

MPC-444

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Project Title:

Data-driven Freeway Performance Evaluation Framework for Project Prioritization and Decision Making

University:

University of Utah

Principal Investigators:

Xiaoyue Cathy Liu, Ph.D.

Assistant Professor

Department of Civil and Environmental Engineering

University of Utah

110 Central Campus Drive, 2137 MCE

Salt Lake City, UT 84112

Phone: (801) 587-8858

Email: cathy.liu@utah.edu

Research Needs:

According to the 2012 Urban Mobility Report, urban congestion costs about \$12.1 billion dollars and a total of 5.52 billion-hour delay in 2011 (Shrank *et al.*, 2012). Congestion has surely been growing over the past years. Transportation agencies are therefore actively seeking for ways to better monitor the traffic, identify bottlenecks, and respond efficiently and effectively to incidents. From operations perspective, using a set of meaningful performance measures to obtain comprehensive assessment of the roadway system is one of the most effective solutions for congestion management. It is also critical to decision making. The Moving Ahead for Progress in the 21st Century Act (MAP-21) establishes performance-based transportation program to guide the transportation capital investment and development. It thus enables the need to carry out a performance-based approach in evaluating the transportation system. Freeway networks play a very critical role in providing accessibility to a multitude of resources and serves as the backbone of a region's economic vitality. It is also the primary focus of operations agencies. Meanwhile, social and economic needs continue to shape the freeway network in turn with the rapid advancement of technology. It is therefore imperative to develop a data-driven freeway performance assessment framework that is able to link the performance measures with investment decisions.

Freeway performance measures is oftentimes considered in three dimensions: temporal aspects, spatial details, and source of congestion (Cambridge Systematics, 2006). Attention will be paid differently depending on the emphasis of specific agencies. For example, senior leader would look at the performance from a holistic view to obtain the overall freeway network conditions. Traffic engineers may need to provide instantaneous operation decision based on the source of congestion, and time of day situation. Transportation planners might consider development plans for alleviating congestion bottlenecks that are most critical to the entire network. In order to

provide comprehensive and useful information to transportation agencies, the performance measures should be developed incorporating the three dimensions mentioned above, as well as to effectively describe the roadway condition to support investment decisions. There is also a growing recognition in the transportation profession in the recent years that performance measures should be viewed from both facility perspective for monitoring and management purposes and user perspective for customer experiences. To address this issue, performance measures need to be focused on both congestion (facility perspective) and mobility (user perspective) of the freeways.

In the meantime, freeway performance measures would not be possibly developed without the utilization of technology and the support of mass amount of data collected from multiple sources and jurisdictions. Utah Performance Measurement System (PeMS) is a freeway performance measurement system developed by Utah Department of Transportation (UDOT). It contains rich pool of information about traffic data and provides an excellent platform to both transportation practitioners and researchers. The system integrates various traffic data sources including traffic detectors, incident logs, vehicle classification data, and roadway inventory, etc. These traffic data have been automatically collected and archived and real-time information is updated from over 28,000 detectors (Iteris, 2013). The PeMS system offers valuable information for developing useful performance metrics for decision making purposes. Meaningful performance metrics should be able to best describe the freeway traffic conditions from a variety of perspective and effectively answer questions as how reliable the current system is operating, how to quantify congestion, and how to incorporate the congestion/reliability information into planning process, etc.

Research Objectives:

The objective of this project is to develop a set of performance metrics that can be incorporated into operational management and planning process for investment decisions. The performance metrics will be based on the traffic data support from PeMS and their spatial and temporal effect will be illustrated on a Geographic Information System (GIS)-based platform. The project also strives to provide linkage between performance measures and decision making by using interpretative indicators and GIS-enabled methods to inform decisions.

Research Methods:

The focus of performance metrics in this project is to describe the congestion and mobility of the freeway networks. Congestion levels are not the same every day. *Strategic Highway Research Program (SHRP) 2* identified seven potential sources that can greatly affect the level of congestion on any day, including incident, work zones, demand fluctuations, special events, traffic control devices, weather, and inadequate base capacity (ITRE, 2012). It is therefore of particular interests to associate the congestion with its source to effectively diagnose the extent. Meanwhile, there are various ways to determine congestion levels. It has been recognized in the recent years that travel consistency and dependability is just as important as the average level of congestion. Hence, the concept of reliability has been drawn significant attention and widely considered to be incorporated into the planning and programming process. Reliability is a particularly crucial performance measure of the freight transportation. With the vast deployment of just-in-time delivery, the freight industry emphasizes most on how reliable the delivery would be, rather than the speed itself. In terms of freeway mobility performance, the measurement is

often based on travel time, with a goal to describe how well users can complete their trips. Travel time is an effective measure because it can be easily understood by both practitioners and the general public, and can be used to describe the day-to-day variation of traffic condition (reliability).

