals and measures were used to track performance and identify areas for improvement. When improvement was needed, it was achieved through training, benchmarking, peer exchanges, and staff development of the local agency.

Braceras noted that the transportation agencies visited on the scan tour tended to speak to the public in broader, outcome-based terms such as “the journey home” or “support for the journey” instead of discussing

pavement serviceability indices or volume-to-capacity ratios. Transportation was translated into user-friendly terms rather than technical engineering, financial, or operational terms. The agencies produced voluminous technical support data, but it was often summarized into general categories that could more easily be understood by stakeholders.

Concern over moving people as opposed to moving vehicles was a significant manifestation of this focus on person-centric outcomes. The agencies seemed to be focused on reducing personal travel time as well as on reducing vehicle delay. This personal focus also seemed to increase emphasis on bicycling, walking, and other forms of active travel.

Braceras noted that many of the discussants on the scan tour said that a successful performance management system is a long-term, iterative process. The metrics and targets evolve over time to meet changing fiscal and policy needs. Successful performance management systems were not viewed as short-term, quickly implemented dashboards. Instead, the ultimate benefit of performance management was the continuous improvement of transportation programs to reach long-term societal goals.

Many of the agency representatives visited on the scan tour suggested that performance measurement should be viewed as a long-term effort built on communication, negotiation, and trust. Targets and outcomes were noted as one form of accountability. The experience in other countries shows, however, that regular reporting and performance reviews are perhaps more important in evaluating progress and potential needs for programmatic adjustments.

It was suggested that state DOTs and large MPOs more aggressively implement performance measurement in their day-to-day activities. Some states and MPOs do this today, but an incentivized performance-based program could accelerate adoption of performance measurement by other states and MPOs. Cross-cutting performance agreements could be explored to bring together diverse agencies at each level of government, such as transportation, housing, health, and commerce.

Braceras succinctly summarized the key findings as “less is more, do it together, and use compelling language.” Other important messages were to use “carrots instead of sticks” and to ensure that performance was not viewed as a black box. He noted that the main audiences for implementation actions in the United States are federal, state, and local policymakers as well as performance management professionals and researchers.

The scan team identified 10 key implementation strategies:

- Brief congressional staff on the team’s findings. Braceras reported that a meeting with House of

Representatives staff had already taken place and that additional meetings with House and Senate staff were to be scheduled.

- Meet with chief executive officers of state DOTs. These meetings were conducted in October 2009 and February 2010; a third meeting was yet to be scheduled.

- Present scan findings to other key stakeholder groups, including TRB, universities, the U.S. DOT, other federal agencies, and national nonprofits.

- Develop illustrative ways to present performance information. This goal was being addressed by NCHRP projects.

- Create a website dedicated to performance management. This goal was being addressed by NCHRP projects.

- Conduct peer reviews on performance management.

- Evaluate comparative safety and greenhouse gas emissions efforts from Australia and Europe. A follow-up report is available at FHWA's Office of International Programs website (see <http://international.fhwa.dot.gov/links/pubs.cfm>).

- Synthesize best practices in a benefit–cost analysis from abroad. Support by FHWA and other contract resources was expected.

- Develop a case study report on the use of public service agreements in Great Britain. Support by FHWA and other contract resources was expected.

- Develop a performance management road map for research and development. Possible elements of this roadmap would include documentation of Australian risk management practices, development of guidance for measuring sustainability and livability, and development of a performance management leadership module. NCHRP Project 20-24 was expected to develop such a road map.

REINVENTING THE AUTOMOBILE

Lawrence D. Burns provided a historical perspective of the automobile and presented a vision for a future focused on new vehicle technologies and energy sources. He presented a variety of emerging concepts, including electrically driven and connected vehicles; the mobility Internet; clean, smart energy; and pricing markets. Burns stated that these ideas will provide transformational change in personal mobility, which will result in enhanced freedom, sustainable mobility, and sustainable economic growth and prosperity. He predicted that a future transportation system would rely heavily on performance measurement.

Roadway transportation in the United States today involves 220 million drivers and 250 million cars and trucks. Each year, Americans travel some 3 trillion vehicle miles on 4 million miles of roads and consume 180

billion gallons of fuel. The United States' transportation system provides unfettered mobility for both people and goods, but its drawbacks include dependence on oil and its carbon footprint.

According to Burns, automobiles are undergoing a transformation change that includes the emergence of new technologies such as electrical drive, electric motors, diverse energy sources, digital components, and autonomous and connected vehicles. One change pertains to the interaction of urbanization, electrification, and connected and autonomous capabilities using small, lightweight vehicles. Combining the mobility Internet and the energy Internet with a new vehicle DNA can result in a reinvention of personal mobility. Burns mentioned a book that addresses these issues, *Reinventing the Automobile: Personal Urban Mobility for the 21st Century*, by William J. Mitchell, Christopher E. Borroni-Bird, and Lawrence D. Burns (Massachusetts Institute of Technology, 2010).

A number of opportunities exist for energy diversity. The primary sources of energy include fossil fuels (oil, natural gas, coal) and nonfossil fuels (biomass, nuclear, wind, solar, and geothermal). These energy sources can be processed into gasoline, diesel fuel, compressed natural gas, liquid biofuels, electricity, and hydrogen. These fuels are used by mechanical drive and electrical drive vehicles. The key is to introduce non–oil energy pathways into the transportation sector with natural gas, biomass, and wind or solar energy among the other possibilities.

Burns shared his vision for combining the information Internet and an energy Internet into a mobility Internet that will enhance how people and goods move and interact. The mobility Internet will do for vehicles what the information revolution did for computers. It will be able to manage large amounts of real-time spatial and temporal data on people, goods, vehicles, and infrastructure. Optimally, the mobility Internet will coordinate safe traffic flow, road space, parking space, vehicle fleets, and energy supply. The transformational synergy of the information Internet, the energy Internet, and the mobility Internet will change how people live their daily lives.

Burns predicted that by 2025, travel demand in the United States could grow by 30 percent, to approximately 4 trillion miles of travel per year. He said that he foresees a sustainable market-driven vehicle portfolio that focuses on market tipping points, consumer value, market price, and supplier cost, with little additional roadway expansion and a broader vehicle mix. The system will continue to be maintained and upgraded for safety and throughput and for the transition to safe accommodation of connected and autonomous vehicles. The system will be funded in part by location- and time-based road pricing.

Burns predicted that the system in 2025 will have a number of performance measurement implications featuring a focus on consumers that will consider the total

experience for both personal and commercial vehicles. Meeting the needs of diverse consumers will be critical, and considering market tipping points will be important.

Burns also predicted that by 2025 there will be both mechanically and electrically driven vehicles powered by hydrocarbon, hydrogen, and electricity. These vehicles will use combustion engines and electric motors and be connected and managed by a mobility Internet. Vehicles will be driven both manually, by humans, and autonomously and will be both highly functional to meet broad requirements and purpose-centric to meet specific requirements. Finally, vehicles will be lighter in comparison to the loads they carry.

In closing, Burns stated that he believes the transportation and energy industries are ripe for disruption and change. The convergence of transportation, energy, and communication will be transformational and will enhance lives and create significant and sustainable growth in jobs and the economy. Performance measurement of transportation systems must anticipate, enable, and accelerate this convergence. Burns concluded with three questions for meeting participants to consider in the breakout groups: Will the U.S. transportation system infrastructure be a bottleneck or an enabler of transformational change? Will inertia or innovation define the future? Will the United States follow or lead?

BREAKOUT SESSION 1-A

Preparing Your Performance Management Program for Reauthorization

Mara K. Campbell, *Missouri Department of Transportation* (Moderator)
 Joshua L. Schank, *Eno Center for Transportation*
 Mary Lynn Tischer, *Federal Highway Administration*

DISCUSSION OF REPORTS FROM THE BIPARTISAN POLICY CENTER

Joshua L. Schank discussed two reports by the Bipartisan Policy Center: *Performance Driven: A New Vision for U.S. Transportation Policy*, published in 2009 (<http://bipartisanpolicy.org/library/report/performance-driven>), and a soon-to-be released report, *Performance Driven: Achieving Wiser Investments in Transportation* (published in 2011; <http://bipartisanpolicy.org/library/report/performance-driven-achieving-wiser-investment-transportation>). He summarized the status of the reauthorization efforts, the long-term vision included in the 2009 report, and seven elements included in the second report to accelerate performance management in the reauthorization. Schank's presentation covered the following points:

- The 2009 report noted that developing national goals is the first step in creating a long-term vision for transportation policy. Developing performance measures related to those national goals is the second step. Linking performance to funding in a meaningful way is the third step. The five goals are economic growth, national connectivity, metropolitan accessibility, energy and climate, and safety. The federal government has a role in all five of these goals, as none of them can be achieved without federal involvement.

- The 2009 report also identified performance measures for evaluating progress in meeting the five goals. The performance measures would be used to measure outcomes and to determine how well states, metropolitan planning organizations (MPOs), and other agen-

cies receiving federal funds were meeting the goals. Good performance would be rewarded. Techniques identified for rewarding good performance included establishing a bonus program and creating larger discretionary programs.

- The Bipartisan Policy Center has developed an approach that would maximize the benefits of the \$40 billion investment included in the Mica bill and introduce performance management. There are seven techniques that would assist in moving toward a performance-based system:

1. Asset management. State departments of transportation (DOTs) and other agencies have been focusing on asset management and are comfortable with it as a performance measure. Rather than recommending targets linked to funding at this point, a first step would be to ensure that agencies can report accurate data on asset management.

2. Employing a metropolitan-area-specific action or strategy that rewards the use of proven techniques instead of trying to evaluate the performance of specific metropolitan areas. Examples include high-occupancy toll lanes, pricing, and ramp metering.

3. A freight program that allows discretionary spending. Using a one-size-fits-all formula to determine freight spending would be ineffective because freight projects are narrowly focused. They require customized treatment and thus are very expensive. Therefore, a discretionary program is needed to provide funding for critical projects.

4. Safety. The safety program at the federal level is already based on performance. A few modifica-

tions should be made, however, such as eliminating set-asides for railroad grade crossings. Since data are already available, rewarding outcomes in the safety area is possible.

5. Advancing research on performance measurement and the data needed to evaluate performance. A more focused federal research program with the specific goal of developing performance, performance outcomes, and the data and tools to evaluate performance is needed.

6. Relaxing restrictions on tolling and on other innovative financing methods. This approach would help leverage available resources. States have the ability to raise funds through tolling; the federal government does not.

7. Changes to the transportation planning process. The current transportation planning process is not conducive to a performance-based system. The key to ensuring that formula funds are used effectively is a planning process that focuses on outcomes. The current planning process does not do that. Moving to a program focus rather than a project focus represents one approach for addressing the lack of an outcome-based planning process.

PERFORMANCE MANAGEMENT: THE GOOD, THE BAD, AND THE UGLY

Mary Lynn Tischer provided an overview of performance management at state DOTs and other transportation agencies. She summarized the state of the practice, presented tips for determining performance measures and setting targets, discussed performance measurement in the context of project selection, and highlighted general tips for implementing performance management. Tischer covered the following topics:

- According to the Pew Foundation, most state transportation agencies already employ performance management. Indeed, all states monitor and manage safety, and 18 states have mature performance measurement programs.
- It is important to remember that developing and implementing performance management programs typically takes longer than anticipated, that unanticipated issues may hinder implementation, and that states may get vastly different results from identical measures and countermeasures, depending on the local situation and other factors.
- There are a number of other challenges associated with the use of performance measurement, including
 - Identifying measures that capture the full meaning of topics like livability, sustainability, and economic competitiveness;

- Setting appropriate targets, identifying strategies, and associating projects with strategies;
- Aligning national targets with those of individual states; and
- Addressing disparities in how states carry out performance measurement.
- Performance management is about connecting goals and objectives to resources and results. First, the goals and objectives are defined to describe the strategic direction of the agency. Second, measures—specific performance metrics that track the accomplishment of those goals and objectives—are developed. Last, a cycle of target setting, resource allocation, and monitoring is set in motion. Quality data are key to effective performance measurement.
- The Pew Foundation found that 47 states and the District of Columbia have goals, and 46 states and the District of Columbia have measures for mobility. All of these 46 states and the District of Columbia have data for the measures. Other common measures focus on jobs, commerce, access, and the environment.
- Common goals among states focus on infrastructure condition, both of pavement and bridges; safety jobs and commerce and economic development; the environment; and access and mobility. Typical measures with infrastructure conditions are increasing the percentage of National Highway System roads with a pavement performance rating of “good” and decreasing the percentage of deck area on structurally deficient bridges. A decrease in fatalities is the typical measure for the safety goal. Measures for other goals are more diverse.
- In setting targets, it is crucial to have good data and to understand the relationship between strategies and outcomes (if one does X, the result is Y) and between input (i.e., resources) and outcomes. It is difficult to determine the impact of projects and programs if these conditions are not met.
- In terms of target setting, it is important to decide on the use of aspirational or realistic targets. Setting targets in consultation with partner agencies and organizations is a good approach. It is also important to evaluate the factors that influence the target before setting a specific metric. Progress toward targets is tracked and reported on a regular basis. It is also appropriate to adjust targets over time.
- Both relatively simple and more sophisticated techniques can be used in setting targets. In setting the targets for decreasing the percentage of structurally deficient bridge decks in the U.S. DOT FY 2012 budget, the percentages from 2007 through 2010 were reviewed. Alternatively, a more sophisticated analytical tool such as the Highway Economic Requirements System (HERS) model can be used to set targets. The HERS model allows comparison of investment and performance relationships. It can be used

to analyze the condition of assets when current spending is maintained, when funding levels are used to maintain the assets in the current condition, or when funding levels are used to improve the assets to a particular level.

- The next step is to use all of this information to determine strategies to meet goals and objectives and to select actual projects. Some states use different approaches in the project selection process. Some states score projects on the basis of how well they address the goals. As part of this approach, some states rank within modes or rank within pools of similar projects. A few states rank projects on the basis of the results of

benefit–cost analyses. For example, Washington state law requires MPOs to use least-cost planning.

- Suggestions for implementing performance measurement include allowing the process to evolve incrementally and implementing performance measures in stages. It is important not to try to do too much too soon. Existing data and work can be used to develop more robust data. A pilot test can be incorporated to better address unexpected problems or unintended consequences. Measures that focus on a single, absolute threshold score should be avoided, as neither low nor high achievers have any incentive to improve.

BREAKOUT SESSION 1-B

Adjusting Your Performance Management Program for Changes in Vehicle and Fuel Technology

Gary L. Cowger, *GLC Ventures, LLC* (Moderator)
 Paul Sorensen, *RAND Corporation*

PERFORMANCE MANAGEMENT IN THE CONTEXT OF EVOLVING VEHICLE AND FUEL TECHNOLOGY

Paul Sorensen discussed the potential impacts that changes in vehicle and fuel technology could have on transportation performance measurement. He also described some of the uncertainties associated with different fuels and technologies. Sorensen's presentation made the following points:

- Evolving vehicle and fuel technologies could affect performance management in two ways. First, they could lead to new dimensions of performance that would be useful to measure and manage. Second, they could influence future performance on measures that were already tracked and managed. Although the latter effect appears likely to be the more dominant, there may be a few new dimensions of performance that will become useful to measure and manage.

- Although the concepts being outlined were speculative, they were informed by two relevant studies. The first, National Cooperative Highway Research Program (NCHRP) Project 20-83(04), *Effects of Changing Transportation Energy Supplies and Alternative Fuel Sources on Transportation*, developed plausible energy use scenarios for 2050 and considered their impacts on state departments of transportation. It also identified robust policy responses. The second study examined performance-based accountability systems. This project focused on the combination of performance measures and linked incentives to improve public service delivery in transportation and other sectors.

- NCHRP Project 20-83(04) considered a range of alternative fuels and vehicle technologies, including improved conventional vehicles and hybrids, natural gas-powered vehicles, biofuels, and flexible-fuel vehicles. Other technologies are electric vehicles, hydrogen fuel cell vehicles, and relevant technologies for heavy vehicles.

- Future prospects for alternative fuel and vehicle technologies are subject to considerable uncertainties, such as future oil prices, improvements in conventional vehicle fuel economy, and technological breakthroughs in alternative fuel and vehicle technologies. Other uncertainties are federal and state climate and energy policies and transportation funding policies.

- Many experts believe it is unlikely that petroleum will be replaced as the primary transportation fuel in the next 20 to 40 years. Factors favoring the continued use of conventional vehicles include moderate oil prices, improved fuel economy, and the lack of cost-competitive alternatives. Factors that could reduce the share of conventional vehicles include higher oil prices, government policies to promote the development and adoption of alternative fuel vehicles, and technology advances in alternative fuel vehicles.

- There is significant momentum toward biofuels, but they are not expected to make up more than 20 to 50 percent of transportation fuels in the future. Factors that would favor increased use of biofuels include higher oil prices, more stringent renewable fuel standards and continued subsidies, public and private research and development support for advanced biofuels, and greater adoption of flexible-fuel or intermediate-blend vehicles.

Factors deterring the increased use of biofuels include feedstock capacity constraints; negative impacts on land, water, and food availability; and the lack of investment in a distribution and refueling infrastructure.

- Natural gas could be a transitional energy source, and the technology is relatively mature. The number of commercial offerings has decreased in recent years, however, and currently accounts for only 0.1 percent of vehicles on the road. Factors that favor an increase in the use of natural gas include reduced costs of natural gas relative to petroleum, reduced vehicle cost premiums, increased model options, and a refueling infrastructure. Other factors include advancements in onboard storage and vehicle range and vehicle purchasing subsidies. Factors that deter an increase in the use of natural gas include moderate oil prices, an increase in the cost of natural gas, and advancements in competing fuel and vehicle technologies.

- Commercial development of electric and plug-in hybrid vehicles is under way. Future success will hinge primarily on advancements in battery technology. Factors that favor the increased use of electric vehicles include higher oil prices and improvements in battery technology to reduce cost, reduce charge time, and increase range. Other factors are increased investments in a vehicle charging infrastructure and electric vehicle subsidies. Factors that deter the increased use of electric vehicles include moderate oil prices; advancements in competing technologies; and generation, transmission, and distribution issues that limit the grid's ability to accommodate a significant additional load.

- Although promising in many dimensions, the technology for hydrogen fuel cell vehicles is not yet mature, and widespread adoption over the next 15 or 20 years remains unlikely. Factors that favor the increased use of hydrogen vehicles include higher oil prices and increased government support for relevant research and development. Other factors are reductions in the cost of fuel, fuel cells, and onboard storage; commercialization of vehicles and a refueling infrastructure; and vehicle purchase subsidies. Factors that deter the increased use of hydrogen vehicles include moderate oil prices and advancements in competing technologies.

- NCHRP Project 20-83(04) included the development of a range of plausible future scenarios that are helpful tools for long-range decision making. The scenarios examined a mix of alternative fuels and vehicle technologies and the effects on the cost of driving and on personal travel and goods movement. The scenarios accounted for relevant trends in population growth, economic growth, land use, and other factors.

- The future energy mix remains highly uncertain. Plausible scenarios include petroleum remaining dominant, a single competitor to oil gaining a significant market share,

and future transportation energy use patterns characterized by a mix of competing fuels and vehicle technologies.

- Developments in fuel and vehicle technology will influence the marginal cost of driving. Plausible scenarios for future per-mile driving costs include these costs declining by half, remaining the same, and doubling.

- The cost of driving will in turn influence travel trends. Plausible scenarios include the following:

- High growth: passenger vehicle miles traveled (VMT) growing at historic rates and no change in transit mode share;

- Moderate growth: moderate growth in passenger VMT and a modest increase in transit mode share; and

- Low growth: constrained growth in passenger VMT and a significant increase in transit mode share.

- Transportation energy use and travel scenarios could pose challenges for transportation agencies. These challenges include revenue shortfalls, higher construction costs, and increased traffic congestion. Other possible challenges are increased transit demand, greater safety risks, and increased pressure to reduce greenhouse gases (GHGs).

- Transportation agencies already measure and manage numerous dimensions of performance, including service quality, state of repair, and safety. Additional dimensions currently measured are energy and the environment, efficiency and cost efficiency, and other dimensions of institutional performance. Although some measures address potential challenges posed by evolving energy use patterns, additional measures may be needed.

- Evolving energy and travel trends could affect what is measured and the agency responsible for measurement. Areas to address if transportation faces greater pressure to reduce GHG emissions include the carbon intensity of agency operations, agency support for low-carbon technologies, incentives and options for low-carbon travel, and GHG emissions production from the transportation sector. Measures to consider if transit demand increases considerably include the coordination of land use and transportation measures. Measures to consider if there is a significant shift to electric vehicles include the demand transportation places on the electric grid and transportation's contribution to air pollution and GHGs via grid power sources.

- The scope of looming challenges may call for greater use of performance-based accountability. Transportation already measures numerous dimensions of performance. Performance measures are often used to inform planning and investment decisions. Performance measures are used much less frequently as a basis for accountability. Explicitly linking performance to incentives can stimulate more efficient service provisions. Performance-based accountability may prove to be a helpful tool in addressing pending challenges in a resource-constrained environment.

BREAKOUT SESSION 1-C

Implications of Climate Change and Sustainability for Performance Management Programs

Josias Zietsman, *Texas A&M Transportation Institute* (Moderator)

Tara Ramani, *Texas A&M Transportation Institute*

Cris B. Liban, *Los Angeles County Metropolitan Transportation Authority*

Carel van der Merwe, *BKS Group (Pty) Ltd.*

GENERALLY APPLICABLE FRAMEWORK FOR SUSTAINABILITY PERFORMANCE MEASUREMENT FOR TRANSPORTATION AGENCIES

Tara Ramani discussed a National Cooperative Highway Research Program (NCHRP) project developing performance measures for state departments of transportation (DOTs) and other transportation agencies. She described the focus of the project, the major work activities, and the elements of the flexible performance measures application framework. Ramani's presentation covered the following points:

- NCHRP Project 08-74, Sustainability Performance Measures for State DOTs and Other Transportation Agencies, focuses on developing guidance to help transportation agencies understand and apply concepts of sustainability through performance measurement. The 2-year project was initiated in 2009 and was to be completed in the summer of 2011. The draft guidebook and report were submitted in May 2011 and were to be available in the fall of 2011. (*NCHRP Report 708: A Guidebook for Sustainability Performance Measurement for Transportation Agencies*, was published by TRB in 2011 and is available at <http://www.trb.org/main/blurbs/166313.aspx>. It describes the application of the framework, which will enable agencies to understand and address sustainability, and includes a compendium of performance measures and extensive examples of application that will serve as a resource for possible measures.)
- A number of activities were conducted for the project, including performing a literature review, developing

a flexible sustainable performance measures application framework, and developing a guidebook for use by transportation agencies in applying this framework.

- The project focused on the three dimensions of sustainability: the environment, the economy, and social systems. In addressing sustainability in transportation, both broad and transportation-centric approaches were examined. The project used the following prescribed principles in the development of transportation-related sustainability performance measures: “[S]ustainability entails meeting human needs for the present and future while preserving environmental and ecological systems, improving quality of life, promoting economic development, and ensuring equity between and among population groups and over generations.”
- Realizing that the definition of sustainability might be contested, the project approach focused on using the principles of sustainability, which are presented as nonnegotiable. The implications of strong versus weak approaches are described, as are balancing a holistic view with sector-specific considerations. The use of goals, objectives, and performance measures is presented.
- The recommended performance measures for sustainability are based on a highly effective hierarchical approach that is based on goals, objectives, and measures that help define robust performance measures. In isolation, no one indicator serves as an accurate gauge of sustainability. Furthermore, the set of measures must be applied appropriately.
- The development of the framework for flexible performance measures for transportation sustainability focused on answering the question “What does a trans-

portation agency need to be equipped with in order to successfully address sustainability issues through performance measurement?" The framework consists of fundamental components, overarching components, and auxiliary components. The framework follows the traditional process of developing goals, objectives, and performance measures related to sustainability. The framework includes an implementation step and a feedback loop.

- A set of 11 key transportation sustainability goals is included in the project report and the guidebook. The goals reflect principles of sustainability in the transportation sector. The goals link back to principles of environmental and ecological systems; quality of life; economic development and prosperity; and ensuring equity. The goals focus on safety, accessibility, mobility, efficiency, security, prosperity, feasibility, ecosystems, waste generation, resource consumption, and air quality. Agencies may select from, add to, or modify the goals.

- The objectives and performance measures presented in the guidebook include goal-specific objectives based on focus areas such as planning operations. The performance measures include process measures, output measures, and outcome measures. There is a compendium of objectives and measures for the goals.

- The guidebook discusses the implementation of sustainability performance measurement and describes measure refinement. It also presents the application level, which may be a focus area, business unit, or agency. The application types focus on description, evaluation, accountability, decision making, and communication.

CLIMATE CHANGE AND SUSTAINABLE TRANSIT PERFORMANCE

Cris B. Liban provided an overview of transit's effect on the carbon footprint of a region and its impact on greenhouse gas (GHG) emissions. He described the Los Angeles County Metropolitan Transportation Authority's (Metro's) approach to sustainability methods used to estimate GHG benefits from mode changes, congestion relief, and changes in land use. Liban's presentation covered the following points:

- Transit can have an effect on the carbon footprint of a region. According to the American Public Transportation Association (APTA), higher levels of public transit and the more compact land use patterns supported by transit can help reduce emissions from mobile sources.

- The APTA-recommended practice for quantifying GHG emissions from transit, published in 2009, provides guidance on estimating transit's impact on GHG emissions and supporting programs on GHG.

- GHG emissions from transit include transit vehicles and fuels; facilities, stations, and maintenance

yards; construction and maintenance; and nonrevenue vehicle fleets. GHG emissions from these elements are subtracted from the benefits of transit, which include mode shift, which avoids trips by private autos; congestion relief, which improves fuel efficiency; and compact development, which means fewer auto trips are required.

- Metro's sustainability approach includes finding ways to significantly reduce its carbon footprint while simultaneously increasing and expanding the transit system using funds from Measure R, the half-cent sales tax increase approved by Los Angeles County in November 2008. Other elements include integrating sustainability principles with planning, construction, operation, and procurement as well as applying principles of environmental management system procurement.

- Metro publishes an annual sustainability report based on the Technical Protocol of the Global Reporting Initiative (GRI), a nonprofit organization dedicated to promoting economic, environmental, and social sustainability. It provides a free and widely used comprehensive framework for sustainability reporting whose indicators reflect performance as related to inputs (e.g., energy, water, and materials) as well as outputs (e.g., emissions, effluents, and waste). Additionally, the GRI protocol considers a wide array of potential effects ranging from biodiversity to regulatory compliance to environmental expenditure. It compares the change in environmental impacts to the changes in service and ridership. The efficiency of growth can also be estimated. The protocol's normalizing factors include the number of passenger boardings and revenue hours.

- Metro uses a number of sustainability indicators. A unit of measurement is associated with each sustainability indicator. Examples of indicators and their corresponding unit of measurement include ridership (boardings), fuel use (gallons of gas equivalents), rail propulsion power (kilowatt-hours), air quality (tons of criteria pollutants), and GHG emissions [metric tons of carbon dioxide (CO₂)].

- Several major indicator trends were identified for the period from 2009 to 2011. Examples of these trend indicators include changes in electricity usage on the basis of reassignment of accounts, not magnitude of usage, and a faster increase in overall water use than in ridership growth. There was also an overall decrease in GHGs because of the move to 100-percent compressed natural gas (CNG) buses and further improvements in ridership, fuel use, and facility electricity use. A significant decrease in criteria pollutants was recorded. A steady increase in nonhazardous liquid waste was attributed to the increase in bus washers and facilities.

- Several benefits have been realized from the annual reporting. The reports enable the Metro Board to adopt informed performance targets. They provide the information necessary to implement plans to meet those

targets. The annual reports also create a structure that can be used to monitor progress regularly. The annual reports are available at <http://www.metro.net/sustainability>.

- Cost-effectiveness analysis is used to evaluate the merit of a strategy to reduce climate change. This type of analysis compares the costs and emissions impacts of potential transit strategies to further reduce emissions. Cost-effectiveness is rated in dollars per ton of emissions reduced. Cost-effectiveness analysis informs decision making, although its use presents some challenges. It also informs the climate action and adaptation plan. It provides a comparative analysis based on specified, conservative assumptions drawn from other studies and data collection efforts. It is not the only decision-making tool.

- The cost-effectiveness calculations examine the changes in the cost elements associated with each strategy. Outlay costs include capital, maintenance, electricity and fuel, staffing, external funding, and water and waste. The same measures are used to estimate the cost savings. Only Metro's costs and revenues are captured in the dollars per ton metric. Net present value is used to compare cost and savings in different years.

- The effects of different programs and projects are analyzed using the cost-effectiveness calculator. The net cost per ton of CO₂ can be estimated for different programs and projects. Projects and programs are grouped into three categories according to GHG benefits: large, moderate, and small.

- The cobenefits of strategies related to transit service, mobility, water conservation, and waste reduction are also considered when the results in the decision-making process are used. Although the range of cost effectiveness for some strategies is too wide to support decision making, the approach does make a case for implementation of cost-saving strategies.

- The largest GHG reduction opportunities are typically those that reduce vehicle miles traveled. Furthermore, many of the most cost-effective strategies address GHG emissions from facility energy use. With only a few years of experience, however, it is too early to generalize from these results.

- Metro has a role to play in creating a sustainable region. Metro's programs organically create a nexus of various sustainable elements. Metro forges partnerships and finds common-ground solutions among different groups. Metro operations consider the environment, the economy, and society.

- Examples of Metro's recent sustainability successes include

- Reducing priority air pollutants per vehicle mile by more than 74 percent through the use CNG buses and
- Recycling approximately 44 percent of agency-generated waste.

- Metro has increased its renewable energy portfolio by more than 50 percent, so that it is now one of the largest in the nation for transit systems. Metro has begun to reduce water use by a quarter of a million gallons per day over a 5-year period.

- Metro plays an important ongoing role in environmental leadership in the region. Metro has established partnerships with federal, state, and local government; nonprofit organizations; and other third-party groups in different programs and initiatives. Metro has a clean, green construction policy and a policy of energy efficiency and renewable energy. Metro has also adopted a climate action and adaptation plan and an energy conservation and management plan.

GAUTRAIN: SUSTAINABLE TRANSPORTATION ON TRACK

Carel van der Merwe discussed Gautrain, a public-private partnership rail project designed to address congestion in Gauteng Province, South Africa, in a rapidly growing corridor that links Johannesburg, Pretoria, and the O. R. Tambo International Airport.

Gauteng Province is the economic engine of South Africa; to illustrate, it represents 1.4 percent of the surface area of South Africa, but 36 percent of its gross domestic product. The province, however, is plagued with transportation challenges such as debilitating congestion as well as with socioeconomic challenges such as poverty and race and gender inequality. Van der Merwe's presentation covered the following points:

- Gautrain is a fixed-price turnkey project; a concession agreement was signed in September 2006. The project is financed from five sources, including grants from the Department of Transport, a medium-term expenditure framework from the Gauteng Provincial Government, provisional borrowing, private-sector equity, and private-sector borrowing.

- Gautrain was procured as a public-private partnership because of the ease of integrating the government's socioeconomic development goals. The Gauteng Provincial Government, which provided a medium-term expenditure framework, was the project's public-sector partner. Its private-sector partners included the Bombela Concession Company as the private-sector concessionaire, the turnkey contractor, the operator, the civil contractor, and the evaluation and management contractor.

- To gauge the actual performance of sustainable development measures at the project level, Gautrain developed a process to translate political objectives into performance indicators that can be entrenched into contractual obligations to ensure credible achievements.

- Sustainability is the primary consideration during selection of transportation solutions, especially when proposed technology is considered. The three dimensions of sustainability are environmental stewardship, economic development, and social equity; corporate governance focuses on the three Ps: the planet (the environment), people (society), and profit (finance).

- Several environmental stewardship benefits are anticipated from the project. The estimated reduction of vehicle-generated emissions is 2.8 percent at the local level and 1.7 percent at the regional level. The project will also reduce the level of waste generated and the total land taken for the transport infrastructure. The environmental impact assessment for Gautrain was one of the largest undertaken in South Africa.

- Because the proposed alignment traversed an urban area, socioeconomic issues were often a greater concern than the environmental impact. The route alignment was modified in response to input from public participation and investigations. The concessionaire held regular community liaison forum meetings to address the issues and concerns of the public and to acquire consent for water uses and building demolitions and authorization for new access roads and relocation of utilities.

- Gautrain is more than just another transportation project; it stimulates economic growth, investment, new development, and job creation, and it is designed to restructure urban areas; reduce travel distance, time, and costs; and improve city sustainability. Gautrain promotes public transport; the development of small, medium, and micro enterprises (SMMEs); broad-based black economic empowerment (B-BBEE); tourism; and business development.

- A key element of the project and the concessionaire agreement is the socioeconomic development (SED) philosophy, which was added as fourth cornerstone in addition to legal, financial, and technical. The SED strategy focuses on a sustainable investment in people through B-BBEE, development of SMMEs, maximizing local content, and job creation.

- Examples of the broad-based SED objectives include black equity participation, the social investment program, procurement, subcontracting from black entities (BEs), and developing new BEs and SMMEs. Other examples include the use of local materials, employment equity, and training. There is an independent socioeconomic monitor to verify the performance of the concessionaire with contracted socioeconomic obligations and a penalty-and-reward system associated with not meeting or meeting the SED commitments. There are monthly and quarterly reporting requirements. To date, the SED commitments are being met, and in many cases surpassed, with the participation of BEs, new BEs, SMMEs, and local businesses; job creation; and human resource development. For example, there are 375 existing BEs, 115 new BEs, and 295 SMMEs. These businesses have accounted for approximately 1.2 million South Africa rand (ZAR) in expenditures (ZAR1 = US\$0.1421 in May 2011).

- Approximately 30,440 direct jobs had been created and sustained as of December 2010. Furthermore, the project activities resulted in the creation and sustainment of an additional 76,060 indirect jobs for suppliers and induced jobs resulting from the increased economic activity. Of the estimated 106,500 jobs that have been created and sustained, approximately 26,070 were filled by historically disadvantaged individuals, 2,780 by women, and 200 by individuals with disabilities. All workers were provided with training and opportunities for skill development.

- The project developed an innovative performance measurement process at the project level and set a benchmark for SED. It will alter land use patterns to support public transport; enhance property values, especially around stations; and act as a catalyst for investment in existing public transport systems. It will also change people's perceptions about public transport and contribute to a more environmentally sustainable transportation system.

PLENARY SESSION 2

Performance-Based Decision Making

The Bucks Start Here!

Thomas Jeffrey Price, *Virginia Department of Transportation* (Moderator)

Debra Miller, *Kansas Department of Transportation*

Cheri Fulginiti, *United Parcel Service*

Shintaro Terabe, *Tokyo University of Science*

PERFORMANCE-BASED DECISION MAKING: THE BUCKS START HERE

Debra Miller, then secretary of the Kansas Department of Transportation (DOT), explained how that department revised and changed its project selection process. She indicated that, in making these changes, her staff relied heavily on economic analysis, which is related to the concept of performance measurement. The outcome was not only a change in the project selection process, but also the reinvention of the agency.

Miller indicated that in 1984, when she joined the Kansas DOT, the state's transportation system was struggling because of the Arab oil embargo of the 1970s and other factors. In 1989 the state legislature passed a transportation bill to address Kansas's transportation needs. The projects funded through this legislation were well received by the public and policy makers, and another transportation funding bill was passed in 1999. The general expectation was that a third bill would pass in 2009 without opposition.

Miller said that when she was appointed secretary in 2003, she had some doubts about the ability to be successful in requesting additional funding from the legislature, because the department had been well funded for 20 years and because, to some extent, it would be harder to make the case when the transportation system was in fairly good shape than when it was in poor shape. She said that although her organization was well respected by the legislature and other stakeholders, the department was not well liked by local communities and

counties and had a reputation of dictating terms rather than working with local and county governments and other groups.

She stated that while the need should be outcome based rather than process based, the process itself is important and does matter. The process is especially important when trying to change the current way of doing things, such as the project selection process. Miller said that she wanted to change the thinking not only of the Kansas DOT, but also of communities, counties, and other stakeholders, to build confidence in the department and in the new project selection process.

As a result of numerous problems in the late 1970s and early 1980s, including a bid-rigging scandal and recommendations from a postaudit study, the legislature passed a statute stipulating a data-heavy project selection process. Miller tried to open up the project selection process while maintaining the credibility of the data-driven process. She wanted to build confidence in the process on the part of all Kansas DOT stakeholders.

Miller described how the Kansas DOT used the long-range plan for 2006 to 2008 to develop this new process. Numerous meetings were held with diverse stakeholders to identify transportation needs and craft a vision for the future. The use of a community-based consultancy process to gain public input was piloted. Community and regional leaders, elected officials, and other groups were assembled, and their discussions led to the department's understanding that system preservation was a top priority for the community and that linking transportation investments to Kansas's economic priorities was important.

