TRANSPORTATION RESEARCH

CIRCULAR

Number E-C223

July 2017

Innovations in Freight Data

May 17–18, 2017
Arnold and Mabel Beckman Center
Irvine, California

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

TRB
TRANSPORTATION RESEARCH BOARD

TRANSPORTATION RESEARCH CIRCULAR E-C223

Innovations in Freight Data

May 17–18, 2017
Arnold and Mabel Beckman Center
Irvine, California

Sponsored by
Federal Highway Administration
Office of Freight Management and Operations

Planning Team
Alison Conway, City College of New York, *Chair*
Donald Ludlow, CPCS Transcom, *Vice Chair*
Chandra Bondzie, Federal Highway Administration
Scott Drumm, Port of Portland
Kathleen Hancock, Virginia Tech
Sherif Ishak, Louisiana State University
Nikola Ivanov, CATT Laboratory
Vince Mantero, Federal Highway Administration
Dan Morgan, U.S. Department of Transportation
Michael Sprung, Bureau of Transportation Statistics
Rahul Srivastava, California Department of Transportation

Edited by
Kathleen Hancock
Virginia Polytechnic Institute and State University

July 2017

Transportation Research Board
500 Fifth Street, NW
Washington, D.C.
www.TRB.org

TRANSPORTATION RESEARCH CIRCULAR E-C223
ISSN 0097-8515

The **Transportation Research Board** is one of seven programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal.

The **Transportation Research Board** is distributing this E-Circular to make the information contained herein available for use by individual practitioners in state and local transportation agencies, researchers in academic institutions, and other members of the transportation research community. The information in this circular was taken directly from the submission of the authors. This document is not a report of the National Academies of Sciences, Engineering, and Medicine.

Transportation Research Board
500 Fifth Street, NW
Washington, D.C.
www.TRB.org

Jennifer Correro, Proofreading and Layout; Lea Camarda, Production Editor

Preface

Emerging "big" freight data have the potential to significantly improve freight planning, freight operations and mobility, and visualization of freight data. The Transportation Research Board's Standing Committee on Freight Transportation Data and Task Force on Understanding Big Data in Freight Transportation initiated a workshop to bring together freight data users and decision makers to learn about and share the latest applications that leverage emerging big freight data sources. This event brought together traditional freight-planning stakeholders with data and technology innovators from related areas to explore opportunities to advance the state of the practice, offering an interactive format to engage in productive dialogue.

An ad hoc committee, chaired by Alison Conway of the City College of New York and selected by the sponsoring committee and task force, carried out the detailed planning for the conference. These proceedings consist of individually attributed summaries. No language should be construed as consensus findings or recommendations on the part of workshop attendees, the planning committee, or the sponsoring committee.

The planning committee represented planners, analysts, and data specialists. The 143 attendees reflected organizational diversity as follows:

U.S. Department of Transportation	6%
Federal, other	5%
State departments of transportation	20%
State, other	1%
Local, regional, port	6%
Association–nonprofit	10%
University	29%
Industry–commercial	1%
Consultant	21%

Special thanks to the Federal Highway Administration Office of Freight Management and Operations for helping to support this workshop.

Contents

APPENDIXES

Introduction

ALISON CONWAY
City College of New York

Over the past decade, the landscape for both data and for freight planning and operations has rapidly changed. Following passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21), then the Fixing America's Surface Transportation Act (FAST), states and metropolitan planning organizations (MPOs) have quickly developed and implemented new strategies to meet federal mandates for freight system planning and performance measurement. Historically, freight planning has relied heavily on expensive proprietary datasets or on major federal products such as the Commodity Flow Survey (CFS) and the Freight Analysis Framework (FAF). While these data sources are critical for understanding how commodities move to, from, and between states and metropolitan areas, alone they are of limited value for understanding local movements or for translating commodity movements into vehicle trips that are distributed over time and across complex supply chains and vehicle fleets. While methods for disaggregating the FAF to estimate local activity have been developed and implemented, these have general relied on land use, employment, and population factors that do not necessarily realistically capture supply chain dynamics. Since discontinuation of the Vehicle Inventory and Use Survey (VIUS) in 2002, no major federal data source has replaced it to link vehicles and commodity types. In urban areas, freight data collection had been sporadic at best, often relying on limited (and expensive) surveying or vehicle classification counts. New and supplementary datasets, not only to improve system level planning, but also to enable system operators to manage road and curb space in real time are needed.

Fortunately, new communications and sensor technologies and new methods for data mining, processing, and storage have led to rapid evolution in both supply chain and transportation system management. These new and emerging data sources present a tremendous opportunity to address longstanding freight data concerns, including lack of granularity; time lags between data collection and use; missing linkages between origins and destinations, vehicles, and commodities; and overall poor quality or inconsistency of data, especially across jurisdictional boundaries. Some new data sources, such as GPS, have quickly been adapted for innovative uses in practice. Others, like satellite imagery, video analytics, crowdsourcing, and instrumented vehicles, are recognized as having huge potential for freight planning and operations management, but are still in early stages of development for practical application. Ultimately, new policies and institutional arrangements can more quickly enable and leverage the uses of these sources.

The goal of this workshop was to provide a forum for traditional freight-planning stakeholders and for data and technology experts to come together to discuss recent advances in the innovative application of these big and emerging data sources for freight planning, operations, and visualization. It provided a venue for not only for sharing best practices, but also for discussing challenges that have been faced and overcome and the lessons that have been learned from working with these new datasets. The event brought together agencies, consultants, industry experts, and academic researchers who have developed innovative data applications. It consisted of a variety of sessions, including a keynote opening speech, focused panels, speed presentations, an interactive demonstration session, and a field presentation of an instrumented truck. Two award winners were recognized for “best application of a new data source” and “best data fusion application.” In breakout sessions at the end of the workshop, attendees reviewed the events of the workshop to identify what real advances have been made, and what critical gaps remain to be addressed through research, strategic partnerships, or other means.

This e-circular serves as a record of workshop events and findings, and as an information source for freight data stakeholders. The remainder of this document details the activities of the workshop.

Importance of Innovations in Freight Data for California
Freight—and You

KOME AJISE
California Department of Transportation

MAP-21 and the FAST Act changed the game for freight across the country and for California. In the past, freight was an afterthought. Decisions were made to improve transportation facilities and then considerations about trucks, rail, or other freight needs were included in implementing those decisions. Including freight in the global conversation was never a priority in California. This does not mean that freight was not considered; just that those activities were associated with planning for and addressing specific freight needs. The mainstream work of the California Department of Transportation (Caltrans), which is focused on highways and bridges, rarely included freight when evaluating the broader impacts and benefits of investments. Having said that, freight plays a major role in California. It makes up a third of the economy and a third of the jobs in the state. With the nation's largest gateway, California is very aware of the importance of freight to both the state and the nation, which makes measuring and understanding its impact all the more critical.

Performance-based freight planning and programming has become a recognized part of the process at Caltrans because of MAP-21 and the FAST Act and has become part of the conversation at the state level. When considering performance management, data are critical. How is performance tracked without the data? Mapping trends and looking at forecasts based on data provides the ability to track the impact of decisions and resulting investments.

However, it is not just about data, with rows and columns of numbers and information; it is now more about how data becomes information so that it is used effectively to inform decision making. That is ultimately the challenge. Caltrans has been working with several agencies within the state to develop an open-source data site where data are readily available and easily visualized, explored, and integrated with other data. The state has so much data that agencies are weighed down with the amount of information, and, often, only its immediate users know about the data that are available. If a stakeholder were to come in and ask for the average daily traffic of trucks on a major trade corridor, the answer should be available with a quick click. Instead, time is spent identifying the necessary data source and the person who can access it, extracting the data that represents the requested corridor, and performing any necessary manipulation to obtain the result. If data and information are available to everyone, their value and use are expanded and limited only by imagination.

Most discussion about freight focuses on highways and rail. However, freight moves by many different modes. In California, water plays a very large role. The economy of California revolves around its port and intermodal facilities. Approximately 40% of the containerized traffic that comes to the United States comes through the Ports of Los Angeles (LA) and Long Beach. As much as freight comes through these ports, a large portion is local. In addition, California moves freight along the coast and between states on the west coast by short-sea shipping and marine highways. The state is also seeing an increasing interest in the use of alternate and emerging modes such as cargo bikes (bicycles with electric motors) and drones.

TRENDS

Major trends are influencing how the freight conversation progresses. Growing consumer demand will continue to increase the amount of freight moving both within and through California. The demand for more goods delivered in shorter time windows is resulting in a rapid expansion of fulfillment centers in major cities, which is increasing last-mile delivery. Data about demand, delivery points, and travel times (TTs) is important to decisions about facility siting.

At the same time, for Caltrans, the transportation infrastructure is aging. With increasing freight comes growth in truck traffic, which accelerates the deterioration of the state's highways. This requires increased downtime for repairs, which, in turn, negatively impacts movement of goods.

Another trend is observed in increasing global competition associated with freight movement. This impacts California directly as other U.S. ports work to increase their market share. As a result, ensuring that freight is moved around and through the state effectively and efficiently has become a major objective.