The project will begin with a critical synthesis of performance metrics available for freeway networks. The measures should be related to typical congestion levels, reliability and freeway throughput to describe congestion/mobility performance of freeways. Supporting measures on the nature of potential sources that impede traffic flow will be investigated as well. Traditional Highway Capacity Manual (HCM) based performance measures (e.g. v/c ratio, level of service) will serve as supplementary measures for comparison purposes. The initial thoughts on several important performance metrics are listed below:

- Travel Time Index (TTI)
TTI is a measure of total amount of congestion and typical delay. It is the ratio of average travel time to the free flow travel time.
- Buffer Index (BI)
BI measures travel time reliability. It is the difference between the 95th percentile travel time and the average travel time, normalized by the average travel time.
- Planning Time Index (PTI)
PTI accounts for both typical delay (from TTI) and atypical delay (from BI). It is the ratio of 95th percentile travel time and free-flow travel time.
- Congestion Duration Index
This is a tentative index proposed in this study to describe congestion duration for planning purpose. The goal is to develop of measure that can easily convey the congestion level to the senior leader and general public in place of v/c ratio and level of services used in the current HCM (TRB, 2010). It is the percent time of day that v/c ratio higher than 1 or percent of time that speed drops below certain threshold.
- Safety index
It describes the severity of incidents happened on hazardous locations that constitute a danger to highway users.

Performance measures describe the nature of problems on the facility, and when tracked over time and space, they provide a comprehensive assessment on how those conditions are evolving. The evolution process, along with the identified source, can be used to inform decisions on improving existing facilities or traffic management. Once proper performance metrics are identified, efforts will be made towards collecting freeway traffic data to support the development of the performance measures. The data collection will be mainly performed on the basis of PeMS. PeMS archives a variety of freeway traffic data including speed, flow, and occupancy from detectors, and aggregates the data at 5-minute, hourly, and daily levels. One year worth of data is proposed to be collected from PeMS for performance metrics development and for analyzing seasonal and time of day effects.

Once the data collected and performance metrics developed, the next step is to diagnose the freeway system by conducting offline analysis on the relationship between congestion/mobility performance and the sources of congestion. During this process, persistent bottlenecks will be identified from the performance metrics repository. And statistical analysis will be performed to

determine why congestion rises. This will help answer questions like how reliability will suffer if certain events take place, and what are the impacts of adverse weather, incidents, and special events, etc.

Eventually, the project will present the performance metrics in a database-enabled GIS platform. The study will also investigate the effective methods to present the results to professionals, especially senior leaders, to inform decisions. This project strives to provide better information on the scope and causes of congestion that can lead towards more open thinking about what to fund to improve the situation.

Expected Outcomes:

This project will provide a performance-based platform for freeway system management and optimization that 1) explicitly utilizes effective performance metrics to describe the freeway traffic conditions; and 2) identify congestion sources and their impacts in both spatial and temporal details. A prototype database-enabled GIS-based platform will be developed to demonstrate the performance evaluation results. This focus of this study is Utah freeway system utilizing the wealth amount of traffic data resources provided by PeMS. The expected outcomes will directly be used by UDOT personnel and consultants working on UDOT projects to obtain holistic view on the freeway performance, and will assist with senior leaders for project prioritization and decision making. Meanwhile, transportation practitioners and researchers can apply the developed performance metrics for evaluating their localized freeway systems. The procedure for diagnosing freeway bottlenecks is transferable for quantifying the impacts of potential congestion sources. The GIS-enabled platform will frame possible applications of the research results in the context of freeway performance monitoring and evaluation. The project will also trigger a series of research in aspects of effective transportation asset management and evaluation, e.g. delay prediction algorithm for both recurrent and non-recurrent congestion, Integrated Corridor Management (ICM), and congestion pricing. Several peer-reviewed journal articles and conference presentations are expected to result from the work in addition to a final report.

Relevance to Strategic Goals:

This project is most relevant to the USDOT strategic goals of “State of Good Repair” and “Livable Communities”.

State of Good Repair

With USDOT’s emphasis on improving the conditions of the aging infrastructure, this project establishes a performance-based framework to better monitor and manage the transportation asset of freeway networks. The project will identify bottlenecks on the existing freeway system using a data-driven approach and quantify the impact of various congestion sources. This performance-based platform will assist with senior leaders in transportation agencies to make comprehensive assessment of the roadway system, and help inform investment decisions and optimize management strategies.