With this knowledge, the Kansas DOT began to develop a list of 400 potential projects that were identified as a result of these community consultations.

In 2008, former Governor Kathleen Sebelius appointed the Transportation-Leveraging Investments in Kansas (T-LINK) Taskforce to help prioritize projects. Fourteen meetings were held, in which 850 Kansans participated. A list of 400 projects was examined, of which 200 were prioritized. The T-LINK Taskforce developed a new project selection process that focused on three general project categories—preservation, modernization, and expansion—and three input measures—engineering data, local consultation, and economic impact (Table 1). Two hundred projects were scored with this process.

In 2008, an economic working group comprising state economists, chamber of commerce leaders, economic development professionals, and city managers was formed to conduct the economic impact analysis. The group evaluated various approaches, from sophisticated models to simple spreadsheet techniques. There was a desire to focus on economic outcomes determined by job creation and gross regional product and to ensure the process was practical, easy to understand, and easy to administer.

The Transportation Economic Development Impact System (TREDIS) model was selected for use in the economic impact analysis. The results were measured in jobs and gross regional product. Customizable data at the county level were used, and local governments provided feedback on inputs into the model. The model inputs included reduced travel time, safety impacts, access to new and expanded markets, and other factors. These items were monetized and fed into an input–output economic model.

Two examples of urban projects in Kansas are the expansion of I-35 in Kansas City from 119th Street to I-435 and the Washington Street interchange on US-54 in Wichita. The expansion of I-35 in Kansas City cost \$16 billion and had an estimated economic impact of \$1 billion. The cost of the Washington Street interchange in Wichita was \$53 million, and the estimated economic impact was \$50 million.

Two examples of rural projects in Kansas are the new I-35 interchange in McPherson and the expansion

of US-54 in southwest Kansas from Greensburg to Haviland. The project cost for the I-135 interchange in McPherson was \$13 million and the economic impact was \$94 million. The project cost for the expansion of US-54 was \$56 million and the estimated economic impact was \$9 million. The Kansas DOT uses the economic impact figures as a general indication of a project's economic benefits, to initiate projects that will more significantly benefit state and local economies.

Miller noted that in 2009, the department obtained additional local input through a series of eight meetings that drew the participation of more than 800 Kansans. The scores for the 200 projects were presented and the projects were ranked by the scores. Participants at the meetings provided feedback on the scores. Some scores were reevaluated on the basis of the public input, and a total of 100 projects emerged from the process. All of these activities were conducted before the 2010 legislative session.

In May 2010, the Kansas legislature passed the T-WORKS program, a 10-year program funded at \$8 billion. T-WORKS includes funding and better business models for all transportation modes. There is no set list of projects, although preservation projects will always be funded first. Approximately \$1.7 billion is available for expansion projects. T-WORKS is funded by a 4/10-cent sales tax and additional bonding authority.

Miller said that in the summer of 2010, the department estimated the spending ranges for the six regions in the state and presented these ranges with information on population, highway and roadway miles, daily miles traveled, employment, sales tax revenue receipts, and other factors for each region. This information helped to explain why the northeast region received the highest percentage of funding in the state, followed by the south central region, as these two regions contained the majority of the population and jobs. In October 2010, the Kansas DOT focused discussions with various stakeholders on how to maximize the regional benefits from the initial 100 candidate projects. From November 2010 to May 2011, Kansas DOT staff continued to evaluate projects. Key factors considered included safety and road condition, cost constraints, and previous investments.

In conclusion, Miller noted that the experience in Kansas pointed to at least three important lessons learned. First, making data a part of the decision-making process, rather than the sole determinant, is key. Second, the economic data were extremely beneficial for legislators who pushed T-WORKS as a jobs bill. Third, there is no substitute for meetings. More than 95 meetings were held with more than 2,000 participants. Meetings provide opportunities for continued input, and tweaking the process helps eliminate resistance.

TABLE 1 T-LINK Taskforce Project Selection Process, 2008–2009

Project Category	Input Measure (%)		
	Engineering Data	Local Consultation	Economic Impact
Preservation	100	na	na
Modernization	80	20	na
Expansion	50	25	25

NOTE: na = not applicable.

DRIVING CHANGE AT UPS

Cheri Fulginiti remarked that, coincidentally, the theme of the conference, “Driving Change,” was also the title of an authorized history of the United Parcel Service (UPS) published in 2007 as part of the company’s centennial anniversary celebration.

She noted that there is drama to be found beyond the algorithms in the making of a successful transportation network performance story. There are human emotions, surprising challenges, unintended consequences, and amazing rewards. At UPS, all these are channeled through ever-evolving, ever-smarter attention to metrics and measurement. Fulginiti noted that, whether internally focused on employees or externally focused on customers, the human components that are so essential to any performance strategy are very much a part of the UPS business culture.

Fulginiti said that her remarks would follow in chronological order because UPS’s past has always been a prologue to its current strategic approaches. She said that one of the most remarkable things about UPS is how it had succeeded in adapting to disruptive changes when many other companies had failed and that survival depends on focusing on the smallest details.

Fulginiti reported that UPS began in 1907 as a company that delivered packages for shoppers of downtown department stores in Seattle. She noted that this business model set the stage for the logistics outsourcing model of UPS today. In the retail mode during the 1920s and 1930s, UPS held down costs by handling deliveries collectively for all the department stores in downtown Seattle. A successful relationship depended on UPS holding information about each client’s deliveries in confidence and becoming a surrogate for each client’s brand.

Post-World War II America brought a disruptive threat to this model. Automobile ownership exploded, the Interstate Highway System was developed, suburban shopping replaced going to downtown department stores, and the car trunk substituted for the delivery person. Because of these changes, UPS turned its focus to serving businesses across state lines. To do so required obtaining regulatory approval state by state, a laborious process that took 28 years.

In 1980 UPS received approval from the Interstate Commerce Commission to provide coast-to-coast delivery service of small packages. With its largest competitor being the government-subsidized U.S. Postal Service, UPS had to excel in all areas of performance management to succeed. The company needed to exceed customer expectations in service, reliability, and speed. Precision, cost management, and the transportation network had to be superior. Meeting these challenges led to UPS’s continual focus on time management research and metrics, which

continue to drive the company’s business decisions and performance.

Today, UPS operates in more than 220 countries and territories, employs more than 400,000 people, flies the world’s ninth-largest airline, and moves 2 percent of the world’s gross domestic product, generating some \$50 billion in annual revenues. Fulginiti reported that, in 2003, UPS became the first company in the industry to publish a sustainability report. This report is devoted to the company’s progress toward its triple bottom-line aspirations: economic growth, social responsibility, and environmental sustainability. Metrics published in the sustainability report have helped UPS become a global business leader in efforts to reduce carbon emissions.

In the most recent of many major transformations, UPS has evolved from a shipping company to a logistics company. Fulginiti shared a saying about performance metrics that arose at UPS: “In God we trust; everything else we measure.” That is why UPS knows that the average delay at a red light is 1.6 seconds and that it takes 1.24 seconds for the eye to read an average package label. The company knows how long it takes a driver to walk up and down a flight of stairs to deliver a package and the optimum speed at which a driver should walk 100 feet to or from a package truck. UPS instructs its drivers to hang their truck keys on their pinky finger to maximize efficiency.

Fulginiti discussed UPS’ move to using different technologies to conduct its business. In 1984, the company’s information technology department employed fewer than 100 people, whose main tasks were billing and filing clerical reports. In those days, UPS drivers used clipboards instead of hand-held computers, engineers used TRS-80 computers, and the ledger system was the McCormack and Dodge. All of these elements worked remarkably well. By the mid-1980s, the manual system of handling customer orders that had been achieved through industrial engineering was so efficient that that the company gave serious consideration to not abandoning it. Going digital on such a large scale would require complete redundancy—an investment of billions of dollars. Was it worth it? Although that question may seem hard to imagine today, it was real at the time.

The decision to adopt new technology was ultimately influenced by customers’ demand for it. The pendulum began to swing toward seeing technology as both a valuable internal tool and a resource for customer growth. After the power of technology began coming into focus, UPS invested billions of dollars to catch up and pass competitors, Fulginiti said.

Under the direction of the chief executive officer and a team of 16 senior executives, UPS developed a rigorous, multifaceted process that connects information technology closely with industrial engineering, customer service,

and other functions in the shared mission of advancing business strategy growth. A key technological undertaking was the Package Level Detail program, which provided the platform that has spawned a number of innovative solutions for network operations as well as customers. Package Level Detail consists of a large body of information embedded in bar codes and a unique UPS maxicode that ensures that a package gets to its ultimate destination on time.

This broad infrastructure has enabled many of today's high-performing transportation network advances, including package flow technology and telematics. Telematics is a technology that emerged from a careful vetting process and involved collaboration between engineering and information technology. Taking an innovation in transportation network technology like telematics from the drawing board to the real world depends in no small part on human behavior. In a network organization that includes 20 districts in the United States alone, three regions, and more than 100,000 drivers (package and feeder), some employees were early technology adapters while others were a little uncomfortable with change.

UPS learned that on the human side, the organization was still new to technology. Some seasoned management people were slower to embrace technology than had been expected. Part of the process change also involved redefining jobs and roles. Technology enables business to be managed differently, so training becomes essential at all levels. To ensure that the process change was understood, UPS conducted detailed training with every senior manager, including the chief executive officer.

The use of telematics grew out of UPS's strategic challenge to increase its focus on working leaner and greener while optimizing performance, employee safety, and service to its customers. Telematics works by capturing data on the delivery package vehicle via the Global Positioning System. More than 200 engine measurements are made, from speed, to starts, to oil pressure. Data are also gathered from sensors on seat belts, cargo doors, and reverse gears.

Four years ago, UPS tested telematics on 334 delivery vehicles at two operation sites in Georgia. The performance metrics centered on mileage savings, safety gains, and other efficiencies. The specific performance metrics included seat belt usage, idle time per driver, how often the bulkhead door was open while driving, miles driven per day, and the occurrence of vehicle backing. Telematics reduced idling time by 15 minutes per day per delivery vehicle. These gains, multiplied by 60,000 U.S. delivery trucks, resulted in fuel savings of 1.1 million gallons annually. Fulginiti reported that by the end of 2011, 70 percent of the UPS package fleet in the United States would be equipped with telematics, with 100 percent implementation planned by the end of 2012.

In conclusion, Fulginiti stated that although it is difficult to predict what the world will look like over the next decade, one certainty is that UPS will continue to learn from and rely on research, metrics, and the ingenuity of its employees to transform and excel. Performance-based organizations set goals that connect to their strategy and priorities, focus on a handful of initiatives, and have a relentless focus on results and execution.

JAPANESE EXPERIENCE WITH PERFORMANCE-BASED MANAGEMENT

Shintaro Terabe provided an international perspective on the use of transportation performance measures. He discussed the performance measures used for public transit and road transportation in Japan, both at the level of the national government road transportation network and at the prefecture level.

The use of performance-based measures of public transit at the national government level was initiated in 2004 with the Index of Comfortable and Easeful public transportation (ICE). This index sought performance measures other than traffic congestion, which had been in use since the 1970s. ICE includes 49 performance measures in four categories: ease of access, comfort, intelligibility, and safety. Of the 49 measures, 11 were identified as first-priority measures, of which nine are reported on an annual basis. The other measures have not really been used. The nine performance measures in use, by category, are as follows:

- Ease of access:
 - Level of congestion during peak times,
 - Percentage of stations with barrier-free access,
 and
 - Percentage of low-floor buses;
- Comfort: percentage of air-conditioned buses;
- Intelligibility:
 - Percentage of platforms with LED displays,
 - Percentage of stations with LED displays, and
 - Percentage of vehicles with LED displays; and
- Safety:
 - Percentage of platforms with station staff or emergency call units and
 - Percentage of vehicles with emergency call units.

These performance measures are monitored by different railway companies and bus operators, who must report their performance to the government annually. The performance of individual lines, such as the Isezaki Line of the Tobu Railway Company, and of companies as a whole can be examined.

In 2003 performance-based management of the national road transportation network was initiated.

Both the 2003 policy evaluation law and the 2003 law for the long-term plan for major infrastructure development influenced the development and use of performance measures at the national level. Twenty-one national performance measures were grouped into seven categories: international competitiveness, traffic congestion and linking regions, safety, the environment, asset management, use of the highway network, and road administration. Targets, actual results, and planned targets for indicators within each of the seven categories or policy themes were developed and monitored.

Performance-based management of the road transportation network at the prefecture level was also initiated. By 2007, 44 prefectures had developed their own performance measures (Figure 2). The Central Office of the Ministry asked regional offices to cooperate with prefectures in this effort. Performance measures at the prefecture level reflected regional characteristics.

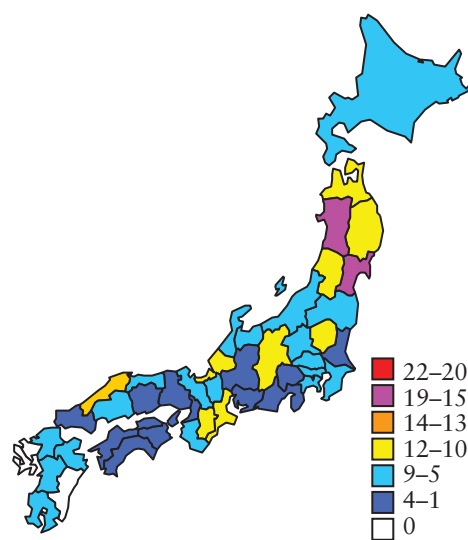
Reporting on road transportation performance measures at the national and prefecture levels was discontinued after 2007. Factors influencing this change included the so-called gas tax diet from January to June 2008, inclusion of the gas tax in the general account in 2009, and a change in the national government in 2009. Concerns about the gas tax were voiced in 2009 by some policy makers and groups. There was criticism that the funds generated from the gas tax were not being used

properly by the Road Bureau. As a result of including the gas tax in the general account in 2009, funding for road infrastructure decreased by 20 percent to the same level as 20 years earlier. The Democratic Party led the change of government in 2009, which resulted in new management at the Road Bureau.

Because of the reduction in funding, the Road Bureau was unable to maintain a viable performance measurement program. There was also a perception that performance measurement reporting was unnecessary. The change in political leadership resulted in a new minister and vice-ministers, and key personnel were rotated to other positions in the Road Bureau.

Performance management is currently included in the policy evaluations of the ministry. There are 233 performance measures for 13 policy goals; 11 performance measures are used for road transportation and 20 for public transit.

In summary, Terabe said that performance measurement in Japan does not have the focus or priority that it did a few years ago. It appears a small number of road and transit performance measures are important and sustainable, however. He concluded that although performance-based management may not be a priority of the current government, it did seem to lead to better results by enhancing transparency, accountability, and motivation.



Number of Measures, 2006–2007

FIGURE 2 Performance-based management of road transportation at the prefecture level, Japan.

BREAKOUT SESSION 2-A

Clash of Priorities

Timothy Lomax, *Texas A&M Transportation Institute* (Moderator)

Randall S. Blankenhorn, *Chicago Metropolitan Agency for Planning*

Ryoichi Watanabe, *Ministry of Land, Infrastructure, Transport and Tourism, Japan*

DEVELOPMENT AND IMPLEMENTATION OF LONG-RANGE PLAN AT CHICAGO METROPOLITAN AGENCY FOR PLANNING

Randall S. Blankenhorn discussed the development and implementation of the GO TO 2040 long-range plan at the Chicago Metropolitan Agency for Planning (CMAP). GO TO 2040 is not a traditional long-range transportation plan; rather, it is a strategic implementation plan that focuses on the place of transportation among other regional issues. Blankenhorn's presentation covered the following points:

- GO TO 2040 is a strategic implementation plan. Transportation is a key component throughout the plan, but there is no individual chapter about transportation. Transportation is a strategy, not a goal. The plan focuses on the vision for the region, the steps necessary to achieve this vision, and on the strategic implementation of the plan elements. The plan is outcome based and performance driven. Planning for the 21st century involves addressing competing priorities.
 - There are approximately 1,200 local units of government in the CMAP region. The performance measures in the plan help communicate the key goals and targets to these local governments and to the general public. The intent is to make the goals real for people. The plan addresses several important issues facing the region.
 - One issue is the split between investing in maintenance of the transportation system elements versus assisting with economic growth. Both are important, but identifying the appropriate balance of maintain-

ing the existing system and supporting future economic growth is not easy.

- Freight represents another issue. Freight is an important element of the regional economy. Chicago is a hub for freight flows to and from other parts of the country. Maximizing the benefit to the region while minimizing the negative impacts to communities is a challenge.

- The use of performance measures and data can assist in the application of innovative approaches to planning, project selection, and problem solving. The development and use of appropriate performance measures can help address past concerns about formulas for different regions or parts of the state, including urban versus rural needs. Focusing on outcomes is important, as that is what policy makers and the public care about; however, tools and models for addressing conflicting priorities still need improvement.

- A national vision for the transportation system is needed. State and regional visions, goals, objectives, and performance measures can then be aligned to the national vision.

- More information on the plan and on other related activities is available at <http://www.metropulsechicago.org>.

TRAFFIC SAFETY MANAGEMENT

Ryoichi Watanabe discussed the traffic safety management efforts being implemented at Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT),

where he is a researcher in the Bridge Division, National Institute for Land and Infrastructure Management. At the time of the conference, however, he was an international research fellow at the Office of Operations Research and Development, Federal Highway Administration, as a participant in the U.S.–Japan Intelligent Transportation Systems Joint Research Program. Watanabe summarized MLIT's use of performance management and accident data for traffic safety, the implementation of traffic safety management, and future activities. His presentation covered the following points:

- MLIT decided to integrate performance management and traffic safety measures because of the numerous high-risk sections on both national highways and local roads and tight budgetary conditions. MLIT's highway budget has been decreasing for more than a decade. The highway budget for FY 2010 was 20 percent less than that for FY 2009.

- To implement a performance management program that will improve effective resource management, it is important to use accident data for project selection and the development of traffic safety projects and to monitor and document the outcomes of said projects. Disseminating these results to the public and policy makers will enhance MLIT's reputation for accountability and transparency.

- The number of traffic accidents, fatalities, and injuries in Japan peaked in 1970 and dramatically decreased over the next decade. The decrease was attributed to new infrastructure, including sidewalks and signals on arterial roads. The number of accidents, fatalities, and injuries began to increase in proportion to the increase in vehicles and vehicle miles traveled in the late 1980s. Improvements in vehicle safety performance and emergency medical services significantly contributed to a reduction in fatalities in the early 1990s. After 2005, the number of accidents declined because of the effects of traffic safety measures as well as the decrease in vehicle miles traveled. There has also been a decrease in alcohol-related accidents and an increase in seat belt usage.

- The numbers of fatalities, injuries, and accidents had slowly decreased since 2004 but seem to have reached a plateau. This leveling off possibly implies that road administrators such as MLIT and local governments have found it difficult to improve safety through investments.

- Data from the Organisation for Economic Co-operation and Development's International Road Traffic and Accident Database indicate that the accident rate in Japan almost leveled off over the past two decades, even though it dropped to about one-third of the 1970s level. On the other hand, accident rates in the United States, Germany, and England have continuously decreased. Because all four countries have different definitions of

what constitutes an accident, a direct comparison of the absolute value of the rates is not possible.

- National highways in Japan are administered by MLIT or prefectural governments. MLIT-administered highways account for only 2 percent of the total length of the nation's roads but carry 18 percent of all traffic and account for almost 20 percent of all fatalities (and 14 percent of all accidents). These figures demonstrate that reducing traffic accidents is a high-priority issue for MLIT.

- The traffic safety management structure is designed to maximize the outcomes of traffic safety investments through a plan–do–check–act (PDCA) cycle management that analyzes factors and defines problems through the use of accident data for project planning and that explores the consequences of implementing countermeasures. One future issue for MLIT will be to tie funding to the achievement of policy goals, a linkage that currently is weak. PDCA management has already begun at the on-site level.

- The traffic safety management procedure includes several steps. First, on the basis of analysis of accident data, the opinions of local residents, and social interests reported in newspapers, MLIT creates a list of roadway sections that are at high-risk for traffic accidents. An open discussion process follows and the list is authorized and announced. Road administrators select project sites from the list on the basis of budget constraints. The projects are then implemented.

- The high-risk sections of MLIT roads are identified with accident data, which indicate that approximately 70 percent of accidents on arterial roads occurred on 20 percent of all sections. These high-rate sections are to be prioritized for traffic safety investments.

- It is also important to predict high-risk sections of roads that may not be clearly described in the data. Surveys and interviews with local municipalities, organizations, and residents who know the local traffic conditions are recommended.

- An open discussion process is being used to assist in selecting high-risk sections. An expert committee was formed to review and finalize the identification of high-risk sections. The committee provides important input from road engineering experts and representatives of road users.

- In December 2010, MLIT created the first nationwide lists of road sections at high-risk for traffic accidents. Approximately 14,000 sections were listed. Approximately 70 percent of these sections were selected on the basis of accident data; the selection of the remaining 30 percent was based on input from local residents.

- MLIT announced its Traffic Accident ZERO Plan in pamphlets and on websites that highlighted the data analysis and selection procedure.

- After determining possible factors that lead to traffic accidents, MLIT designed countermeasures such

as shifting and extending the length of right-turn lanes at high-risk intersections. These extended lanes were demarcated with colored asphalt. The project was successful in decreasing the number of accidents, and all data associated with the project were added to MLIT's accident database.

- Upcoming initiatives to promote traffic safety management include annual selection of sections for new projects, implementation of countermeasures, and examination of whether these countermeasures reduce the number and severity of accidents. MLIT will continue to accrue data in its project database for future development of countermeasures.

BREAKOUT SESSION 2-B

Levels of Decision Making

Keith Gates, *Federal Transit Administration* (Moderator)

Ernest F. Wittwer, *University of Wisconsin–Madison*

Mark Pisano, *University of Southern California*

Arthur L. Guzzetti, *American Public Transportation Association*

LEVELS OF DECISION MAKING IN FREIGHT PROJECTS

Ernest F. Wittwer discussed the traditional project analysis process for freight projects and potential enhancements to the process. He described the limitations of the current process, potential measures and indicators for an enhanced process, and other improvements. Wittwer's presentation covered the following points:

- Decisions related to different elements of the transportation system are made at different levels and by different agencies and private-sector groups. Decisions related to the highway system are made at the state, metropolitan, and local levels. Private railroads are responsible for rail decisions. National, local, and private groups are responsible for decisions related to water modes. State, metropolitan, and local agencies are involved in decisions for airports.

- Traditional project analyses consider the projected costs and the benefits. Examples of projected costs include construction, environmental, and maintenance and operation costs. Time, safety, and environmental benefits are considered. These costs and benefits are used to conduct a benefit–cost analysis (BCA).

- There are shortcomings to the traditional approach to analyzing freight transportation projects. The traditional approach assumes that all costs and benefits are local and also tends to be unimodal rather than multimodal. The impact of unreliability is often not considered. Further, the traditional approach may not reflect

broader issues and goals and tends to delay the implementation of very large projects.

- The impacts of freight projects typically extend beyond the jurisdiction in which the project is located. Freight projects are often multimodal in nature and may include an intermodal facility. A more complete project analysis for a freight project would include reliability, agreed-upon measures, geoincidents, and multimodal components. It would also include a BCA.

- Potential indicators can be identified for different categories of measures, as follows:

- Mobility and accessibility indicators: origin and destination data by commodity, destination, mode, value, and tonnage; travel time; modal choice; and delay.

- Reliability indicators: origin and destination data, deviation of travel time, percentage of on-time arrivals, and frequency of nonrecurring delays.

- Safety indicators: roadway-specific data, information on the cause of crashes, and rates of freight-related crashes and accidents.

- Operational efficiency indicators: origin and destination data, vehicle miles traveled, passenger miles traveled, and average speed.

- Time savings, safety benefits, and changes in air pollutants may be considered in a BCA. The buffer time index provides a measure of the extra time needed to make a trip to ensure on-time arrival. Other factors to be considered in an improved process include the potential to use different modes, the geodistribution, and the benefits to different areas and industry groups. All of these

factors can be considered in an enhanced project analysis process. The ability to obtain data on origins and destinations, commodity, and value is also important.

TRANSFORMATIONAL LEADERSHIP AND INSTITUTIONAL DESIGN

Mark Pisano discussed the need for transformational change in policy making at all levels of government. He described key elements of a process for redesigning policy making and financing and the characteristics of transformative leadership. Pisano's presentation covered the following points.

- Transformative change, which demands new ways of making public policy choices, financing projects, and implementing public goals at all levels of government, will be required. The current policy-making process needs to be refocused and redesigned. The traditional process is input driven. Citizens and stakeholders convey their needs to political leaders. Tax dollars are allocated to implement specific projects and programs. Public agencies make decisions by evaluating alternatives, which are often driven by specifications. The resulting outcomes may not meet expectations or benefit the long-term public interest.
- The redesign of the current system should begin with goal identification, clarification, and prioritization. A new dynamic process that uses backward mapping is needed. The first step in this process is focusing on the desired outcome. Performance standards are used. The process spurs creative new technologies and infrastructure that will unleash America's competitive advantage. The resulting investment strategy provides a return on investment that maximizes the collective self-interest of the country.
- This approach also requires a new leadership strategy. This strategy begins with a collective purpose, which leverages existing assets and works to change behaviors to achieve intended outcomes with measurable benefits. Transformational leadership focuses on leaders applying strategies that result in design choices that create new institutional designs, which are implemented organizationally.
- This redesigned approach focuses on the golden rule of paying for utility. Decisions based on outcomes yield quantifiable results. Consumers and users historically pay for desired results. Institutional design allows results and funding to be captured. This approach also requires transformational behavior, however.

PERFORMANCE MEASUREMENT AND REAUTHORIZATION

Arthur L. Guzzetti, Vice President of Policy, American Public Transportation Association (APTA), discussed

recent activities at the national level related to the reauthorization of the surface transportation act. He presented 11 items for consideration in developing and using performance measures at the national level.

President Barack Obama's State of the Union Address on January 25, 2011, included three paragraphs on transportation. The President discussed transportation in the context of overarching national priorities such as job creation, energy security, and international competitiveness. The administration reaffirmed transportation as a priority in the FY 2012 budget proposal. The President also presented a new energy strategy for America, part of which focused on providing Americans living in urban, suburban, and rural areas with options that would enable them to travel without having to drive and pay for gasoline.

Transportation plays an important role in achieving these overarching priorities or goals. Using performance measures to reflect national goals and national investments in transportation is reasonable. Many transit agencies and state departments of transportation are already using performance measurement. The use of outcome-based performance to better connect investments with national goals is logical. The national goals for transportation, however, have yet to be fully articulated.

In collaboration with other national organizations, APTA has identified potential national goals for the transportation system. These goals include safety, environmental protection, economic health and economic competitiveness, mobility and accessibility, and the preservation of the existing infrastructure. There are 11 items to consider when developing performance measures at the national level:

1. There is a lot of state and local funding in transportation projects. If federal funding represents a small amount of the total funding, it is difficult to understand why federal performance measures should be driving the process. Consideration should be given to the level of funding for different sources and the associated performance measures.
2. Local perspectives should be considered. An area may have completed a visioning process or have approved a local funding referendum. These activities should be considered in establishing performance measures.
3. Funding that is tied to a predictable funding mechanism and funding stream needs to be in place before performance measures are implemented. In general, stable funding is good business.
4. Accurate and timely data are critical. There may be a need to collect additional data, but new data requirements should be clearly linked to agreed-upon measures.
5. National goals need to be stable; they should not change from administration to administration.

6. Performance measurement should not be a mere checklist.

7. Asset management and state of good repair are often viewed as downward information processes; that is, they are used for managing downward in an agency. Data and performance measures can also be used in an upward manner, however. Information could be included in the annual conditions and needs report or provided to Congress in another document. The use of performance measurement should flow both ways.

8. Performance measures should not be used as pass-fail metrics. Grants and other funding should not be held up if an agency does not meet certain performance measure targets. A plan for improvement should be required, but funding should not be withheld if a measure is not met.

9. The U.S. Department of Transportation has indicated that an incremental approach will be used in developing a performance-based program. This incremental approach could begin by focusing on performance mea-

asures associated with the state of good repair and with safety goals. Developing performance measures for other goals could follow. This incremental approach makes sense.

10. Performance measures should not be used to compare the performance of different agencies. Many unique local features contribute to the performance of an agency. Performance measures should be used to improve the performance of agencies, not to make the performance of agencies equal.

11. The U.S. Chamber of Commerce has developed a transportation performance index that focuses on measures that illustrate the economic importance of the transportation system to commerce. A recent Government Accountability Office report indicated that the Transportation Investment Generating Economic Recovery (TIGER) program—a federal stimulus program included in the American Recovery and Reinvestment Act of 2009—has done a good job of meeting the stated program goals.

BREAKOUT SESSION 2-C

Lessons Learned

Lance A. Neumann, *Cambridge Systematics* (Moderator)
 Patricia G. Hendren, *Washington Metropolitan Area Transit Authority*
 Daniela Bremmer, *Washington State Department of Transportation*
 Lisa Klein, *Metropolitan Transportation Commission*
 Thomas Jeffrey Price, *Virginia Department of Transportation*
 Mara K. Campbell, *Missouri Department of Transportation*
 Shintaro Terabe, *Tokyo University of Science*

This breakout session included brief comments from panel members and an open discussion among all participants. The summary of the panelists' main points below is followed by a list of the major discussion topics.

Patricia G. Hendren spoke about the experience of the Office of Performance, Washington Metropolitan Area Transit Authority (WMATA):

- WMATA's Office of Performance was established in 2009. It focuses on providing performance products for departments within WMATA, the general manager, the board, the media, and the public.

- The office developed a Vital Signs Report that focuses on the key performance measures. There was concern at first that the media and other groups would be critical of WMATA regarding the information provided. The reaction has been very positive, however. The report has been well received both inside the agency and by outside stakeholders.

- The performance measures and the Vital Signs Report focus on how performance has changed and on what WMATA is doing about the change. Information is provided at the department level, to the general manager, to the board, and to external groups.

- The plans in the various departments link day-to-day work to agency goals (Figure 3). The performance measures help build support from line personnel, including bus operators and maintenance personnel, for agency goals. The performance measures also provide a link to the capital program. The goal of the Office of Perfor-

mance is to use performance measurement to inform, promote, and unify.

- Four challenges were highlighted. The first is making the agency's goals meaningful for all employees, including bus operators, maintenance personnel, and other front-line staff. The second challenge is that the office had to show its work quickly as well as on an ongoing basis. When funding is limited, performance measures are often viewed as an easy area to reduce or eliminate. The third challenge is that transit agencies in general are data rich but information poor. WMATA collects extensive data, but resources for analyzing that data are very limited. The fourth challenge is that data and information are sometimes seen as taking power away from other agency personnel and the board.

Daniela Bremmer spoke about the experience of the Washington State Department of Transportation (DOT):

- The Washington State DOT has extensive experience in the use of performance measurement and management. The *Gray Notebook*, the quarterly performance report that contains the performance measures publicly reported by the department, has been published for 10 years. The department links performance measures with strategic planning and investment decision making. Performance measurement has become part of the culture of the Washington State DOT. The use of performance measurement is expected and is no longer viewed as a special activity. Performance measurement is also part of the culture of the Governor's office and the state legislature.

M metro Execution Plan Components

✓ Inform
✓ Unify

Linked to Goals and Objectives

-Measures show progress towards agency goals
-Quantitative & trackable

-Actions outline how you will make progress
-Balance specificity and flexibility

Action owner makes sure action gets completed

Targets set where want to end up

Offices listed to foster unity and establish accountability

Objective	Ref	Performance Measure	Target	REF T	Key Actions	Responsible Office	Action Owner
1.1. Improve customer and employee safety and security ("preventian")	A	Percent reduction in vehicular accidents	10% below FY 10	A1	Develop Safety Program Action Plans which are designed to include programs and processes to reduce accidents and workers compensation	SW/T	Ryan Richards
				A2	Ensure Local Safety Committee (LSC) meetings are being conducted with minutes being disseminated within established guidelines	SW/T, SW/T	Ryan Richards
	B	Percentage reduction of Workers Compensation Claims submitted	41% over base year 2007	B1	Facilities, general housekeeping and		Ryan Richards
	C	Percentage of safety conversations conducted	60%	C1	Conduct biweekly superintendent meetings		Phil Wallace
				C2	Develop, implement Preventative Maintenance (PMs) to provide proactive maintenance for new buses as they are into fleet and ending bus fleet by December 2016	BB/IG	Jim Faulstich
1.2. Strengthen Metro's safety and security response ("reaction")					Coordinate Safety Officer visits of facilities and protection equipment	SW/T, SWE/T	Ryan Richards
					Develop, review, and update Standard Operating Procedures and Service Bulletins	BB/IG, SW/T	Larry Shelton
	E	Percentage of On Board cameras installed	100%		Install DriveCam digital video recording system on existing fleet by December 2010	SW/T, BB/IG	Darius Wat
	F	Number of 1000 incidents	Zero		Review all reported incidents to determine root cause and preventions	BB/IG, SW/T	Larry Shelton

FIGURE 3 Components of WMATA execution plan.

- Many lessons have been learned over the years from the use of performance measures. The *Gray Notebook* created a brand for performance measurement at the Washington State DOT. The data in the *Gray Notebook* are just the beginning of the story, however. It is the use of that data in decision making and in reporting results to policy makers and the public that is critical. Performance measurement is not static. It is an ongoing interactive process. The specific metrics may not always be as important as the process.

- The current budget situation presents a challenge. Maintaining performance measurement practices during a time of constrained funding is difficult but critical. Doing more with less continues to be the new normal. Addressing hard-to-measure goals and objectives also continues to be a challenge. These goals and objectives relate to sustainability, livability, and economic competitiveness.

Lisa Klein spoke about the experience of the San Francisco Bay Area Metropolitan Transportation Commission (MTC):

- MTC's long-range plan includes performance measures at both the scenario level and the project level. The San Francisco Bay Area is a multimodal environment, and 60 percent of MTC funding goes to transit.

- The use of performance measurement and performance measures at MTC has evolved since 2001. Performance measures were initially introduced at MTC in

response to a legislative mandate. The first performance measures focused on travel time, trip time reliability, and state of good repair. The state legislation on greenhouse gas emissions included other requirements. This legislation and other factors resulted in more of a focus on housing, health, and preservation of open space as well as on transportation in the new long-range plan. This shift in focus evolved and has been reflected in new goals, objectives, and measures over the past decade.

- MTC is facing three challenges associated with the use of performance measures: better understanding of the outcomes of broader measures, creating a level playing field for all modes and topics, and better understanding of the impacts of specific projects. Identifying appropriate performance measures and data for objectives related to health, housing, and the regional domestic product has been challenging. Different tools and different partnerships are needed for performance measures in these areas. The use of different data sources to comparing a wide range of projects over different time periods has also been challenging. Tracking the impacts of projects and programs through before-and-after studies represents still another challenge.

Thomas Jeffrey Price spoke about the experience of the Virginia DOT:

- The Virginia DOT uses performance measures in several different ways. Performance measures are used to

evaluate maintenance and operation needs every 2 years and to evaluate safety projects.

- The Virginia DOT's Dashboard is a visual tool that is accessible to the public. The Dashboard is used to graphically track project delivery, including measures for being on time and on budget.

- One challenge is the lack of comparable performance measures for use in the project selection process. Another challenge is obtaining and using customer input as part of the performance measures process. Still another challenge is that employees begin to manage to a measure, which results in unintended behavior and outcomes. Measures may need to be modified to address this issue. A final challenge is institutionalizing performance measurement so that performance measures remain in place even when agency leadership changes.

Mara K. Campbell spoke about the experience of the Missouri DOT:

- The use of performance measures is well established at the Missouri DOT. Performance measures are used in all areas of the department.

- One challenge in using performance measures is that personnel want to perform in the middle; that is, no one wants to be at the bottom or the top. Another challenge is maintaining performance measurement when there is a change in leadership at an agency.

Shintaro Terabe stated that obtaining the support of agency leaders for developing and using performance measurement is a major challenge. Performance measurement is often viewed as an area that can be cut back or

eliminated when budget reduction is necessary. Another challenge is maintaining existing performance measurement programs when changes in political leadership or agency personnel occur.

OPEN DISCUSSION

- Another challenge with regard to nontraditional performance is that the transportation or transit agency does not have responsibility or control for programs and projects. Establishing partnerships with the agencies responsible for these areas is important.

- Different techniques for obtaining input from customers were discussed, along with how this information is used in performance measures. Various measures of customer satisfaction, from roadway smoothness to on-time trains, were highlighted. Obtaining information from truckers and freight users was also noted as important.