A new trend that is highlighting the expanding freight conversation is the increase in funding dedicated to improving goods movement particularly because of the federal FAST Act funding authorization. For California, that translates to about $100 million per year for 5 years specifically for freight. Furthermore, California passed landmark legislation (Senate Bill 1, or SB1) in April 2017, which carved out an additional $300 million per year for 10 years for freight. As a result, California went from $0 dedicated to freight a couple of years ago, to $400 million every year.

PLANNING FOR FREIGHT PROJECTS

After the implementation of MAP-21, California developed its California Freight Mobility Plan (CFMP), which is the statewide, long-range plan for the state's freight transportation system.[1] It was developed as a partnership between the California State Transportation Agency and Caltrans in consultation with the 62-member California Freight Advisory Committee, which consists of members from a broad spectrum including the trucking industry, the ports, beneficial cargo owners (BCOs), and communities among many others. Because of the wide diversity of the stakeholders involved, it was important to define freight mobility and to develop a working definition for a freight project as spelled out in Figure 1. To obtain agreement, the focus became identifying what a freight project would do and establishing a balance between the benefits to business and the economy and the impacts on the community and the environment.

A new initiative is the California Sustainable Freight Action Plan, which was signed by Governor Brown in 2016 to "improve freight efficiency, transition to zero-emission technologies, and increase competitiveness of California's freight system."[2] The participating departments are the California Air Resources Board (CARB), Caltrans, California Energy Commission, and the Governor's Office of Business and Economic Development (GO-Biz) and their parent agencies. As might be expected, each agency has different goals and objectives. Caltrans is focused on mobility and throughput. The CARB as well as constituents from the community are focused on emissions including greenhouse gases (GHGs) while GO-Biz wants to bring business to the state. With a mandate to work together, the four agencies had to develop a vision for freight in California to 2050.

The vision includes three specific targets. One is efficiency. The goal is to improve efficiency by 25% with the challenge of defining exactly what is meant by efficiency. The agencies agreed on

FIGURE 1 Definition of a freight project from the CFMP.

the efficiency of moving a piece of freight and its economic value in relation to its carbon footprint or, in other words, the amount of GHG emissions it takes to move a unit of gross domestic product. A 25% reduction translates to obtaining 1990 levels by 2020. Even with this more narrow definition, understanding how to achieve this goal is challenging since it includes identifying the appropriate North American Industry Classification System codes that map economy and freight and then determining the portion of resulting GHGs that attach to goods movement.

The second target of transitioning to zero-emission technologies translates to having about 100,000 zero-emission vehicles in the freight business by 2030. This is challenging because most fleets are owned and managed by the private sector. As a result, this goal will require incentives in combination with regulations.

Increasing competitiveness is the final target and has its own challenges. The first two targets directly impact competitiveness. California must maintain and enhance its value proposition associated with moving freight into and through the state. This means working with the workforce and negotiating labor issues, ensuring that the solo trucker can compete with corporate trucks and so on.

The plan includes nine agency actions. One of the most important was working with the legislature to provide a dedicated funding stream. This was achieved with SB1. Other actions include accelerating the use of advanced technologies and renewable fuels, establishing a think tank to ensure the continuation of the conversation at a higher level, and for Caltrans, continuing the work of the efficiency task force to achieve the 25% efficiency goal.

FREIGHT DATA

With the expansion in freight planning and projects comes a much greater requirement for and reliance on data. One of the greatest challenges was the loss of the federal VIUS in 2002, which provided information on commercial vehicle activity. As a result of this loss, California initiated the California VIUS (CA-VIUS), piloting it in 2014–2015. Examples of other data initiatives include using information from weigh-in-motion (WIM) facilities for more than truck counts and weight, partnering with the WAZE app to exchange road improvement and construction activity data for their crowdsourced traffic and incident information, and more effectively leveraging the performance measurement system in the Highway Performance Management System.

As new technologies become more mainstream, consideration should be given to how data are gathered. For example, surveys have been used to obtain information that is not available from other sources. However, the expense and time for conducting these surveys result in substantial data latency. For example, household activity surveys are performed once every 10 years and require an additional 5 years to process and incorporate into travel demand models to predict behavior 20 years in the future. This cycle is untenable and identifying alternatives or methods for reducing that latency is important.

Caltrans uses data for project identification, project development, and compliance. With the increase in emphasis on freight movement, it is more critical than ever that projects are objectively defined and selected to address identified problems. This requires having very good, objective data. With the more structured freight programming that is occurring in California because of the plans discussed above, data has become an underpinning to decisions; and even political considerations are taking advantage of data.

The big challenge that California has is the complexity of the system. Unlike congestion where most of the infrastructure is managed publicly, the freight system is a combination of public and private infrastructure, operators, users, and stakeholders. Obtaining data from the private sector requires different resources and different relationships. Working with each entity that is involved in freight—such as the trucking industry, rail companies, and the ports—has different challenges with different incentives and constraints. Even after these issues are addressed, physically obtaining, anonymizing, and integrating the information into a structure that aligns with decisions presents another set of challenges.

Figure 2 gives a representation of the logistic system of systems, which adds another dimension to the complexity faced by California, bringing into focus the "you" in the title of this presentation. Freight movement ultimately comes down to the individual package that shows up at a single person's door. Managing the complexity of this system becomes one more aspect of an already difficult process.

CONCLUSION

You, the workshop attendees, have the more difficult task of thinking through some of the items that were briefly outlined. In closing, I wish you well and I thank you for your attention. I also want to thank the Transportation Research Board (TRB) and the sponsoring committees for hosting this workshop and the related meetings in southern California. We like to think that California is the hub of freight and we are proud that you came to California to talk about freight. In closing, I wish you energetic and positive deliberations. Thank you.

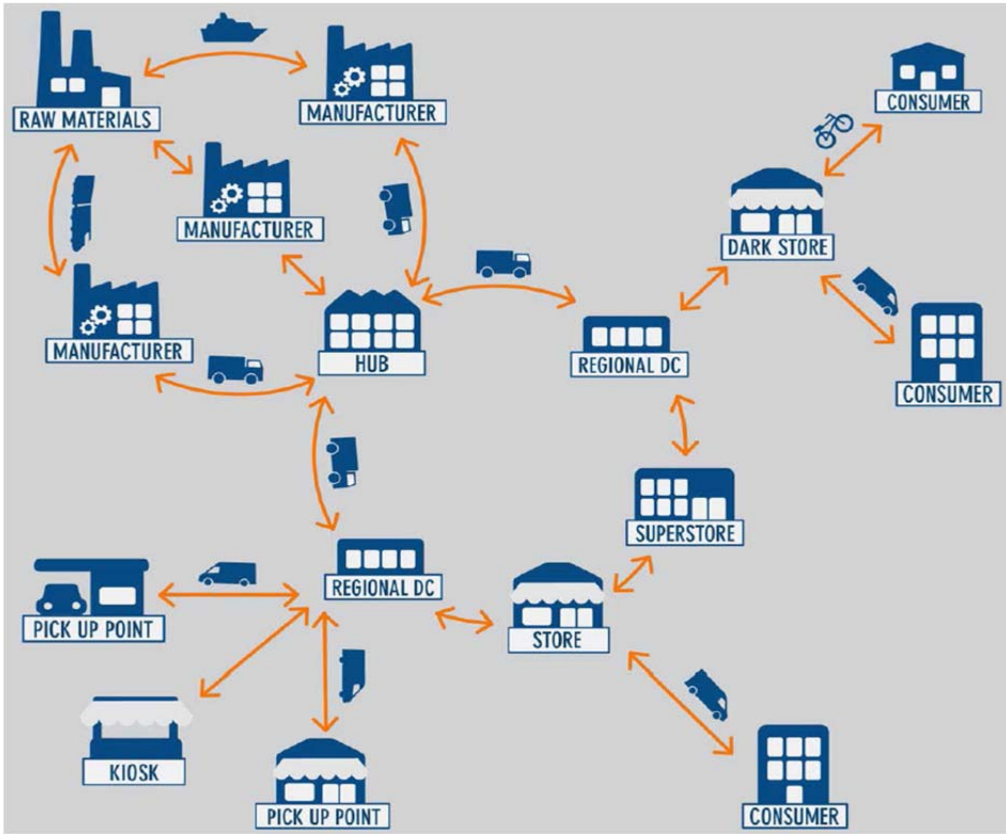

FIGURE 2 A complex logistic system of systems.
(Source: http://www.zetes.com/sites/default/files/solutions /infographic-supplychain-visibility-zetesolympus-1.jpg)

NOTE: This presentation was transcribed and edited by Kathleen Hancock, Virginia Tech.

Freight Data Applications and Needs

SARAH HERNANDEZ
University of Arkansas, presider

VIVEK SAKHRANI
CPCS Transcom, recorder

Agencies are capturing value from existing and emerging data sources by developing applications to collect, combine, and visualize freight data in new ways. The three presenters addressed the general objective established by the keynote speaker that agencies must continue to innovate in how they acquire, assess, and use freight-relevant data to improve safety, enhance the economy, and safeguard the environment.