Livable Communities

The expected outcomes will support explicit considerations of mobility and accessibility of the existing roadways to provide users efficient travel experience. The performance-based framework developed in this project would inspire a series of research, including incident-induced delay prediction, real-time traveler information system, ICM, etc. These will provide roadway users, either en route or planning their trip, rich information to make sound travel decisions (e.g. alter departure time, seek for alternative routes and travel modes, etc.) From the agency's perspective, the research outcomes might lead to investment decisions of transportation asset management, such as park-and-ride facilities, dynamic message signs, and transit centers, to increase transportation choices and pursue a well-coordinated transportation system.

Educational Benefits:

One graduate student will be heavily involved in this research. He/she will lead the preparation of journal publications resulting from the work, and in most cases, deliver conference presentations. The project will serve as a basis for his/her dissertation work. The University of Utah will open an undergraduate/graduate level course on "Traffic System Operations" in 2014. The procedure for retrieving traffic data from data repository, developing performance metrics, and displaying the result on a GIS-based platform will lead to new material included in the course to teach the students practical skills on freeway performance analysis.

Work Plan:

The work plan consists of seven research tasks to be accomplished over a 15-month period as described below:

Task 1. Execute a critical synthesis of freeway performance metrics analysis, as well as state-of-the-practice on how the developed metrics incorporated into the transportation planning and programming process.

Task 2a. Identify appropriate performance metrics that can be used to describe freeway congestion/mobility from Task 1.

Task 2b. Organize a focus group that represents a general public audience. Present the potential performance metrics and identify which of them are the most useful to the general public and which are the easiest for them to understand.

Task 2c. Refine the results on performance metrics based on the feedback from the focus group.

Task 3. Collect data from PeMS and archive them into a database housed at the University of Utah server for further data processing and statistical analysis.

Task 4. Calculate performance metrics using the data collected with identified study period. Offline analysis for diagnosing the freeway bottlenecks will be conducted to determine the relationship between congestion/mobility performance and the sources of congestion.

Task 5. Develop a database-enabled GIS platform to effectively present the result of freeway performance evaluation including source of congestion, spatial and temporal evolvement of congestion.

Task 6. Prepare a draft final report describing all previous tasks of the research. Circulate the draft report for peer review.

Task 7. Submit a final report that addresses comments received during the peer review.

A schedule of activities is provided on the following page.

Technology Transfer Plan

The potential audiences for this research are individuals involved in the traffic operations and transportation asset management, including traffic engineers, planners, and senior leaders at FHWA and at individual state DOTs. The following agencies, offices, and committees are those most likely to take a leadership role in implementing the research results:

- Utah Department of Transportation
- FHWA Office of Operations
- TRB Managed Lane Committee
- TRB Highway Capacity and Quality of Service Committee
- TRB Freeway Operations Committee

The proposed principal investigator routinely interacts with UDOT, FHWA, SHRP 2 Reliability Program, and the listed TRB Committees. The 2014 Midyear Meetings of TRB Highway Capacity and Quality of Service Committee, TRB Managed Lane Committee, and TRB Freeway Operations Committee will be an opportunity to share early results and future directions of the research project. The proposed principal investigator will work with the committee chairs to possibly get a presentation on the project added to the agenda. The proposed principal investigator and her graduate students routinely attend TRB's annual meeting as well. At least one TRB paper on this work will be submitted for presentation and publication.

Schedule of Research Activities

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Month 13	Month 14	Month 15
Task 1 Conduct critical synthesis of freeway performance metrics analysis	■	■	■												
Task 2 Identify appropriate performance metrics			■	■	■										
Task 3 Data Collection and Archival				■	■	■									
Task 4 Performance metrics development and diagnosis						■	■	■	■						
Task 5 Develop a database-enabled GIS platform									■	■	■	■			
Task 6 Prepare draft final report													■	■	
Task 7 Submit final report															■

 Research Task
 Peer Review

Project Cost:

Total Project Costs: \$ 60,000

MPC Funds Requested: \$45,000

Matching Funds: \$15,000 Source of Matching Funds: Utah Department of Transportation

TRB Keywords: Performance measures; operations; traffic management; reliability; congestion; highway capacity.

References:

Cambridge Systematics, Inc. Guide to Effective Freeway Performance Measurement: Final Report and Guidebook. NCHRP Document 97, 2006.

Interis, Inc. Performance Measurement System (PeMS) Overview. http://udot.bt-systems.com/?dnode=Help&content=help_calc. Accessed September 28th, 2013.

ITRE. SHRP 2 L02: Establishing Monitoring Programs for Travel Time Reliability Guidebook. Transportation Research Board. September 2012.

Schrank D., Eisele, B, and Lomax, T. *TTI's 2012 Urban Mobility Report Powered by INRIX Traffic Data*. Texas A&M Transportation Institute. 2012.

Transportation Research Board (TRB). Highway Capacity Manual (HCM) 2010. 5th edition. Washington, D.C. 2010.