- The need to present information on performance measures to decision makers and the public in easy-to-understand ways was discussed. Avoiding jargon and providing information that resonates with different groups were two strategies noted as being important.

- Different technologies and methods for data collection, including new and evolving technologies, were discussed. It was suggested that although these new technologies can provide a wealth of data, it is important to determine that the data are needed and will be used. Collecting data for data's sake is irrelevant; what matters is obtaining data that yield information that can be used to make decisions.

PLENARY SESSION 3

The Future Is Now!

Daniela Bremmer, *Washington State Department of Transportation* (Moderator)

Rick Schuman, *INRIX, Inc.*

Terry C. Bills, *Esri*

Alexander Sohr, *German Aerospace Center*

THE FUTURE IS NOW

Rick Schuman began his presentation with a quotation from science fiction writer William Gibson cited in a new book by Steven Levy, *In the Plex: How Google Thinks, Works, and Shapes Our Lives*: “The future is already here—it is just not evenly distributed.”

Schuman’s presentation focused on mobility performance measurement, emphasizing that the tools for revolutionizing mobility performance management are already in place today. He believes that the utilization of available technology is still in its early stages and that, as a result, complete game changers, or what some people call disruptive innovation, is possible. Some of these activities will happen with no thought or coordination, while others will require coordination to occur.

Schuman highlighted seven converging technology trends that he believes will result in changing the way mobility is measured and monitored: smartphones, data plans, app stores, vehicle application programming interfaces, cloud computing, crowdsourcing, and the mash-up economy. These seven trends focus on the increasing level of connectivity among people and places. The first three trends are interconnected, but separate.

1. Smartphones. According to Chetan Sharma Consulting, in the first quarter of 2011, 51 percent of all phones sold in the United States were smartphones and one-third of all smartphones sold worldwide were sold in the United States. During the first quarter of 2011, there were approximately 24 million connected devices in the United States. That figure represents a growth of

50 percent from the first quarter of 2010. Only about 15 percent of all iPads and other tablets are connected via cellular networks. The smartphone is the principal connected device today.

2. Data plans. With regard to smartphones, the United States is probably the most connected country in the world. Roaming charges, which are still an issue in Europe, are not a problem here. From January to April 2011, data carriers made approximately \$65 billion on data transmission, which is growing at a rate of 10 to 20 percent annually. The trend lines indicate that data will soon pass voice as the major revenue producer for carriers. Data transmission now represents 35 percent of carriers’ revenue, and it is growing. Investments are being made in speed, coverage, and capacity. Pricing models to deal with heavy users of bandwidth, such as video, should improve service for all users.

3. App stores. App stores are a relatively new phenomenon. Anyone can build apps to take advantage of sunk investments in the network infrastructure. Individuals can benefit from apps. Many apps are available to the general public, while others are for limited group of users, such as a company or subscribers. Apps may be free or there may be a fee for added support or subscriptions. There are some caveats with apps. The rules are set by the ecosystem owners, such as Apple, and are subject to change. The other caveat is the chaotic nature of the development, introduction, and discontinuation of apps.

4. Vehicle application programming interfaces. Schuman stated that the vehicle is becoming an audiovisual product interface and that vehicles with such capability are becoming commonplace. Current dem-

onstration examples include the Ford AppLink and the Toyota Entune. An emerging mass market model uses the consumer's phone and data plans as the interface to the cloud and apps. This approach allows for much faster innovation. It better aligns consumer electronics and auto development cycles and addresses issues like driver distraction and security.

5. Cloud computing. More and more, computing is being done off-board the device or vehicle, in the cloud. This change means there is no longer a need to build massive data centers to scale solutions, which requires lots of capital investment. Schuman stated that cloud concepts have been around for a while but that the mobile ecosystem provides critical mass.

6. Crowdsourcing. User-generated input, or social media, is changing the game now, and changing it fast. Individuals can provide information anonymously or, if the user agrees, as personally identifiable data. There are people who want to be recognized as providing information on traffic incidents. NAVIGON recently released an app in Europe called traffic4all. In the 2 weeks after the app was released, the number of reported incidents received at INRIX in the pan-European data feed increased fourfold. Most of these reports were legitimate information. There are, however, issues associated with quality and participation, as well as real and perceived privacy.

7. The mash-up economy. An entire section of the economy is focused on mash-ups, that is, the connection of existing products and services. Mash-ups combine data or functionality, or both, from more than one source. Whole industries are now built around connecting things that already exist. There are people who do not create anything new but do connect existing dots.

Schuman noted that these seven areas are all converging today, with implications for mobility performance measures. Friction, or congestion in the system; the exact locations of this friction; and the days and times that congestion occurs can now be instantly identified for commuters and for freight.

The *Urban Mobility Report* developed by the Texas A&M Transportation Institute at the Texas A&M University now uses INRIX data as its source of nationwide consistent speed data. A quote from the press release for the 2010 *Urban Mobility Report* highlights the importance of this change: "The methodology used to calculate congestion has been improved more than a dozen times since the *Urban Mobility Report* was first published in 1984, but the changes made possible by access to hourly-by-hour speed data are the most significant improvement yet." The creation of reliable volume estimates to match these data now is the biggest current data quality issue.

A growing number of progressive metropolitan planning organizations (MPOs) and state departments of

transportation (DOTs) have embraced mobility performance measures. Some, such as the Washington State DOT, have their own infrastructure and processes for obtaining the data. Many states and MPOs are beginning to rely on data from private sources. For example, at least 10 states and MPOs are using INRIX data for mobility performance measurement. The University of Maryland's Vehicle Probe Project Suite represents the new frontier. This project is bringing performance measurement data and tools together for more than 10 MPOs and seven states, thanks to the I-95 Corridor Coalition. These agencies now have performance measurement tools at their fingertips. Schuman said he believes that friction analysis is going to grow everywhere as a tool for mobility performance measurement. The growth of friction analysis will continue to happen naturally, with or without national leadership.

Two areas for enhanced coordination are improving volume data and improving the collection of origin-destination data. Bringing volume estimates up to par with speed estimates is critical. Volume estimates by time, day, and road segment are needed, and it is unnecessary to put sensors everywhere. Good coverage that enables weighted friction analyses is also needed. Schuman predicted that over the long term, it would be possible to collect these data without agency coordination, but for the near future, road-based sensors would be needed. An issue to be addressed is the need for national consistency in good-enough data. Another area for improvement is using technology to improve the collection of origin-destination data. Although there are issues of privacy and representation, technology can be used to improve travel surveys, which would allow movement away from total reliance on the National Household Travel Survey and representative sample state and regional household travel surveys.

In his closing remarks, Schuman reminded the participants of all of the technological changes that had occurred since the approval of the recent surface transportation acts. The passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 was followed by the introduction of the World Wide Web and then by Netscape in 1994. The passage of the Transportation Equity Act for the 21st Century (TEA-21) in June 1998 was followed by the introduction of Google and then by iTunes and the iPod in 2001, the Blackberry in 2002, Facebook and the TomTom portable navigation device (PND) in 2004, and the Garmin PND in 2005. The passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) in August 2005 was followed by Twitter in 2006, the iPhone in June 2007, Google's Android operating system in November 2007, Apple's App Store in July 2008, Google's Android Market in November 2008, and the iPad in 2010.

Schuman said he believes that the automobile timescale and the consumer product timescale are mismatched. Supply chain managers and the freight infrastructure are mismatched. Fuel prices, currency values, and population and demographic changes are mismatched. The world is more mobile, transient, volatile, and flexible than ever before. Long-term modeling is basically impossible now. The chances are greater than ever that billion-dollar, multi-year megaprojects will be outdated when completed. The fiscal reality is that less funding is available, which means that better use of resources is required and that investment must obtain the biggest bang for the buck. He argued that the only way to regain confidence at a national level is by showing tangible value for investment and plans.

EMERGING TRENDS IN SPATIAL TECHNOLOGY

Terry C. Bills addressed emerging trends in spatial technology and the ability to work with very large data sets. He identified four trends that he believes will influence performance measurement and performance monitoring:

- Access to rapidly expanding sources of new data, including many data sets that are very large;
- Access to time series data, which facilitate the examination and analysis of data sets over time;
- The use of 3-D for visualization and analysis of data; and
- Spatial statistics, the ability to incorporate the dimension of space in standard inferential statistics.

IBM has focused an entire campaign around the proliferation of millions of real-time sensors installed in the field. These sensors, which include meters, cameras, toll tags, and many other technologies, are used to monitor a wide range of assets, not just traffic. Real-time sensors are combined with real-time probe vehicles, and some commercial vendors are obtaining data directly from cell phone companies. The major vehicle manufacturing companies are increasing the number of vehicles equipped with the Global Positioning System (GPS) as part of the standard package. As a result, consumers will have access to tremendous amounts of data, much of it real-time information, from very large data sets that provide information on transportation networks. Transportation professionals have a large number of traffic count and traffic incident data, and the networks being analyzed are increasing in size.

The increasing number and size of data sets pose several challenges for data users and data analysts. These challenges include managing the large volume of data, analyzing billions and billions of observations, integrating data from different sources, and actually mining and analyzing the data.

The technology and tools available today are better for collecting and storing large data sets as well as for integrating and analyzing the data. Examples included the following:

- The International Maritime Organization regulation that requires commercial vessels to provide their position every 5 minutes. This regulation enables the location of every vessel over the past 5 years to be traced in 5-minute increments as well as to be displayed in real time. This data set has billions and billions of observations. Mining and analyzing this rich data source can be challenging.
- The truck toll-collection system in Germany. Every truck is equipped with the GPS and the tolls are calculated with GPS data. The GPS records when trucks enter and leave the tollway. The toll is generated automatically, with no human intervention. This GPS-based system may be used in the United States for tolls, parking, and distance-based fees.
- The use of imbedded sensors on California freeways. These sensors provide data on speed, volume, and incidents. The data set is very large. When a call comes in to the California Highway Patrol dispatch, it is captured automatically and geocoded, and the incident is located on a map. A log is maintained for each incident. Los Angeles County alone experiences an average of 3,000 incidents per day. Incident data from multiple states can be integrated, as is being done in the I-95 corridor along the East Coast.

The emerging field of spatial statistics is being used in analyzing these large data sets. Spatial statistics, which is very different from the standard statistics courses taught in graduate school, uses geographic information system (GIS) software to help identify patterns. Mapping 1 year of crash data in upstate New York illustrates the location of all the crashes but is not of much help in really analyzing the data. Spatial statistics can be used to examine and understand hot spots and clusters of crashes. Software is capable of examining highway segments in a rolling sequence to identify hot spots or the top 5 percent of the most dangerous roadway segments and intersections. After these locations have been identified, the software can analyze the types of crashes occurring at different types of areas. The software can also analyze crashes by county or other subcategory. A county with higher crash rates can be examined in more detail to identify the factors influencing this higher rate. Databases that capture volume, speed, and roadway characteristics can be integrated with the crash database to assist in the analysis.

Time series data, the second trend, can be used to examine and monitor performance over time and to identify emerging patterns. One example of time series

data examines the stimulus package projects. All of the projects can be shown and the status of each project over time can be monitored. Another example is a website that monitors the impact of global climate change over time and uses Cardiogram, another unique method for presenting data, to examine the counties that emit the most carbon dioxide.

The third trend is the increasing use of 3-D visualization and analysis. It is not just the visualization that is 3-D; sophisticated analyses that incorporate 3-D spaces can be run. This technique was used to analyze the land use, redevelopment, and mobility impacts of a new light rail transit line in Philadelphia. This approach can allow better design of cities and transportation systems.

Traffic data can also be presented in 3-D. The Utah DOT uses 3-D to present data on the current capacity of roadways and on the points in time at which the different facilities became congested. Traffic congestion data and air quality data can be combined in 3-D to analyze the location of hot spots. Air pollutants can be displayed in 3-D. The use of 3-D and GIS to locate the optional alignment of a highway project represents still another application. A highway project in Greece used GIS to help identify the best alignment as well as to analyze soils, archeological sites, and other features.

The fourth trend is the rapidly evolving field of spatial statistics. Several geostatistical analysis tools have been developed to assist users in navigating large data sets. The process allows users to analyze and understand patterns, clusters, and trends. Similar tools have also been developed for analyzing 3-D data.

The Pennsylvania Turnpike is using this type of approach for an executive management system that includes about 100 performance measures. Many of these measures are generated from real-time data. The system uses a continuously updating database to generate the performance metrics. Examples of performance measures include gross toll revenues, operating costs per mile, net operating margins, and E-ZPass penetration. Performance on the different measures can be displayed and examined by highway segment and by district. The same systems are used for the turnpike traffic management system. This example highlights the ability to bring together a lot of information, much of it in real time, and analyze it to more effectively manage the turnpike on a daily basis.

CURRENT AND FUTURE USE OF FLOATING CAR DATA

Alexander Sohr discussed the German Aerospace Center's (DLR's) use of data from probe vehicles called floating cars. He described different data collection techniques and the use of the data in traffic management,

including traffic data recording and traffic simulation and prediction. Other research focuses on traffic control and management and traffic quality.

Traffic data have historically been collected with stationary methods, such as induction loops, which provide data on traffic flow, local speed, time gap, and occupancy, and infrared sensors, which are used to collect traffic flow data. These methods usually are used only on major roadways. They provide precise local data, although travel times are not measured directly. These methods represent significant financial investments and need ongoing maintenance and repair.

Recent traffic detection methods include stationary video detection, video detection on a mobile platform, and mobile phone movements. Other methods include car-to-car data (Car2X, Car2Car, and Car2Infrastructure) and floating car data (FCD) from the GPS. The cost of the infrastructure for these methods is relatively low. These techniques provide area-wide detection and direct measurement of travel times. Only part of the flow is measured, however, and spatial and temporal data may be noisy and incomplete.

Taxis are equipped with GPS for FCD because they provide good coverage of the region and operate 24 hours a day, 7 days a week. The FCD system architecture includes the taxi headquarters (the disposition system), the FCD server (data processing), and the service provider (data usage).

One FCD application is Cityrouter, a traffic condition map. It also includes dynamic routing and location-aware route monitoring. For example, DLR has a map that displays travel conditions from its office to Berlin's Tegel Airport. Employees and visitors can check travel times before departing for the airport.

Another application uses density profiles from the FCD to analyze traffic flow at intersections. This application is based on the correlation between the density profile and the queue lengths at intersections. A density profile analyzer (DPA) was developed to match the density profiles to the estimated queue lengths. Calibration of the parameters of the DPA is needed to obtain the current density profile. Another application analyzes turn-dependent travel times. This process includes defining the inflow from one junction, defining the different turn segments, decomposing the trajectories, and comparing the travel times on the inflow. The positions within the estimated queue lengths are deleted. The distance and travel time for every inflow and outflow pair outside the traffic jam area is calculated for every trajectory. This approach increases the accuracy of the delivered travel times. Not surprisingly, travel straight through the intersection is fastest. Vehicles making left turns experience the longest delays. During peak periods, however, vehicles making left turns may move faster than vehicles traveling straight through the intersection because traffic on

the main road is congested. The results from this analysis are used in dynamic routing applications.

The final application that Sohr highlighted is one that uses FCD to analyze delay time–based control of traffic signals (Figure 4). The concept is to switch the signal when vehicles with delay time have passed the intersection. The results from the simulation indicate that this approach works better than fixed-time control and time-gap control strategies when traffic demand is higher.

An alternative approach for collecting traffic data uses short-range radios and other devices, which are being tested with Bluetooth and Wi-Fi. A Bluetooth inquiry delivers a media access control address. The recognition of the same media access control address at two points allows the calculation of travel time. A roadway section was equipped with 45 loop detectors to measure traffic flow. Laser scanners, cameras, and Bluetooth and WiFi detection units were located on gantries at the begin-

ning and end of the roadway section. The Bluetooth and Wi-Fi travel time data were compared with the travel times obtained from the loop detector data.

Sohr stated that DLR is also testing dynamic detection through the use of vehicles with cell phones and Bluetooth devices or vehicles with Wi-Fi. The advantages of this approach include network-wide recognition with the ability to collect travel times and create origin–destination matrices. The small equipment rates should yield better results than classic FCD. The challenges of this approach include the accuracy of positioning in some ranges and the ability to classify vehicles, which is needed to ensure that bicycle travel times are not being counted with vehicle travel times. The next steps in the project include equipping a fleet of vehicles and finding the critical mass of vehicles needed for delivery of area-wide information that is comparable to the information currently provided by the taxi fleet and FCD.

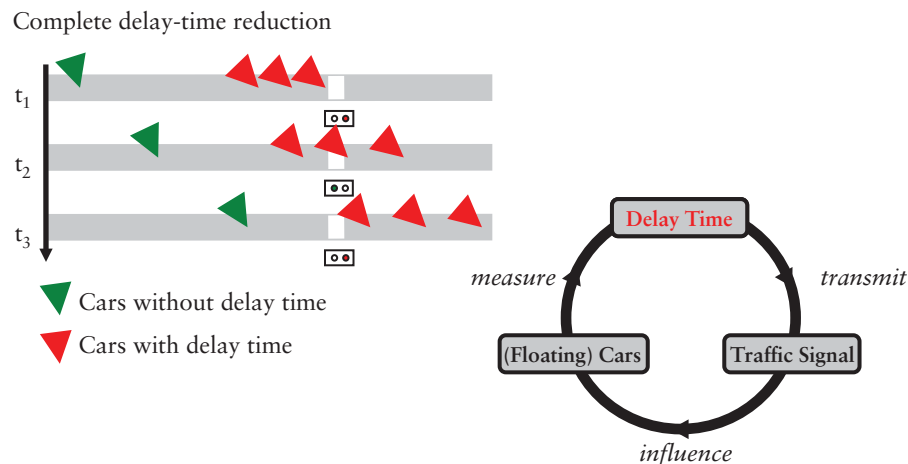


FIGURE 4 Analysis of FCD delay time–based traffic signal control.

BREAKOUT SESSION 3-A

Digital Breadcrumbs

Mobility Data Capture with Social Media

Johanna Zmud, *RAND Corporation* (Moderator)

A. J. Brush, *Microsoft Research*

Munmun De Choudhury, *Microsoft Research*

DIGITAL BREADCRUMBS AND TRAJECTORY PREDICTION WITH THE GLOBAL POSITIONING SYSTEM

A. J. Brush discussed the potential applications of activity-based navigation, including trajectory searches. She described the focus of Microsoft Research, the study of human–computer interaction, and recent studies and surveys related to trajectory searches. Brush’s presentation covered the following points:

- Established in 1991, Microsoft Research has more than 850 researchers engaged in 55 areas of research. Overall, Microsoft Research is a small part of Microsoft, with less than 1 percent of all Microsoft employees. Microsoft Research focuses on advancing state-of-the-art computing through a combination of basic and applied research.
- The computational user experiences group at Microsoft Research focuses on the study, planning, and design of interaction between people and computers. It is an interdisciplinary group with researchers from the computer sciences, the behavioral sciences, and design.
- One current research area is mobile context sensing and activity-based navigation. Activity-based navigation uses a cell phone’s sensors to construct a trail of activities (Figure 5). People can play the trail back to help retrace their steps. Activity-based navigation does not require a map. It can be especially useful when the Global Positioning System (GPS) is not available.
- Research on activity recognition suggests it is possible to sense steps, compass direction, and a change in

building floors. Photos of surroundings have the potential to be added. Absolute position can be identified when GPS is available.

- Possible applications for activity-based navigation include finding a lost object by retracing steps to the location in which it was last seen, following trails shared by other users to find an unfamiliar meeting room when a colleague is already there, and finding a friend in a concert hall, dark cinema, or sports arena. Activity-based navigation can also be used in real-world pervasive games for finding a hidden object or person.
- One of the research areas in activity-based navigation is the presentation of sensed information to users. One small, 10-person study examined finding cars by using combinations of sensed data from a compass, the GPS, and images. The study examined human-level inference versus sensor-level inference. The results indicated that human interpretation of where breadcrumbs started and ended was significantly different from naïve inference. These results seem to indicate that reporting excessive detail may be counterproductive.
- A trajectory search combines the user’s trajectory with a mobile local search. It uses a destination prediction service to present more relevant results. The location is static. Speed and direction are not considered, and user preferences are not taken into account.
- A survey of mobile search behavior was conducted to better determine the usefulness of trajectory searches. The survey results indicated that people do search while they are mobile. Sixty-four percent of the survey participants responded that they searched while in an automobile or bus, and 11 percent responded that they searched

Construct a *trail* of activities using the phone's sensors



Play trail back to help people retrace their steps

- ✓ Does not require a map
- ✓ Useful when GPS is not available

FIGURE 5 Activity-based navigation.

while walking. Half of the time the respondents indicated they were looking for a brand or chain, rather than a specific location. Forty percent wanted a place on their route or at their destination, 27 percent wanted a place at their destination, 12 percent wanted a place near their destination, and 12 percent wanted a place on their route.

- The survey results indicated that individuals search even when they are familiar with an area. Furthermore, searches were collaborative; 67 percent of survey participants reported that they discussed the search with someone. Restaurants represented 48 percent of the searches. The survey results indicated that people will use trajectory searches.

- Location prediction services use GPS data. No training or previous history is required for individuals. In a user study, individuals were asked to travel to four locations and to select a place to eat lunch at each one. The study logged whether the restaurant they selected came from the current location, a trajectory, or an inter-section.

- Trajectory-aware search capabilities represent a valuable feature for augmenting conventional local mobile searches. Trajectory-aware searches are viable for open-ended searches and for hands-free situations. Additionally, trajectory prediction has many other applications.

EXPLORING THE SOCIAL MEDIA LANDSCAPE TO STREAMLINE EVERYDAY EXPERIENCES

Munmun De Choudhury discussed the potential use of social media in trip planning and other transportation applications. She described two recent research projects that used social media. Choudhury's presentation on the first project covered the following points:

- There are numerous modern modes for social interaction. Facebook, Twitter, Myspace, and YouTube are probably the best-known online modes. Other online social media include Digg, Reddit, Blogger, LiveJournal, MetaFilter, Orkut, Slashdot, and Engadget. These social

media have been important communication methods during recent worldwide events, such as the elections in Iran and the earthquake in Haiti. They also streamline everyday life. Little is known, however, about the use of geotemporal social breadcrumbs to enable better individual decision making or about the role of social media in providing information on locally and globally distributed events.

- Researchers from Rutgers University collaborated with personnel at Yahoo! Research in New York to explore the use of social media in travel planning. The project examined the use of social geotemporal breadcrumbs in planning a travel itinerary. The project goal was to construct intracity travel itineraries automatically by tapping a latent source that reflected geotemporal breadcrumbs left by millions of tourists. Flickr was the Internet source used. The approach extracted photostreams of individual users and aggregated all user photostreams into a point-of-interest (POI) graph. The orienteering algorithm was applied to construct itineraries. Survey-based user studies of approximately 450 workers on Amazon Mechanical Turk (AMT) indicate that high-quality itineraries can be automatically constructed from Flickr data.

- A three-step process was used to develop timed paths: (a) developing the photostreams, (b) developing the photo-POI mapping, and (c) segmenting the photostreams and constructing the timed paths. Constructing the itineraries, or the POI graphs, also involved several steps. The goal of constructing the itineraries was to aggregate the actions of many individual travelers into coherent itineraries for a given set of timed paths while taking into consideration the popularity of the POI. Predicates used in the formula for developing the POI graph included the visit time at each POI (determined by the longest visit time for each user; the 75th percentile among all users was used), the median transit time between two POIs, and the prize or value that an itinerary received from visits to each POI.

- Five popular and geographically distributed cities were selected for the research project: Barcelona, London, New York, Paris, and San Francisco. For each city, a list

of POIs was developed by pooling information from different sources, such as Lonely Planet and Wikipedia. Four itineraries were generated for each city. The city's four most popular POIs were identified and listed in order of popularity. The four itineraries for each city were constructed by setting the beginning point and ending point at different combinations with a time budget of 12 hours.

- To compare the automatically constructed itineraries with the baseline itineraries, the researchers obtained itineraries provided by the top tour bus companies in each city; these were considered the ground truth itineraries. Because typical bus tour itineraries do not list visit and transit times, these times were derived from online tourist guides.

- AMT-based Human Intelligent Tasks (HITs) were used to design user studies. The studies obtained feedback on various aspects of the itineraries from a large number of anonymous users. The concept of AMT is to provide a crowdsourcing marketplace in which requesters (individuals or institutions who have tasks to be completed) and workers (individuals who can perform the tasks in exchange for monetary reward) can come together. AMT provides a platform where HITs are hosted and executed, money is transferred securely, and the reputation of workers and requesters is tracked.

- The survey included qualification questions on lesser-known POIs. The user study design included side-by-side evaluations that compared the itineraries with the ground-truth data and an independent evaluation that examined the itineraries in detail. The evaluation questions focused on comparison of the overall quality of the itineraries, evaluation of the quality of the suggested POIs, and evaluation of transit time across consecutive POIs.

- An evaluation metric was developed to estimate the usefulness of the itineraries from two aspects: the overall utility of the itineraries and the appropriateness of the POIs. The mean response volume was calculated to measure the number of worker responses received per option. Itinerary usefulness received a high percentage of ratings of "significantly better" or "somewhat better." Although POI appropriateness also received high percentages in these two rating categories, it also received a large number of ratings of "similar."

- Other evaluation metrics included the mean weighted response, which aggregated the responses to each question from the workers in the same group into a single number. The mean average error fraction was also computed as the percentage of the total number of POIs, visit times, or transit times that were considered bad or inaccurate by a particular worker.

- The study examined the development and use of automatic generation of travel itineraries for popular tourist cities from large-scale user-contributed rich media repositories. The survey-based user studies on AMT showed promising results relative to bus tour company itineraries. Additional studies will focus on optimizing parameters, incorporating traveler diversity, examining POI time constraints and covisitation patterns of users, and expanding city and POI coverage.

Choudhury's presentation on the second project covered the following points:

- This project examined geographically dispersed events by identifying user categories that correspond to events that are widely discussed on social media, primarily Twitter. The categories tracked include organizations, journalists and media bloggers, individuals, and celebrities. Study activities included developing a background training model, testing it on a variety of events, and exploring the user categories corresponding to these events.

- Approximately 5,000 labeled Twitter accounts were identified through Twellow (www.twellow.com), a directory of Twitter users; Muck Rack (www.muckrack.com), a directory of journalists who tweet; and Twitter Public Timeline, users of which were labeled by means of AMT. Network affiliation, behavior, and content were used to describe users.

- The user categories related to different events can be explored. Understanding these user categories helps in understanding the character of today's geographically dispersed events. Social media is useful in understanding these temporal phenomena. Social media enables easier journalistic inquiry and thus eases virtual transportation planning.

BREAKOUT SESSION 3-B

Transforming Experiences

From Data to Measures, Measures to Information, and Information to Decisions with Data Fusion and Visualization

Robert M. Winick, *Motion Maps, LLC* (Moderator)

William Bachman, *GeoStats*

Yoshihide Sekimoto, *University of Tokyo*

Patricia S. Hu, *Bureau of Transportation Statistics, U.S. Department of Transportation*

TERABYTES TO DECISIONS: THE INCREASING POTENTIAL OF LOCATION-BASED ANALYTICS FOR TRANSPORTATION PLANNING

William Bachman discussed how location-based data can be used to improve transportation planning. His presentation highlighted existing commercially available databases and described their potential applications.

- Location-based data are widely available today. Some areas are beginning to use location-based data in a broad range of transportation planning applications. There are numerous opportunities to expand the use of location-based data in transportation planning, performance measurement, and decision making.

- INRIX, AirSage, and TomTom Traffic Stats are examples of commercially available sources of location-based data.

- INRIX, which publishes an annual report on congestion in urban areas throughout the country, provides a rich source of data on historical traffic patterns. INRIX data are now being used in the mobility reports published by the Texas A&M Transportation Institute and in before-and-after studies, bottleneck analyses, and support for congestion-monitoring programs. The INRIX database provides for flexible aggregation of travel time and speed.

- AirSage origin–destination (O-D) data provide information on movement patterns and long-distance travel patterns. The data are used in support of travel demand models.

- TomTom Traffic Stats provides speed and travel-time data based on routes and segments. It boasts online query capabilities, O-D data, and a wide range of Global Positioning System data from sponsored surveys.

- Although these data are intrinsically attractive, there are still questions concerning their use in transportation planning, performance measurement, and travel forecasting models. The data requirements of the various topic areas associated with transportation planning are different. For example, the data needs associated with system performance evaluation include separating data on nonrecurrent and recurrent congestion, focusing on arterials and intersections, and capturing speed and volume data. Transportation development models and maintenance models require data on baseline speed by link and class level, O-D travel times, bottlenecks, and travel behavior. The data needs related to the effectiveness of transportation improvement include before-and-after delay data, facility measures, and regional measures. Also needed are data on real-time speeds and travel time, arterials and intersections, atypical events, intelligent transportation systems, and traffic operations.

- Historical travel speed data are available now and are being used by some metropolitan planning organizations and state departments of transportation (DOTs) in network performance studies. The use of data from cell phones and other sources is being included in recent requests for proposals from metropolitan planning organizations and other agencies.

- Location-based data can also capture atypical events and provide information on the movement of freight and

goods. These data can also be used in activity-based modeling and travel blending. Still other applications include community planning, analyzing livability and mobility, and safety planning.

- There are different levels of data needs and fixed data collection standards and methods. For example, decision makers in state DOTs are interested in return on investment, while division managers may be interested in regional percentage of delay reduction. A project manager would focus on measures such as percentage of delay reduction, stopped time delay, and percentage of travel time change. A consultant team would possibly be interested in lengthy formatted reports, methods, schedules, and analysis. Task lead engineers and analysts are focused on maps, charts, tables, formatted reports, and raw and processed data.

- In conclusion, location-based data solutions are increasing the ability of planners to accurately understand existing conditions. Scientific methods are still valid with these data sources. The market value of the data is not clear, however. Questions on data quality and bias exist, but should diminish with frequency of use and acceptance.

TRANSFORMING EXPERIENCES IN TRANSPORTATION SYSTEMS IN JAPAN

Yoshihide Sekimoto discussed the following projects underway in Japan for collecting traffic and pedestrian

data: a new initiative by Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) for collecting and analyzing road traffic data, the People Flow Project (PFLOW), and a geospatial information exchange involving the national government and local governments. Sekimoto's presentation covered the following points:

- The MLIT project focuses on new methods for collecting and analyzing traffic data. It is intended to address some of the issues associated with current data collection techniques.

- Japan conducts a road traffic census once every 5 years. Human observers positioned at 24,000 locations throughout the country for 1 day conduct a traffic volume survey. The survey is an efficient, low-cost method of data collection. The data for the particular day in the fall are used as the average annual road traffic data. This approach is not adequate for detailed analysis. Because the daily distribution of traffic volume fluctuates widely, determining recurrent and nonrecurrent congestion on the basis of only 1 day of observation is difficult.

- In the future, traffic volumes will be obtained by observation of key road sections 24 hours a day, 365 days a year. The constant observation data will be used to estimate the traffic volume of other road sections. To date, the collection of travel speed data from probe vehicles has been limited (Figure 6). In the future, however, collection of probe information from vehicles on a 24-hour basis should be possible.

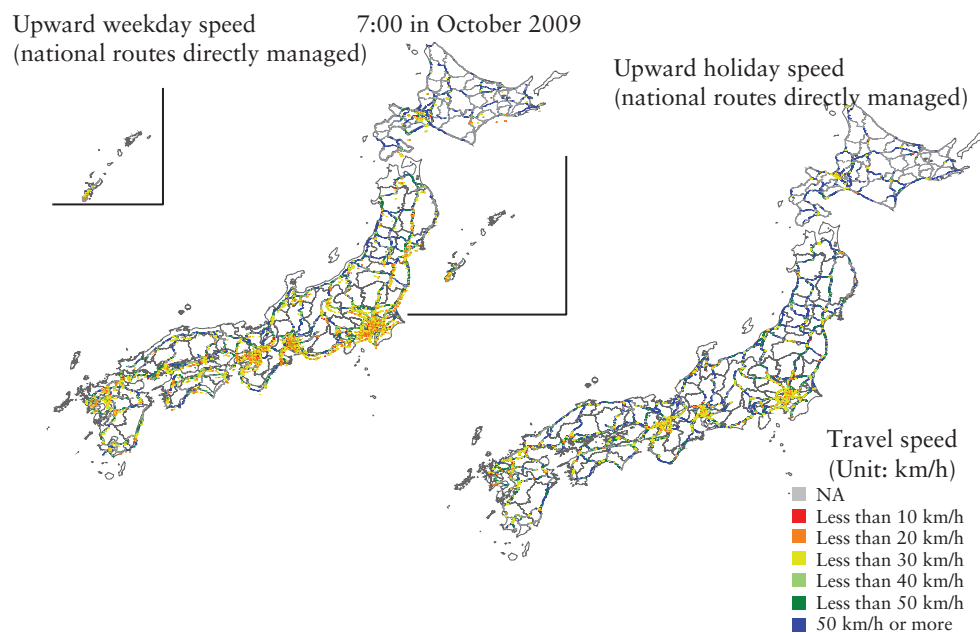


FIGURE 6 Nationwide travel speed in Japan, October 2009.

- New result indices are being introduced to evaluate the smoothness of traffic. One of these focuses on a quantitative evaluation of time loss caused by traffic congestion. The time loss is the extra time it takes to make a trip under congested conditions. The time-loss rate is the ratio of time loss to car utilization hours. In fiscal 2009, car use on national routes throughout Japan was approximately 13.3 billion hours. The number of hours required was approximately 8.3 billion, so some 5 billion hours were lost as a result of congestion.

- The PFLOW project addresses the increasing need for time-based location information for large segments of the population. The recent earthquake in Japan is one example of this need. Having real-time data may help prevent or reduce the impact of secondary disasters in complex urban settings. Real-time data may also be used to help manage special events involving large groups of people.

- The PFLOW project uses large-scale, real-world data to reconstruct macroscopic people flow. Person trip data are available from the personal travel survey conducted by the Tokyo Metropolitan Region Transportation Planning Commission. O-D information can also be obtained. Data from these and other sources are used in the spatiotemporal modeling of people flow.

- The PFLOW data set is being used in numerous research projects that cover a wide range of areas, including transportation, spatiotemporal analysis, risk analysis, personal information, security, the environment, and marketing.

- The experimental geospatial information exchange consortium was initiated in FY 2009–2010. The national government and local governments provide data to the consortium exchange platform. The data users, which include various companies and organizations, can access the data via the exchange program. There are 125 consortium members, of which 85 are private companies. Other members include foundations, universities, associations, nonprofit organizations, national organizations, and local governments. The exchange platform contains a wide range of data from different sources. Data fusion is supporting the logistics response to the recent earthquake and tsunami.

ENHANCING PERFORMANCE MEASUREMENT AND DECISION MAKING WITH VISUALIZATION TOOLS

Patricia S. Hu discussed visualization tools for enhancing the presentation of data used in performance measurement. She provided examples from the Oak Ridge National Laboratory (ORNL), the Bureau of Transportation Statistics, the U.S. DOT, the National Geospatial-

Intelligence Agency, and other groups. Hu's presentation covered the following points:

- A visualization tool is software that provides visual displays and representations. One of the key benefits of visualization tools is the ability to integrate many different layers of data and analytical capabilities. Visualization tools can range from the relatively simple to the very complex, depending on use and the desired analysis and display capabilities. The size of the spatial coverage can add to the complexity of the analysis.

- Visualization tools integrate layers of data. Users select the layers of data needed to analyze a specific question or issue. Visualization tools are also scalable and adaptable; additional layers can be added or removed as needed. Visualization tools can be used for the following purposes:

- To communicate large amounts of data, system performance, and other measures;

- To present the results of simulation models and analyses; and

- To plan scenarios for special events and emergency responses.

- One application at ORNL focused on displaying freight data. Data from the Freight Analysis Framework were used to examine freight flows in a corridor. Another application examined the travel needs of older individuals.

- Several visualization tools were demonstrated, including tools on the websites of the Bureau of Transportation Statistics and the U.S. DOT and the Bomb Card developed by ORNL. This application can be used by first responders to determine the evacuation distance and take-cover distance related to different types of bomb threats. The number of buildings and employees on the ORNL campus that would be affected can be identified. Another visualization tool can be used to evaluate different routes for the shipment of hazardous materials. The routes displayed depend on the criteria selected (e.g., shortest distance, avoiding major population centers, avoiding environmentally sensitive areas).

- Several lessons have been learned from the experience to date in developing and using some of these visualization tools. Collaborating and working with stakeholders is critical. Identifying data needs, data availability, and data compatibility is also important, as is fusing the data. Additional collaboration with stakeholders as the tool is being developed is needed to ensure that it meets the intended purposes and the capabilities of the users. Ongoing refinements and enhancements are common after the tool is developed.