The presenters described innovative applications for three modes—rail, trucks, and ships—that address the following practitioner challenges in the freight data space:

- Understanding crude oil train routes by integrating crowdsourced data with traditional datasets and visualizing these data geospatially;
- Improving understanding of truck movements, behaviors, and operations in a specific region over time by surveying, compiling, and fusing datasets and visualizing the results; and
- Assessing the relative intensity of freight activity at U.S. ports by applying a scoring and benchmarking technique populated by fused datasets.

Each presenter addressed both the limitations of and lessons learned from their approach and presented opportunities to refine their approach in future work.

CROWDSOURCING TO OBTAIN CRUDE-OIL-ON-RAIL ROUTE INFORMATION

Shih-Miao Chin
Oak Ridge National Laboratory

Shih-Miao Chin of Oak Ridge National Laboratory (ORNL) theorized that crowdsourced publicly available big data could be used to reveal hidden or otherwise obscured information of interest to the public sector. In particular, the proliferation of geo-tagged media from GPS-enabled devices such as phones and cameras coupled with cloud storage and sharing makes a vast amount of information that can be used for object identification and geolocation available. This hypothesis was tested in an application that identified and geolocated crude-oil trains using crowdsourced imagery.

This choice of application is motivated by the expected increase in crude-on-rail movements, given the growth in crude oil tonnage moved by rail since 2012, and a rail mode share in excess of 50% in moving crude from the Bakken shale due to limited pipeline capacity. Some high-profile safety and environmental incidents involving trains carrying crude have reminded decision makers and community stakeholders of the importance of understanding the nature of such movements.[3] However, because trains carrying crude are not subject to the same routing restrictions and reporting requirements as those carrying other hazardous materials, identifying potentially hazardous sites and preparing for emergency response is difficult in the absence of detailed data. As a result, a detailed crude-by-rail flow database that can be linked to energy commodity origin–destination (O-D) data and rail operations data could provide a valuable resource.

This method employed an inference approach, shown in Figure 3, which relies on rapidly evolving feature recognition capability of identifying crude-carrying trains from crowdsourced still imagery. By joining location information obtained from such images with network maps and crude terminal information, the approach is able to generate crude flow maps or routes over time. The results can be used for identifying the proximity of communities to routes, and developing emergency preparedness and response plans. Future work can include a more active approach to manually downloading posted images, in which an appropriate agency could solicit and provide incentives for sourcing imagery.

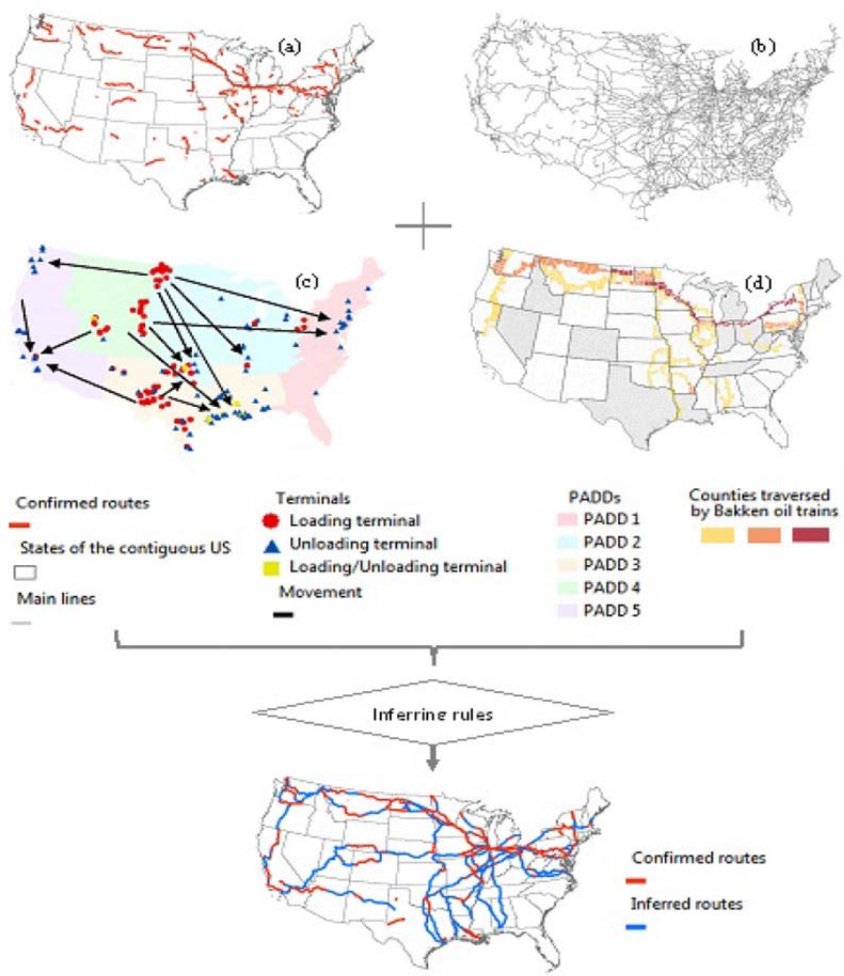

FIGURE 3 Inference, or integrating photo locations with rail network and other information.

CALIFORNIA VEHICLE INVENTORY AND USE SURVEY

James Brogan
Cambridge Systematics

James Brogan of Cambridge Systematics described an extensive and systematic truck data collection program to populate the CA-VIUS. The objective of CA-VIUS is to enable Caltrans to improve the information it uses for infrastructure and operations decisions that must consider truck activity in the state of California, such as for updating the California Statewide Freight Model and the California Statewide Travel Demand Model. For California, this program replaces the previously discontinued federal VIUS and many of the elements of CA-VIUS are modeled on that 2002 federal survey.

The study approach fuses data from new surveys with other datasets to compile information on freight truck activities, operational characteristics, physical characteristics, and other truck inventory information as listed in Table 1. Two subsets of the truck population were identified based on their domicile: those registered in California and those registered in other states.[4,5] These data are complemented with operations data (trip chronology, distance, geolocation, fuel consumption) and behavioral parameters (idling, on–off hours, acceleration and braking, and emissions) obtained from a combination of GPS and onboard devices. The study distributes about $1 million to incentivize fleets to participate in the surveys through a combination of small cash incentives of $40 to $100 per truck, or donations to charities nominated by participating fleets. Brogan reported that more than 5,650 of the 12,000-truck target sample have been surveyed, at a rate of about 300 trucks per week. Resulting data will be cleaned and filtered and used in survey expansion techniques with cross-validation to reflect population-level estimates. Data collection will continue through 2017.

The team learned a number of lessons in the areas of study design and sampling. Having the CARB and American Transportation Research Institute (ATRI) as participants helped with perception of survey respondents and did not hinder respondent participation as originally expected. Further, the number of trucks participating does not generate a disproportionate fleet bias, as only a few trucks from any fleet tend to participate. An important realization was that over 50% of trucks in the International Registration Plan clearinghouse do not operate in

TABLE 1 Notable Approach Elements (GPS and Onboard Diagnostics)

Parameter	Included in CA-VIUS	Raw Data Provided to Caltrans
Trip date, time, duration	✓	✓
Trip distance	✓	✓
Latitude–longitude	✓	✓
Trip fuel usage	✓	✓
Idling percentage		✓
Idling fuel usage		✓
Engine-on hours		✓
GHG emissions		✓
Acceleration and braking scores		✓
Speed	✓	✓

California, which led to erosion of the available sample and reallocation of GPS units to California-domiciled trucks. Working with small operators and fleets to obtain participation in the GPS program, and installing and activating devices posed greater challenges than anticipated.

ANALYSIS AND DISPLAY OF MARITIME FREIGHT DATA IN FULL CONTEXT

Douglas Scheffler
U.S. Coast Guard

Douglass Scheffler of the U.S. Coast Guard (USCG) described a project to assess the economic impact of U.S. ports by assessing the relative intensity of freight and passenger activity at ports. The activity intensity profiles of ports can be used in port-specific narratives to convey information about the nature of their impact and to support allocation of resources at or across ports.

The study included 51 ports in 25 metropolitan statistical areas across the country. These include major ports on the eastern seaboard, the west coast, Gulf of Mexico, and major inland ports. Data were collected to support a number of indicators such as the number of trips by dry cargo, tankers, towing vessels, dry cargo barges, tank barges, cruise vessel, recreational vessel, and ferry trips. These data were obtained from sources such as Waterborne Commerce Statistics from the Army Corps of Engineers, the Maritime Administration, USCG vessel registrations, Bureau of Transportation Statistics, and National Census of Ferry Operators. Data were combined to generate both unweighted and weighted indicator scores (that is, scaled 0–5) for each port, with scores aggregated to indicate the relative activity intensity of the port as outlined in Figure 4. In future work, the methodology could be enhanced by further refining the component indicators, data sources, or weighting criteria.

This approach demonstrates the value of having a nonproprietary and open-source approach for a wide range of public and private entities. The fused data sets are accessible and available for conducting analyses on a subset of ports or regions.