BREAKOUT SESSION 3-C

Asking the Right Questions

Timely Advice for Emerging Tools, Better Data, and Approaches for Systems Performance Measures

Michael Pack, *University of Maryland* (Moderator)

This session was an open discussion on the technical tools, data needs, and political and institutional issues associated with transportation performance measurement. The discussion focused on three areas: the factors limiting the use of performance measurement in transportation, technical challenges, and political challenges.

FACTORS LIMITING THE USE OF PERFORMANCE MEASUREMENT IN TRANSPORTATION

- Participants discussed the need to focus on the drivers of performance measurement, the audience for different measures, and how the measures would be used and applied. It was suggested that there is a need to engage the public and stakeholders in broad debates about performance measures as well as in discussions about transitions to new metrics. It was noted that identification of measures related to the priorities of the public is important. Methods for obtaining input from the public and policy makers were discussed.

- The development and use of performance measurement in the public and private sectors were discussed. It was suggested that setting measures may be easier in the private sector because goals are clearer. In the public sector, the mission or vision for some measures is not always clear, and there is often little incentive to manage and measure what already exists. In the private sector, there is an incentive to measure what already exists, as increasing productivity translates into increasing profit.

- Participants discussed the importance of a common vision in performance measurement. It was suggested that a vision at the national level can be carried over to the state and local levels. Using measures to make a complex subject simple was discussed, as was focusing on the resulting benefits.

- Current examples of the use of performance measurement by transportation agencies were described, and the value of highlighting these examples was discussed. A focus on best practices, the availability of data, and analysis tools may help agencies begin to use performance measurement. The success stories of agencies that have used performance measurement for several years should be highlighted to encourage other agencies.

- The importance of the support of top agency leadership in developing and maintaining performance measurement was noted. Leadership and transparency were identified as two factors that are key to the long-range success of performance measurement programs. Methods for maintaining performance measurement when top agency leadership changes were also discussed.

- The need for accurate and timely data was discussed, along with the timing and interpretation of available data. Decisions will be made with or without data. It is important to use the data that are available and note any limitations.

- It was suggested that top-down and bottom-up support for performance measurement are important. Buy-in throughout an agency is also needed.

TECHNICAL CHALLENGES

- Participants suggested that the technical challenges associated with performance measurement are diminishing. A great deal of data are available, as are visualization tools. Areas noted as being important included not trying to make data and models perfect and interpreting data for decision makers and the public.

- Participants discussed taking the opportunity to learn from other agencies and the private sector. Sharing best practices would be beneficial for all groups.

- There was general agreement that many technical tools are available. Training in their use may be necessary. New technical tools may be needed in some areas. The private sector may be able to help with developing new data analysis methods. The key still is interpreting the data and linking it to the decision-making process.

- The potential for developing federal data sets to generate standard analysis tools was discussed. There are limitations to the data that the federal government can collect. The need for the data has to be justified.

- The advantages and limitations of using private-sector data were discussed. Opportunities to use private-sector data were noted as important. It was suggested that identifying and addressing barriers to partnering with the private sector should be explored and that pilot tests of the use of private-sector data in a few areas should be conducted. Demonstrating benefits can help make the justification.

POLITICAL CHALLENGES

- Participants identified and discussed the political challenges associated with performance measurement. One challenge was the development of measures that are not attainable. Three common mistakes were suggested: not starting, waiting for perfect data, and not thinking about the audience in reporting results. Understanding how to interpret and use data is important.

- Potential issues regarding the use of performance measures to determine funding were discussed. The potential for performance measures to cause a breakdown in cooperation when comparisons are presented was also discussed. It is important to ensure that everyone is measuring the same item in the same way.

- Discussion of whether a strategy should always be included when setting goals ensued. Some participants suggested that to attain goals, an action plan is needed. Others suggested that just setting the goal or target may motivate the people involved to attain the goal.

- The potential use of performance measurement in the reauthorization of the federal surface transportation legislation was discussed. The importance of an open process that involves all stakeholders in developing performance measures and metrics was noted. The potential roles of different agencies and groups were described. Also noted was the possible downside of performance measures, especially in relation to unintended consequences, a focus on midlevel rather than top-level performance, and measurement of the wrong things.

PLENARY SESSION 4

Tools and Methods

What Are We Doing and How Are We Doing It?

Sue McNeil, *University of Delaware* (Moderator)

Jeffrey F. Paniati, *Federal Highway Administration*

Paula J. Hammond, *Washington State Department of Transportation*

Jenne van der Velde, *Rijkswaterstaat Centre for Transport and Navigation, Netherlands*

MOVING TOWARD A PERFORMANCE-BASED FEDERAL-AID HIGHWAY PROGRAM

Jeffrey F. Paniati, Executive Director, Federal Highway Administration (FHWA), spoke on how FHWA is looking at performance management as part of moving toward a performance-based federal-aid highway program. FHWA's FY 2012 budget proposal specifically establishes a performance-based highway program and reflects the administration's four broad goals: building for the future; spurring innovation; ensuring safety; and reforming government and exercising responsibility.

It is this fourth goal, reforming government and exercising responsibility, that relates directly to performance measurement. This goal also pertains to greater accountability and transparency in using public funds. It builds on the American Recovery and Reinvestment Act of 2009, which is generally characterized as being reporting heavy and performance light. Paniati stated that FHWA is trying to focus more on using data for performance and analysis rather than merely for reporting.

The National Highway System (NHS) elements in the 2012 budget have received a more positive response from Capitol Hill. The Highway Infrastructure Performance Program (HIPP) provides for investments in the state of good repair, operational performance, and safety on an enhanced NHS, and the Flexible Investment Program (FIP) provides for investments in any part of the federal-aid highway system and in off-system bridges. Suballocations are recommended for both HIPP and FIP. The Highway Economic Requirements System model was used to estimate funding levels for maintaining a

state of good repair. The enhanced NHS would be a 220,000-mile network that would carry 55 percent of all traffic and 97 percent of all truck freight. The current NHS extends for a comparatively low 165,000 miles. In addition, the enhanced NHS would provide a more comparable system in all 50 states.

Considering that recent national commissions have recommended increased transparency, accountability, and a performance-based system, the current fiscal situation of the United States also calls for more transparency and accountability. Paniati predicted that a performance-based federal-aid program will be part of the next authorization and remarked that FHWA is working with state and congressional partners to better define the salient elements and processes. FHWA has identified several principles that should inform the development of a performance-based federal-aid program:

- Development of the program needs to be an evolutionary process. More than one step will be required to reach the desired program.
- The program must be built from existing data and measures so that all states will be able to use it. FHWA should tailor the framework to support comprehensive and robust programs.
- The responsibility for goals and target-setting is shared by FHWA and the states. FHWA realizes the need to provide accountability; in the first stage, however, accountability will probably not be tied to funding levels.

The FY 2012 budget creates a framework that outlines the key elements of a performance-based program. The

budget recognizes the need to address performance in the national goal areas of safety, infrastructure condition, economic competitiveness, environmental sustainability, and livability. Initially, it focuses on performance in the areas of safety, and pavement and bridge conditions.

The FY 2012 budget also outlines a performance management process. According to Paniati, FHWA would not look to legislation to establish the definition of the specific measures, goals, or targets, as that task should be performed by the U.S. Department of Transportation (DOT) in conjunction with state DOTs and local agencies. The process would begin with the Secretary of Transportation, who would establish quantifiable performance measures and national performance goals. The states would work in partnership with FHWA to set state targets, which would need to be tied to available funding, so there would be some negotiations in this phase. FHWA envisions using the existing planning process, with some modifications, to implement performance management. The states would be called on to publish annual reports on their progress in meeting targets. States would be allowed budgetary flexibility when targets are met but would be required to submit a performance improvement plan when performance falls short of targets.

For the safety goal, the U.S. DOT would build on the states' Strategic Highway Safety Plans. The U.S. DOT has called for an additional investment in safety data as part of the authorization. The Highway Safety Improvement Program provides improved information on highway characteristics to match existing crash data. This program provides the data needed to better understand the relationships between highway improvements, enforcement programs, and efforts targeting changing behavior as well as results.

According to Paniati, the U.S. DOT envisions beginning with fatalities as a performance measure but transitioning over time to the use of serious injuries as a measure. This approach reflects the evolutionary development of appropriate measures and targets and also provides accountability.

The approach for pavement and bridges is similar and builds upon previous work on asset management. A risk-based asset management plan would be required, and performance requirements would be limited to the enhanced NHS. The tentative plan is to move from using asset management for informational purposes to using it for decision making. The initial measures would focus on pavement smoothness, with the international roughness index (IRI) as the starting point, before moving on to structural adequacy and other related issues.

In closing, Paniati highlighted FHWA's ongoing efforts to advance all elements of performance management and the administration's ongoing dialogue with

the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Performance Management, which has been a central part of developing a program for both federal and state agencies. FHWA is continuing to develop data and systematic measures for safety, pavement, and bridges; the work on the IRI will be instrumental in developing national pavement measures. FHWA is also continuing to invest in research in areas such as reliability, the environment, and livability, but additional research is needed to define measures in these areas. Finally, FHWA is brainstorming about how it can integrate performance management with planning, and pilot tests are being implemented within several states and metropolitan planning organizations.

Under its Office of Infrastructure, FHWA has established an Office of Transportation Performance Management whose director, Peter J. Stephanos, is working to define the role and agenda of the office to ensure alignment with the AASHTO Standing Committee on Performance Management. The Office of Transportation Performance Management coordinates the cross-cutting aspects of performance management, as well as the efforts of individual offices. For example, the Office of Safety will still lead safety performance measures, but the Office of Transportation Performance Management will ensure internal coordination.

One effort that is underway is building the internal capacity to support a performance-based program. Field staff who interact with state DOTs are being trained in this area. FHWA is also developing analysis tools and training to assist states and local governments in advancing performance management and is working with the Federal Transit Administration to facilitate collaboration between the highway and the transit communities.

Paniati indicated that he sees this process as a natural business evolution to improve decision making; resource allocation; and transparency and accountability for federal, state, and local funds. He noted that FHWA is not waiting for authorization but is already working with its partners.

MEASURING TRANSPORTATION SYSTEM PERFORMANCE: EXAMPLES OF APPLYING PERFORMANCE MANAGEMENT TOOLS AND STRATEGIES

Paula J. Hammond described the use of performance measurement and performance management at the Washington State DOT. She stated that performance management is a key part of the Washington State DOT's corporate culture and that the department was celebrating the *Gray Notebook's* 10-year anniversary of reporting on transparency and accountability. (The *Gray*

Notebook is the Washington State DOT's quarterly performance report that measures programs and reports on their progress.) This publication is used internally to manage the agency and externally to communicate with policy makers and with the public.

Hammond noted that a strong and reliable transportation system is the backbone of a healthy economy and that performance measures play an important role in the Washington State DOT's system management. The department's plan to reduce congestion and improve mobility in the state is called Moving Washington.

Hammond described the Washington State DOT's broad and diverse transportation portfolio, which includes highways, ferries, passenger rail, freight rail, general aviation, and support for transit. The department owns, manages, and maintains 20,000 lane miles of state highway, 225 lane miles of a planned 320-mile-long high-occupancy vehicle (HOV) freeway system, and more than 3,600 bridges and structures. The ferry system includes 20 terminals and 22 ferry vessels that average 500 daily sailings and carry 23 million passengers annually. The Washington State DOT is a partner in the Amtrak Cascades state passenger rail, which carries more than 700,000 passengers per year, and it also owns, operates, and maintains the Grain Train, which includes 1,432 miles of short-line rail and 89 grain cars. There are 17 department-managed airports and 138 public-use airports in the state. The department's commute programs support more than 810,000 commuters, and its vanpool fleet of more than 2,400 vans is the largest in the United States.

Hammond discussed the three primary reasons that drive the use of performance measurement at the Washington State DOT and the data collection needed to support the use of performance measures. First, performance-based investments best utilize the agency's limited resources. Data are used to determine the highest-priority needs. Second, performance measures are used to demonstrate progress toward completing projects and programs and are the basis for communicating this progress to the public. Third, measures and research are used to improve system performance by identifying problem areas and solutions.

The public expects the Washington State DOT to build, maintain, and operate the transportation system in the most open and transparent manner possible. To this end, the department's performance-based strategic plan outlines agency goals, and the *Gray Notebook* provides quarterly updates on agency performance and accountability. Under Daniela Bremmer's leadership, the Washington State DOT has been using and expanding performance measurement over the past decade. As a result, the *Gray Notebook* is known nationally and internationally as a brand that stands for agency credibility, transparency, and accountability. It is a vital and effective internal and external communication tool that

has supported the passage of two critical increases in gas tax revenue.

The Washington State DOT's performance is tracked in several areas:

- Safety. Fatalities on Washington roads are at their lowest levels since the 1950s. In 2007, there were 571 fatalities on Washington roads; in 2009, there were 491, a decrease of 14 percent.
- Mobility. The movement of people and goods contributes to a strong economy and a better quality of life. Washingtonians experienced 22 percent less delay on state highways in 2009 than in 2007.
- Asset management. The department focuses on preservation and maintenance. In 2009, 93 percent of the department's roadways were in fair or better condition.

Investments to improve the system are made on the basis of performance data. For example, collision and congestion data are used to direct the department's roving incident response trucks to the areas of greatest need. Limited funds for bridge and pavement preservation are allocated to the facilities with the highest priority projects. Collision data and before-and-after analyses are used to determine investments in safety measures such as rumble strips and cable median barriers in high-collision corridors.

Preservation and maintenance are important for performance-based investments. The maintenance accountability process sets targets for 31 key activities and responsibilities. In 2010 the Washington State DOT met 65 percent of its performance targets, including pavement repair and snow and ice removal. Aging vessels and terminals are issues for the Washington State ferry system, whose fleet is among the oldest of the major ferry systems in the country. A condition-rating system helps preserve and update vessels and identifies when vessels and terminals need to be replaced.

Hammond noted the importance of demonstrating and communicating performance. The 2003 and 2005 gas tax investments, in combination with lower levels of driving resulting from higher fuel prices and the economic recession, are making a difference in system mobility. Between 2007 and 2009, statewide travel delay declined by 21 percent on state highways, and the average peak travel time improved on 31 of 38 high-demand commute routes. A study of 15 completed projects funded by the 2003 and 2005 gas tax investments showed that morning and evening average speeds increased by 23 percent and that peak period travel times decreased by 15 percent.

The Washington State DOT addresses congestion by managing the freeway system to maximum throughput speeds that help achieve maximum system efficiency. For example, the I-405–South Bellevue Widening Project, which was completed in 2009, added northbound

and southbound general-purpose lanes and a southbound HOV lane near Bellevue. After the new lanes were opened in 2009, the typical commute time on I-405 between Tukwila and Bellevue, which had been 42 minutes in 2008, was 26 minutes—a decrease of 16 minutes (Figure 7).

The department's technology systems help improve the efficiency, safety, and security of truck freight movement throughout the state. Weigh-in-motion scales and transponders electronically screen trucks. In 2009, the program saved the trucking industry an estimated 87,000 hours and \$6.5 million dollars. Freight rail helps move goods to and from Washington's ports and serves as a sustainable, efficient, and environmentally sound alternative to truck transportation for long-haul routes. In 2008, freight railroads in Washington carried 116 million tons of freight over 3,604 route miles.

Active traffic management and variable tolling are examples of using data to make the freeway system work better. Active traffic management is being implemented on I-5 in Seattle and on other selected facilities to reduce collisions and improve traffic flow. In addition, variable tolling was implemented in the fall of 2011 on the SR-520 bridge across Lake Washington. Variable tolling is expected to encourage drivers to use the bridge at off-peak times, when the toll is lower. Legislatively directed tolling studies are considering other routes for future tolling options, including the Columbia River Crossing and the Alaskan Way Viaduct.

The Washington State DOT uses data on travel time and speed to identify the least congested routes. Communication tools such as dynamic message signs are used to advise drivers of traffic conditions and thus improve system efficiency.

Examples of new initiatives include focusing on sustainability, measuring the economic impacts of trans-

portation investments, and preparing for the potential of a performance-based authorization at the federal level. Sustainability targets the triple bottom line of the economy, the environment, and equity and provides performance management opportunities and challenges. The Washington State DOT continues to explore better ways to measure and report on the value of completed projects and new programs and is also preparing for possible new requirements and national performance goals as part of the federal authorization.

There are many ways to effectively measure infrastructure to highlight key policy goals and agency priorities. Rebuilding Washington State's economic vitality requires commitment to maintaining and preserving a strong and reliable transportation system. Transparency and accountability help develop stronger, more consistent partnerships between government and the public.

ASSET MANAGEMENT IN THE NETHERLANDS AT RIJKSWATERSTAAT

Jenne van der Velde focused on the use of asset management in the Netherlands' Rijkswaterstaat, which was founded in 1798. He noted that his organization employs approximately 9,000 staff members at 240 sites throughout the country. There are 10 regional departments, five specialized departments, 35 districts, and three project departments. The agency's annual budget is approximately €4 billion to €5 billion (US\$6 billion to US\$8 billion). Rijkswaterstaat manages three national infrastructure networks: the national highway network, the main waterway network, and the main water system.

In the national highway network, the Rijkswaterstaat manages 3,102 kilometers of highways, including traffic signal systems; 1,259 kilometers of slip roads, exits, and

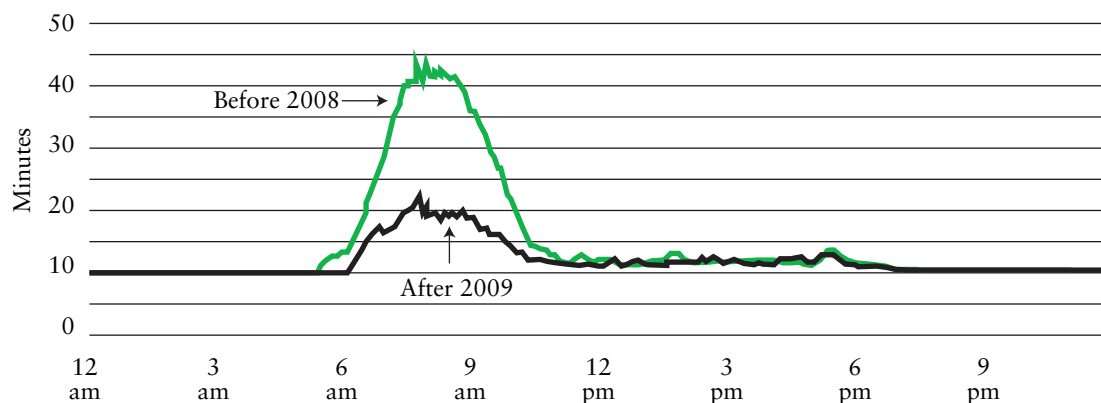


FIGURE 7 Travel time (minutes) before and after capacity additions to 10.2-mile corridor on I-405 northbound from SR-167 to Northeast 12th Street. Travel time was measured Tuesday through Thursday in October 2008 and October 2009. (Data Source: Washington State DOT Northwest Region Traffic Office.)

connecting roads; 25 rush-hour lanes; 2,533 viaducts; 15 tunnels; 715 moveable and fixed bridges; and seven aqueducts. Van der Velde commented that traffic congestion on the Netherlands' main highways is a policy conundrum.

Maintaining the waterway network is paramount, as most of the Netherlands is located below sea level. Ports like Rotterdam, as well as the waterway network as a whole, are critical for commerce and economic vitality.

Asset management is central to the work of Rijkswaterstaat, which uses a life-cycle approach that focuses on strategic goals. This approach is a systematic and coordinated process that manages assets, performance, risks, and costs by focusing on understanding the extent and condition of infrastructural elements and identifying possible risks. The goal is to minimize and avoid costs by balancing acceptable risks with the budget level to meet performance targets.

Staff members examine the various elements of the network and use a process called decomposition of the networks. This process begins with the network and the overall system and then examines the system and subsystems to identify their basic objectives, maintenance objectives, and inspection objectives. For example, a specific highway represents one overall system. Various roadway segments are the subsystems. A basic objective might be to maintain the bridges in a subsystem section, with construction and pavement as the maintenance and inspection objectives.

At the decision-making level, there may be choices between the networks, such as rail or highway. Funding, policies, and other factors may influence short- and long-term investments in the rail and highway infrastructure. At the sublevel, decisions may focus on maintenance or replacement needs. Asset management makes the connection between costs, targets, and risks over the long term and maintenance and projects in the short term.

Rijkswaterstaat has roles, responsibilities, and tasks related to being the asset owner, the asset manager, and the service provider. As the asset owner, the agency focuses on the strategic future of the network within the framework of targets, risks, and costs. As the asset manager, the agency focuses on tactical plans associated with investment strategies, maintenance concepts, and technology standards. Program management addresses risk management, network management, and performance management. As the service provider, the agency focuses on operations—renewal, expansions, and maintenance. The tasks are project management, process, and asset data management.

Asset data management helps put the pieces of the jigsaw puzzle together. Ownership links to money, which links to knowledge and asset management. People and the service provider are the final two pieces. Connecting all of these pieces is critical to maintaining economic vitality and quality of life in the Netherlands.

Van der Velde observed that Rijkswaterstaat faces many of the same issues and trends noted by other conference speakers. Funding for both new projects and maintenance and rehabilitation is limited, and the organization is challenged by being asked to do more with fewer employees. Responding to rapid changes in technology and new methods requires employees with new skills and technical knowledge. Key performance indicators for the future are based on reliability, availability, maintainability, and safety (RAMS) and on security, health, the environment, economics, and politics (SHEEP). Service-level agreements with the minister are based on RAMS.

Future research focuses on technical applications and other subjects. One joint project involves 13 countries and has a budget of €2.7 million (US\$3.6 million). At the time of the conference, the results from this project and other studies were expected to be available in 2012.

BREAKOUT SESSION 4-A

Measuring Regional and Community Outcomes

Sue McNeil, *University of Delaware* (Moderator)

Peter Hurley, *North American Sustainable Transportation Council*

Keith A. Bartholomew, *University of Utah*

PERFORMANCE MEASURES IN THE SUSTAINABLE TRANSPORTATION ANALYSIS AND RATING SYSTEM

Peter Hurley reviewed the Sustainable Transportation Analysis and Rating System (STARS), including its development and purpose. Hurley's presentation covered the following points:

- STARS is a voluntary, national system that provides a framework for developing and rating projects, plans, and programs. It is similar to Leadership in Energy and Environmental Design, but is for transportation. For use by public agencies and private-sector consultants, STARS is a performance-based system that focuses on access, climate and energy, and cost effectiveness and local economic benefit. STARS compares performance across all modal strategies and includes full life-cycle analysis. Development of STARS began in 2010, and a pilot project phase was initiated in 2011.
- The purpose of transportation is to give people access to other people, places, goods, and information. Sustainability requires more than greening-up a project. The STARS principles focus on moving toward true sustainability; improving economic, social, and environmental performance; and measuring what customers want. Goals drive strategies in STARS. STARS goals focus on transforming transportation industry practice to improve access for all people, reduce oil dependence and climate pollution, maximize cost-effectiveness, and move toward true sustainability.
- The triple bottom line metrics for STARS are similar to the triple bottom line metrics for sustainability.

The three Es of sustainability—the environment, equity, and the economy—are roughly analogous to the core STARS credits. True sustainability requires optimizing all three Es: economic benefits, environmental benefits, and equity and social benefits. STARS is grounded in the basic principles of the Natural Step. It focuses on an integrated process and access, climate and energy, and analysis of cost-effectiveness.

- STARS was developed through a partnership between the City of Portland, Oregon, and the North American Sustainable Transportation Council. There are numerous other public and private partners, including the Santa Cruz County Regional Transportation Commission, CH2M Hill, Parsons Brinckerhoff, Confluence Planning, ECONorthwest, David Evans & Associates, and Brightworks. National peer reviewers from public agencies, consulting firms, and academia are also involved.
- The STARS credit structure includes five required credits and 24 optional credits; 12 core credits were developed for the pilot phase. Credits are accrued to earn certification at the completion of each of three phases: evaluation, implementation, and operations. Not all credits are applicable to all projects.
- The STARS process has five steps:
 1. Create a multidisciplinary team and host workshops on training and sustainability,
 2. Backcast goals addressing (a) access and (b) climate and energy,
 3. Develop economic evaluation strategies,
 4. Select alternatives and implement projects and activities, and
 5. Monitor and improve performance as appropriate.

- Several strategies may be considered and analyzed to achieve the identified objectives. Examples of potential strategies include transportation demand management; transportation system management; provision for vehicle capacity; the addition of transit, bicycle, and pedestrian capacity; and changes in land use.

- STARS performance measures for access include modal access; mode split; vehicle miles reduced; travel time consistency; modal capacity; and travel quality focused on safety, user satisfaction, and physical activity. Additional performance measures address greenhouse gas emissions, fossil fuel consumption, and cost-effectiveness.

- The STARS performance dashboard can be used to present information on impacts with STARS and without STARS. The dashboard was used in the Portland community of Gresham to examine the impact of changing current bicycle and pedestrian trips to automobile trips. STARS pilot projects include analysis of Highway 1 in Santa Cruz County, California, and the Fourth Plain Boulevard project for C-TRAN, the transit agency in Vancouver, Washington.

- There are several potential benefits to the STARS approach:

- Simplifying and standardizing projects and plans on the basis of triple bottom line goals;
- Allowing direct comparison of alternatives and projects through the use of triple bottom line metrics;
- Identifying green dividends; that is, money that was leaving the local economy is retained by reducing fuel spending;
- Saving time and money through simplified processes and focused goals;
- Increasing healthy transportation—walking, cycling, and the use of transit—on the part of employees and residents; and
- Helping meet economic, climate, livability, and equity goals.

SCENARIO ASSESSMENT: INPUTS, PROCESSES, AND OUTPUTS

Keith A. Bartholomew discussed the use of scenario planning for land use and transportation. He summarized the basic elements of the approach, the input measures, and the outputs. Bartholomew's presentation covered the following points:

- Land use–transportation scenario planning builds on the federal continuing, comprehensive, and cooperative (3C) transportation planning process and on the alternatives analysis process laid out in the 1969 National Environmental Policy Act. It also utilizes elements from military and business scenario planning. Land use–transportation scenario planning incorporates variable land use assumptions but does not incorporate broader economic and environmental considerations.

- Since 1999, land use–transportation scenario planning has been used in projects throughout the country. The key elements of the process are scenario inputs, assessment tools, and assessment outputs (Figure 8). Examples of scenario inputs for transportation system elements include road lane miles and transit service hours. Examples of land use elements include the number of persons per developed acre, the number of persons per newly developed acre, the density of alternative scenarios, and the number of households near transit.

- Assessment tools can be identified on the basis of their degree of sensitivity to smart growth strategies. Low-sensitivity models include daily vehicle trip models and simple mode choice models. Moderate-sensitivity models include income stratification in distribution and mode choice and the use of nonmotorized modes in the mode choice elements. High-sensitivity models include activity- and tour-based models and integrated land use and transportation models. The availability of these different tools in different metropolitan areas has been identified.

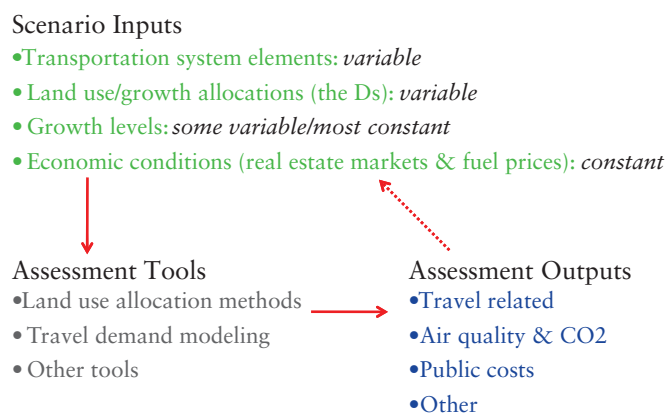


FIGURE 8 Land use–transportation planning: scenario inputs, assessment tools, and outputs.

- Examples of assessment outputs include daily vehicle miles traveled (VMT) per person, vehicle hours of travel, and vehicle hours of delay for alternative scenarios. Outputs for alternative scenarios are agricultural land consumed, nitrogen oxide emissions, and greenhouse gas emissions. Still another type of assessment output is analysis of multiple variables, examples of which include developed acres versus VMT, persons per acre versus VMT per person, and the percentage of households near transit versus VMT per person. Assessment outputs can be presented graphically in a number of different ways.

- In conclusion, denser development patterns result in less driving per person, which indicates an increased level of transportation efficiency. Denser development patterns are less costly per person for road infrastructure than are more dispersed patterns; depending on the circumstances, the level of cost savings may be substantial. Scenario planning is an effective method for understanding these relationships and communicating them to decision makers and the public.

BREAKOUT SESSION 4-B

Measuring Transportation System and Mode Performance

Jerry R. Benson, *Utah Transit Authority* (Moderator)

Richard Perrin, *Genesee Transportation Council*

Steven M. Pickrell, *Cambridge Systematics*

INTEGRATING SYSTEM AND MODE PERFORMANCE INTO PLANNING AND PROGRAMMING

Richard Perrin discussed integrating system and mode performance into the transportation planning and programming processes. He provided examples from the Genesee (New York) Transportation Council, including the Long-Range Transportation Plan for 2035 (LRTP 2035). Richard's presentation covered the following points:

- There are several keys to performance-based decision making:
 - Identify what is important to customers. What is meaningful and important to staff might not be meaningful to customers and other stakeholders.
 - Ensure that measures are also understandable to stakeholders.
 - Use performance measures to articulate results and needs.
 - Embed performance measures in investment decisions.
- The LRTP 2035 is based on four guiding principles: plan for people, recognize that place matters, maximize existing assets, and accept uncertainty. Planning for people, not just modes, is key. The region is very diverse, and performance measures have to be appropriate for all places. When resources are limited, maximizing existing assets is important. Maintaining flexibility to deal with uncertainties is also necessary.
- The LRTP 2035 includes performance measures related to safety, system preservation, mobility, acces-

sibility, and the environment. There are multiple performance measures for each of these areas, and they cover all modes and multiple environmental concerns. The performance measures provide benchmarks, desired changes, and likely changes for key metrics of transportation system performance.

- Outcome-based measures are used in the LRTP 2035 to the greatest extent possible. Each measure is clearly defined, and actual data are used rather than modeled data.
- Determining what matters to customers and how to measure it is the key to targeting indicators. Surveys, focus groups, and other methods can be used to obtain information from customers about what is important to them. Reviewing current and past behavior is also important, however. Stated preferences in surveys can be compared with revealed preferences.
- Performance measures must be meaningful—that is, have significance—and must be able to be understood by stakeholders. These definitions may vary by audience and purpose. It is also important to ensure that the data used in assessing the measures will continue to be available.
- Results must be presented in meaningful and understandable ways. Performance measures are key to transportation decision making and resource allocation decision making. They can be used to articulate results and needs and to increase understanding of why transportation matters and what the impacts of continued underinvestment are.
- Embedding performance measures in investment decisions can help ensure consistency between the evaluation criteria and the performance measures. Performance

measurement is an ongoing process. Current measures and current evaluation criteria should be reevaluated on a regular basis. Revisions can be made as needed to reflect changing goals and objectives.

- Ensuring consistency between criteria and measures may be more difficult than linking measures to broad goals and objectives. Consistency between criteria and measures requires an improved understanding of the factors that determine system and modal performance. Prioritization, such as putting safety first, is difficult but necessary.

- In assessing current evaluation criteria, it is important to remember that change for the sake of change is not progress. Assessing current criteria provides the opportunity to highlight the quality of existing practices or to make improvements. Formalizing or codifying the criteria is important to establishing an ongoing process. The criteria can be reassessed on the basis of changes in performance measures, which may reflect changes in goals and objectives.

- Ensuring that evaluation criteria are mode neutral is important, although it is not necessary to have the same criteria for each mode. Both shared and mode-specific evaluation criteria can be used. It is also important to match funding sources to the best projects rather than select projects on the basis of fund source eligibility. The Genesee Transportation Council uses 25 different criteria for each mode. Between 12 and 13 criteria are individual to each mode, and 12 or 13 are shared by all the modes.

SYSTEM-LEVEL PERFORMANCE MEASUREMENT

Steven M. Pickrell discussed system-level performance measurement. He described the major components of system performance, the utility of measuring at the modal and system levels, techniques for measuring system performance, and linkage with community and regional goals. He also identified areas for further research. Pickrell's presentation covered the following points:

- System performance measurement is distinct from program, corridor, and project-level performance measurement, in that it focuses on the performance of the system as a whole. System performance measures focus on the condition, health, and state of good repair of key modal system components. Systems performance measures should reflect the impact of operational measures, as well as capital investments, and should focus on both primary (system) measures and secondary measures such as community and regional impacts.

- There is utility in measuring and reporting on system-level performance. The National Forum report by the American Association of State Highway and

Transportation Officials notes that “the objective of a performance-based planning and programming process is to provide the guidance required for resource allocation decisions that deliver the best system performance results possible. . . . [P]erformance-based planning and programming is not a panacea. Without adequate and predictable funding levels, system performance will degrade.”¹ System performance results should be used to build support for adequate, stable funding sources and not solely to squeeze the best possible results from available funding.

- System-level measurement and reporting is done for several reasons:

- Benchmarking to state or regional performance targets or expectations,
- Informing and influencing transportation policy and funding decisions,
- Reporting to broad stakeholder groups to build funding coalitions,
- Determining the contribution of transportation projects to state and national goal areas,
- Determining accountability for funding expenditures, and
- Conducting trade-off analyses between programs or modes.

- The Metropolitan Transportation Commission in the San Francisco Bay Area, California, provides an example of setting regional performance targets. The commission has set the following performance targets for the Sustainable Communities Strategy–Regional Transportation Plan:

- Decreasing per-trip travel time by 10 percent for nonautomobile travel;
- Decreasing automobile vehicle miles traveled per capita by 10 percent; and
- Maintaining the transportation system in a state of good repair by increasing the local road pavement condition index to 75 or better, decreasing distressed lane miles of state highways to less than 10 percent of total lane miles, and reducing the average transit asset age to 50 percent of useful life.

- Reporting results for multidisciplinary stakeholder groups is also important. For example, the Maryland Department of Transportation's *Annual Report on Transportation System Performance* has improved communication with stakeholders and fostered engagement with elected officials. The Washington State Department of Transportation's *Gray Notebook* is another example of reporting system-level performance on a regular basis.

- The potential for tracking performance and accountability for key national goals is also being explored. One

¹Cambridge Systematics, Inc., *Report on a National Forum on Performance-Based Transportation Planning and Programming* (American Association of State Highway and Transportation Officials, Washington, D.C., 2010), p. ES-1.

approach being discussed identifies goals according to a three-tier system: Tier 1 measures are ready for deployment; Tier 2 measures require additional development; and Tier 3 measures are in the proposal stage (Table 2).

- System-level performance measures can also be used in trade-off analyses. The trade-off analysis has been variously defined as

- Selecting the combination of modal solutions to best meet goals and objectives;
- Identifying investments to obtain the best combination of immediate and longer-term benefits to users, regardless of the modal system;
- Selecting the optimum funding levels for modal programs on the basis of the consequences of increased or decreased investment; and
- Assessing the consequences of not investing in services or facilities.

- Trade-off analyses offer several potential benefits to agencies, system users, and the public. The results of a trade-off analysis may reduce agency costs by reducing or deferring expansion expenses and by preserving condition and reducing maintenance costs. Potential benefits to system users include improving performance and conditions, expanding feasible options, and increasing system resiliency. Benefits to the general public include improving productivity, reducing externalities, and lowering total public expenditures on transportation.

- There is a need to be able to measure the factors that drive mode choice decisions, such as travel time, trip cost, and system reliability and availability. There is also a need to develop mode-neutral measures that capture the benefits to agencies, users, and the public. Exam-

ples of such mode-neutral measures include total costs, economic benefits, resource consumption, emissions, and other externalities. These measures can be used to improve the ability to forecast future performance at varying investment levels, particularly for economic, environmental, and freight-related benefits and impacts.

- System-level evaluation and analysis is one component in a broad suite of performance management tools. A system can have multiple definitions, depending on the scale, the jurisdiction, and other factors. It is necessary to be able to assess the overall impacts and benefits of alternative investment choices and to capture the interactive, dependent nature of those choices for the system as a whole and for the surrounding community. Because investment choices may be mutually exclusive, competitive, or supportive, project evaluation in isolation is not sufficient.

- System performance can also be linked to broader community goals and objectives. For example, transportation investment may be viewed as a means of achieving other objectives. Typically, the intent is to maximize the benefits from the transportation system and minimize the negative impacts. It is often difficult to capture costs and benefits at secondary and tertiary levels (e.g., energy extraction, power generation, health). A recent study by the Pew Center on the States and the Rockefeller Foundation identified widely accepted goals for state departments of transportation. Frequently cited goals included safety, jobs and commerce, mobility, access, environmental stewardship, and infrastructure preservation.

- The Columbia River Crossing (CRC) project in the Portland, Oregon, area provides a recent example of system performance applied to long-term planning,

TABLE 2 Tracking Performance and Accountability on Key National Goals

Goal Area	Tier 1: Ready for Deployment	Tier 2: Additional Development Required	Tier 3: Proposal Stage
Safety	5-year moving average of state number of fatalities	5-year moving average of state number of serious injuries	
Pavement preservation	IRI on NHS	Structural adequacy on NHS	
Bridge preservation	Deck area of structurally deficient bridges on NHS		Structural adequacy of NHS bridges
Congestion and operations		Travel time-based metric Congestion cost Reliability on Interstate system	Incident management on NHS routes: response time; clearance time Work zone closure
Environment		GHG emissions	Stormwater runoff
Freight and economic competitiveness	Speed and travel time on freight corridors Reliability on freight corridors		Rural highway accessibility
Livability			Definition to be identified and draft measures proposed
Connectivity			To be decided in future work

NOTE: IRI = international roughness index; NHS = National Highway System; GHG = greenhouse gas.

operations, and management. This project examined options for improving the I-5 bridge crossing the Columbia River. The project examined alternatives for accommodating automobiles, trucks, passenger rail, bicycles, and pedestrians on a major interstate freight connector and commuter route. Policy issues related to land use, growth management, and revenue were also examined. A performance warranty concept of monitoring performance and managing the CRC to achieve the desired levels of benefits and impacts was explored. Available levers for accomplishing the desired outcomes included toll rates, transit fares, speed management, throughput, and lane availability and assignment.

- The CRC performance goal areas that were related to system condition and performance focused on access,

mobility and reliability, financial responsibility, and asset management. The broader goals at the community and regional levels addressed economic vitality, land use, safety, and security. Higher-level goals addressed climate change, energy, and public health.

- Areas for further development and testing include identifying and applying practical mode-neutral measures and fairly assessing the benefits of operations improvements. Ensuring the availability of uniform data across modes, including freight, is also important. There is also a need for improved analytical tools for projecting and predicting future levels of performance, especially in relation to safety, the environment, economic development and economic benefits, travel time reliability, and risk-based asset management.

BREAKOUT SESSION 4-C

Measuring Service Quality, Effectiveness, and Efficiency at the Program, Project, or Service Levels

Shintaro Terabe, *Tokyo University of Science* (Moderator)
 Lacy Bell, *Regional Transportation District, Denver, Colorado*
 Willem Ebersöhn, *National Railroad Passenger Corporation (Amtrak)*

FASTRACKS: QUALITY OF LIFE STUDY

Lacy Bell discussed the Quality of Life (QoL) Study conducted by the Regional Transportation District (RTD) of Denver, Colorado. She summarized the services operated by RTD and the projects included in its FasTracks Program. Bell's presentation covered the following points:

- RTD operates public transit covering a service area of 2,300 square miles in eight counties in the Denver metropolitan area. RTD is funded by sales and use taxes and is governed by a 15-member board of directors. To meet the diverse needs of the region, RTD operates a family of services that includes 35 miles of light rail transit (LRT) and 150 bus routes.

- In 2004, voters in the Denver region approved a 0.4 percent tax increase to fund the expansion of the regional transit system. The FasTracks program includes 122 miles of new commuter rail and LRT, 18 miles of bus rapid transit, 21,000 new parking spaces at rail and bus stations, and enhanced bus service that facilitates bus and rail transfers across the eight-county district.

- As part of the 2004 FasTracks Plan, the RTD board adopted three core goals for FasTracks: to balance transit needs with future regional growth, to increase transit mode share during peak travel times, and to provide improved transportation choices and options. The plan also outlined the anticipated benefits of FasTracks projects to the region. Those involved with the planning process were interested in ensuring that the core goals were being met and that the anticipated benefits from the projects were being realized.

- The QoL study is a multiyear monitoring program whose primary goal is to objectively track and measure how the region changes as the FasTracks program is planned, constructed, and operated. The study also fulfills the before-and-after data requirements for corridors receiving federal New Starts funding.

- The study objectives for each of the three FasTracks goals are as follows:

- Goal 1: establish a proactive plan that balances transit needs with future regional growth—meeting future transportation needs, providing opportunities for development near transit, and environmental sustainability;

- Goal 2: increase transit mode share at peak times—transit usage, travel safety and security, and customer satisfaction; and

- Goal 3: improve transportation choices and options—system mobility and travel choices and accessibility.

Multiple QoL study indicators and measures are associated with each objective.

- The QoL study measures the effects of the FasTracks program at three geographic levels: the region, rapid transit corridors, and rapid transit station areas. Only representative stations are used in collecting station area data.

- Several reports are being prepared as part of the QoL study. The first detailed report, which was completed in 2006, established a baseline of data for the full set of 70 measures. Detailed reports are issued every 3 to 5 years. Reports that provide updates on a subset of 11 high-level measures are issued annually between detailed reports.

Bell gave several examples of measures used to evaluate progress toward the FasTracks objectives.

- Objective: provide opportunities for development near transit. This objective includes measures related to economic activity and property value.

- Economic activity: One such measure is the amount of taxable retail sales within the district. These data give a critical measure of the economic strength of the Denver region. At the time of the conference, the results for this measure indicated a general increase between 2004 and 2007; this increase was followed by a significant decrease that was associated with the economic recession and that had continued into 2009. Another measure of economic activity is new development within half a mile of existing and future rapid transit stations. Completed development is a lagging indicator, as many projects were started several years earlier. The majority of development completed in 2009 occurred downtown and along the Southeast Corridor.

- Property value: The total property value (price per square foot) of areas within one-half mile of a station is being monitored. At the time of the conference, the US-36–Northwest Rail Corridor showed higher property values at stations as compared with the surrounding area.

- Objective: transit usage. One measure of this objective is annual transit boardings per capita. Between 2000 and 2009, transit boardings increased 29 percent. With the opening of the Southeast Corridor LRT, transit boardings increased significantly between 2006 and 2007, but then dropped between 2008 and 2009.

- Objective: travel safety and security. One measure associated with this objective is the crime rate on RTD property. A downward trend in this measure was observed between 2004 and 2009. Between 2008 and 2009, the crime rate on RTD property decreased by approximately 30 percent; the crime rate on the LRT decreased by 46 percent, and the crime rate on buses decreased by 19 percent.

- Objective: system mobility. This objective includes measures related to travel times and travel time variability.

- One measure related to corridor travel times is the travel time to reach downtown Denver during the morning peak period. Automobile travel time has increased in both the Southeast and Southwest Corridors, but transit travel time has decreased in both corridors. The Southeast Corridor LRT improved transit travel in the southern I-25 corridor by reducing travel time by 15 minutes.

- The travel time variability measure assesses the additional time required to arrive on time at downtown destinations during the morning peak period. A refinement to the travel time variability method

showed an overall increase in travel time variability for automobiles.

- Objective: travel choices and accessibility. This objective includes measures related to destination access, transit access, and land use.

- Destination access: the percentage of regional destinations served by high-frequency transit. This measure focuses on high-frequency transit service areas, defined as those within a half-mile radius of rail stations and within a quarter-mile radius of bus stops with peak and off-peak headways of 15 minutes or more. At the time of the conference, 30 percent of Denver's regional destinations were served by high-frequency transit, compared with 25 percent before the opening of the Southeast Corridor LRT.

- Transit access: population within walking distance of representative stations. Walking distance was defined in terms of a half-mile walkshed instead of a half-mile radius. Walkable streets were defined to include all roadways except limited-access freeways.

- Land use: changes in transit-supportive zoning. These are changes that increase densities and encourage mixed-use development around existing and future rapid transit station areas. Zoning changes were implemented in 2006 and 2007 around 10 stations. The zoning around the Louisville station was changed in 2008. There were no transit-supportive zoning changes in 2009.

Bell concluded by discussing the challenges and opportunities encountered in conducting different elements of the QoL study and long-term performance monitoring program. Transferring academic research to a transit agency can present challenges related to the quantity of different data and to presenting results to nontechnical audiences. The use of new data sources and methodologies also presents challenges; it is important to be clear about program goals and to decide when to change and when to remain consistent. Considering the costs of housing plus transportation is one newer approach. Another important challenge is maintaining objectivity; determining differences between correlation and causation is not easy. Potential opportunities include partnerships in data collection, analysis, and using the results.

MEASURING AMTRAK'S TRAIN SERVICE PERFORMANCE: MANAGEMENT INFORMATION SYSTEM DESIGN

Willem Ebersöhn provided an overview of Amtrak that described the Amtrak Enterprise Data Model and its operational and financial performance measures. Ebersöhn's presentation covered the following points:

- Amtrak operates on approximately 21,000 miles of track throughout the country. Most of this track is owned by private freight railroad companies, but Amtrak owns track from Boston to Washington, D.C., along the Northeast Corridor. Amtrak charges an access fee to private railroads for carrying freight along its track in the Northeast Corridor. This operation creates a unique maintenance situation for Amtrak.

- The Amtrak Railroad Enterprise Data Model includes many components. Customers purchase a ticket with the expectation of arriving on time. Amtrak must have the vehicle fleet, track routing, working signals, and necessary crew to provide services. The company seeks customer feedback and estimates costs to provide services. Incidents are caused by problems with infrastructure or mechanical equipment, by weather, and by other issues. Several data elements are needed to manage the system and to turn the data into useful performance information for decision making.

- Amtrak's performance is the sum of its operational performance and financial performance. Amtrak's man-

agement information system uses standards related to preparing trains, providing the service, and termination of the trip. The system monitors actual times and values for aspects of these three elements. Comparisons are made to the standards, and these comparisons allow Amtrak to identify factors that influence nonattainment of the standards and actions to fix any problems.

- To evaluate performance, Amtrak has created a train transportation order flow and data model to simulate performance. Amtrak also has an enterprise resource planning system that is integrated with the enterprise asset management system.

- Several actions may be considered and taken when objectives are not met. These actions include refining the investment strategy, allocating infrastructure maintenance and dispatch cost on the basis of measured train movement and performance data, and identifying systemwide constraints. Other areas include (a) leveraging the data model to identify future opportunities to better utilize and increase the efficiency of current assets and (b) using a framework to develop rapid growth.

PLENARY SESSION 5

Measuring the Immeasurable

Pitfalls and Opportunities for Gauging Livability, Economic Prosperity, and Transit State of Good Repair

Joseph Crossett, *High Street Consulting Group* (Moderator)

Allen D. Biehler, *State Smart Transportation Initiative*

Susanne Trimbath, *STP Advisory Services*

Patricia G. Hendren, *Washington Metropolitan Area Transit Authority*

SMART TRANSPORTATION: THE PENNSYLVANIA EXPERIENCE

Allen D. Biehler, who served as secretary of the Pennsylvania Department of Transportation (DOT) from 2002 to 2010, drew on his experience in the department to discuss Pennsylvania's experience with smart transportation. He recounted that the State Smart Transportation Initiative (SSTI) was established when he served on the board of the American Association of State Highway and Transportation Officials. Several states helped identify technical assistance needs related to smart transportation. The SSTI, headquartered at the University of Wisconsin–Madison, was established to address these needs and is currently working with 15 to 20 states in examining potential smart transportation options.

Pennsylvania's highway system includes 40,000 miles of state highways and 76,000 miles of local roads. The Pennsylvania DOT ranks fifth in the country in state-maintained highway miles. There are 25,000 state-maintained bridges in the system, many of which are old (the average age is 52 years).

Transit is an important component of the transportation system in Pennsylvania, both in large cities such as Philadelphia and Pittsburgh and in smaller jurisdictions. All 67 counties in the state have some type of public transit service. There are 18 smaller urban transit systems, 16 rural systems, and 59 community and shared-ride systems. The total transit ridership in Pennsylvania is approximately 420 million per year. Intercity rail and bus lines, including Amtrak, also operate in Pennsylvania.

Class 1 railroads constitute about half of Pennsylvania's 5,000 miles of freight rail track, and short-line railroads constitute the other half. Pennsylvania has more than 100 general aviation airports and 12 commercial airports. The Pennsylvania DOT owns and operates only the road system, but the department acts as a grantsman for other modes of transportation. The public transit system is supported by more than \$1 billion in grants and other funding that flows through the state.

During the 1980s and 1990s, Pennsylvania's growth rate was relatively low; developed land increased by 41 percent, but the population grew by only 1.4 percent. Between 2000 and 2009, the state experienced a 2.6 percent growth in population. Between 1997 and 2008, however, vehicle miles traveled grew by 9 percent.

Improving the link between land use and transportation planning to enhance economic development has been an interest over the past decade. Pennsylvania created the Interagency Land Use Team in 1999 to identify ways to coordinate programs across state departments. One of the recommendations from this group was to hold a workshop or conference to promote communication and coordination across agencies.

This recommendation was pursued by the new administration in the state. Along with the Pennsylvania DOT, the Pennsylvania Departments of Community and Economic Development, Environmental Protection, and Agriculture sponsored a statewide conference in 2003 that was attended by 250 stakeholders from various backgrounds. The conference resulted in a series of recommendations, and in 2006, 10 Smart Transportation themes were developed:

- Redevelop first.
- Provide efficient infrastructure.
- Concentrate development.
- Increase job opportunities.
- Foster sustainable businesses.
- Restore and enhance the environment.
- Enhance recreational and heritage resources.
- Expand housing opportunities.
- Plan regionally; implement locally.
- Be fair.

These themes served as a guide and starting point for further discussion; no specific metrics were identified.

Biehler said that one of the game changers during his tenure at the Pennsylvania DOT occurred in 2004, with the development of the updated Transportation Improvement Program (TIP). It was realized that there were 26 large-capacity projects, at a total cost of \$5 billion, for which realistic funding and delivery dates could not be identified. He indicated that he communicated this problem to the directors of the state's metropolitan planning organizations (MPOs) at a meeting in March 2004. The state clearly had a funding crisis for transportation and transit infrastructure as well as operations.

In response, former Pennsylvania Governor Ed Rendell issued an executive order creating the Transportation Funding and Reform Commission. Biehler served as chair of this nine-member commission, which was charged with assessing the efficiency of highways, bridges, and public transit in the state and with recommending reforms and funding. The commission developed the following set of principles to guide its work:

- Select reliable, dedicated, and inflation-sensitive funding sources.
 - Make the funding level, structure, and distribution responsive to performance and needs.
 - Give the highest priority to the core network.
 - Integrate transportation with land use, economic development, and environmental policies.
 - Use stringent criteria for expansion projects.

The commission's 2006 report, *Investing in Our Future: Addressing Pennsylvania's Transportation Funding Crisis*, identified the need for an additional \$1.7 billion in annual revenues to meet the needs of highways, bridges, and public transit (<ftp://ftp.dot.state.pa.us/public/pdf/STCTAC/TFRC/Reports/TFRC%20Preliminary%20Report.pdf>).

The commission examined both the consumer price index and the bid price index (BPI), which tracks the inflationary growth of the Pennsylvania DOT's construction bids, over the past 20 years. From 2003 until the recent economic downturn, there was a significant spike in the BPI, indicating major project cost increases.

Although the Pennsylvania DOT had had a "fix it first" philosophy for many years, the combination of high construction costs, lower funding levels, and increasing maintenance needs lead to a change in the project funding mix. The Pennsylvania DOT had traditionally allocated approximately 25 percent of available funding to new capacity projects. By the end of 2010, the department had allocated only about 4 percent to new capacity projects; the remaining 96 percent was allocated to repair and replacement.

These funding concerns and other issues lead the Pennsylvania DOT to focus on smart transportation, which considers the full range of transportation options and calls for better coordination of land use, development patterns, and transportation. Biehler worked to develop a general concept for smart transportation in Pennsylvania: partnering to build great communities for future generations of Pennsylvanians by linking transportation investments, land use planning, and decision making. Pennsylvania adopted the following 10 smart transportation themes:

- Money counts.
- Leverage and preserve existing investments.
- Choose projects with high value-to-price ratio.
- Safety always and perhaps safety only.
- Look beyond level of service.
- Accommodate all modes of travel.
- Enhance local networks.
- Build towns, not sprawl.
- Understand the context, and plan and design within the context.
 - Develop local governments as strong land use partners.

Implementing smart transportation in the state required a change in the rules (that is, in the way the Pennsylvania DOT conducted business), a change in the decision-making process, and the realization that increasing partnership efforts was critical to the success of smart transportation.

To change the rules, the Pennsylvania DOT worked with the New Jersey DOT to develop the *Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities*, which focuses on planning and designing highways and streets that support sustainable and livable communities (<http://www.state.nj.us/transportation/community/mobility/pdf/smarttransportationguidebook2008.pdf>). The Guidebook encourages the use of flexible design in all projects to better meet the needs of different communities. It also promotes increasing coordination with local municipalities, linking existing and future land use contexts and roadway design values, and designing to a desired operating speed.

The Pennsylvania DOT staff worked with staff from MPOs, transit agencies, local communities, and other groups to produce a series of documents on various elements pertaining to smart transportation. One report, which addressed the improved highway occupancy permit process, included an improved process that was consistent with smart transportation and that provided earlier communication between parties. The process focused on applying consistent alternative mitigation across the state.

The department also prepared a series of planning documents highlighting practices that would help communities accommodate growing traffic and development while preserving their quality of life. The topics covered in these reports included access management, transportation impact fees, the integration of transportation and land use, and local implementation tools.

The Pennsylvania DOT addressed the need to change the decision-making process by focusing on revising the project delivery process. The department included its partners—municipalities, MPOs, rural planning organizations (RPOs) and resource agencies—in the development of the new process, which emphasized planning up front and focused on linking the Mobility Plan, the Long-Range Transportation Plans (LRTPs), and the TIPs and on reducing delivery times. Smart transportation selection criteria for TIPs and LRTPs were also developed.

Increasing partnership efforts was a key focus of the revised project delivery process. The factors that make a partnership effective include ensuring that all groups are participating, sharing information, and understanding the interests of others; developing procedures jointly; avoiding unilateral decisions; and reaching consensus. Biehler stressed that developing and maintaining partnerships is an ongoing process.

Numerous methods were used to promote the smart transportation message. These methods included strategic discussions with partner agencies and organizations and local municipalities, and outreach activities and interactive workshops with local officials and professionals. The groups involved included the Pennsylvania DOT central and district offices, other state agencies, MPOs, RPOs, legislators and elected officials, the Federal Highway Administration (FHWA), counties, municipalities, the development community, and the general public. The smart transportation concept received media coverage both in Pennsylvania and at the national level. Communities of varying sizes—including Lancaster County, Cranberry Township, and Wellsboro—undertook smart transportation planning.

The Pennsylvania DOT developed a pilot program to advance smart transportation projects. This program, the Pennsylvania Community Transportation Initiative (PCTI), focused on the use of smart transportation principles. A total of \$60 million was set aside for the

initiative. Numerous applications for these limited PCTI funds were received. The following selection criteria were developed and used to evaluate the projects: the connection with land use, collaboration with stakeholders, the building of towns rather than sprawl, readiness, the leveraging of other funding, consistency with regional plans, innovation, and teachability.

A mix of projects was selected in areas throughout the state. These projects included intermodal and transit-oriented development, land use and transportation planning and redevelopment, bicycle and pedestrian projects, streetscape projects, improvements to roads and intersections, and regional plans. The PCTI was so successful that a second round was funded at \$24 million.

A project on US-202 exemplifies the application of smart transportation principles. Design and environmental approval for an 8-mile limited access expressway on US-202 had been completed before 2003. The project cost was estimated at \$465 million; however, this project was one of the major capacity projects identified in 2004 that did not have funding sufficient to begin construction.

A community-based task force was created to help reexamine the proposed US-202 project. The effort resulted in the redesign of the project, which took 3 years from redesign to construction. There was broad community and stakeholder support for the redesigned project, which included \$185 million in cost savings. The project is under construction today.

The following are a few additional examples of PCTI projects:

- The City of Altoona constructed a 2.5-mile trail connecting the Penn State Altoona campus to the downtown area.
- The Borough of Carlisle, which includes Harrisburg, focused on increasing downtown walkability, connecting to multiuse trails, and enhancing safety and mobility.
- The Oakland–Carnegie Mellon Pedestrian Safety and Mobility Study in Pittsburgh focused on an area that includes the highest concentration of academic and medical institutions in the state, with a daytime population of 100,000 and 60,000 vehicles traveling on the main arterials.

The Pennsylvania DOT developed metrics in conjunction with the 10 smart transportation themes listed earlier. By theme, the metrics are as follows:

- Money counts: (a) the percentage of TIP funding directed to preservation and (b) the percentage of projects for which programmed costs are within 10 percent of the design engineering estimate;
- Preservation of existing infrastructure: whether the MPO and RPO asset management component of the

L RTP and TPI are within 5 percent of the asset management goal for a given year;

- Safety: (a) the decline in annual fatalities, (b) the percentage of safety projects that address identified safety problems, and (c) the decline in serious injury crashes;
- Accommodation of all modes of travel: the percentage of MPOs and RPOs that (a) have multimodal evaluation criteria for projects and (b) achieve a decline in per capita vehicle miles traveled;
- Multimodal considerations: the percentage of projects that incorporate multimodal elements;
- Land use considerations: (a) the percentage of transportation investments within existing growth areas, (b) the presence of land use controls, and (c) up-to-date land use plans and comprehensive plans;
- Economic development: (a) the percentage of projects in growth areas that address economic development and (b) the percentage of transportation investments that support economic growth, competitiveness, and tourism within a county; and
- Creation of strong local government partnerships: (a) the planning of regions with coordinated land use and transportation corridor studies for capacity projects and (b) municipalities or counties with which the Pennsylvania DOT has established collaborative project coordination.

It is also important to consider the impact of smart transportation on the conditions of assets, including roads, bridges, and transit facilities and services. Biehler stated that when he joined the Pennsylvania DOT in 2002, 11,099 miles of state roadways were in poor condition. By 2009, the number of miles in poor condition had been reduced to 7,033. The number of structurally deficient bridges increased from 5,561 in 2002 to 6,034 in 2008 before declining to 5,592 in July 2010 and then to fewer than 5,300 by early 2011. Funding for public transit in the state increased in 2008 and 2009, and between 2006 and 2009, annual ridership increased by 25 million. Additional information on the experience at the Pennsylvania DOT is available at <http://www.slideshare.net/renewlv/smart-transportation-by-penn-dot>.

MEASURING THE IMMEASURABLE: TRANSPORTATION INFRASTRUCTURE PERFORMANCE

Susanne Trim bath began her presentation by discussing how gross domestic product (GDP) is used to measure the health of the economy. She then went on to explain how the transportation performance index (TPI) is used to measure the health of the transportation infrastructure. She discussed the development of the TPI and its application to states as well as to the United States as a whole. Trim bath also described the considerable effect

that transportation performance has on the U.S. economy. She said that her presentation would include information from Janet F. Kavinoky of the U.S. Chamber of Commerce (the Chamber), which funded the TPI study, on the use of the results to move the national debate on transportation onto a more productive path that includes performance requirements.

The TPI is built on a rigorous, quantitative, and scientific approach. The TPI study developed a method for measuring the performance of the transportation infrastructure nationwide and in all 50 states and the District of Columbia. The study measured across all modes of passenger and freight transportation to show how well transportation is serving the needs of businesses and the overall U.S. economy and created the TPI, an index representing the performance of the national transportation infrastructure. The full technical report on the TPI, as well as a shorter version with a nontechnical presentation of the results, is available at the U.S. Chamber of Commerce website at <http://www.uschamber.com/issues/transportation/transportation-performance-index>.

Trim bath described GDP as a measure of the performance of the national economy and discussed the similarities between GDP and the TPI. GDP is an estimate of the total output of all production that occurs in the nation, as estimated by the Bureau of Economic Analysis (BEA) within the U.S. Department of Commerce. In estimating GDP, BEA uses a variety of assumptions based on information reported from surveys conducted by the Census Bureau and from tax returns submitted to the Internal Revenue Service.

BEA began by creating concepts and a structure of accounts to generate estimates for GDP. If the data were accurate, always available, and fit their definitions exactly, then the estimate of income would always equal the estimate of output; however, it does not. The statistical discrepancy between estimated income and output for the first quarter of 2011 was 1.3 percent of GDP, or about \$180 billion. If GDP were an accounting statement—that is, if it worked exactly as BEA designed it—then income would always equal output.

Because some data simply are not available, BEA has to make assumptions about the direction of the changes that it cannot record. For example, for the first quarter of 2011, BEA assumed that nondurable manufacturing inventories increased, exports increased, and imports increased. However, the increase in exports is a BEA assumption; BEA did not actually have any data with which to measure exports when it released the new GDP numbers.

Some data that BEA needs, such as new car sales, simply are not reported anywhere. Thus, BEA developed estimating methods that adjust the data it can collect to match its concepts. To fill in missing data on new car sales, BEA uses estimates based on average list prices

rather than actual sales prices. For example, an estimate of expenditures on new cars is calculated as the number of cars sold times the average list price for all cars (at transaction prices—i.e., the average list price with options adjusted for transportation charges, sales taxes, dealer discounts, and rebates). One problem with this approach is that few people pay the actual list price for a car. Moreover, the estimate is not calculated by adding the number of 2010 Toyota Corollas sold times the list price of the 2010 Toyota Corolla, the number of 2010 Mercedes C240s sold times the list price of the 2010 Mercedes C240, and so forth. Rather, the estimate of expenditures on new cars is calculated as the number of all cars sold times the average list price of all cars.

Some of the data that the BEA uses come from Internal Revenue Service income tax reports, which use different definitions of depreciation and other factors, and from surveys conducted by the Census Bureau, which does not survey all the categories used by BEA. Import data are obtained in a bilateral data exchange with other countries. Some data come in as valued at the point of manufacture; BEA adjusts these data to foreign port value by adding the cost of transporting the goods within the other country from the point of manufacture to the point of export to the United States. Average known costs of transportation are used to make this adjustment.

BEA estimates wages as the number of people employed times average hourly earnings times average hours worked. As income inequality rises—that is, as salaried employment wages move farther away from hourly employment wages—these reported incomes may become increasingly less accurate. An estimate of interest received may be calculated as the stock of interest-bearing assets times an effective interest rate. BEA collects employment data in the middle of the month, which is assumed to represent conditions for the entire month, and therefore makes judgment calls to adjust employment data when there are significant events (e.g., blizzards on the east coast or hurricanes in Florida) that occur after the data are reported.

Sometimes there are no primary source data and the entire category is an estimation. BEA makes seasonal adjustments, uses moving averages, inputs new data as “best level” or “best change,” interpolates and extrapolates data series, and adjusts the figure to account for inflation.

Even when all these adjustments are taken into account, there are still discrepancies that cannot be accounted for by anything other than how the numbers were created. Trimboth urged attendees not to feel discouraged if they are unable to measure every inch of road and rail in their jurisdictions. When politicians compare transportation infrastructure with GDP, it is not just apples and oranges—it is apple sauce! The TPI does not attempt to measure every inch of road and rail in the

nation in the way the GDP attempts to measure every aspect of the economy.

In contrast to GDP, which is based on estimates, the TPI reports only what can actually be measured. The TPI is based on a sample of metropolitan statistical areas (MSAs) for which public data on transportation infrastructure are available. The calculation uses both normalization and standardization to make unlike numbers comparable, and the inputs are all weighted by expert and user survey responses. The key difference between all prior studies on the economic contribution of transportation infrastructure and the study that used the TPI is that the previous studies measured how much was spent on transportation and compared that amount with the economy. The problem with such an approach is that the cost of building and maintaining transportation infrastructure is already included in GDP. Before the TPI was created, there was no way to separate the impact of spending from the impact of having new infrastructure.

A wide range of stakeholders was interviewed, workshops in four cities in four different geographic regions were conducted, and meetings with many key members of the U.S. Chamber of Commerce were held. Certain words and themes emerged again and again from these meetings. No matter what subject of infrastructure was put before them, every group that was visited wanted to spend more time talking about transportation than water, energy, or communications combined. All infrastructure touches us every day, but transportation is on everyone’s mind.

Ultimately, integration of results from academic and municipal studies with input from users as well as experts yielded the following three performance categories:

- **Supply.** The availability of infrastructure is a key consideration for businesses when deciding where to locate facilities.
- **Quality.** Is the infrastructure and the service it enables reliable, predictable, and safe, and does it minimize the time traveled?
- **Utilization.** How much capacity is available to support future growth and expansion?

These elements are key considerations for companies that use the transportation infrastructure. Companies such as FedEx Freight look 20 years into the future to inform the decisions they make today about where to locate their facilities. Efficiency also matters, but efficiency is hard to define without including the cost of transportation—which leads back to the problem of measuring the same dollars on both sides of the economic equation. Infrastructure, as the word suggests, provides the underlying base that supports all economic activity. Trimboth said that she and her colleagues set out to assemble data on

the entire base, including the following components of transportation infrastructure:

- Transit: brings labor to the place of production;
- Highways: move inputs to production and outputs to customers; transport labor to the place of production;
- Airports: move high-tech inputs, outputs, and products (low-weight, high-value goods) and enable the service sector, where transportation accounts for the highest valued input;
- Railways: move commodities from the point of production to wholesalers and users;
- Waterways and ports: connect U.S. producers to global consumers of goods and commodities and bring valuable inputs to producers; and
- Intermodal transportation: provides local producers with access to global consumers by moving products such as corn from fields in Nebraska to buyers in Taiwan.

For each of the three performance categories—supply, quality, and utilization—specific data were identified that could be used to obtain an indication of how well transportation was performing in that category. Trimboth highlighted only a few elements of each category to provide an indication of the level of data incorporated into the TPI. The data had to be publicly available so that anyone interested in continuing to work on the measurement of infrastructure performance would be able to do so without having to purchase data. This was a key point. Trimboth and her colleagues anticipate that this approach will enable a larger number of researchers to advance this work into the future and incorporate it into the framework for various infrastructure project assessments.

After the performance indicators for the TPI were identified, the data were gathered and combined. In the end, more than 10,000 items of data were used to provide 21 indicators of the performance of the national transportation infrastructure from 1990 to 2008. Measurement of performance rather than the cost or quantity of infrastructure allows identification of what happens when the transportation infrastructure does or does not provide the level of service expected.

The data-gathering process began with identification of a representative sample of the population, geography, and economic sectors, all of which affect what is expected from a transportation system. Because of the size of the United States and, especially, the variation in its geography, a random sample of MSAs was required. The sample of MSAs in the study represents about 35 percent of the U.S. population and has economic characteristics parallel to that of the nation as a whole.

Between 1990 and 2008, the TPI increased by approximately 6 percent overall, with the biggest gains achieved by the mid-1990s. Considering that the U.S. population grew by 22 percent, passenger travel increased by 39 per-

cent, and freight traffic grew by 27 percent during the same time period, the transportation infrastructure was just not keeping up. Trimboth stated that she believes it is a testimony to American ingenuity that the national TPI score is not worse.

Moving average trends were identified both in terms of the TPI and the moving average. The moving average trend in the past 5 years was decidedly negative:

- 1990 to 1995 (moving average period, 1994 to 1999): improvement.
- 1995 to 2000 (moving average period, 1999 to 2000): decline.
- 2000 to 2003 (moving average period, 2000 to 2004): improvement.
- 2003 to 2008 (moving average period, 2004 to 2008): decline.

The trends in the moving average and the raw index suggest that these changes were significant.

No single indicator, project, or specific location will change the index substantially. During the period from 1990 to 2008, there were many events that influenced infrastructure performance, including

- An increasing emphasis on security;
- Simultaneous recognition of the importance of creating sustainable infrastructure and of the burdens of regulation;
- An increasingly burdensome project delivery process that led to an interest in streamlining the permitting process as well as environmental impact assessments;
- Significant changes in the Highway Trust Fund, the Aviation Trust Fund, and the Inland Waterway Trust Fund;
- Challenges to local, state, and regional governments' ability to match federal funds, including the willingness of citizens to support infrastructure improvements;
- Delays in passing federal authorizing legislation;
- Significant increases in the cost, in real dollars, of construction, repair, and maintenance;
- Increasing awareness of infrastructure issues;
- State-specific initiatives, such as Illinois First and California's Proposition 13 (long-term impacts); and
- Increasing interest in improved operations for more throughput, multimodal approaches, regional and corridor issues, impacts of bottlenecks, and synergies between modes.

Understanding and correlating these changes with changes in the TPI is challenging and warrants further research.

The TPI is important because it can be used to measure the direct relationship between how well the transporta-

tion system is meeting the needs of business and those of overall economic growth. Using a very basic growth model that controlled for the size of the economy, government policy, and population, Trimboth performed an economic analysis. Free market institutions and open economies are also important variables for studying economic prosperity; however, free market institutions are prevalent in the United States, and advances such as the Uniform Commercial Code had opened U.S. markets across state borders for decades.

Trimboth's economic analysis showed that for every one-point increase in the TPI, GDP increased by one-third of 1 percent. That one-third of 1 percent is an ongoing gain that is sustained beyond any spending required to make the improvements. President Obama said recently that a 1 percent increase in the growth of GDP would offset the Bush tax cuts. That same gain could easily be achieved naturally by making improvements in the performance of the transportation infrastructure.

Trimboth emphasized the significance of this figure by comparing it to the 2011 earthquake and tsunami in Japan. The damage to the global economy caused by these events is estimated at 0.5 percent of GDP growth. In this context, a 0.3 percent improvement in economic growth is not insignificant; indeed, such an improvement would mean the addition of \$420 billion per year to the U.S. economy, which would support millions of new middle-income jobs.

Can investment in the transportation infrastructure increase economic growth? It can, if it is done right and produces real results. For years, the U.S. Chamber of Commerce has been sounding the alarm about the nation's crumbling transportation infrastructure. Until now, however, no one has measured how well the transportation infrastructure works or made a direct link between the performance of the system and economic growth. The landmark TPI study is the first step on the path to proving a direct relationship between transportation infrastructure performance and GDP. This relationship does not concern stimulus spending or temporary job creation for construction workers; rather, it involves economic expansion at a fundamental level.

After TPI results were obtained for the nation as a whole, the next step was to generate measures for the individual states and the District of Columbia. The same methodology was used; however, data that are not available at the state level had to be omitted. Additionally, given the data collection effort necessary to create a state-by-state TPI, the state-by-state calculation was not performed for every year.

Between 1990 and 2007, the TPI in about half of the states improved or remained steady. Only two states grew consistently worse during that period. Better TPI scores were found in states in the Great Plains, and worse scores were found among states along the eastern seaboard. In

2007, the top states were North Dakota, South Dakota, Nebraska, Montana, Iowa, and Kansas; the bottom five states were Massachusetts, California, Nevada, Hawaii, and New Jersey. The District of Columbia, Pennsylvania, Connecticut, Rhode Island, Delaware, and West Virginia were among the bottom 20 states.

Although the top states are largely rural, this is not the same thing as no growth. Although these states have not experienced the periods of high growth that states along the coasts and other populous states have experienced, most have maintained constant, moderate growth in both population and economy over the past 40 years. An economic analysis at the state level was not done but is now being planned by several researchers. New research that is just getting started shows early indications that businesses in states with bad transportation infrastructure are finding ways to work around the problem that are allowing them to maintain good economic outcomes despite the poorly performing transportation infrastructure.

The economic study also found a significant positive relationship between investments by foreign companies opening new businesses in the United States (creating new jobs) and the performance of the transportation infrastructure as measured by the TPI. Trimboth said that she believes this type of investment is very dependent on the transportation infrastructure because of the need to move goods and people between the home country and the United States. She said that she had used data on newly established businesses—excluding financial investments and the acquisition of existing businesses—because the TPI reflects changes in infrastructure that might reasonably induce this specific kind of foreign investment. Most of the goods these firms import and about half of those they export are shipped from and to the parent company in the home country.

That businesses locate and create jobs where the transportation infrastructure works cannot be emphasized enough. The last time the World Competitiveness Report ranked the United States in first place for basic infrastructure was in 2005; by 2010, the United States had dropped to 11th place. If other countries are racing ahead, those jobs will go where the transportation system works better.

The question is what to do about this problem. The U.S. Chamber of Commerce is activating its resources to address this issue. On the basis of the analyses described in Trimboth's presentation, her recommendation to the Chamber is to fundamentally change the way transportation infrastructure is conceived of and discussed. The Chamber is using the results of the TPI research to engage with the public, elected officials, and policy makers.