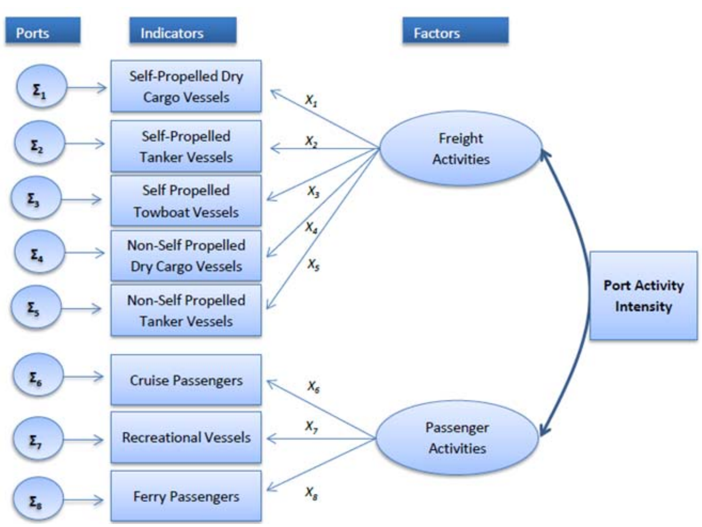

FIGURE 4 Port activity intensity estimation method.

SESSION SUMMARY

Looking across the diverse modes and applications discussed in this session, the following broad takeaways and lessons emerged:

- Careful consideration is important for designing studies involving new or emerging freight-relevant data to ensure sample representativeness.
- Piloting of data collection approaches helps to address both foreseen and unforeseen challenges before projects are executed at scale.
- These innovative applications are based on data fusion, that is, the joining or integration of many different types of data sets.
- Heavily dispersed big data such as crowd-sourced data might benefit from active participation of an appropriate organization or agency.
- Developing open source or non-proprietary techniques and sharing these across practitioner groups can enable wider adoption and refinement of approaches.

Technologies for Monitoring, Tracking, and Data Collection

DONALD LUDLOW
CPCS Transcom, Presider

ROMEO ESTRELLA
CalTrans, Recorder

Practitioners are capturing and applying data from sensors, telematics devices, and imagery to close data gaps. This panel presented emerging technologies for data collection and application.

INTEGRATED FREIGHT SURVEY, SHIPMENT TRACKING, AND VEHICLE TRACKING

Fang Zhao and Jing Ding-Mastera
Massachusetts Institute of Technology

This project used vehicle-tracking devices such as GPS loggers and smartphone or tablet applications to collect raw data for freight activities in both urban and intercity environments. These quantitative data are supplemented with qualitative data compiled from surveys, which assists with the behavioral modeling component of the project. The overall dataset is post-processed using Future Mobility Sensing (FMS) technology, an adaptive algorithm for shipment tracking.

The FMS tool is used to enhance freight survey and modeling techniques. The adaptive model, represented in Figure 5, allows for more robust reporting of data that is accessible via mobile and web–desktop interfaces. The sample results show activity patterns associated with intercity and urban tours, highlighting time–space relationships by driver group and activity type.

Based on questions from attendees, the researchers explained that a presurvey was used to establish parameters in the model before post-processing with the FMS tool.[6] These parameters represent aspects not directly associated with GPS data such as value of time and motivation behind route choices. Similarly, presurveys or additional data from other sources like a stop-sequence choice model can assist with unanticipated or emerging factors such as discrepancies in planned routes or the introduction of self-driving trucks.

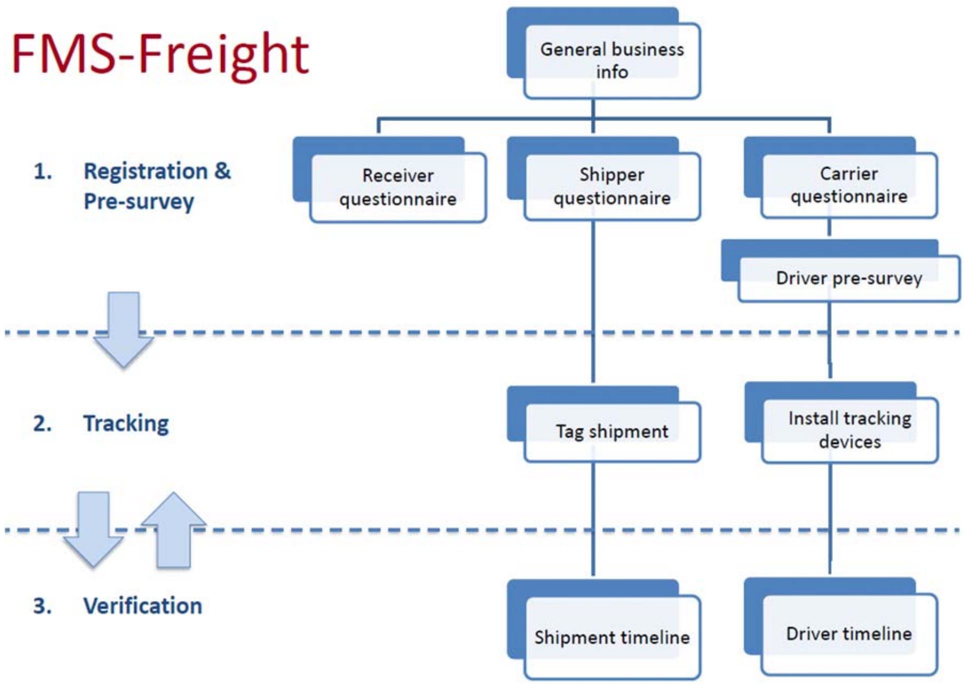

FIGURE 5 FMS for freight movements.

USING SATELLITE RADIOMETRY TO DEVELOP DATA FOR MODELS

Hector Guillermo Lopez Ruiz
King Abdullah Petroleum Studies and Research Center

The focus of this project is to obtain data from satellite night-light radiometry from the Visible Infrared Imaging Radiometer Suite (VIIRS) provided by the National Aeronautics and Space Administration for use in refining travel modeling techniques.[7] Color composites, as shown in Figure 6, are developed from night-light VIIRS using the open source framework, SOFIA-T (Simple Open Framework for Informed Assessments in Transportation). These composites are then used to obtain indicators of human and economic activity, which can be used to seed transportation flow estimation.

To supplement the satellite data, other open sources, such as Google Distance and Google Streetview, were used to help refine and calibrate the color composites. Inferences of affluence and shipment tracking are also possible from the model output.

Discussion from attendees about the sensitivity of the inferences extrapolated from the light data followed the presentation. Some areas of the world are known to use more light than others, such as Belgium. The presenter indicated that as long as the output is calibrated against the available light of that specific area, enough granularity in the data is available to make the necessary adjustments to identify the required categories in the VIIRS radiometry.

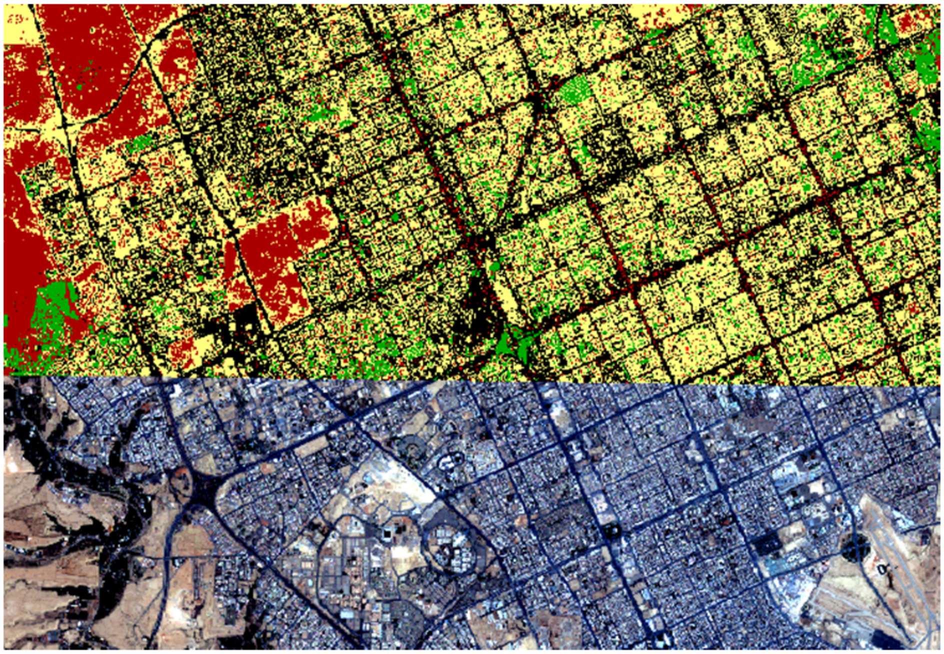

FIGURE 6 Example of resulting color composite from VIIRS night-light radiometry (red = desert; green = vegetation; yellow = infrastructure).