The debate must shift to a focus on investment for performance that will add to long-term economic growth. The U.S. Chamber of Commerce is encouraging elected officials to recognize, acknowledge, and act on the fact

that investment in transportation infrastructure is a growth leader. The Chamber is engaging policy makers to create more effective, targeted policies and programs. For example, the Chamber advocates both focusing federal highway and transit programs on current traffic congestion and bottlenecks and building the capacity to handle increases in moving goods and people in the next 50 years. The Chamber's priorities are to

- Create capacity for the future,
- Fix traffic congestion today,
- Target bridges, and
- Focus on intermodal freight access.

More information about the U.S. Chamber of Commerce's policies and updates on its Let's Rebuild America initiative are available at <http://www.uschamber.com/lra>.

The TPI demonstrates a weak relationship with federal spending. Although this result is an indication that the technical goal—to measure performance rather than spending—has been achieved, it also indicates that federal spending is not accomplishing what it was intended to do. Less than 10 percent of spending resulted in a change in performance, and Trimbath believes this is the most basic problem with spending on infrastructure. She quoted Oscar Wilde: "What is a cynic? A man who knows the price of everything and the value of nothing."

However, the good news is that, according to a September 2010 Gallup poll, 65 percent of Americans believe that the federal government should have more responsibility for developing and maintaining the nation's transportation system. The only federal roles that scored higher were protecting Americans from foreign threats (93 percent), protecting consumers against unsafe products (76 percent), and preventing discrimination (66 percent). Many of today's headline topics scored lower than transportation on the public's list of priorities. These topics include making sure Americans have adequate health care (57 percent), making sure that those who want jobs have them (51 percent), and providing a minimum standard of living for all (45 percent). Other topics that ranked lower than transportation were upholding moral standards (39 percent) and reducing income differences between the rich and the poor (34 percent).

Unfortunately, these results do not seem to translate into support for increased transportation funding at the state level. A survey conducted by the Pew Charitable Trusts in October 2011 included a question on support for raising state taxes for certain activities. Only about 25 percent of the respondents indicated they would be willing to pay higher taxes to support transportation.

The TPI and the economic analysis provide policy makers with the quantitative proof that there is a rela-

tionship between the health of the economy and a transportation system with supply and quality of service today and the ability to handle future growth. The bottom line for the U.S. Chamber of Commerce is that the United States may be missing a huge opportunity to ignite economic growth, improve global competitiveness, and create jobs. Addressing this opportunity is a major priority for the U.S. Chamber of Commerce and its members.

There is clearly room to improve the performance of the transportation infrastructure on the national level. On average, the individual states scored about 10 points higher on the TPI than the nation as a whole. If there is some potential gain to be had, the economic model suggests that it can be achieved by making maintenance, modernization, and expansion of the transportation infrastructure a national priority. In closing Trimbath stated that it is time to move out of this paralysis by analysis and focus on requiring more cost-benefit studies.

BRINGING PERFORMANCE-BASED MANAGEMENT TO TRANSIT

Patricia G. Hendren discussed the use of performance-based management in public transit. Her comments focused on the Office of Performance at the Washington Metropolitan Area Transit Authority (WMATA; also known as Metro). She began by providing an overview of the services offered by WMATA, discussed the purpose of the Office of Performance, and described how her agency is using performance information to better manage the agency. She concluded her comments by discussing some of the lessons learned and necessary research that would benefit WMATA and other transit agencies.

WMATA provides transit services within a 1,500-square-mile area that includes the District of Columbia, two suburban counties in Maryland, and three counties and three cities in northern Virginia and is home to 3.5 million residents. WMATA's average weekday ridership is 1.2 million passengers. Its rail system serves approximately 750,000 passengers a day, making it the second largest rail system in the United States. With more than 300 bus routes, WMATA has the sixth largest bus network in the United States, and it is the fifth largest paratransit operator in the country.

The WMATA Office of Performance was created in 2010 to expand the use of performance measurement to guide decision making, promote WMATA's benefits in the region, and unify employees to accomplish agency goals. The office is staffed by a small team formed by reallocating existing agency resources. It focuses on moving strategic thinking beyond the executive offices to frontline employees and on increasing

accountability and transparency. The office's founding was also a response to the national focus on performance measures.

All of WMATA's performance work is guided by the agency's five strategic goals:

- Create a safer organization.
- Deliver quality service.
- Use every resource wisely.
- Retain, attract, and reward the best and the brightest.
- Maintain and enhance Metro's image.

To make progress toward these goals, the Office of Performance created a range of products that vary by audience (e.g., the board of directors, the general manager, and internal departments). The performance products are designed to turn data into information and to tell WMATA's story to key internal and external stakeholders. The focus is positive, not punitive.

Hendren used a pyramid to illustrate WMATA's different audiences. The board of directors and the public—the agency's external stakeholders—are at the top of the pyramid; the general manager/chief executive officer (GM/CEO) is in the middle; and the agency departments are at the base. There are different performance tools for each audience. For the board of directors and the public, WMATA developed the monthly Vital Signs Report (VSR) which tracks systemwide, long-term trends through 12 key performance indicators: bus, rail, and paratransit on-time performance; escalator and elevator availability; crime rate; employee and customer injury rates; arrests and citations; mean distance between failures (bus and rail); and customer comment rate. The VSR is different from other performance reports and dashboards in that it answers two key questions: Why did performance change? and What actions are being taken to improve performance?

There are several keys to the success of the VSR. First, it opened a performance dialogue with operations. All of the content of the VSR is driven by operations rather than by headquarters staff. Second, the measures used are based on external stakeholder input. Third, the measures are tied to WMATA's strategic goals and objectives; this practice keeps the agency unified in a common direction. By going beyond a dashboard, the VSR provides ongoing communication with key stakeholders.

Numerous benefits have been realized from the VSR. The agency has received positive feedback from policy makers, including a complimentary letter from Virginia Governor Robert F. McDonnell. The accuracy of reporting by the media has improved because reporters have easy access to correct information. Displaying the reports in the lobby of the WMATA building has enhanced internal ownership and use. The content of the VSR continues

to become richer. Performance is improving on most of the measures. The VSR provides brand recognition for performance measurement within the agency and with external stakeholders.

Research has documented that support from executive leadership is key to successfully developing, implementing, and using performance measurement. WMATA's new GM/CEO, Richard Sarles, is at the middle level of the agency's performance pyramid. He established a 6-month action plan that evolved into his current GM/CEO execution plan. This plan includes performance measures and targets as well as actions necessary to make progress. In February 2011, Sarles submitted his execution plan to the WMATA board of directors. The 12 measures contained in the plan include eight measures from the VSR (customer feedback, escalator availability, the crime rate, employee and customer injury, and on-time performance for rail, bus, and paratransit services) and an additional four measures (operating expenses on budget, capital funds expended, the brand image survey, and media audit results). Sarles holds his executive leadership team accountable for the actions listed in the execution plan through one-on-one monthly meetings with each team member.

At the base of the WMATA performance pyramid are the agency's departments. The focus of efforts here has been on developing execution plans that link day-to-day work to agency goals. Like the GM/CEO execution plan, the departmental execution plans contain measures, targets, and actions. The measures, which are quantitative and trackable, enable departments to show progress toward agency goals. The targets establish the desired end results. The actions outline the steps necessary to make progress toward the targets and, in turn, agency goals. In addition, an individual is identified as the action owner to increase accountability and to help ensure the action is completed.

Execution plans give everyone a common playbook. Performance measures track progress, and targets define and declare success. Again, the focus is positive, not punitive. The execution plans are designed to move departments from being reactive to being strategic, foster unity around agency goals, focus staff and resources, demonstrate the benefit of their actions, and help justify additional support and resources. The Office of Performance is working across the agency to turn data into information, to tell WMATA's story, and to focus on positive rather than punitive actions.

WMATA uses several tools to track performance. Two of these tools are the Bus Transportation Department Execution Plan Dashboard and MetroStat, which tracks transit-related offenses and daily escalator availability. The transition to performance-based management at WMATA has not been uniform. The bus maintenance department has by far outshined the other departments by using performance measurement as a management

tool, as evidenced by improvements in the bus mean distance between failure.

WMATA has a strong connection to the six livability principles outlined by the U.S. DOT:

- Providing more transportation choices,
 - Promoting equitable and affordable housing,
 - Enhancing economic competitiveness,
 - Supporting existing communities,
 - Coordinating policies and leveraging investments,
- and
- Valuing communities and neighborhoods.

For example, WMATA's job is to provide transportation choices throughout the region; the agency also promotes equitable and affordable housing by decreasing the amount households need to spend on transportation. A recent study showed that transit-rich areas spend, on average, 9 percent of disposable income on transportation, while automobile-dependent areas spend 25 percent. WMATA also enhances the economic competitiveness of the region by connecting people with their places of employment. A 2008 travel study found that 17 percent of the region's commuting trips use WMATA services, compared with 5 percent nationally.

WMATA is important to the operation of the federal government. Federal employees account for almost half of WMATA's peak ridership. WMATA also creates jobs. A recently rereleased report from the American Public Transportation Association indicates that \$1 billion in transit capital investments translates to 24,000 jobs. WMATA supports existing communities through transit-oriented development and transit services. For example, the area surrounding the Ballston, Virginia, Metro station consisted primarily of used car lots when the station opened in 1979; today, the station is surrounded by restaurants, shops, housing, and offices.

WMATA works with other agencies to coordinate policies and leverage investments. For example, implementing traffic signal priority for buses in a corridor requires coordination with local communities, the District of Columbia, and state DOTs. WMATA values communities and neighborhoods. As FHWA's *Livability in Transportation Guidebook: Planning Approaches that Promote Livability* notes, "Publicly funded transit programs . . . [are] increasingly viewed as critical community anchors and catalysts for more concentrated economic growth and development" (http://www.fhwa.dot.gov/livability/case_studies/guidebook/livabilitygb10.pdf, p. 2). Therefore, transit does equal livability.

Finally, WMATA's actions reflect the U.S. DOT livability principles. WMATA provides more than 1 million trips on an average weekday. The agency promotes transit-oriented development and is working on a new mixed-use development around the New Carrollton rail

station. WMATA received a Transportation Investment Generating Economic Recovery (TIGER) grant to promote bus priority corridors as a result of its partnership with regional stakeholders. Recently, WMATA implemented a peak-of-the-peak fare to encourage riders to change their travel times slightly to address capacity constraints. The appointment of a new sustainability coordinator at WMATA has further promoted livability. The challenge, however, is quantifying WMATA's contribution to livability principles.

Regarding the condition of its assets, WMATA is committed to maintaining a state of good repair and has identified its capital needs for the fiscal years between 2011 and 2020; the amount came to \$11.4 billion. WMATA divided its needs into two categories—those with a performance focus and those with a customer-demand focus. The performance focus category includes projects that maintain and replace assets on a regular life-cycle basis to deliver the same level of service. These needs keep WMATA in a state of good performance, in which assets are replaced not simply with an exact replica, but with assets that take advantage of the latest technology and materials for greater efficiency. This category accounts for 67 percent of WMATA's capital needs, or \$7.6 billion. The customer-demand focus category includes projects that help meet growing ridership and improve the rider's experience. Capital projects in this category account for some \$3.8 billion, representing 33 percent of WMATA's total capital needs. The agency then prioritized its capital needs on the basis of its five strategic goals. WMATA used the prioritized needs to demonstrate what the region would get and not get at different funding levels.

WMATA is similar to other agencies, in that the transit arena is working on improving asset management. However, the Federal Transit Administration's *2010 National State of Good Repair Assessment* found that few transit agencies had capital asset inventories ([http://www.fta.dot.gov/documents/National_SGR_Study_072010\(2\).pdf](http://www.fta.dot.gov/documents/National_SGR_Study_072010(2).pdf)). That report also found that transit lagged behind other sectors in monitoring asset condition. Almost no prioritization or what-if tools are used by transit agencies. There is clearly work to do in the transit field.

WMATA's recent experience illustrates important lessons in introducing and using performance measurement at a transit agency. One lesson learned is that language matters. In the performance field, the terms "goals," "targets," and "objectives" can all be used differently and, unfortunately, interchangeably. Better coordination occurs when everyone uses the same terminology. WMATA uses specific terms to describe its cascading strategic framework:

- The mission establishes the overarching purpose of the organization.

- Goals provide direction for the organization to attain the mission.
- Objectives break goals into manageable bits that can be acted on.
- Performance measures track progress toward goals and objectives.
- Targets set the end point or direction for measures.
- Actions are the steps taken to move toward goals and objectives.
- Execution plans capture all of these elements at a departmental level to document responsibilities and schedules.

Another lesson learned is that moving away from being data rich and information poor—the so-called DRIP syndrome—is difficult. A wealth of data is insignificant unless someone is able to interpret it. Turning data into information, information into knowledge, and knowledge into decision making is important, but it is a very lengthy process.

A further lesson learned is that the benchmarking of public transit systems will not go away, despite limitations with available data and other issues. For example, it is nearly impossible to do apples-to-apples comparisons of U.S. transit systems by using the National Transit Database. Disparate agency characteristics and differences in definitions skew such comparisons. Erroneous benchmarking will make agencies more reluctant to engage in this potentially beneficial activity in the future. Therefore, finding peer agencies first and using common definitions for performance measures is critical to encourage benchmarking. Additionally, data must be interpreted before they can be released to the media and the public. For example, WMATA does not just release the number of crimes that have occurred in the system to the board of directors or post this number on its website; rather, it explains criminal trends along with policies implemented and future action items.

Hendren also advocated establishing public expectations for public reporting, deemphasizing dashboards and fancy tools, and focusing on actions and analysis instead of data trends. She emphasized that external buy-

in does not end; it must continually be reinforced. She also encouraged a positive approach to overcoming resistance, noting that peer pressure does work. With regard to data, Hendren stated that it is impractical to wait for perfect data, as the data will improve as they are used. Because data often contradict managerial logic, it is important to be ready to use data to defend the conclusions inferred from the data. Finally, it is important to remember that developing, implementing, and using performance measurement takes time, but the benefits are worth it.

Hendren flagged several areas for additional research, citing first the development of an asset management database as well as tools for transit. The past approaches of FHWA and state DOTs could serve as a starting point.

Effectively sharing research and best practices is also essential. One suggestion is to create a U.S.-based transit benchmarking organization. Some international examples include the Community of Metros (CoMET) and Nova, both operated by the Railway and Transport Strategy Centre at the Imperial College of London. Evaluating the quality and usefulness of the National Transit Database also would be beneficial, as would additional case studies on the use of performance measurement in transit and other related topics.

Peer exchanges, conferences, and webinars would provide an excellent venue for pushing innovation forward. Visualization tools that utilize existing software packages and free technology would be useful in presenting this information. In conducting research that focuses on public transportation and transit agencies, it is important to remember that transit agencies do not have unlimited resources with which to analyze the troves of data that have been collected. Although data collection is automated, analysis is not, and agencies often lack the staff resources to conduct extensive analysis. Furthermore, transit agencies are constrained by limited opportunities to persuade policy boards.

The final area for additional research on Hendren's list was how to get performance-based management to front line employees. Identifying ways to better translate performance information for frontline employees is essential.

BREAKOUT SESSION 5-A

Breaking Down Boundaries for Transportation, Land Use, and the Environment

How to Choose and Use Livability Metrics

Angela Dluger, *Federal Transit Administration* (Moderator)

Mike Hoglund, *Portland Metropolitan Government*

John S. Miller, *Virginia Department of Transportation*

FEDERAL TRANSIT ADMINISTRATION AND THE PARTNERSHIP FOR SUSTAINABLE COMMUNITIES

Angela Dluger discussed the Federal Transit Administration's (FTA's) role in the Partnership for Sustainable Communities, an interagency partnership of the U.S. Department of Transportation (DOT), the U.S. Department of Housing and Urban Development (HUD), and the U.S. Environmental Protection Agency (EPA). She described the six principles of the partnership, the roles of the three agencies, and the activities FTA is conducting. Dluger's presentation covered the following points:

- Several trends are influencing the investment in transportation and other infrastructure in the United States. These trends include a growing and aging population, growing transportation energy use, plans for reducing carbon emissions, a growing need to repair and maintain existing infrastructure, a need to leverage existing resources, and a desire to protect open spaces and farmland.

- Infrastructure investment decisions affect household budgets. According to 2004 data from the Bureau of Labor Statistics, the average family spends 19 percent of its household budget on transportation. However, households in automobile-dependent neighborhoods spend 25 percent of their budget on transportation, and households with good access to transit spend just 9 percent. This savings can be critical for low-income households.

- Infrastructure investments also influence local government budgets. For example, the population of Cuyahoga, Ohio, remained relatively constant at almost 1.4 million people from 1950 to 2002. The same popu-

lation was spread out over a much larger area in 2002, however, so that the taxpayers' cost for providing infrastructure, police and fire protection, and other services was greater (Figure 9).

- The Partnership for Sustainable Communities is based on six principles developed jointly by representatives from all three agencies:

- Provide more transportation choices.
- Expand location- and energy-efficient housing choices.
- Improve the economic competitiveness of neighborhoods by giving people reliable access to employment centers, educational opportunities, and other basic services.
- Target federal funding toward existing communities through transit-oriented development and place-based policies.
- Align federal policies and funding to remove barriers to collaboration, leverage funding, and increase the effectiveness of existing programs.

- All three agencies play important roles in the partnership and are in charge of numerous programs:

- HUD has a long history of using community development block grants to fund projects. Recent programs include \$100 million for regional planning grants and a local challenge grant program. HUD also has expertise and programs in affordable housing.
- EPA oversees a broad range of subjects and programs, including the Smart Growth Office, which provides technical assistance and localized help to

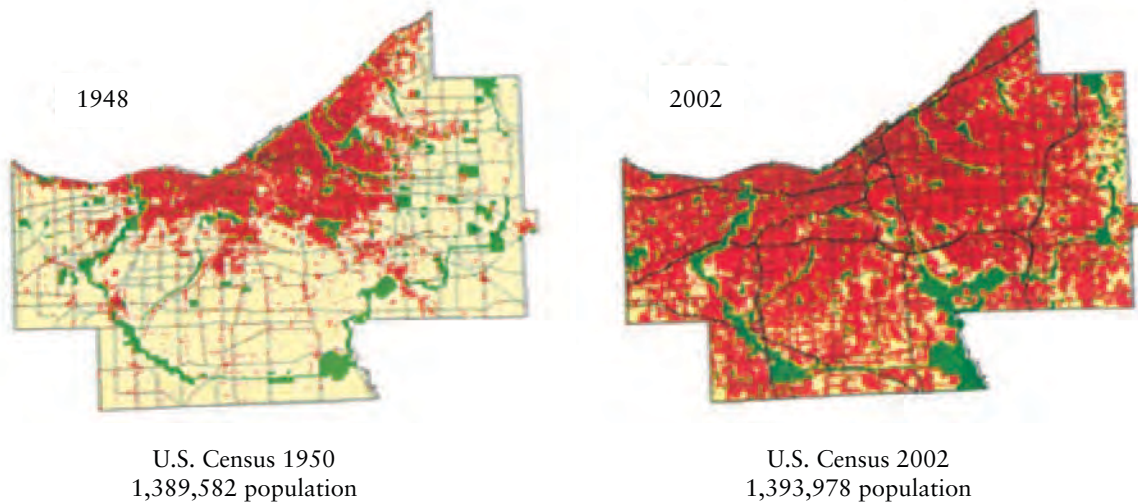


FIGURE 9 Population of Cuyahoga County, Ohio: 1950 and 2002. (Source: Cuyahoga County Land Use Maps, Cuyahoga County Planning Commission.)

communities. EPA also has technical assistance programs for brownfields restoration. Furthermore, EPA has more than \$3 billion in a revolving water infrastructure fund program that is available to states.

– The U.S. DOT has numerous programs that support livable communities. The Transportation Investment Generating Economic Recovery (TIGER) grant program, the FTA programs, and the Federal Highway Administration (FHWA) flexible funding programs represent just a few examples. Existing partnerships, such as the United We Ride program, which focuses on human services transportation, are also being leveraged. FHWA's livability efforts, state and metropolitan activities, and railroad infrastructure programs are a few other examples of related efforts.

- There is also an expanding relationship with the U.S. Department of Agriculture (USDA) to address rural needs and activities. USDA has significant resources targeted to rural America. Although USDA is not officially part of the partnership, a rural working group to address livability in rural America has been formed.

- FTA's role in the Partnership for Sustainable Communities focuses on four areas: infrastructure investment, capacity building, policy and guidance, and research. FTA provides approximately \$11 billion in grants to urban and rural transit systems annually. This funding includes formula-based programs and discretionary programs. One new grant program is Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER).

- FTA has many capacity-building activities underway. Many of these programs, including peer-to-peer exchanges, are undertaken with FHWA. FTA also provides technical assistance, supports demonstrations, and develops case studies on livable communities initiatives throughout the country.

- The joint development policy provides flexibility in the use of federal funds to purchase real estate for transit projects that would also support joint development projects. FTA does not have a transit-oriented development program, but can fund infrastructure investments to help leverage those investments through the joint development policy. A clarification of the FTA policy regarding the use of local funds for bicycle and pedestrian access to transit projects was announced in 2010. Information on flexible funding from FHWA that can be used for transit projects is being provided. Further, FTA is encouraging environmental management systems within transit agencies.

- FTA is supporting research related to livable communities. Over the past 5 years, HUD and FTA have funded research projects that examine issues associated with providing affordable housing near transit. FTA is also working on research projects related to transit-oriented development with staff from the Center for Transit-Oriented Development, a joint venture of the Center for Neighborhood Technology; Strategic Economics, an urban economics firm; and Reconnecting America, a nonprofit working to integrate transportation systems and the communities they serve. Other research efforts focus on examining the impacts of climate change on transit, including adaptation, and enhancing access to transit, including access by individuals with disabilities and implementation of the complete streets philosophy.

- There are several recent accomplishments. Regional engagements across the country have showcased efforts of the Partnership for Sustainable Communities in each region. Enhanced policies focusing on alternative transportation solutions, including public transportation, bicycles and pedestrians, and rail are being discussed. Leveraging other partnerships is

another important activity. Joint efforts with the U.S. Department of Energy (DOE) are under way in rural areas. The Centers for Disease Control and Prevention and United We Ride—Coordinating Council on Access and Mobility are partners in health and health access projects. The National Endowment for the Arts is partnering on community design projects. DOE and the U.S. Department of Commerce’s National Oceanic and Atmospheric Administration are involved in climate and energy projects.

- The efforts of the Partnership for Sustainable Communities were to focus on five major areas in the coming year: distributing project and program funding, improving technical capacity, identifying new funding opportunities, continuing to showcase communities, and continuing to break down barriers to facilitate projects and programs.

- The Obama administration’s FY 2012 budget request to Congress included several programs supporting the partnership:

- HUD: \$150 million for sustainable housing and communities, \$250 million for a choice neighborhood pilot program, power saver loans, and \$3.69 billion for community development block grants;

- EPA: \$11.2 million for sustainable communities, \$94.5 million for cleaning brownfields, and \$5 million for urban waterways; and

- U.S. DOT: \$22.4 billion for major investments in transit, \$8.3 billion for rail, \$70.5 billion for highways, FHWA and FTA proposals for new livable communities programs, and a new infrastructure bank for multimodal investments.

- The FTA highlights in the FY 2012 budget request included an increase in the overall funding request for transit; \$119 billion over 6 years was requested—a 128 percent increase over the amount in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This funding would establish a new state-of-good-repair program, a consolidated specialized transportation program, an emergency relief program, and a livable communities demonstration program. The FTA budget proposal also streamlines the New Starts program, gives the agency rail safety authority, and provides temporary relief for operating assistance in large transit systems. Additionally, it enhances technical assistance, research, and oversight efforts.

BREAKING DOWN BOUNDARIES FOR TRANSPORTATION, LAND USE, AND THE ENVIRONMENT: HOW TO CHOOSE AND USE LIVABILITY METRICS

Mike Hoglund discussed regional data and performance indicators and described the development and use of the Greater Portland–Vancouver Indicators (GPVI) and

some of the lessons learned in the process. He also highlighted best practices from Boston, Massachusetts, and Jacksonville, Florida. Hoglund’s presentation covered the following points:

- There are several reasons for using regional indicators. First, regional indicators help ensure that appropriate attention is paid to performance and measurement. Developing a vision, goals, and plans is a key element in the regional planning process. As plans and projects are implemented, measurement is needed to ensure the goals are being met. Regional indicators are also used to better understand and focus actions toward triple-bottom-line progress.

- GPVI is a partnership between Metro and Portland State University. From the perspective of Metro, GPVI

- Broadens the participation of experts and leaders in the region who work in areas that link to and have an impact on Metro’s six desired outcomes;

- Helps Metro’s regional leadership broaden and diversify support for those desired outcomes;

- Fosters a more strategic approach to overall regional success by supporting the dialogue necessary for coordinated action on shared and interconnected goals;

- Helps link indicators to projects and practice; and

- Assists Metro in forming new partnerships, such as those related to health and equity.

From the perspective of Portland State University, regional indicators can stimulate research and understanding and are critical to the university’s mission. GPVI focuses on gathering and disseminating information, convening regional partners in a neutral setting, stimulating dialogue and action, and promoting regional partnerships.

- Regional indicators should be outcome oriented, collaboratively developed, used and useful, and applied to the decision-making process. They should serve multiple users, be comprehensive, and be both vertical and horizontal. Regional indicators should not be project-specific, too detailed, or mechanical.

- The GPVI project approach included several steps and activities. During the start-up phase, an advisory team composed of leaders, funders, and big-picture thinkers provided oversight. There were nine results teams, one for each of the following nine categories: education; quality housing and communities; economic opportunity; healthy people; safe people; healthy natural environment; arts, culture, and creativity; access and mobility; and civic engagement. The teams were composed of policy and data experts from each of the major sectors and were responsible for the development and implementation processes for choosing and using indica-

tors. The results team examined outcomes, drivers, indicators, and data for each category.

- The GPVI theory of action is that data lead to actionable knowledge, which leads to coordinated action, which leads to the desired results. The GPVI performance indicators are intended to be useful and used. Users groups include elected leaders, foundations, public agencies, business leaders, grant writers, and the public.

- The Boston Indicators Project is a national leader in regional indicators. It produces biennial reports on civic vitality, the arts, the economy, education, the environment, housing, safety, and transportation. Because education affects many other outcomes, the Boston Indicators Project published a special closer-look report, *Boston's Education Pipeline: A Report Card* (http://www.bostonfoundation.org/uploadedFiles/Indicators/Indicators2006/Global/Generic_Templates/Education_Report_Card/EdReportCard_Final5.pdf). This report inspired community leaders to acquire an additional \$27 million to support education from the early childhood through postsecondary levels and to hold themselves accountable to the results tracked by the Pipeline report.

- The Jacksonville Community Council, Inc. (JCCI) is home to the longest running regional data reports in the country. A topic is picked from each report for further study and strategy recommendations. In 2006, this led to the report *Retaining Talent: People and Jobs for the 21st Century*. JCCI tracks progress and reports that each of the three main recommendations from the *Retaining Talent* report were implemented.

- Several products and reports are being prepared as part of GPVI. The first indicators report, which is intended to be a beta test version, was scheduled to be available in the summer of 2011. An equity report and a business plan have also been developed. Consistent themes from the equity panel include disaggregation, mapping, the need for better data, and taking a community perspective. The business plan addresses an institutional home for GPVI, governance, and funding.

- Data on the following topics are being examined: employment, education, access and mobility by different modes, and the natural environment. The emerging theme for the beta GPVI report focuses on well-being, which includes natural, human, physical, and social capital requirements. The presence of these elements attracts talented people, firms, and jobs, and thus improves outcomes. The increased revenues and decreased demand that result from these improved outcomes lead to stronger public and private services, which feed back to regional well-being.

- GPVI's lessons learned are as follows:
 - There may be plenty of talk but limited results.
 - Partnerships are critical.
 - Build on existing efforts.
 - Focus on outcomes.

- Brand the effort, but do not market it.
- Find a champion for the effort.

LESSONS LEARNED FROM TRYING A JOBS–HOUSING BALANCE INDICATOR FOR VIRGINIA REGIONAL PLANNING

John S. Miller discussed the development and use of a method for analyzing the jobs–housing balance of jurisdictions and regions in Virginia. He described the potential impacts that changes in the jobs–housing balance could have on the transportation system. Miller's presentation covered the following points:

- The jobs–housing balance, which affects a variety of outcomes, including traffic congestion, is just one element in a matrix of livability measures being developed and used in Virginia. Virginia is just one state that has considered using the jobs–housing balance.

- A general motivation for considering the jobs–housing balance is that it is appealing as a congestion-reduction technique because it avoids the controversy associated with pricing and travel demand measures. In Virginia, the jobs–housing balance must be considered in the statewide and regional planning processes.

- Regarding the jobs–housing balance, Section 33.1-23.03 of the Code of Virginia states that the "Statewide Transportation Plan shall establish goals, objectives, and priorities that cover at least a 20-year planning horizon, in accordance with federal transportation planning requirements. The plan shall include quantifiable measures and achievable goals relating to, but not limited to, congestion reduction and safety, transit and high-occupancy vehicle facility use, job-to-housing ratios, job and housing access to transit and pedestrian facilities, air quality, movement of freight by rail, and per capita vehicle miles traveled. The Board shall consider such goals in evaluating and selecting transportation improvement projects for inclusion in the Six-Year Improvement Program."

- Other studies throughout the country have examined the impacts of the jobs–housing balance on commute times. Four studies found no impact, four found a modest impact, and three identified substantive impacts.

- The linear dissimilarity index was developed as one method of examining the jobs–housing balance. If employment and population are in perfect balance, the linear dissimilarity index will be 0.0; if there is no balance, the index will be 1.0. Virginia used the linear dissimilarity index to examine the jobs–housing balance in different jurisdictions in the state.

- The Virginia study examined the potential impact of changes in a jurisdiction's jobs–housing balance over a 10-year period. A longitudinal model showed

that the jobs–housing balance had a moderate statistically significant impact. A 20 percent change decreased commute times by 2.2 minutes, but only in urban areas, where other factors are carefully controlled. If these factors are not controlled, there appears to be no impact.

- The regression equation for jurisdiction commute time in 2000 (JCT_{2000}) was used in the analysis. The equation is as follows:

$$\begin{aligned}
 JCT_{2000} = & A \text{ [jurisdiction commute time in 1990]} \\
 & + B \text{ [dissimilarity index in 2000 – 1990} \\
 & \quad \text{index]} \\
 & + C \text{ [jurisdiction jobs–labor force – region} \\
 & \quad \text{jobs–labor force]} \\
 & + D \text{ [proportion of persons commuting outside} \\
 & \quad \text{their jurisdiction of residence in 2000 –} \\
 & \quad \text{1990 proportion]}
 \end{aligned}$$

- The Virginia data show that the impact of the jobs–housing balance on commute time is within the range of findings from other studies. The Virginia data are dependent on whether the impact is measured spatially at a single point or longitudinally.

- One option for implementation of this approach with a selected urban project is to determine whether the project connects a jurisdiction with a high jobs–labor force ratio to a jurisdiction with a low jobs–labor force

ratio. This determination could be used as one of many factors when considering potential projects. The quantifiable measure is the number of projects connecting a jurisdiction with a high jobs–labor force ratio to a jurisdiction with a low jobs–labor force ratio. The achievable goal is to increase the percentage of qualifying projects.

- Issues that may need to be addressed with this approach include whether the region should be defined by existing administrative boundaries and whether the metric should be stratified by job type. Policy issues to be considered include which urban regions should use this option, who should compute it, and whether transportation investments should connect regions with high and low jobs–housing balances.

- The following lessons learned from this analysis may extend to other performance metrics:

- Given a range of multiple performance metrics, practitioners can select the right one.

- Geographic and methods imperfections may be tolerable in the computation of the performance metrics.

- Legislative incentives exist to encourage use of these metrics. Their interpretation rests with decision makers.

- There are two distinct roles in developing metrics: quantifying the numerical value of the metric and determining the relevance of the performance metric for some societal goal.

BREAKOUT SESSION 5-B

Incorporating Economic Impact Yardsticks into Transportation Investment Decision Making and Performance Management

Joseph Crossett, *High Street Consulting Group* (Moderator)

Julie Lorenz, *Burns and McDonnell*

Jeffrey Short, *American Transportation Research Institute*

YARDSTICKS FOR TRANSPORTATION INVESTMENTS AND PERFORMANCE

Julie Lorenz discussed the Kansas legislation for Transportation Works for Kansas (T-WORKS) and the development and use of a new project selection process at the Kansas Department of Transportation (DOT). She described the partnership and the development of its economic analysis tool. Lorenz's presentation covered the following points:

- The Kansas Legislature approved the T-WORKS bill in May 2010. T-WORKS is an \$8.2 billion, 10-year multimodal transportation program funded by a 4/10-cent sales tax and additional bonding authority (Figure 10). Although no projects are included in the legislation, preservation is the top priority of the Kansas DOT. The department built support for T-WORKS by highlighting the relationship between transportation investment and economic priorities and by making project selection more flexible.

- Past transportation investments were examined and the benefits were provided to policy makers and the public. One example was the K-96 bypass project in Wichita, Kansas, which cost \$103 million, added 24,000 jobs, and added \$1.6 billion in economic value. A second example was the Nall Avenue interchange in Overland Park, Kansas. This project cost \$48 million, added 17,500 jobs, and added \$4.1 billion in economic value.

- The department also wanted to examine the future performance of transportation investments. Other

objectives included operationalizing priorities; building credibility with the public, policy makers, and other stakeholders; and creating and maintaining transparency. The Kansas DOT's 2003 Partnership Project focused on changing the internal culture at the department.

- The Kansas Long-Range Transportation Plan, developed between 2006 and 2008, focused on linking investments with stakeholder priorities. An economic impact working group was established in 2008 to develop an economic impact analysis for transportation projects. The group reviewed available models and tools and selected the Transportation Economic Development Impact System (TREDIS) model for use in the economic impact analysis. TREDIS is an input-output economic model that assesses congestion relief, travel time savings, market access expansion, safety impacts, and contingent development. The analysis used customizable data at the county level. Local governments provided feedback on inputs into the model. The results of the analysis were measured in jobs and gross regional product.

- The Transportation-Leveraging Investments in Kansas (T-LINK) task force was appointed by the governor in 2008 and charged with developing the framework for a new project selection process. The task force also identified spending targets and helped operationalize the new business models. Local consultation meetings were held to discuss project needs and the business model changes. A three-prong selection process, which is described below, was piloted with proposed projects ranked by the new process. On the basis of comments received at the meetings, the department was willing to add projects and revise scores.

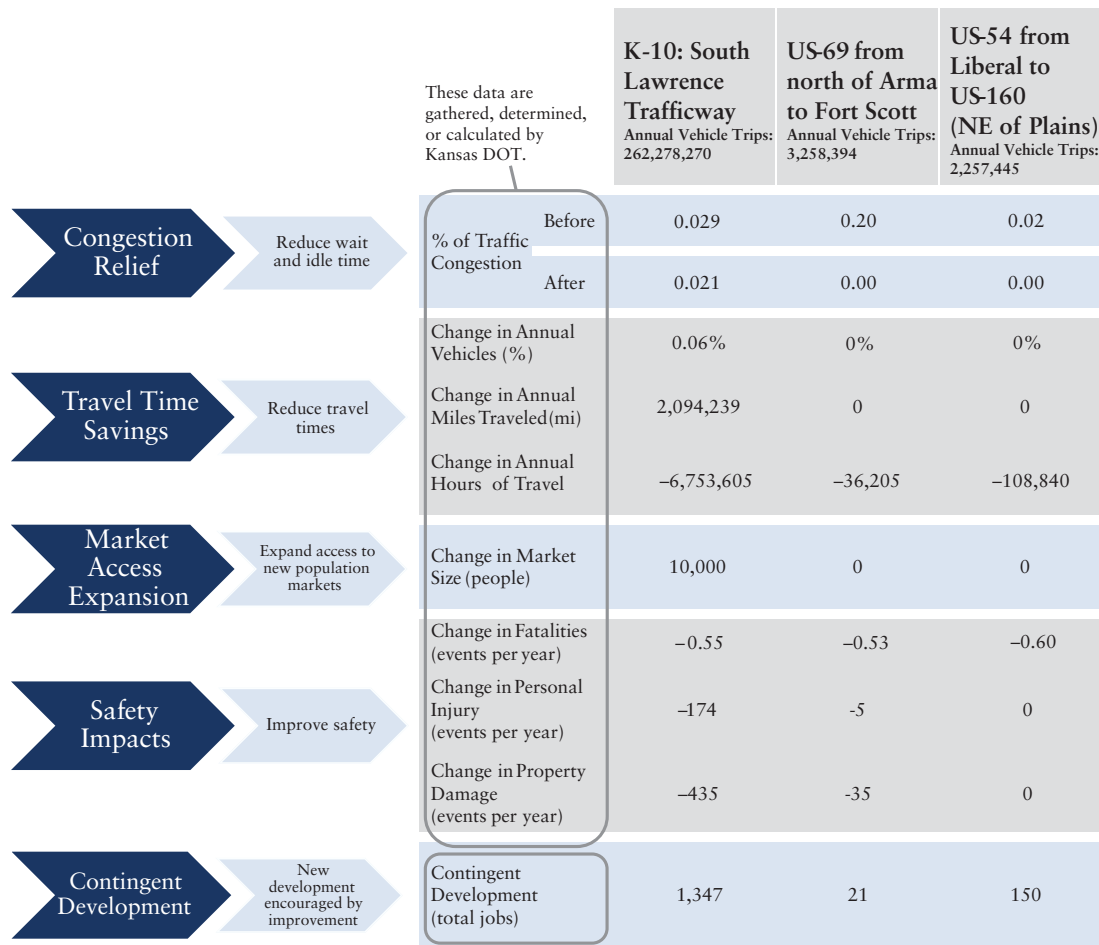


FIGURE 10 T-WORKS: Transportation Works for Kansas (NE = northeast).