CLASSIFYING CALIFORNIA TRUCK ACTIVITY USING LOOP SENSORS

Andre Tok
University of California (UC), Irvine

This project developed and validated an advanced method for classifying vehicles from detailed inductive loop signatures. A software interface, the Truck Activity Monitoring System (TAMS), was developed to process the signatures and display information related to truck classification as shown in Figure 7.[8] This system capitalizes on existing WIM infrastructure and only requires the installation of Advanced Signature Detector smartcards in the roadside cabinet. At the time of publication, 73 inductive loop detector (ILD) sites and 22 WIM sites in California have been fitted with this card.

TAMS determines the number of trucks by type and time of day, allowing for scenario testing and modeling. It has the following characteristics:

- Temporally continuous: data collection and transmitted in real time 24/7;
- Spatially representative: deployed at over 90 major truck corridors across California;
- Accessible and automated: hosted on an interactive geographic information system-enabled web-based user interface
- Sustainable: leverages existing ILD and WIM detector infrastructure;
- Advanced: adopts ILD signature technology; and
- High fidelity: identifies more than 40 truck–trailer body configurations.

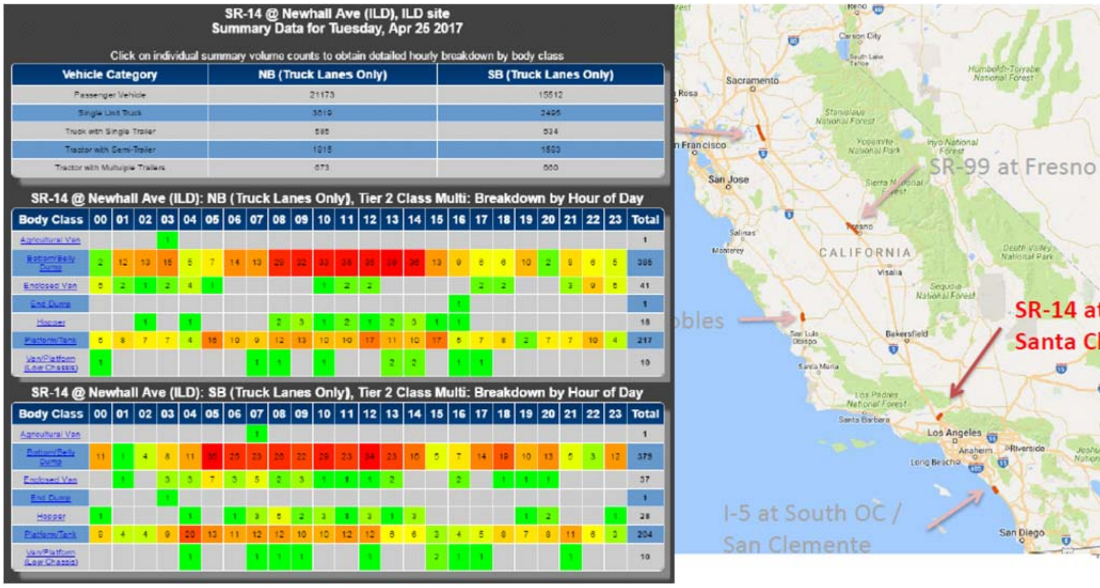

FIGURE 7 Example of information provided by TAMS.

Possible applications include estimating proportions of freight and nonfreight truck movements, analysis of empty movements, temporal and spatial travel patterns of trucks by industry, and proportions of long- and short-haul trips along major and restricted truck corridors. A specific example measured the magnitude of impacts of a port closure on the surrounding transportation network.

Participants identified several aspects that were discussed after the presentation.

- The ILD sites do not capture vehicle weight but this information is available at the WIM sites.
- Slow-moving vehicles have the potential to distort the waveform but the overall signature remains consistent.
- Currently, the smartcard hardware is manufactured and distributed by a single vendor although other companies have indicated interest in the product. The systems are calibrated by the researcher to preserve data integrity.

Data Collection and Use Challenges
Observations from the Field

BILL EISELE
Texas A&M Transportation Institute, presider

RAHUL SRIVASTAVA
Caltrans, recorder

A panel consisting of Nicola Mammes, New York City Department of Transportation (DOT) and Magnus Swahn, Conlogic, presented case studies highlighting the challenges of collecting, processing, and using freight data to make meaningful decisions. This was followed by a facilitated discussion.

APPROACHES TO MONITOR TRUCK LOADING ACTIVITY IN NEW YORK CITY USING VIDEO ANALYTICS

Nicola Mammes
New York City Department of Transportation

With the recognition of the need to study freight in New York City, the DOT expanded their Office of Freight Mobility with the mission of reducing the impacts of trucks on communities and infrastructure, while also supporting the city's economic competitiveness. Their 2016 Strategic Freight Goals included the following:

- Improve the safety, environmental performance, and economic efficiency of truck deliveries across the five boroughs, in partnership with the freight industry.
- Foster a culture of regulatory compliance in the trucking industry.
- Expand partnerships with the freight and trucking industry to encourage sharing of data to better manage truck movements throughout the city.

The presentation highlighted a key pilot project to develop a quantitative approach for predicting freight demand to manage curbside loading space management. The project included the following goals:

- To pilot video analytics for transportation data collection, planning analysis, and policy development;
- To develop a data-driven methodology for projecting freight demand in New York City;
- To validate a prototype formula developed by WXY Architecture + Urban Design (funded by the New York State Energy Research and Development Authority) to calculate off-street loading and unloading capacity; and

- To align off-street loading capacity with on-street loading availability for improved street efficiency.

The first step in validating the prototype formula to calculate the unmet loading capacity included calculating the loading berth needed per hour and subtracting the available on-street and off-street loading capacity to calculate the unmet need. Trucks counts were made using a video analytics pilot. The metrics for counts included the following:

- Traffic volumes by classification of through traffic on street;
- Parking utilization on-street by truck classification;
- Loading dock utilization off-street by truck classification; and
- Double parking by truck classification.

Future data collection includes determining freight trips that are generated by individual stores based on trajectories to and from individual trucks. This pilot will provide quantitative data that will be used to validate the WXY formula.

Some key lesson learned and take-away message from the pilot project are as follows:

- Analytics need to run at the camera (video analytics at the edge):
  - NYCWin: city-owned wireless network but cannot transmit video to run analytics,
  - Hard-wired networks: not suitable due to difficulty and cost to set up infrastructure,
  - Cellular networks: suitable and can support streaming video but are cost-prohibitive to use,
  - Managed Wi-Fi: not suitable for live video, and
  - Cloud analytics: need ongoing subscription and licensing costs;
- Need dedicated technical vendor staff to help troubleshoot and calibrate cameras;
- Need customizability given the uniqueness of each location–neighborhood cluster; and
- Installation and repair of camera to be done early morning before morning traffic begins.

Next steps in the further advancement of implementing the video analytics capabilities include the following:

- Transmit data from cameras and verify that analytics are working properly;
- Build a database to retrieve–ingest data ; and
- Develop a framework to process–digest metadata and to display it on a real-time dashboard for analysis and verification of loading formula.

Future plans include incorporating machine learning into the New York City–based video analytics architecture to support more robust vehicle classification.

In conclusion, the project demonstrates innovative video analytics technology with the potential for freight planning at a streetscape scale at a substantial time and cost savings in addition to producing detailed data for curbside management analysis. It also provides an opportunity to share the challenges that come with implementing such technologies.

REAL-BASED DATA IN REAL TIME: THE KEY ENABLER OF A PARADIGM SHIFT IN TRANSPORTATION AND TRAFFIC

Magnus Swahn
Conlogic

Sweden has one unified Transport Administration that owns and operates the entire transport system to support the country's economy. Its functional goal is to create the availability for travel and to manage transportation. The structure, function, and use of the transport system is to provide fundamental availability to everyone with good quality and ease of use, and to develop the strength of the country. The goals include safety, environment and health, in combination with a sustainable transport system. The goals also serve as support to inspire regional and local authority planning and to show the politically prioritized areas within the government transport policy. The state manages most of the resources and provides for joint financing of infrastructure as well as providing subsidies for private roads, contracted traffic, and support for research and innovation in the transport area.

The study focused on the need to increase knowledge about present traffic and freight flows to enable a more-efficient and -adaptive operation. Digitalization of data and increase in connected vehicles and cargo will enable access to real-based data (operational data), which will provide new opportunities both for the state and for shippers and carriers to improve transport logistics efficiency.

Overall conclusions of the study include the following:

- Operational data will be tomorrow's way of assessing information supporting maintenance, operation, and development of present and new traffic infrastructure.
- Operational data are likely to become a main pillar for long-term planning through statistical extrapolation of data or for use in calibrating present statistical models.
- Operational data should also include growth or downsizing decisions of larger local and regional actors and corresponding investment plans so that resulting impacts can be incorporated into transport demand.
- Access to operational data is also likely to heavily impact business models of transport logistics through new operative and tactical possibilities.

The study distinguishes between data about the movement of trains, ships, aircrafts, and trucks and data about the cargo being transported by these modes. The former is easier to obtain although not readily available while the latter is almost impossible to obtain.

The project conceptualizes centralized database architecture as shown in Figure 8 to support independent applications for the following purposes:

- Public authority applications include infrastructure planning and infrastructure management;
- Market-based measures for traffic management; and
- Commercial applications for horizontal collaborations.

Several data issues require further analysis prior to implementation to ensure success and include the following:

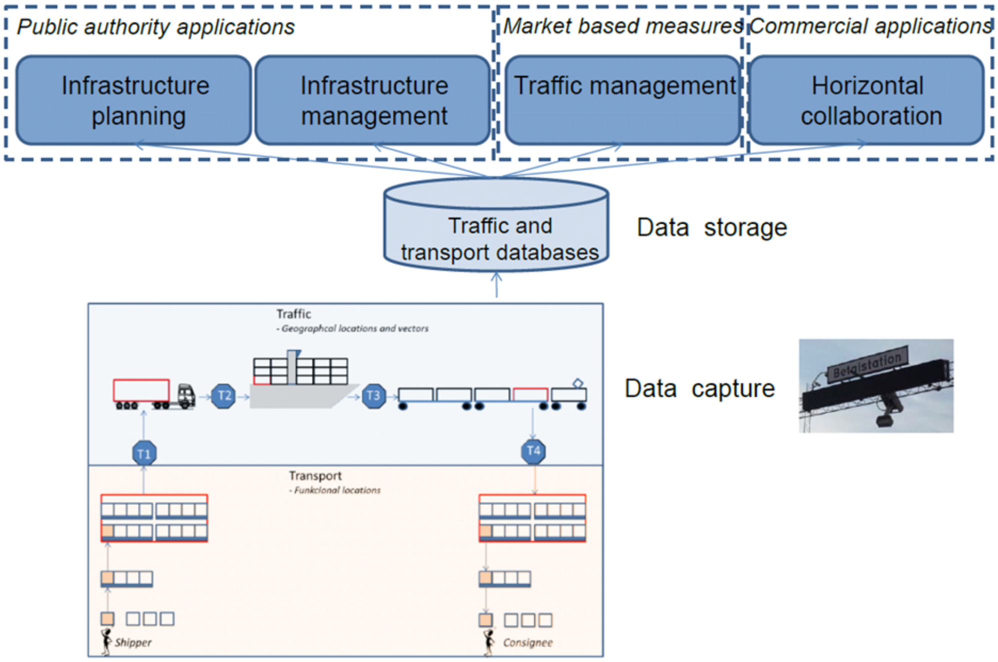

FIGURE 8 Conceptual architecture for operational freight data management.

- Integrity,
- Secrecy,
- Quality (validity and reliability),
- Accessibility,
- Costs and resources to capture, store, and use the data, and
- Building trust.

In conclusion, the project demonstrates the potential to structure one unified freight flow database with individual modules for focused data analysis for separate uses and applications by individual agencies and partners based on their need. It also highlights the need for coordinated efforts and partnership building to build such as unified data system.

FREIGHT DATA COLLECTION AND USE CHALLENGES: FACILITATED DISCUSSION

Bill Eisele
Texas A&M Transportation Institute

Following the presentations, workshop participants had the opportunity to ask questions and solicit additional information and perspectives from the presenters. The discussion provided insights into the challenges of data collection and highlighted the need for coordination and planning for freight as the state of affairs becomes increasingly complex. Key points that were raised by participants or expanded on by panel members are listed below and are generally grouped by general freight issues, technology, and urban considerations.

- Freight is being talked about at the National Association of City Transportation Officials.
- The risks and challenges of sharing data provided by logistic providers and private firms are real and should be addressed directly.
- Obtaining timely data is a constant challenge and understanding its latency more so.
- The full potential of machine learning for improving data collection and analysis and for being more cost-effective and scalable is unknown at this time.
- Agencies are challenged to adapt more quickly to changes in technology.
- Multiple studies using video analytics are ongoing in several locations around the world.
- Video collection techniques are appropriate for vehicle counts.
- New York City video recordings are only stored for 2 weeks to manage privacy issues. Information is saved as text files and some image files.
- For video analytics, typical costs are $2,000 to install and $10 per year to maintain and operate the equipment.
- The focus of video capture in New York City was delivery vehicles, commercial loading zones, and service vehicles such as telephone utility vans.
- Load matching to coordinate cargo is a known method to reduce truck traffic but a participant hypothesized that truckers do not share that information due to a perceived loss of competitive advantage.
- Unused capacity of up to 30% exists due to structural imbalance in the system. Independent truckers often take “return loads” to make extra money but typically may not disclose it. As a result, capturing the extent and characteristics of this trip type is unavailable to planners and policy makers.
- The public dislikes trucks on their local roads but are more accepting when asked if they shop online.
- Planning and operational analysis and tools are typically not available at the block or street segment level. For example, what tools are available to manage curbside space in a city or nationwide?
- Dwell time for vehicles in loading zones could be expedited if dedicated freight elevators are available and optimized for movement between floors.
- Reduction of failed deliveries could minimize dwell times at loading zones but reducing these is a business challenge and not in the purview of public agencies.
- City laws on loading zones are often outdated and as a result are unenforced.
- It is not clear who manages building design versus street design.
- New York City considers bike–pedestrian interactions with automobiles but not yet with freight vehicles.
- New York City has several freight-related initiatives including enhancing its capability to visualize streetscape to include freight, developing a citywide freight plan and street planning for freight, updating its street design manual, incorporating green loading zones, including electric vehicle charging stations, and encouraging e-bikes for freight–package delivery.
- A series of innovative concepts were hypothesized including:
  - An underground freight system similar to an underground transit system,
  - Double deck truck parking, and
  - Turn tables for trucks in cul-de-sacs.

Big Data Analytics, Supply Chains, and Artificial Intelligence

SCOTT DRUMM
Port of Portland, presider

ALISON CONWAY
City University of New York, recorder

Supply chain practitioners, technology firms, and cities are developing innovative ways of applying big data to improve operations, safety, and strategic objectives. This panel introduced innovations that have potential application to freight data development.

ANALYTICS AND DATA MANAGEMENT DRIVES FREIGHT DECISION MAKING

Katy Salamati
SAS

Katy Salamati described three use cases for freight data. The first project is being conducted for the North Carolina DOT. Major growth in freight transportation activity has occurred with rapid population growth in the state, particularly in the Research Triangle region. Previously, freight planning relied on vehicle counts by class and WIM data. However, these sources present some challenges; for example, results are impacted by the time of year during which counts are conducted and it was difficult for North Carolina DOT to integrate various sources of data together for better analysis. Changes over time are also difficult to measure as the locations of nonpermanent counting stations change annually. To provide insights into freight activity, SAS integrated multiple sources of data including traffic counts, waybill data, and WIM data and conducted various advanced analytics such as clustering to study how freight activity around major activity centers has changed over time. Future work will add port data. The purpose of the project is ultimately to provide improved data for planning models and to provide a project score to quantify impacts associated with freight movements that will assist with making more-objective decisions for prioritizing state transportation improvement plan (STIP) projects. Figure 9 provides a mock-up of a dashboard of supporting freight analytics and facilitating this decision making.

The second project shows how SAS used edge analytics capability through SAS Event Stream Engine to identify proactive maintenance requirements for a fleet of more than 40,000 trucks. The initial model in predicting the probability of turbocharger failure was developed using SAS Asset Performance Analytics. Edge analytics were employed to minimize the amount of data sent and stored in the cloud and to enable fast decision making. SAS Event Stream Processing Engine is embedded in an Intel chip. Live data streams from more than 60 sensors were checked against models in real-time. The models can also be updated in real time using machine learning. The models predicted the probability of engine turbocharger failure within 30 days with 90% accuracy, allowing the operator to realize significant cost savings.

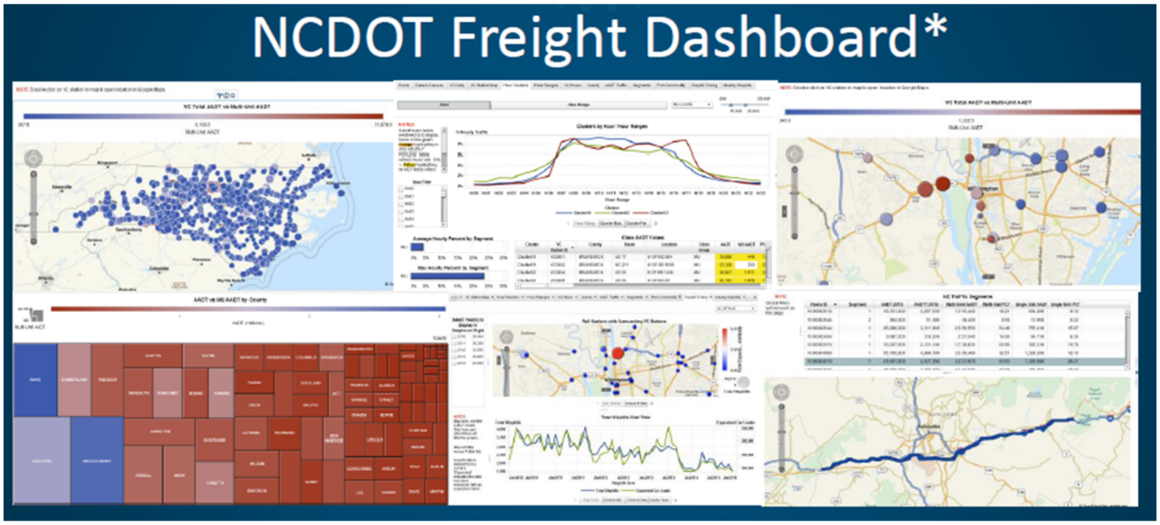

FIGURE 9 Mock-up of North Carolina DOT freight analytics dashboard. (Note: Work is in draft form and subject to North Carolina DOT acceptance. The content does not represent North Carolina DOT's point of view.)