- The new project selection process developed by the T-LINK task force focuses on three project categories—preservation, modernization, and expansion—and three selection factors—engineering data, local consultation, and economic impact. The selection process for preservation projects is based solely on engineering data. The selection of modernization projects is based on two factors: engineering data (80 percent) and local consultation (20 percent). The section of expansion projects is based on all three factors: engineering data (50 percent), local consultation (25 percent), and economic impact (25 percent).

TRUCK DATA AND PERFORMANCE MEASUREMENT

Jeffrey Short discussed freight mobility and the economy. He described the importance of trucking and freight to the U.S. economy, the development and use of data from the Federal Highway Administration (FHWA) freight performance measurement program, and freight perfor-

mance measures. Short’s presentation covered the following points:

- The trucking industry is a key component of the U.S. economy. It moves 10 billion tons annually, which represents 68 percent of the total domestic freight tonnage, and employs 7.3 million people. There are 3 million Class A trucks (i.e., 18-wheelers) in operation.
- The freight performance measures program was initiated in 2002, and data were first collected in 2003. The program is sponsored by FHWA’s Office of Freight Management and Operations. The American Transportation Research Institute (ATRI) collects Global Positioning System data on truck movement, and these data are integrated into a centralized database. A geographic information system and other software are used to graphically represent and illustrate various performance metrics. Examples of these measures include average truck speeds, reliability, and truck volumes.
- ATRI provides FHWA with a monthly report on the performance of 25 Interstate freeways. The map

illustrating average truck speeds on the Interstate system is one of the well-known products from the data. The data can also be used to examine specific urban congestion problems.

- The travel patterns of trucks beginning their trips in a specific metropolitan area or state can be tracked. Following are two examples:

- One thousand trucks that were beginning their trips in Georgia were tracked over a 10-day period. Most of these trucks remained in the eastern portion of the United States, traveling along the East Coast to Florida.

- Commercial vehicles stopping at truck stops were filtered out of the data to highlight trucks that were picking up or delivering goods. This analysis illustrated the high number of stops at Georgia cities (Atlanta, the Port of Savannah, Augusta, and Macon) and locations along the I-75 corridor. The networks connecting these locations are key to efficient movement of goods and economic vitality.

- Recent analyses have examined truck movements at a regional level and at a county level. An analysis in the Baltimore area highlighted the freeways with the highest levels of truck movements, including I-95. The destinations of trucks can also be identified. For exam-

ple, 7 percent of the trucks in Laredo, Texas, are going to Ontario, Canada.

- Truck speed on the Interstate system is an important consideration in the site selection process for a new manufacturing facility or other type of business. The trucking industry uses operational measures associated with fuel costs and driver wages. The freight data can be used to analyze the impacts of delays at bottlenecks on fuel costs and driver wages. Two hundred fifty bottleneck locations are being monitored. This type of analysis was conducted for an interchange in Atlanta. The mean speed in the section was 25 mph, with segments at 10 mph. ATRI estimated that this slowdown cost the trucking industry approximately \$21,000 a day, or \$5.7 million annually, in lost productivity.

- The data can be used to identify the need for new infrastructure as well as for resources to move freight efficiently. For example, the loss of an important connection, such as the reduction in the use of I-40 in Tennessee and North Carolina by a rockfall, has a significant impact on truck movements, the trucking industry, local businesses, and the economy. Understanding the intensity of truck movements between city pairs is also important for maintaining key routes.

BREAKOUT SESSION 5-C

State-of-Good-Repair Data, Performance Measures, and Capital Program Decision Making

Keith Gates, *Federal Transit Administration* (Moderator)

Michael S. Tanner, *Bay Area Rapid Transit*

Naomi Renek, *New York State Metropolitan Transportation Authority*

CAPITAL PROGRAMMING AT THE BAY AREA RAPID TRANSIT

Michael S. Tanner discussed capital programming at the Bay Area Rapid Transit (BART), which services four counties in the San Francisco Bay Area. His presentation covered the following points:

- BART, which is 40 years old, encompasses dense, urban cities such as San Francisco and Oakland as well as suburban and rural areas. The transbay tunnel is a key link connecting San Francisco and Oakland. BART is composed of 100 miles of track that carries 350,000 riders per day, and it has an annual budget of \$600 million. Its capital program has a funding shortfall.

- The Metropolitan Transportation Commission (MTC) is the designated recipient of federal funding for the Bay Area. As result, all 20 transit operators in the Bay Area, including BART, go through MTC for federal funding. MTC has established a set of priorities for transit capital investments in the region. Maintaining the existing system, including the purchase of new transit vehicles to operate current service, is the top priority. Rail and track, stations, and related facilities all fall within this high-priority category. Because of the capital needs of other operators in the region, it will take approximately 20 years to replace BART's existing 669 rail cars. BART's use of a wide-gauge rail requires a unique rail car design, which is more expensive than standard rail cars. The estimated cost to replace one rail car is \$3 million. The rail cars are 40 years old, and a midlife overhaul of all the rail cars was completed 15

years ago at a cost of \$1 million per rail car. Funding for system expansion has not been identified.

- Evaluating the condition of BART's assets is important. Maintaining other elements of the BART infrastructure is key to meeting the state-of-good-repair goal. Maintaining the system to ensure safety, reliability, and attractiveness is critical. Public input is being obtained on the design, seating, and other features of the new rail cars. BART also has a major earthquake safety program that is funded locally through a property tax increase.

- There is a concern that service extensions will come at the expense of maintaining the existing core system. There are plans to extend service to San Jose, the Livermore Valley, and other areas.

CAPITAL PROGRAM AND PERFORMANCE MEASUREMENT AT THE NEW YORK METROPOLITAN TRANSPORTATION AUTHORITY

Naomi Renek discussed capital program planning, funding, and performance measurement at the New York State Metropolitan Transportation Authority (MTA). She provided background to MTA's capital program and described issues associated with prioritizing projects. Renek's presentation covered the following points:

- MTA is composed of several agencies that operate subway, bus, and commuter rail service in the greater New York metropolitan area. The headquarters office is responsible for managing certain centralized functions, including capital programming, legal services, real

estate, and grants management. The MTA service area covers 500 square miles.

- MTA serves 14 counties in two states; it carries approximately 8.5 million riders a day, including 7.4 million riders on the New York City subway and bus system. There are three metropolitan planning organizations (MPOs) in the MTA service area. The New York Metropolitan Transportation Council (NYMTC) is the largest MPO and includes three smaller working areas (Figure 11). NYMTC suballocates funds from the Urbanized Area Formula Program (5307) to transit operators according to the 5307 formula; transit operators prioritize their own projects, thus providing predictability in capital planning.

- In considering both capital programs and performance measurement, it is important to remember that one size does not fit all. There is a great deal of variation among states, MPOs, regional planning groups, and local jurisdictions throughout the country. In addition,

prioritizing investments is a multifaceted and complicated process that takes time. Furthermore, agency priorities may not always match funding criteria.

- Approximately \$70 billion has been invested in MTA's capital program since 1982. Numerous benefits have been realized from this investment. For example, annual subway delays fell by 59 percent, the mean distance between failures for subway cars increased by 1,800 percent, and the mean distance between failures for buses increased by 670 percent. In addition, the system is experiencing the highest ridership levels since the early 1950s. Even with these investments, there is still a substantial state-of-good-repair backlog.

- Establishing priorities for a capital program is a multifaceted process. Conducting an assessment of the condition of the facilities, vehicles, and other assets is a good place to begin. Many factors may be considered in determining the condition of assets. The age of vehicles, rolling stock, and facilities may be considered. Inspec-



FIGURE 11 NYMTC comprises three working areas: the Mid-Hudson Transportation Coordinating Committee (MHTCC), the Nassau–Suffolk Transportation Coordinating Committee (NSTCC), and the New York City Transportation Coordinating Committee (NYCTCC). The other two MPOs in the New York metropolitan area are the Poughkeepsie–Dutchess County Transportation Council (PDCTC) and the Orange County Transportation Council (OCTC).

tions of structures and bridges are typically undertaken. The performance of ventilation and electric systems may be examined. A numerical rating is not enough to prioritize projects, however. Some key inputs are difficult to quantify. Other factors to consider in the prioritization process include emergent safety issues, the ability to maintain rather than replace, mobility, and customer service.

- In some cases, agency priorities do not match funding criteria. For example, the Congestion Mitigation and Air Quality Improvement (CMAQ) program addresses a clear national objective. Eligible projects must demonstrate air quality benefits; however, many transit state-of-good-repair projects do not qualify for CMAQ funding because, although these projects retain existing riders by providing more reliable or more frequent

service or improving the transit environment, these benefits are not considered in the CMAQ criteria. The livability programs Transportation Investment Generating Economic Recovery (TIGER) and Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) are other examples of programs whose funding criteria may not correspond to agency priorities. Transit state-of-good-repair projects may not show the desired benefits. The measures of additionally requiring increased economic activity, denser land use, and more riders is a poor match for big cities.

- The experience at MTA demonstrates three things: measures should be established locally, transit providers are best positioned to prioritize projects, and outcome-based measures generally do not support system preservation projects.

Concluding Remarks

Sue McNeil, *University of Delaware*

Daniela Bremmer, *Washington State Department of Transportation*

Katherine F. Turnbull, *Texas A&M Transportation Institute*

DRIVING CHANGE AND BEING DRIVEN BY CHANGE

Sue McNeil highlighted a few of the topics discussed in the five conference tracks, which were driving forces for change; performance-based decision making: the bucks start here; data collection and analysis technologies; drivers and applications; and capturing system performance: new measures for difficult-to-measure topics.

Several driving forces for change were discussed. These forces included opportunities associated with new initiatives, the response to limited resources, and inertia from efforts already underway. The elephant in the room was the reauthorization legislation. Speakers in the session on performance-based decision making illuminated the perspectives of the Kansas Department of Transportation (DOT), the Japanese government, and private-sector entities such as the United Parcel Service, relating performance measurement to decision making and accountability.

Speakers in the session on data collection and analysis technologies, which was titled “The Future Is Now!”, provided new vocabulary, terms, and concepts relating to technologies and trends. They also highlighted new opportunities for linking these new concepts and technologies to performance measurement. The speakers pointed to a wealth of data available through various technologies to support performance measurement.

Speakers in the session on drivers and applications discussed policy, data, frameworks, processes, computer tools, and computer systems needed to support performance measurement systems. The final session focused

on capturing system performance with new measures for difficult-to-measure topics such as sustainability, economic competitiveness, the state of good repair, and livability. Even though speakers highlighted more success stories, it was noted that these topics could still benefit from further research.

Several sessions revolved around the economy, social equity, and the environment—the triple bottom line and three-legged stool of sustainability. It was noted that the conference lacked a thorough discussion of how to capture the performance of networks and intermodal facilities, how best to measure performance, and how to put the various pieces together.

Daniela Bremmer thanked all of the speakers for their excellent presentations and noted that the discussions were very lively and thought provoking, particularly the interactions between participants from the private and public sectors.

The speakers, said Bremmer, noted both challenges and opportunities associated with the more widespread use of performance measurement by transportation agencies at all levels. She observed that while much has been accomplished since the first conference on performance measurement in 2000, the significant challenge in this new era of severe revenue constraints and rapidly emerging information and data technologies may lie in promoting and applying performance measurement. Much has been done, however, and that work has provided a solid base for future efforts. As reiterated throughout the conference, new technologies and innovations can assist in the provision of timelier and more accurate performance data to aid in decision making.

Bremmer noted the accomplishments in the area of performance measurement over the past 10 to 15 years. Focusing on key agency and organization goals is important, along with developing appropriate measures. She cited the benefits of performance measurement, including greater accountability and transparency. She emphasized that many speakers had noted that what gets measured gets done. If this statement is true, she said, then there is a unique opportunity for leaders to shape and influence the future of transportation through the application of appropriate and innovative approaches to systems measurement and analysis. Bremmer concluded her remarks by expressing that she looked forward to continuing to work with the Transportation Research Board and by emphasizing the numerous opportunities to build on the strong foundation established over the past decade.

FUTURE RESEARCH, TECHNOLOGY TRANSFER, AND TRAINING NEEDS

Katherine F. Turnbull observed that participants at the conference had numerous opportunities to identify areas for further research, technology transfer, and training. Most of the breakout sessions included time for the discussion of research gaps, research needs, and other related topics. The closing session provided the opportunity for the discussion of research, technology transfer, and training to advance the widespread use of performance measurement and performance measures within transportation agencies at the local, regional, state, and national levels.

Common themes emerged from these discussions related to additional research needs. Several suggestions focused on economic impact analyses and on performance measures related to the following topics:

- Transportation and the economy,
- Sustainability and livability,
- Mobility,
- Intermodalism,
- Agency customer service,
- Emergency management, and
- Long-distance travel corridors and megaregions.

The conference participants identified the following areas as subjects for additional research:

- Asset management, especially for transit agencies;
- The use of technology to collect needed data;
- Visualization techniques for displaying the results of data collection;
- The linking of public- and private-sector transportation data and performance measures;
- Travel behavior; and

- Techniques for building public trust in transportation agencies.

Training in the use of available tools and models was also suggested. Examples of possible research, technology transfer, and training to address the needs listed above are presented in the following sections.

Economic Impact Analyses, Benefit–Cost Analyses, and Economic Development

- Examine appropriate performance measures to assess the economic impact of the transportation system and the impact of economic development on transportation. The study would identify performance measures currently being used by transportation agencies and would develop new performance measures for potential use by state departments of transportation, transit agencies, metropolitan planning organizations (MPOs), and other groups. Data needs would be identified and analysis methods summarized. Techniques for presenting this information to the public and to policy makers would be described. A guidebook on assessing the economic impacts of the transportation system would be prepared. Workshops and online training sessions could be provided.

- Examine methods for economic impact analysis and benefit–cost analysis (BCA) assessments for transportation projects. This project would review current techniques for economic analysis and BCA and examples of the use of these techniques for transportation projects. Case studies of best practices from both the public and the private sectors would be presented. The project deliverables would include guidelines for conducting a transportation BCA and economic impact analysis, data needs, case studies, and techniques for presenting the results to policy makers and the public.

- Conduct training on existing tools available for use with performance measures related to operations, economic analysis, safety, and other topics. Examples of available tools include the Highway Economic Requirements System (HERS), the ITS (intelligent transportation system) Deployment Analysis System (IDAS), PLANSAFE, and the Transportation Economic Development Impact System (TREDIS). Training would focus on presenting the basic elements of the tools and examples of applications in performance measures and would include hands-on example problems. Follow-up technical assistance could also be made available through different mechanisms.

Livable Communities and Sustainability

Build on existing research, including the recent National Cooperative Highway Research Program project and

efforts by the Federal Highway Administration and the Federal Transit Administration, in order to conduct a comprehensive assessment of performance measures relating to transportation, sustainability, and livable communities. Elements to be examined in the study would include the correlation of existing performance measures with sustainability and livable communities, identifying reference points and benchmarks on sustainability, and assessing trade-offs between various social, economic, and environmental factors. The study would consider best practices in sustainability and livable communities from a transportation perspective and would explore the scale and scope of possible performance indicators at the global, national, state, regional, and local levels. The study would also examine measures related to different transportation modes and the integration of metrics into the decision-making process and would develop quality-of-life indicators.

Agency Customer Service and Internal Operations

- Review the use of performance measures of customer service. The project would identify the performance measures currently in use at state departments of transportation, transit agencies, and other organizations. The techniques used to develop the performance measures, obtain input from customers, and monitor performance would be included. Case studies of best practices would also be presented.

- Explore the use of customer service performance measures in the private sector and how these measures can be applied in the public sector. The project would examine how performance measures related to customer service are developed, monitored, and used by companies and businesses. Approaches and techniques that may be appropriate for transportation agencies would be identified. Strategies for transferring experience in the private sector to transportation agencies would be described.

- Examine the use of survey techniques, including stated-preference surveys, panels, and other techniques for determining customer expectations related to different aspects of the transportation system, in order to set performance measures and benchmarks. To obtain input for establishing targets, some states have used stated-preference surveys, panels, and other methods to survey motorists, shippers, and other stakeholders and customers. Other transportation agencies can benefit from using this approach. The study would document the use of stated-preference surveys, panels, and other techniques; report on the advantages and limitations of different approaches; and provide guidance in the use of these methods. Case study examples would be presented to highlight the application of different techniques for setting performance measure

targets and for monitoring progress toward meeting those targets.

- Examine the use of performance measures in decision making that resulted in transformational change within an agency or business. This project would explore the nature of the agency or organization, the nature of the desired change, and how performance measures were used to accomplish that change. The benefits, lessons learned, and applications to other agencies would be discussed.

- Document case studies of how public agencies have used performance measurement as well as outreach, market research, and other techniques, to overcome public distrust and accountability concerns and to build trust with policy makers. Information on the advantages and limitations of different approaches, the key elements of successful efforts, and potential new strategies would be presented.

- Review current uses of performance measurement for internal operations at transportation agencies and future opportunities to expand the use of performance measures to enhance internal management. The study would document the current state of the practice and provide case studies of the use of internal performance measures at state departments of transportation, transit agencies, MPOs, and other public-sector transportation organizations. The role of leadership in integrating performance measures into the agency would be explored, and the different measures and benchmarks used by various agencies would be highlighted.

Freight, Goods Movement, and Intermodal Facilities

- Examine the use of performance measures for freight and goods movement by state DOTs, MPOs, and other transportation agencies. The study would also examine the use of performance measures by private-sector freight industries and identify approaches used in the public and private sectors to coordinate performance measures related to freight and goods movement. Freight and goods movement performance measures used by public transportation agencies, shippers, railroads, trucking firms, businesses, and other groups would be identified, analyzed, and compared. Both compatible measures and those that may conflict would be identified. The results of this assessment would be used to develop coordinated and compatible public- and private-sector performance measures that focus on a shared vision for the freight system.

- Examine performance measures for freight and goods movement with regard to livable communities and sustainability. The movement of goods is paramount to the economic health of communities; however, how freight movement fits into livable communities is being

debated. This research project would explore current performance measures for freight with regard to livable communities and would develop new performance measures that could be applied to meet different goals and objectives related to freight and livable communities. The project would also include outreach to the private sector to obtain its input on possible performance measures and would identify data needs, analysis methods, and possible benchmarks.

- Examine the use of performance measures for intermodal facilities involving multiple agencies and the private sector. The project would document examples of best practices related to the goals and objectives of the intermodal facility, the performance measures, the roles and responsibilities of different agencies and businesses, the data needs, and the analysis methods. The techniques used to present the performance measures would be highlighted, and the use of the measures for decision making and investments would be discussed.

- Review partnerships between state DOTs, other transportation agencies, and public- and private-sector groups to develop, implement, and monitor performance measures. Many issues—including air quality, goods movement, safety, and sustainability—involve numerous diverse groups. Research on methods that have been used effectively to bring various groups together to address common concerns through the use of performance measures would be of benefit to all organizations. The research should include case studies of best practices.

Corridor and Megaregion Performance Measures

Investigate the use of performance measures at the corridor and megaregion levels. The study would explore the use of performance measures to monitor and report on corridor performance, including that of long-distance corridors and megaregions. The following elements would be included in the project: the agencies and organizations involved in developing and using the measures, the actual performance measures and benchmarks, the data collection methods and analysis techniques, the reporting methods, and the use of measures in management and operations decisions. The project would include case studies of best practices.

Technology and Visualization

- Investigate how to use technology, geographic information systems (GIS), and social media more effectively to communicate performance measurement and

transportation funding needs to policy makers, stakeholders, and the public. The use of technology by public agencies and the private sector would be examined. The potential to use techniques and approaches commonly applied by businesses and private-sector groups would be explored.

- Explore technologies and techniques for improving current data collection methods and explore future strategies and techniques for data collection. The first part of this study would focus on assessing approaches for improving current methods of collecting, archiving, and analyzing transportation data. Case studies of public agencies and private-sector groups that have been able to improve on current techniques would be highlighted. The second part of the study would explore future techniques and strategies for data collection. The ability to utilize advanced and emerging technologies as well as innovative strategies would be examined. The costs associated with different strategies, alternative management approaches, techniques for building participation among multiple public agencies, and partnerships with businesses, shippers, and other groups would be examined. The most promising technologies and strategies would be identified, along with possible demonstration projects to advance their deployment.

- Examine how current applications of visualization techniques, including GIS, and emerging visualization techniques are used in displaying performance measures. The initial phase of the study would identify current visualization tools used by state DOTs, transit agencies, and other public-sector groups to display the results of performance measures. Case studies of best practices would be presented. This phase of the study would also identify methods for promoting the use of visualization at public agencies. The second phase of the study would explore the potential application of emerging visualization techniques. Technologies and techniques that appear most feasible would be identified, and possible pilot projects would be described.

Multiagency Performance Measures

Conduct a more detailed assessment of multijurisdictional, multimodal performance measures programs. This study would identify how current programs are organized and operated and describe how the information on network performance is used in decision making. It would also explore new methods and techniques for data collection and analysis that could enhance multimodal performance measures. New and improved methods for measuring network corridor performance would be identified. The various institutional arrangements

used to support current performance measures for multimodal corridors would be examined, and approaches for enhancing multiagency coordination and cooperation would be described.

Asset Management

- Survey various transportation agencies' use of asset management in both the public and private sectors. The project would document current best practices and provide tips on how to implement asset management within all types of agencies. Asset management within public transportation agencies would be a major focus. One product from the project would be a guidebook outlining the steps for developing, implementing, and maintaining an asset management program.

- Develop and provide training on the use of the asset management guidebook developed in the previous research project. The training would include both classroom and online applications. Special attention would be given to training for transit agency personnel. Training sessions, workshops, and online courses could be offered in coordination with scheduled activities of agencies and organizations.

Emergency Management Performance Measures

Explore how performance measurement can improve emergency management and preparedness. The project would identify current performance measures for emergency management that are used by state DOTs, transit agencies, MPOs, and other agencies. It would also explore performance measures for emergency management that are used by the private sector. Examples of best practices would be documented. Approaches for developing performance measures for emergency management would be presented, along with data needs, measures of effectiveness, and techniques for presenting the information to technical staff, policy makers, and the public.

Public–Private Partnerships

Review performance measurement for public–private partnerships. This study would document performance measures used by state DOTs, transit agencies, and other public agencies with public–private partnership projects. Case studies of best practices would be presented, along with the advantages and limitations of different approaches.

APPENDIX A

Poster Summaries

Twenty-two posters were presented at the conference in an interactive poster session. The poster authors were available during the session to discuss key elements of the projects and to answer questions. The summaries prepared and submitted by the poster authors are presented in this section by topic, in the order in which they were listed in the conference program. Not all authors provided summaries. The posters were listed in the program by the following topic areas: data collection and analysis, performance-based decision making, new approaches to livability and economic and transit performance, and freight.

DATA COLLECTION AND ANALYSIS

REGIONAL MOBILITY CORRIDOR ATLAS

Mike Hoglund, Deena Platman, and Matthew Hampton, *Portland Metropolitan Government*

The Regional Mobility Corridors Atlas was conceived as a way to visually present the integrated mobility corridor concept developed for the Portland, Oregon, metropolitan region. This concept emerged from the region's latest long-range transportation plan as a new approach for advancing multimodal mobility for people and goods in the region. A mobility corridor encompasses the network of freeways, arterials, high-capacity transit lines, frequent-service bus routes, freight and passenger rail lines, and multiuse paths and the land uses they service. The function of these corridors is to facilitate travel

between different parts of the region and, in some cases, to connect the region to the remainder of Oregon and beyond.

The atlas displays current land use and multimodal transportation data for each of the region's 24 mobility corridors. It was designed as a tool that would enable decision makers and planners to easily understand existing system conditions and identify needs for different parts of the region. For each corridor, the atlas provides a general overview that includes location in the region, primary transportation facilities, land use patterns, and an assessment of gaps and deficiencies for different travel modes. The structure of the atlas allows for the comparison of data for different mobility corridors and provides the ability to merge multiple corridors for a broader analysis. The atlas also serves as a tool for monitoring the effectiveness of different land use and transportation strategies in achieving desired outcomes over time.

For each corridor, the atlas presents a series of maps showing the corridor's geographic location, transportation facilities, land use patterns, and current operational attributes. The maps are accompanied by short explanatory narratives, data tables, and a "quick facts" sidebar. Atlas data were generated from Oregon Metro's Regional Land Information System, the Regional Travel Forecast Model, the Oregon Department of Transportation's bridge inventory, and the 2035 Regional Transportation Plan. An atlas user's guide describes each map to facilitate usability for the reader.

Completed in spring 2010, the atlas document was broadly distributed to Metro's regional partners to aid local planning activities. Metro designed a web page

for easy viewing and downloading of Atlas data: <http://www.oregonmetro.gov>.

AGGREGATED PERFORMANCE MEASURES FOR INTERDEPENDENT ASSETS

Mohammedsaied Dehghanisanij and Gerardo Flintsch, *Virginia Institute of Technology*

This poster evaluates the strengths and weaknesses of different approaches to measuring the performance of interdependent assets. For example, the index approach aggregates components or alternative system data into a single measure; another method involves the use of an infrastructure system's unique but possibly correlated measures for components—that is, assets. These various approaches to performance measurement pertaining to interdependent assets were studied to develop a generalized framework that would be able to measure the performance of a system consisting of multiple components that work together to provide service as infrastructure.

The framework was used in a simplified case study to measure the performance of a highway corridor on I-81. The assets evaluated in this case study were limited to pavement and bridges. The performance indicators evaluated were associated with the functional and structural condition of the highway. The data and information were collected by the Virginia Department of Transportation. The poster demonstrates how this framework provided integrated performance measures for the corridor in a more enhanced way than an index approach. The poster also emphasizes this model's capacity to be generalized for other infrastructure systems and to incorporate more assets.

MEASURES OF EFFECTIVENESS AND COLLECTION IN THE SIMULATED INTELLIDRIVE ENVIRONMENT

Ramkumar Venkataranya, Noah Goodall, and Brian Smith, *University of Virginia*

Wireless communication between vehicles and the transportation infrastructure will provide significantly more timely and comprehensive information about arterials and their performance. However, most measures of effectiveness were developed on the basis of data available from traditional point sensors. The information made available with vehicle-to-infrastructure wireless communication, referred to here as “connected vehicles,” requires new metrics that can fully utilize the data.

This research identified several new arterial performance metrics made available with connected vehicles, as well as several existing metrics that can be evaluated

more accurately and frequently than before. The new metrics are person-delay, sudden deceleration, change in lateral acceleration, and aggregate regulation compliance. Person-delay is the measure of a vehicle's lost time multiplied by the number of passengers; it allows for more efficient movement of high-occupancy vehicles and sophisticated transit signal priority. Sudden deceleration and change in lateral acceleration are measures of activities such as unexpected braking and swerving, which may be leading indicators of unsafe conditions. Aggregate regulation compliance detects information on unsafe driving behavior, including speeding and illegal U-turns, that is difficult to collect in the field.

Engineers can address problem areas through signal timing changes, traffic calming, and other measures. The proposed metrics all require high-resolution detection and are difficult or impossible to measure with existing point detection. The compatibility of each new metric with existing standards is discussed, and the required SAE J2735 DSRC Message Set Dictionary data elements for the metric are identified.

PERFORMANCE-BASED DECISION MAKING

USING RISK AS A BASIS FOR PROJECT PRIORITIZATION AND PERFORMANCE TARGET SETTING

John Patrick O'Har, Adjo Amekudzi, and Michael D. Meyer, *Georgia Institute of Technology*

This research examined risk assessment and risk management at transportation agencies with regard to project prioritization and setting performance targets. Because transportation asset management (TAM) systems are already in place at many transportation agencies—particularly larger agencies such as state departments of transportation—these systems can be used as a platform for incorporating risk into project prioritization and the setting of performance targets. Transportation agencies are at various stages in the implementation of TAM systems. Some agencies—particularly several international agencies—are quite advanced. For example, all of the international agencies examined in the Federal Highway Administration (FHWA)–American Association of State Highway and Transportation Officials 2005 international scan tour practiced some degree of risk assessment in some areas of their TAM processes; furthermore, all of the agencies used the concept of risk to establish investment priorities (1). A 2006 domestic scan tour in the United States identified best practices in TAM (2); at that time, there was little evidence of risk being used

in TAM. Again, several of the few agencies that have applied risk assessment methods have done so when conducting scenario analyses. Different scenarios that are projected to result from different levels of funding are typically presented.

Perhaps the most common use of the term “risk” as it is applied to transportation infrastructure refers to the risk of failure of a transportation infrastructure asset. However, this risk of failure is not well defined, as performance targets for transportation infrastructure condition are not standardized (3). The objectives of this research were to review approaches being used to enhance TAM decision making and to demonstrate the value of addressing uncertainties by comparing the results of bridge prioritization in which uncertainties were addressed with those in which uncertainties were ignored. This poster presents a discussion on risk approaches being used to enhance TAM decision making and the preliminary results of a comparative study on project prioritization with and without risk considerations. Some of the preliminary results of this research are from prioritization scenarios developed by using multiattribute decision-making methods and data from the National Bridge Inventory (NBI) and the Georgia Department of Transportation. A final product of this research will be a case study in which several scenarios that incorporate uncertainty are compared with deterministic scenarios to demonstrate the effect that addressing uncertainty has on prioritization outcomes.

Risk-based decision making typically describes a systematic process that evaluates uncertainties, develops policies based on these uncertainties, and addresses the possible consequences of these policies (4). Risk is defined as the probability that a negative event will occur, and the severity of the consequences of this negative event are estimated (1, 5). Although closely related to risk, uncertainty carries a different meaning. Uncertainty is an inherent component of the decision-making process when choices are made on the basis of incomplete knowledge (5).

Risk assessment, which refers to the scientific process of measuring risks in a quantitative and empirical manner, usually precedes risk management (4, 5). Risk management is a qualitative process that involves judging the acceptability of risks (4) within any applicable legal, political, social, economic, environmental, and engineering considerations (5). Decision making for various engineered systems will benefit from risk assessment and risk management. Safety factors applied to various engineered facility designs are an attempt to address uncertainties.

Aktan and Moon emphasized the importance of performance monitoring in an effective asset management system and presented specific steps that are necessary for performance-based asset management (6). In this sort of asset management framework, prioritization is driven by

the risk of failure, or nonperformance. Ultimately, these steps would provide an asset management framework that identifies critical assets; the risk of nonperformance of these assets should be minimized.

Scenario analysis, also known as scenario planning methods or scenario assessment, is a collection of tools that can be used to evaluate risk and uncertainty (5, 7). The alternative that provides the greatest benefit, is the most cost effective, and has minimal risk is usually the best alternative. A scenario analysis serves as a means of evaluating different alternatives in project development. It is not a forecast, nor does it calculate the specific probability that a given event will occur (5).

Program optimization, also referred to as “project prioritization,” is another component of the asset management process that typically incorporates some level of risk assessment techniques. These prioritization techniques can be used at a number of different levels in the asset management process, ranging from a broader network level to a more specific project level. Project programming, or project selection, involves analyzing a range or combination of alternatives to determine which is the best investment. This process usually involves scenario analysis, which presents decision makers with trade-offs between different alternatives (7).

Probabilistic models account for risk by taking uncertainty into account (5, 7). These models use statistical methods in which mathematical functions of decision-making factors are developed. Uncertainties of the model inputs are calculated by using probability distributions and statistical parameters such as the coefficient of variation and the mean. The uncertainties associated with the input variables, such as variation in user demand, need to be estimated to conduct a probability-based risk assessment.

There are several examples of risk applications in TAM systems at the local, state, and national levels in the United States and Canada. For example, the City of Edmonton, Alberta, Canada, places infrastructure assets into various risk severity zones (8). Another example includes an analysis of past NBI ratings that was done for the Louisiana Department of Transportation and Development to predict bridge system preservation needs (9). Dabous and Alkass developed a method for ranking bridge projects on the basis of multiattribute utility theory (10).

Several different methods can be used to prioritize bridge projects, including benefit–cost ratio analysis, the California Department of Transportation’s Bridge Health Index (11), and FHWA’s sufficiency rating formula (12). Another example is a framework developed by Cambridge Systematics that can be used to prioritize bridge inspections or to minimize the risk of service interruption (13). Risk can be incorporated into TAM in various areas to achieve different objectives. Another feature of the frameworks highlighted above is that decision-maker

input is a factor. This input is valuable because, as mentioned in the international scan, risk assessment can be used as a way to inform and garner support from elected officials (2).

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NEW APPROACHES TO LIVABILITY AND ECONOMIC TRANSIT PERFORMANCE

APPLYING SUSTAINABILITY THROUGH PERFORMANCE MEASUREMENT

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Virginia Reeder and Joanne Potter,
Cambridge Systematics

This poster showcases ongoing research under National Cooperative Highway Research Program Project 08-74, A Guidebook for Sustainability Performance Measurement for Transportation Agencies. The goal of this project is to develop guidance that will help state departments of transportation and other agencies understand and apply concepts of sustainability through performance measurement.

Increasing attention is being given to the topic of sustainability, which is concerned with providing a balanced approach to social, economic, and environmental issues while considering both the present and future needs of society. Transportation, as a major consumer of fossil fuels and a major generator of emissions, is an important concern from the perspective of sustainability. However, the application of the concept of sustainability by transportation agencies is often limited by agencies' understanding of what sustainability means and how it can be integrated into their regular functions. The concept of performance measurement can help transportation agencies understand and apply sustainability. Understanding what sustainability means is the first step to being able to apply a framework for it.

This research posits that the concept of sustainability goes beyond the transportation sector and is reflected in general, nonnegotiable principles. These general principles of sustainability are made operational with respect to the transportation sector in the form of 11 goals that cover a range of sustainability concerns within the sphere of influence of transportation agencies. The goals developed in the framework are broad and generally applicable to the entire transportation sector.

Goal-specific objectives are used to define how each goal can be applied to different aspects of the transportation agency's functions. Objectives are more specific and measurable and lay the foundation for performance

measurement with measures that can be tied directly to the objectives. This framework uses a set of focus areas to classify and describe the broad functions of a transportation agency in support of its core mission and functions. The objectives for each goal are developed on the basis of the focus area.

The development of performance measures is closely linked to the development of objectives, and many of these measures are a small shift to help quantify each objective. Ideal performance measures are easily understood, provide clear indication of moving toward an established goal, and can be tracked with accessible and available data. The implementation of performance measurement is the final step in applying the framework. This step involves refining selected performance measures and quantifying or applying the measures for various purposes, such as description, evaluation, decision support, accountability, and communication.

The research products include a user-friendly guidebook, a detailed project report, and an electronic compendium of performance measures. These measures can be applied and adapted for transportation agencies, including state departments of transportation and metropolitan planning organizations, and can help further the use of performance measures for a difficult-to-measure area like sustainability.

This poster presentation includes

1. Highlights of case studies conducted and other general findings,
2. The framework for sustainability performance measurement developed as part of this research,
3. Mock-ups of the user-friendly guidebook, and
4. Demonstration of an electronic application containing a compendium of performance measures with various usability features.

MEASURING THE IMPACT AND PERFORMANCE OF TRANSPORT RESEARCH PROGRAMS

David E. Kuehn, *Federal Highway Administration*

Effective research is critical for meeting emerging transport challenges. Research, however, is difficult to measure. There can be significant time lags between the conduct of the research and the return on the investment. Further impacts can be diffused and may accrue to unexpected parties who build on the work of others.

The Federal Highway Administration's Exploratory Advanced Research (EAR) program has been developing a suite of measures for monitoring and improving the overall performance of the program portfolio and predicting the potential impact of research (1). The EAR program uses different measurements of performance to provide a bal-

anced scorecard for day-to-day program management and communication of results to internal and public stakeholders. This brief paper provides information on EAR program measures and background on the search for appropriate program measures that could suggest approaches for other transport research programs. Many examples of transportation research program measurement are limited to process management, measurement of outputs, and some indirect measurement of value or impact.