The third application—the United Nations Comtrade database—provides free online access to historic global trade data.[9] The database includes more than 335 million records of data bought and sold around the world since 1998. Previously, the data had to be downloaded 50,000 records at a time; now the full data can be accessed using online tools for data manipulation and aggregation. In 2015, SAS used these data to help International Organization for Migration locate and order metal sheet roofing to help with the Nepal earthquake victims.

VIDEO ANALYTICS TO CLASSIFY MOVEMENTS AND VEHICLES

Yinhai Wang
PacTrans

Yinhai Wang presented a project conducted in partnership with the University of Washington (UW), the City of Bellevue, and Microsoft. While video has been widely implemented, it is usually transmitted to a traffic management center where it is manually reviewed by human staff. Some agencies have video image processors (VIPs), but these are expensive to operate. Surveillance with video analytics offers an opportunity to provide similar performance to VIPs at a lower cost. Initially, Bellevue began working with UW to collect information about collision near misses. Microsoft then joined the project. The goal was to capture not only the fatal–serious injury incidents commonly recorded, but also slight and potential conflicts. Another objective was to generate incident records unbiased by individual reporting.

The project uses a video feed from a real-time system to identify near misses, which are sent to a traffic management center for review and analysis as conceptualized in Figure 10. From this information, the system identifies and maps high conflict locations where many near misses occur. The system also calculates vehicle trajectory, identifies turning movements, and is useful for obtaining vehicle classification counts. The project employs neural network methods, which

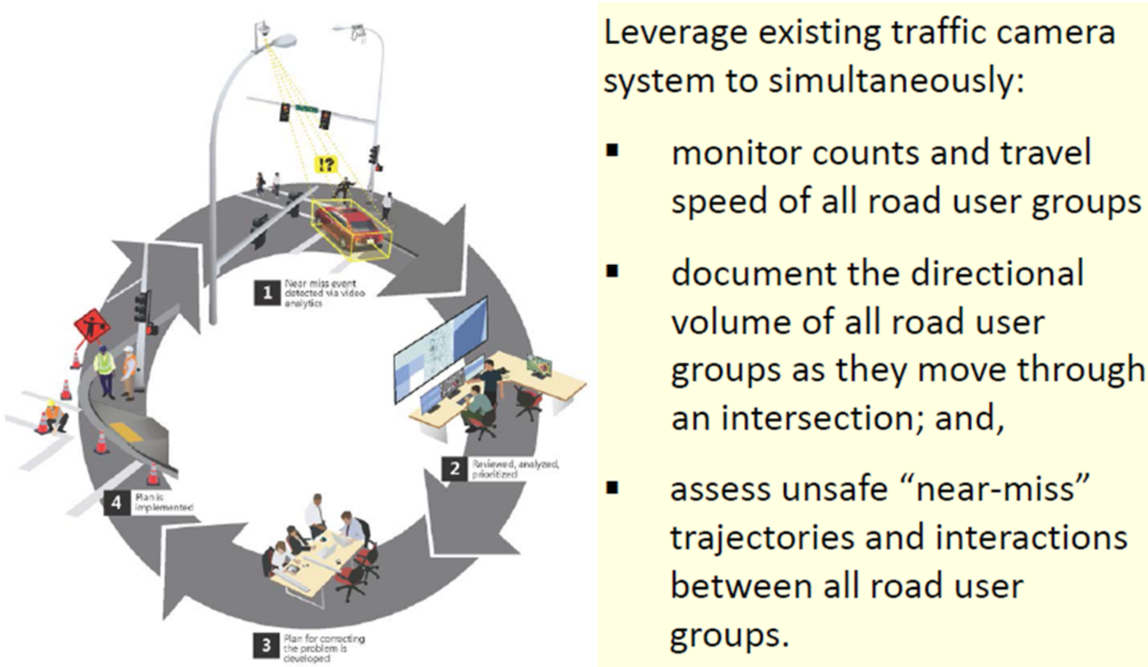

FIGURE 10 Video process for real-time traffic analytics.

rely on training images to learn to detect bikes, pedestrians, and vehicle types. In examining ground truth, the performance is good but can be improved with a larger training dataset.

Wang also mentioned the Mobile Eye project, which uses combined video and telematics to detect near misses.

In response to a query about how accuracy is measured, Wang responded that analytics are compared to manual video observation.

TRUSTED DATA COLLABORATIVES TO BENEFIT CITIES

Bill Mitchel and Connie Fan
Microsoft

Bill Mitchel described Microsoft's data Collaboratives program. The goal of the program is to take a high-level look at urban problems and to connect partners to solve these problems through the application of technology. Implementation requires partnership between diverse stakeholders whose interest are not necessarily aligned without a concerted effort by a city government. Data often exists in silos and while data may be of little value in isolation, it is often protected for security reasons or because of its recognized potential market value. The challenge is that leveraging the value of data typically requires that it be merged with other datasets, which traditionally has meant that data has to be openly available. Within this constraint, cities are looking for business models where they can derive a revenue stream from their data.

The concept of a "Trusted Data Collaborative" is not a new idea but builds on early thinking from the New York University Center for Urban Science and Progress. The challenge becomes breaking down silo barriers and providing a technology platform that integrates open

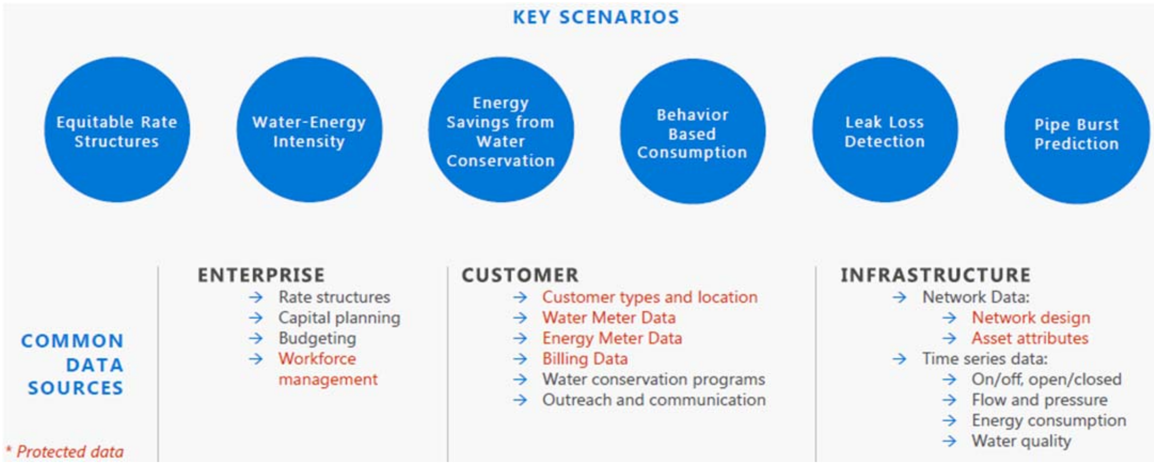

FIGURE 11 UC Davis Center for Water Energy Efficiency architecture using the Microsoft Cloud.

data with private and secured data, at scale. The platform must ensure security and privacy through controlled access. This includes a method for validating compliance with data access rules. One example is the UC Davis Center for Water Energy Efficiency, which integrates a number of datasets including infrastructure data and personally identifiable information from customers as outlined in Figure 11.[10] Use of some of these data is also governed by the U.S. Department of Homeland Security through the Critical Infrastructure Information Act of 2002. Sensitive data are aggregated at scale in a secure platform and stored in the cloud, ensuring security and privacy.

Mitchel emphasized three guiding principles for data collaboratives: (1) transparency, to provide clarity on motivations, policies, and regulatory constraints; (2) accountability, to protect rights and interests and maintain provenance, chain of custody, and analytical–algorithmic transparency while ensuring access; and (3) fair value exchange.

User Breakout Discussions

Following the formal sessions, workshop participants were divided into three breakout sessions and were tasked with discussing workshop findings and identifying promising findings, gaps, and possible next steps. Each group was asked to respond to three questions based on individual experience and information from the four panel sessions:

- What new data sources have been identified?
- Which areas of freight data analysis seem most promising?
- Which gaps have been addressed and what gaps remain?

Summaries of each breakout session are presented in the following sections.

BREAKOUT DISCUSSION 1

Donald Ludlow
CPCS Transcom, presider

Michael Ruane
Delaware Valley Regional Planning Commission, recorder

Introduction

This breakout session consisted of individuals from federal, state, and regional agencies, consulting firms, and academia. The discussion was divided approximately equally between the three questions related to new data sources presented at the workshop, identification of those that seemed most promising, and evaluation of data gaps.