Common measures include projects started, projects in progress, projects completed, products developed, adherence to budget, and adherence to schedules (2, 3). Similarly, university transportation centers report process and output measures, including projects funded, reports issued, papers presented, and personnel participating in research.

An examination of research measurement outside of transportation still provides limited examples of effective measurement of program impact (4). Federal agencies and programs have been engaging in performance measurement at least since the passage of the Government Performance and Results Act of 1993. Research, however, has been a particularly difficult area for developing performance measures.

Federal guidance allows research programs a pass on quantitative performance and suggests that expert review continues to be the most effective method for assessing research (5–9). The guidance, however, does go further by suggesting that programs review performance in three areas:

1. Relevance to an agency's mission, assessed with methods such as prospective and retrospective reviews by independent experts, regular review by primary customers, published multiyear program plans (or road maps) with clear goals and priorities and regular updates, clear articulation of potential public benefits, and stakeholder involvement throughout the process;
2. Research quality, assessed directly through retrospective reviews by technical experts and indirectly through competitive, merit-based allocation of funding; and
3. Performance, which could be assessed on the basis of annual retrospective documentation (performance report), cost-benefit analysis, benchmarking, and expressing the public benefits of results.

A federal research program that included a clear measure of impacts was the Advanced Technology Program of the National Institute of Standards and Technology (NIST) (10, 11). The program, which was designed to accelerate private-sector high-risk and innovative research, conducted a retrospective survey of applications over the history of the program. This survey included both applicants that received awards and those that did not to assess whether awards resulted in a new direction for the company,

changed the company's estimate of risk, or resulted in economic benefit, including impact on revenue and size of the market. Although the retrospective survey was designed to assess the impact of the program, it began with about 900 potential companies that had been involved with the program over the course of more than 5 years—an evaluation effort in both cost and time that would be difficult for many transportation research programs to replicate.

For the EAR program, the development of program measurement began by scanning measures commonly used by other transportation agencies' research programs as well as those used in other federal programs with a focus on engineering research—that is, NIST, the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the U.S. Army Corps of Engineers. The intent of program measurement was twofold: to report program value to critical stakeholders and to improve program management.

As with many research programs, measurement issues for the EAR program included finding an appropriate scale of effort and maximizing the use of available data. Discussions with internal and external stakeholders led to the development of baseline and target measures from an initial set of possible measures. The EAR program currently is refining measures that reflect the quality and availability of program data.

To report results, the EAR program adopted a balanced scorecard approach that aligns measures under four perspectives: the financial perspective, the customer perspective, the perspective of internal business processes, and the perspective of innovation and learning (12).

With regard to the financial perspective, the EAR program sought measurements that could respond to the question, "How efficient does the program appear to Congress and leadership?" Congressional and leadership inquiries frequently focus on efficient and effective use of program resources. Two measures that demonstrate good stewardship of program resources are the percentage of funds awarded to research and the amount of matching nonfederal funds by sector. Neither of these measures nor any other measure that the EAR program considered provides clear information on program impact from the financial perspective because of the long time scale and diffused return on investment in research.

With regard to the customer perspective, the EAR program sought to answer the question, "How does the program appear to internal and external customers?" One important customer segment is the teams that have the ability to conduct the research, and they are interested in the yield rate, or percentage of applicants who receive awards. Other customers, both internal and external, are interested in how the program supports research in different national strategic areas (e.g., safety, mobility, and environmental stewardship), so the program is developing the measurement of project results by goal area. With the development of a persuasive logic chain, the program

should be able to imply impact in advance of retrospective review that could not take place until 5, 10, or more years after projects are completed.

With regard to the perspective of internal business processes, the EAR program addressed the question, "In which process should the program excel?" One area of concern was overlooking potential areas of science or engineering that could have a dramatic impact on the transportation industry. Accordingly, the EAR program promotes breadth with depth, scanning a large number of topics through initial-stage investigations and then filtering results to find a limited number of topics in which to invest in multiyear research. To monitor the breadth of the initial investigations, the program developed and is refining a measure of initial-stage investigations by program focus area. Another critical EAR program element is ensuring access to and use of research results. Rather than follow a typical outcome measure such as the number of papers published—which is important for providing information about research results—the EAR program is developing a measure for tracking the percentage of topics that gain follow-on funding from other sources. The EAR program believes that this is better validation that results are being used.

With regard to the perspective of innovation and learning, the EAR program asked the question, "Where should the program improve and change?" To answer this question, the EAR program is tracking new personnel involved in the program—an indication of increased internal research capacity—and topics that involve multiple offices—an indication of increased capacity to work across traditional disciplines. Under development, the EAR program is seeking a measure of projects that lead to the closure of persistent knowledge gaps, result in new fundamental data, or significantly change current understanding.

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SUSTAINABLE COMMUNITIES: MEASUREMENT FOR MANAGEMENT

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A new generation of transportation performance measures is taking root in regional and local government

agencies, including metropolitan planning organizations (MPOs), and city and county governments. This shift is driven by a broader interest in generating sustainable development outcomes. To manage growth and development sustainably, agencies require a comprehensive set of performance measures along with a robust measurement approach.

Although the previous generation of transportation performance measures was limited to traditional transportation objectives, including maximizing throughput and minimizing delay, the new generation is far broader. It includes measures related to environmental preservation (such as greenhouse gas emissions and land consumption), quality of life (such as bicycle and pedestrian level of service and location efficiency), and multimodal access (such as access to employment and access to transit).

The importance of sustainability in transportation decision making is highlighted by the interagency Partnership for Sustainable Communities (the Partnership). On June 16, 2009, the U.S. Environmental Protection Agency joined the U.S. Department of Housing and Urban Development and the U.S. Department of Transportation in this partnership, whose goal is to improve access to affordable housing, provide more transportation options, and lower transportation costs while protecting the environment in communities across the United States. Subsequently, the Partnership announced the availability of \$100 million in grant funding for regional integrated planning exercises. Grant recipients will be expected to adhere to the livability principles developed by the Partnership.

This poster provides an overview of four broad types of sustainable performance measures that support the objectives of the interagency Partnership. Each measure can be represented in a variety of metrics. Some measures are appropriate for MPOs to use in designing and selecting long-range transportation plan alternatives. Some metrics are appropriate for individual communities wishing to measure their progress toward sustainable goals.

The four measures presented are

- Transit-accessible homes and jobs,
- Household transportation costs,
- Preserving open space, and
- Promoting alternative modes over single-occupancy vehicles.

For each measure, the poster provides several examples of metrics. Data needs and measurement challenges are also discussed. Calculation requirements, including modeling tools and input data, can vary substantially from metric to metric. Policies that can affect the outcome of metrics are described. For each measure, one or more examples of an MPO that has applied the measure in the long-range transportation planning process is provided.

PERFORMANCE-BASED METRICS: THE RIDER'S PERSPECTIVE

Janice S. Wells and Ellyn Shannon, *Permanent Citizens Advisory Committee to the Metropolitan Transportation Authority (New York)*

This research by the Permanent Citizens Advisory Committee (PCAC) to the Metropolitan Transportation Authority (MTA) of New York investigates performance metrics presented by the operating agencies of the MTA and makes recommendations for improvement or adjustment, with an eye to better capturing impact on riders. PCAC represents the interests of the riders of the nation's largest public transportation system and comprises three rider councils that were created by the New York State Legislature in 1981: the Long Island Rail Road (LIRR) Commuter Council, the Metro-North Railroad (MNR) Commuter Council, and the New York City Transit (NYCT) Riders Council.

The genesis of this study arose from commuters expressing skepticism at some of the on-time metrics presented by LIRR (Figure A-1). PCAC began investigating the data used in the computations, and it became clear that trains had impressive on-time percentages but that the time delay that riders experienced from canceled trains was not being captured. A 3-month analysis of

LIRR delay data revealed that although a canceled train was counted as late, the added 20- to 30-minute delay for a rider who was forced to wait for the next available train was never captured. To inform board members, riders, and the general public about the frequency of delayed and canceled trains and their impact on passengers, PCAC asked LIRR and MNR to place these statistics in the MTA Board Committee Book and on the MTA website in a searchable database. The railroads implemented this request in September 2010.

In light of these initial findings on canceled trains, PCAC decided that a more in-depth study of metrics at all three MTA agencies might lead to

- Development of true on-time performance measures for passengers,
- Identification of the magnitude of passengers affected by delays and canceled trains, and
- Better linkage of capital investments to improvement in passenger service.

This inquiry included a literature review; a review of the history of metrics at MTA and current performance measures; a comparison with metrics at other leading transit agencies, as displayed on their websites; and a discussion of how the Capital Program relates to better service.

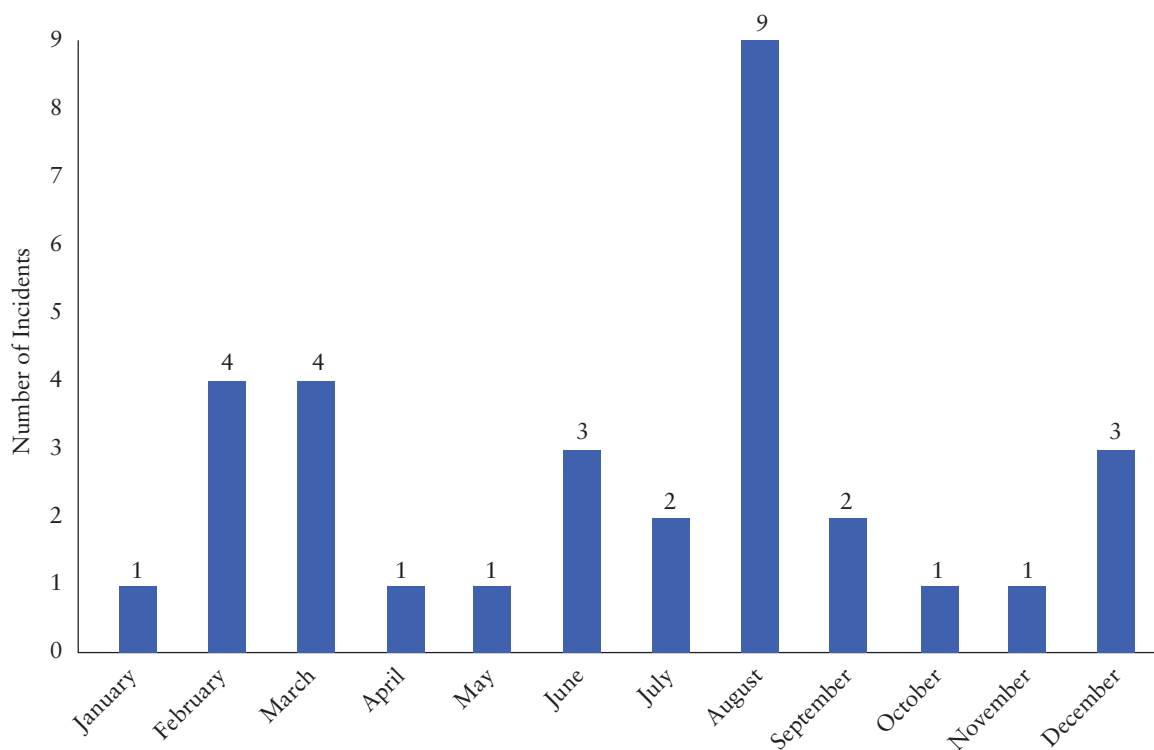


FIGURE A-1 LIRR megadelays: Is this 95.2 percent on-time performance? (NOTE: A megadelay is an incident that causes 50 trains or more to be delayed. The impact of the Hall Tower Fire lasted 9 days, and more than 50 trains were delayed or canceled each day; therefore, each day of this event is considered an incident in August.)

Findings

MTA and its operating agencies provide some of the most transparent and detailed operational metrics among U.S. transit agencies, and this information is readily available on the MTA website. No major commuter railroad comes close to the level of operational performance disclosure at MNR and LIRR. In addition, NYCT is to be lauded for the improvement of its performance indicators over the past 15 years, particularly the implementation and refinement of its wait assessment metric. Yet, a true passenger-based on-time metric still eludes MTA. Further, the effect of terminated and canceled trains on the commuter railroads—the magnitude of riders that are affected by delays and the resulting economic impact of lost work time—has yet to be captured.

Finally, despite the high level of disclosure, MTA's operational metrics are often omitted in discussions of capital investments and the impact they will have on reducing slow, delayed, and canceled trains. The average rider does not necessarily understand what new interlockings, switches, and signals are, let alone appreciate how the improvement of these things will enhance his or her commute.

Recommendations

1. MTA should continue to foster investment in operational and measurement technology, as new technology is providing the means for refining and improving both performance and performance measurement.

2. LIRR and MNR should place their ridership books, which contain average train ridership by specific train, on the MTA website in a searchable database. With these data, the number of LIRR and MNR passengers on board each delayed and canceled train could be estimated. Researchers should be encouraged to use these data to model the economic impacts of delayed and canceled trains on workers and employers.

3. For improved transparency, LIRR and MNR should change their categories of delay in the MTA Board Committee Book from categories that relate to departments responsible (as is currently done) to categories that reflect the actual reason for the delay.

4. In the same vein, NYCT should define what factors constitute a major delay in the subway system and identify them each month in the Transit Committee Book by line(s), cause, number of trains, and length of time the trains were delayed. Currently, no information on major system delays is provided to the public.

5. Online performance databases for NYCT subways and buses should be searchable and available to developers of software applications. Currently, the MTA website has no searchable databases of subway or bus performance that provide information on wait assessment.

6. NYCT should consider describing the wait assessment metric in more user-friendly terms for the general public. As currently presented, NYCT's wait assessment percentage means little to the average rider.

7. LIRR and MNR should strive to develop a canceled train delay factor—that is, the time until the next train arrives or the actual wait time for a rescue train or bus. This factor should be included in the average-minutes-late metric. What happens to riders in the case of a canceled train should be a matter of record. If in-house resources are not available, outside sources, such as academic researchers, should be contracted to develop a methodology for capturing the true impact of a canceled or terminated train.

8. LIRR and MNR should strive to develop a true passenger-based on-time performance metric for the morning peak period to closing that incorporates a canceled train delay factor. Again, if in-house resources are not available, outside academic researchers would be a good choice for tackling this analysis.

ECONOMICS OF RETURN ON INVESTMENT: EVALUATING THE LIFE CYCLE TO DRIVE PERFORMANCE

Nathaniel D. Coley, Jr., *Federal Highway Administration*

Public and private organizations have given advice on the level of investment required to maintain and restore the transportation system in the United States to a safe and economically competitive level. A limited budget for addressing transportation needs has also been a common circumstance. This poster presents a practical approach to managing transportation assets through return-on-investment analysis. The approach uses established software tools and existing data sources to estimate expected trends in network performance. Project-level investment candidates are then identified to address these trends. Economic analysis processes such as benefit–cost analysis and life-cycle cost analysis are used to determine the mix of actions that would maximize the returns from available budgets.

EVALUATING INVESTMENT NEEDS AND PROJECTING SYSTEM PERFORMANCE WITH THE HIGHWAY ECONOMIC REQUIREMENTS SYSTEM

David M. Luskin, *Federal Highway Administration*

The Highway Economic Requirements System (HERS) model projects the overall conditions and performance of the highway system at alternative potential levels of

investment in highway preservation and capacity. The model is designed for use with data from the national sample of highway sections in the Highway Performance Monitoring System (HPMS). Potential improvements to individual sections are identified according to engineering criteria and then evaluated with a cost-benefit analysis that considers potential savings in the costs of travel time, vehicle operation, crashes, emissions, and highway maintenance.

Analyses based on HERS inform congressional deliberations on the highway federal-aid program and underpin the highway portion of the biennial report to Congress *Status of the Nation's Highways, Bridges and Transit: Conditions and Performance*. In the 2008 edition of this report, needs for investments in highway preservation and capacity were evaluated for the 20-year period from 2007 to 2026. Over this period, the investment required to implement all cost-beneficial improvements was estimated to average \$115.7 billion per year in 2006 dollars; the actual investment in 2006 was \$48.2 billion. The projected 20-year change in average delay per vehicle mile of travel was a decline of 8.5 percent at the higher of these investment levels versus an increase of 11.0 percent at the lower level.

The HERS analysis for the conditions and performance report also indicated that implementation of economically efficient congestion pricing would substantially reduce preservation and capacity investment needs. The HERS model is continuously undergoing refinement, including work in progress to improve the prediction of pavement performance.

In response to state needs for a data-driven tool to support decisions regarding needs assessment, performance management, and program development, the Federal Highway Administration (FHWA) developed a version of HERS for state and local agency use: HERS-State Version (HERS-ST). During the development of HERS-ST, the state agencies played a major role in making the tool more user friendly and applicable for state use; subsequent upgrades of HERS-ST have been performed by a partnership of FHWA and selected state agencies.

Twenty-one state agencies and several local government agencies and planning organizations have used HERS-ST for various applications. The most common uses have been reporting and evaluating highway system performance and estimating needs for investment in highway preservation and capacity as an input to long-range planning. Transportation agencies have also used the model to examine the impacts of investment level on highway condition and performance; such analysis can support the setting of performance targets in a fiscally constrained environment. Although the data input to HERS-ST must conform to the format in the HPMS sample, some transportation agencies supplement the

HPMS-required sample with additional highway sections on which they collect data to support corridor- and regional-level applications of HERS-ST. Additionally, given the cost-benefit analysis capability of HERS-ST, some agencies use the tool to evaluate programmed projects. Like the HERS model, HERS-ST is being refined to better serve transportation agencies in supporting performance management and resource-allocation decisions. The new HPMS data input format is currently being incorporated into HERS-ST, as will be the new pavement performance prediction models currently being developed for HERS.

In summary, the engineering and economic analytics in the HERS and HERS-ST models support the evaluation of highway system condition and performance, investment scenarios, programmed projects, and the development of performance targets.

TOOLS AND METHODS

Jamie M. Fischer, Adjo Amekudzi, and Michael D. Meyer, *Georgia Institute of Technology*

The field of performance management in transportation is rapidly evolving and many faceted. Guidance, case studies, and tools representing the state of the field in performance measurement, target setting, and performance management are abundant but are also spread out across a wide range of literature. This presentation gives an overview of the *Performance Management Resource Catalog*, which is being developed to provide easier access to existing performance management resources. The catalog is being developed by the Georgia Institute of Technology as part of a project on best practices in performance management sponsored by the Georgia Department of Transportation.

The *Performance Management Resource Catalog* compiles and categorizes various resources on performance management into a collection of seven color-coded sections, each of which groups and tabulates resources according to a common theme of performance management. Each section further categorizes resources by topic within its theme and provides separate subsections for guidance, case studies, and tools according to topic. The seven thematic sections are as follows:

Section 1. Strategic Planning (yellow): Strong performance management programs are linked to strong strategic plans. Specifically, performance measures and targets are the tools with which an agency can track progress toward its strategic goals and objectives. This section lists resources for creating focused strategic plans. Its topics include definitions for performance-based planning, visioning, and how to set goals and objectives.

Section 2. Performance Measures (orange): Appropriate performance measurement will help an agency focus its data collection efforts on collecting the information that is most relevant to tracking progress toward strategic goals. This section lists resources for the design of simple, measurable, and actionable performance measures. The topics include how to select and organize measures step by step; specific measure formulations for outputs such as infrastructure condition and system efficiency; specific measure formulations for outcomes such as accessibility and environmental, economic, and community impacts; and how to deal with attribution issues—that is, the question of how much of a measured outcome can be attributed to agency actions. This is the largest section of the catalog.

Section 3. Performance Targets (red): Performance targets provide short-term mile markers along the road to achieving strategic goals. This section lists resources for setting targets that are both achievable and ambitious and thus helps an agency to make visible progress within a constrained budget.

Section 4. Funds Allocation and Programming (green): Performance-based resource allocation makes targets achievable; it lends consistency and accountability to agency processes. This section lists resources to help an agency make efficient use of a constrained budget. Topics include innovative funding sources and how to set priorities for project selection.

Section 5. Organizational Structure (light blue): The success and longevity of a performance management program depend on an organizational context that supports and sustains the program. This section provides resources for creating such a context and deals with topics of both intraagency structure and interorganizational cooperation.

Section 6. Data (dark blue): High-quality performance measures can only be effective with high-quality data. This section provides resources for developing robust data collection, analysis, and management processes. Topics include how to structure data collection responsibilities, what types of data are needed for different types of measures, and how to link condition data to performance information.

Section 7. Communication with Stakeholders (purple): A successful performance management program will gradually increase the transparency and accountability of transportation decision making. This is accomplished primarily through the various means of communication with both internal and external stakeholders. Topics in this section include how to build relationships with legislators, how to strengthen trust with customers (system users), and how to increase employee buy-in to the performance management program.

The *Performance Management Resource Catalog* provides a tabulation of the various resources on transportation performance management. Each table entry provides information in four columns: (a) whether the resource offers guidance, case studies, or tools; (b) the topic within the theme; (c) the document in which relevant information can be found; and (d) the relevant page numbers within that document. Many relevant resources may be listed for a given topic, in which case the most recent resource is listed first. Additionally, the same resource may appear in several sections if it is relevant to multiple topics. This method is used so that practitioners can easily search for resources by topic. Transportation agencies will be able to use the catalog as a basis for accessing the appropriate resources as they refine their performance management programs.

USE OF A MAINTENANCE INVESTMENT NEEDS ASSESSMENT TOOL TO INCORPORATE PERFORMANCE MEASURES INTO BUDGET DECISION MAKING AT THE VIRGINIA DEPARTMENT OF TRANSPORTATION

Thomas Jeffrey Price, Wenling Chen, and Larrie Henley, *Virginia Department of Transportation*

A maintenance and operations (M&O) needs assessment tool was recently developed at the Virginia Department of Transportation (DOT) to support budget decision making for traffic signal and intelligent transportation system (ITS) assets. The tool estimates M&O funding needs on the basis of service-level performance targets. Specifically, use of the tool allows the linking of varying funding levels to the corresponding work performance measures.

The tool provides an analytical framework with which users can compare various funding scenarios with different work performance targets. This framework also allows users to quantify and better understand the performance consequences of different maintenance investment strategies or decisions, especially in the current financially constrained environment.

Virginia DOT's System and Performance-Based Budgeting Approach

Virginia has approximately 57,000 centerline miles of roads and 20,000 structures. The Virginia DOT is responsible for more than 33,000 signals and ITS devices. In FY 2011, the department's M&O budget for signals and ITS assets was about \$90 million. Since FY 2006,

the Virginia DOT has adopted a performance-based approach to identifying M&O needs of many assets on the basis of inventory and condition. The improved data on inventory, condition, and performance-based needs led to a 10 percent increase (\$97.4 million) in FY 2006 M&O funding over the original planned allocation. The new approach has allowed a shift from an M&O allocation based on historical expenditure to one based on an objective, quantified needs and data-driven method for many assets.

The tool developed recently for traffic signals and ITS assets allows the linking of funding requirements to corresponding work performance measures such as frequency or extent of preventive maintenance, rate of responses to repair calls, and the extent of delays in life-cycle-based replacement. Figures 1 through 5 in the poster provide details on the analytical framework. Specifically, the tool calls three types of inputs for determining needs (Figure A-2):

1. Asset characteristics: component, quantity of a component per device, age, life expectancy, and replacement cost;
2. M&O work: work category, work definitions, frequencies, resource requirements, and unit cost of work; and
3. Performance criteria: objectives or targets behind the needs.

The tool allows assessment of needs related to the following work categories:

- Preventive maintenance,
- Repair,
- Replacement,
- Operating needs, and
- Miscellaneous needs such as payment to localities, which maintain their assets at the Virginia DOT's cost.

Incorporation of Work Performance Measures in Budgeting

The tool provides an analytical framework for linking different levels of work performance targets with their corresponding funding requirements. Typical performance targets incorporated in the tool include the frequency or extent of preventive maintenance, the response rate to repair calls, and the extent of delays in life-cycle-based replacement.

Figure 6, *a* and *b*, in the poster provides an example of two signal needs scenarios in which different targets for the extent of preventive maintenance performed, the extent of delays in life-cycle replacement, and optimization frequencies lead to different funding implications. Conversely, in a funding-constrained environment, the tool may also be used to demonstrate potential work

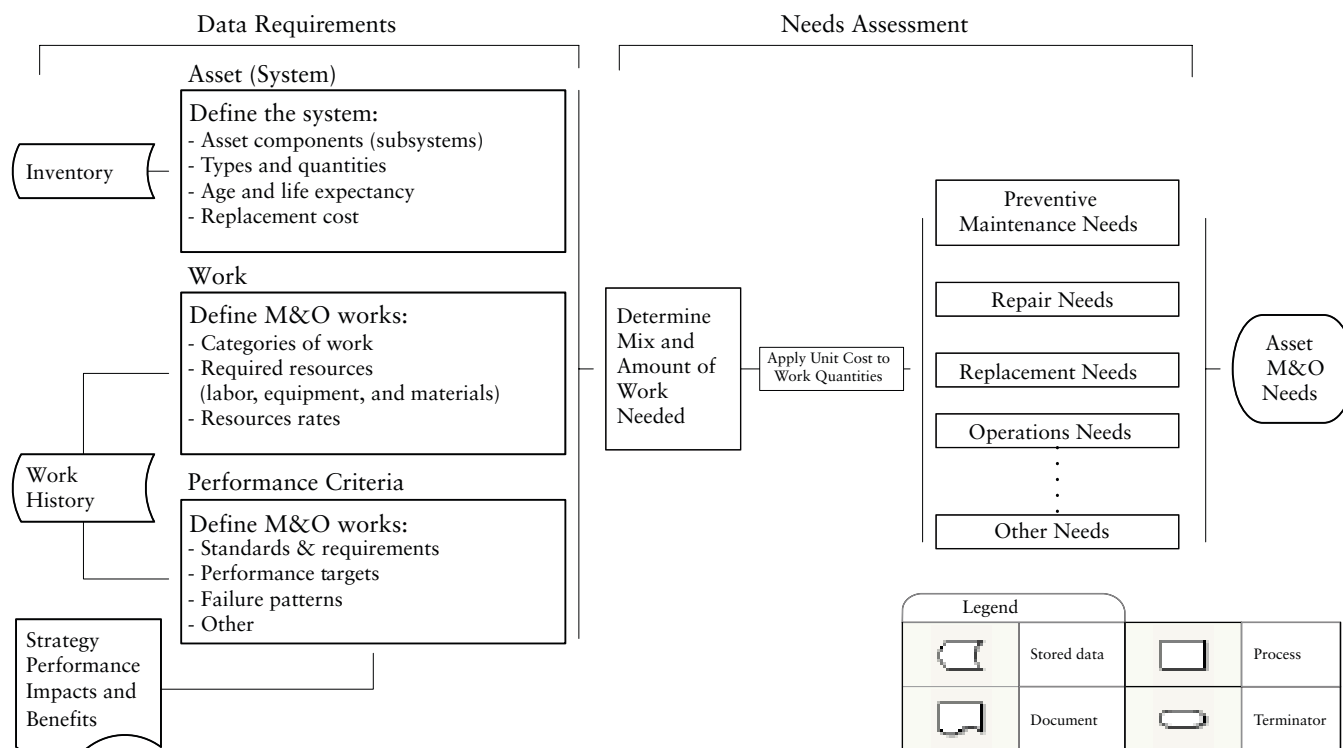


FIGURE A-2 Virginia DOT M&O needs assessment tool.

performance consequences associated with a reduced-funding scenario.

The M&O needs assessment tool has allowed users to compare funding scenarios with different performance targets. It has also allowed decision makers to better understand the performance consequences of funding decisions.

All opinions are the responsibility of the authors and do not necessarily reflect the official views of the Virginia DOT.

MEASURING TRANSPORTATION INFRASTRUCTURE PERFORMANCE FOR THE UNITED STATES

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The transportation infrastructure of the United States is understood to be the foundation for economic health and competitiveness. However, no study has taken a comprehensive quantitative look at infrastructure performance over time. Most of the past studies have focused on trying to correlate infrastructure expenditures, rather than infrastructure performance, with economic productivity. An ongoing project funded by the U.S. Chamber of Commerce Foundation has developed a transportation infrastructure performance index and related this index to economic growth and productivity.

Publicly available data for a representative sample of 36 metropolitan statistical areas (MSAs) were used in constructing the index. An iterative process was used to identify and select the indicators. In the first iteration, a set of indicators was identified on the basis of a literature review that included reports and websites. The second iteration involved an in-depth evaluation of the available data and the ease of data collection. The third iteration involved discussions with a small group of transportation academicians with expertise in air, freight, and transit. The experts suggested additional data sets and alternative measures. They also stressed the value of initiating discussion rather than seeking perfect indicators. In the fourth iteration, the U.S. Chamber of Commerce recruited stakeholders to participate in half-day meetings focused on understanding which aspects of infrastructure performance were important to businesses. The meetings were held in Chicago, Illinois; Atlanta, Georgia; Houston, Texas; and San Jose, California. The fifth iteration involved experts from U.S. Chamber of Commerce member organizations with transportation interests. These experts were asked to comment on the indicators, and adjustments were made as needed. Finally, the academic experts were invited to comment on the revised list, and further adjustments were made.

Twenty-one indicators representing supply, quality of service, and utilization for highway, transit, air, rail, and intermodal passenger and freight transportation were identified. Data for these 21 indicators were assembled for the period from 1990 through 2008. Although the process is replicable and transparent, the data have significant limitations, including varying levels of data aggregation; missing or incomplete and erroneous data; challenges involved in prediction and forecasting; and institutional issues related to ownership of and access to the data, changing data formats, and changing jurisdictional boundaries and names (1).

The index itself is constructed by normalizing the data and developing weights derived from the relative importance of the indicator as determined by the analytic hierarchy process and the relative contribution to the economy of each of the sampled MSAs. The calculated transportation performance index and 5-year moving average showed relatively little change over the past two decades, despite growing awareness of aging infrastructure, improvement in operations, and greater investment in infrastructure.

Relationships between per capita economic growth on the one hand and transportation infrastructure performance and foreign direct investment on the other have also been demonstrated. Specifically, a 1-point change in the transportation performance index increased gross domestic product per capita by 0.3 percent. The index was also shown to correlate with the American Society of Civil Engineers' report card for the period of 1998 to 2008—the period over which the two measures have similar inputs. Finally, the transportation performance index can play a role in communicating national needs and the importance of infrastructure.

Additional details may be found in the technical report documenting the construction of the index and the analysis of the results (2).

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FREEWAY PERFORMANCE INITIATIVE TRAFFIC ANALYSIS STATES

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This poster illustrates the methodology of the Freeway Performance Initiative, an example of performance-based decision making for analyzing the existing and future operating conditions of freeway corridors and identifying and prioritizing improvement strategies. The Metropolitan Transportation Commission (MTC) in Oakland, California, developed this methodology to assess major highway corridors throughout a nine-county region.

The performance measures used to analyze the corridors include

- Travel time or speed,
- Vehicle miles traveled or vehicle hours traveled,
- Delay,
- Reliability (buffer index),
- Length of queues, and
- Safety.

The poster shows how these measures are used to determine the causes of existing and future recurrent traffic congestion problems in the corridor and to identify the locations of freeway bottlenecks. The poster summarizes the analytical tools used, which include sketch-planning tools; travel demand models; tools based on the *Highway Capacity Manual*; traffic signal optimization tools; and macroscopic, mesoscopic, and microscopic simulation models.

The methodology steps are as follows:

- Calibrate the simulation models to existing conditions and use with travel demand models to project horizon year conditions.
- Develop mitigation strategies for alleviating the identified congestion problems. The proposed mitigation measures are segregated into short- and long-term implementation timelines. Mitigation measures include the following:
 - Capacity improvements such as widening and high-occupancy vehicle lanes;
 - Operational improvements such as auxiliary lanes and interchange modifications; and
 - Transportation management strategies such as ramp metering, changeable message signs, and closed-circuit television.
- Assess the identified strategies individually or as packages that group multiple strategies and projects together.
- Develop planning-level cost estimates of each strategy, broken out by capital and operations and maintenance costs.

- Evaluate the proposed congestion mitigation strategies and projects with benefit–cost analysis to arrive at a prioritized list of recommended strategies.

The methodology for the Freeway Performance Initiative was developed by MTC. It has been successfully applied in the San Francisco Bay Area to identify improvement strategies for multiple freeway corridors.

FREIGHT

PERFORMANCE MEASURES FOR EVALUATING MULTISTATE FREIGHT PROJECTS

Ernest F. Wittwer, Robert Gollnik, Jason J. Bittner, and Teresa M. Adams, *University of Wisconsin–Madison* and *Mid-America Freight Coalition*

Performance measurement for freight is a common topic of discussion, with travel speed and dependability being the two most commonly discussed measures. Safety, as expressed by crash numbers or rates or fatality numbers or rates, is another frequently suggested measure. Such measures are useful in examining the performance of a transportation system, and they can also increase understanding of the impact of an infrastructure improvement on freight productivity.

At a time when transportation officials are increasingly being asked to understand the regional nature of freight-related transportation facilities and projects, are travel speed, dependability, and safety the most appropriate measures? If so, how can they be used to understand how the benefits of an improvement to the system will be distributed to states or other political jurisdictions beyond the one that hosts the improvement?

These are the questions that this research attempted to answer. Investments in the built environment have only rarely been analyzed for their effect on economic development and on increased movements for freight. In many cases, the link between system improvements and system performance is anecdotal at best. The CREATE project in Chicago, Illinois, was used as a test case for understanding the measurable benefits projected to occur with the completion of the project. Improved travel time and enhancements in reliability and safety were three primary benefits documented by the project sponsors. Although a significant portion of those benefits will accrue to the Chicago metropolitan area and the state of Illinois, a large share will be enjoyed by the businesses located in surrounding states that use the highway and rail systems that converge on Chicago.

On the basis of previous reports, researchers assembled a table of commonly used transportation performance measures and assembled data within these

categories for each of the 10 states in the Mid-America Freight Coalition. A focus was placed on using data that are publicly or widely available, or both. The research effort found many gaps in the available data and in the analytic procedures used to develop the project if the benefits are theoretically allocated to adjoining states. The research team made an assignment of benefits on the basis of available data. It also noted key assumptions that must be made in producing these assignments and suggested steps that might be taken to improve the data and make the assumptions more reliable.

The poster presentation details the processes used by the research team, the outcomes to date, and the future opportunities for the project. It also highlights relatively recent results from an April 2011 workshop for the 10 state departments of transportation that make up the Mid-America Freight Coalition.

DEVELOPING AND APPLYING FLUIDITY PERFORMANCE INDICATORS IN CANADA TO EVALUATE FREIGHT SYSTEM EFFICIENCY

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As part of its Gateways and Trade Corridors Initiative, Transport Canada's Directorate of Economic Analysis was interested in developing freight performance measurements for goods entering Canada's international gateways and traveling along its freight transportation corridors. These performance indicators, termed "fluidity measures," will assist Transport Canada in painting a clear picture of system efficiency for its freight-significant corridors. The indicators will ultimately aid Transport Canada in identifying the extent to which the Canadian government's policies and investment in infrastructure are being leveraged and operated to support trade and economic prosperity.

Transport Canada contracted the Texas A&M Transportation Institute to develop and apply indicators for measuring freight system performance. Researchers used

an index approach to create two fluidity indicators: the fluidity index (FI), which captures average conditions, and the planning time index (PTI), which captures daily variations in travel time. Because freight moves according to both travel time and delivery schedules and varies according to mode, performance measures use a normalizing concept to allow comparisons within a certain mode and across an entire supply chain. Researchers used both truck Global Positioning System data and truck dispatch data from shipping manifests to estimate the measures.

Researchers developed and applied both of the measures. Two applications of the measures were performed. The first application used shipping manifests to demonstrate how the fluidity measures were computed and presented. This application indicated the importance of computing the performance measures for each trip urgency group (i.e., fast drivers, medium drivers, and slow drivers). In the second application, researchers demonstrated the use of the fluidity measures for monitoring freight system performance for an international multimodal corridor from Shanghai, China, to Toronto, Canada. In this example, the multimodal trip included the following transport elements:

- Ocean travel time,
- Port dwell time,
- Port drayage time,
- Rail dwell time awaiting departure,
- Rail travel time,
- Rail dwell time upon arrival,
- Rail drayage time to distribution center,
- Truck travel time, and
- Truck dwell time upon arrival.

Individual trip FI and PTI values were weighted on the basis of their contribution to the entire supply chain to calculate a representative "weighted" overall FI and PTI for the entire supply chain. Researchers used TEU-hours (TEU = 20-foot equivalent unit) to weight individual trip indexes. They demonstrated how the FI and PTI can provide supply chain performance information by mode and explained how to create annual measurements by weighting monthly values by cargo amount.

APPENDIX B

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