New Data Sources

Discussion about new data sources focused on new video and computer vision technologies as well as the reuse or extension of existing data products.

Several participants identified the use of night-lights satellite radiology for estimation of freight activity, especially for regions with limited base data or to supplement other open data sources. Additional computer vision and video applications were highlighted in the discussion as new and interesting methods for data collection and analysis.

Some participants highlighted the use of inductive loop sensors to identify more specific vehicle profiles. A specific characteristic of this technology was the leveraging of machine learning and technology upgrades at inductive loop stations to further enhance the detail of data collected, providing industry-specific truck counts.

Also discussed by participants was the fact that many of the presentations demonstrated applications of computer vision, machine learning, or deep learning. The fusion of multiple data sources coupled with some level of artificial intelligence was noted as an advancement over previous techniques in data collection and analysis.

Promising New Data Sources

Building on the first question, participants considered that the most promising new data sources might come from potential fusion opportunities. For instance, several participants noted that the inductive loop collection of industry-type truck counts could be coupled with WIM station data to provide further detail on not only the body style of trucks but also their loaded weight. This could possibly facilitate a better understanding of empty miles traveled or other measures of efficiency for truck moves along major corridors.

Several participants considered that the reuse of existing technology or data collection infrastructure was promising. Repurposing or improving existing infrastructure such as cameras, inductive loop sensors, or archived video and image data using new technologies was noted as a very promising advancement in the collection of new or enhanced data for freight planning. As noted in the previous section, the use of machine learning or other artificial intelligence was identified as a fundamental improvement over previous techniques because it provides new opportunities to fuse data and to extract advanced information from existing data.

Evaluation of Gaps

The breakout group closed with a discussion about what data gaps had been addressed by new data sources at the workshop and what gaps remained. The conversation was further framed around gaps in granularity, linkages, and consistency.

Related to gaps that are being addressed, individuals identified several improvements. The truck vehicle information gap was noted as one that is closing, especially given the multiple datasets that could be integrated—GPS, improved loop detectors, video, and WIM. Several members also mentioned reduction of latency and multiplication of uses for data that is collected through singular or existing infrastructure as addressing existing gaps. These characteristics were also noted as enabling expanded cross-disciplinary collaboration.

The group spent more time discussing some of the remaining gaps as well as considerations for going forward with the development of new methods of data collection and analysis. Some participants observed that standardization of data remains an obstacle and, at the federal level, it makes answering some basic questions a long and challenging task. Rail data was noted as a remaining gap that has unique obstacles. Concerns were raised by participants about the need to create work arounds to collect rail data when the industry has everything that is needed to answer questions that researchers and practitioners are trying to address.

Individual members also raised concerns about the definition of research questions that are being answered by new data efforts. These participants were concerned that data have defined uses and applications. To prevent resource allocation to the development of data for data’s sake, a participant suggested that the questions that must be answered by freight practitioners and policy makers be articulated and, from these questions, existing data that can be used to answer these questions be identified. Gaps that remain would then be identified. This was suggested as a useful research initiative to help focus data development and improvement on areas that have the highest potential return.

BREAKOUT DISCUSSION 2

Taso Zografos
ZDEVCO, presider

Kate Hyun
University of California Irvine, recorder

Introduction

This breakout session included federal agency officials, individuals from other agencies, users of data, and those from academia. The group discussed new data sources, promising freight analysis areas and remaining gaps throughout the discussion. Discussions of are summarized below related to each question.

New and Promising Data Sources

Innovative data sources that were discussed included video images from surveillance cameras, GPS, Bluetooth, onboard devices, Wi-Fi, inductive signatures from loop sensors, night-light images from satellites, and acoustic sensing. Among these, video analytics was identified as one of the most promising sources because it allows for a potential automated data collection, particularly for vehicle classification and identification. Participants indicated that these data sources were expected to provide better estimates of TT and congestion and to expand real-time broadcasting, which could also enhance smart city evolution. Participants also expressed interest in expanding research in new ways to better use traditional data sources.

Participants discussed several methodologies to clean data and to integrate datasets including machine-learning technologies to fuse information from multiple data sources. From a discussion on big data aggregation, one participant indicated that it is important to maintain the complete unique elements within those data sets. Some participants pointed out that data collection methods, data access, and standardization are the key issues in data integration.

Part of the discussion focused on areas that were not covered during the workshop including:

- Multimodal supply chain,
- Unit standardization, and
- Intermodal data.

The promising areas suggested by attendees focused on analytics and techniques, such as predictive analytics and back-casting analysis. In particular, a participant stated that back-casting analysis was considered important for decision makers, since it supports improved prediction for future scenarios.

As part of this discussion, participants identified safety, environmental impacts, mobility and security as promising application areas. Disaster response was chosen as another key area for the freight data analysis and application.

Another part of the discussion revolved around looking at data from the perspective of business needs as well as from the public agency perspective. Also, different stakeholders have different roles with respect to freight data. The public sector typically addresses policy issues and performance measurement, while academia explores new methodologies and tools associated with data collection and analysis. A few participants indicated that inefficiencies often occur in data analysis because tools and roles are not fully understood or shared between sectors.

Evaluation of Gaps

The following data gaps were discussed:

- Data from drones;
- E-commerce information to evaluate effects of big companies like Amazon and Google;
- Commodity data at a specific roadway level;
- Aviation related data including regulation information;
- A better knowledge of proprietary and private data; and
- Life span of data.

The following analysis gaps were identified:

- Impacts of freight on the infrastructure such as pavement operation and maintenance and
- Impacts on nonfreight trucks (that is, service vehicles).

Participants identified freight behavior movement as a promising area and as being distinctly different from conventional forecasting in that motivating factors are critically important as input to freight analysis.

BREAKOUT DISCUSSION 3

Alison Conway
City College of New York, presider

Heather Manteiro
University of Nevada Las Vegas, recorder

Introduction

This breakout session included participants from a wide range of backgrounds. Although participants considered the first two questions about new data sources, much of the discussion focused on gaps that were not addressed during the workshop.

New Data Sources

In response to the first question, participants focused on three areas: data sources, current successes, and applications of data analysis seen in the workshop.

Data Sources

Several new data sources were presented and mentioned including crowdsourcing data, UN Comstat data, sensor loops and their applications, visual recognition data, and satellite data. While some participants felt there were no new data sources presented, others emphasized the power of integrating data sets, which stood out to them during this workshop.

What Is Currently Being Done Well?

The group discussed data collection and analysis methods that were considered to be effectively implemented and leveraged. Participants identified progress towards scalable integration of different data sources, real time data availability, and enhanced data collection technology such as that found on the Volvo truck demonstration at the workshop.

Applications

While the technologies mentioned in the previous sections were lauded, some participants expressed doubt about their efficacy, considering that the resulting data may be a notable asset, but that they lacked a business case, that is, these are technologies in search of a problem.

Promising New Data Sources

The discussion shifted from promising data sources to future needs for data collection, analysis, and sharing.

Magnitude of Progress

Some participants considered that the innovations presented during the workshop are marginal and incremental for use by transportation researchers and planners, and are not the paradigm-changing evolution that is needed. A participant posed the question: what are the larger paradigmatic changes that are on the horizon for freight data and its analysis? Another concern is simply how what is currently being done can be done faster and more economically.

Sharing

Two themes were discussed about sharing data, methods, and related knowledge. First, participants raised the issue of trust related to sharing data between private companies and research and planning organizations. Some participants emphasized the need for researchers and planners to provide a value proposition to private companies from whom obtaining data would be beneficial such as making a business case or providing some value in return for private companies providing data. The second theme focused on sharing progress, innovations, and data among the research and planning communities. This workshop illustrated several groups of researchers and planners who are approaching a similar problem or research question from different angles. If knowledge of these efforts were shared, more progress might be possible from combining efforts.

Evaluation of Gaps

While many participants expressed appreciation for what they learned during the workshop, some voiced concerns about gaps they saw between the presentations and the current needs of transportation research and planning. These gaps fell into four main categories: access, data quality, data limitations, and research questions.

Access

As indicated in the previous section, several participants noted the gap in approaches to sharing data, particularly by private organizations.

Data Quality

There was also discussion of data quality. A participant stated that many samples are convenience samples; that is, trucks are tracked by GPS and because one private company made their data available for tracking (known as a convenience sample), this is not generalizable to all trucks, calling into question the generalizability of the conclusions made from the analysis of such data.

Limiting

Another gap is the limitations of data collection and analysis, that is, for long-haul freight, measuring only vehicles instead of cargo, and being focused solely on first world countries, while being unaware of the challenges of less-developed nations. Several respondents emphasized the need for focusing on other freight movements including urban freight, drayage, and last-mile delivery.

Open Research Issues

While many participants were excited about the technological innovations in the workshop, some were concerned that these technologies are not focused on solving any particular business problem or research question. Several respondents thought that these are technologies in search of a problem or question.

While many participants in the group reported feeling optimistic and satisfied with the direction of freight data collection and analysis, others pointed out the lack of magnitude of progress in methods. Concern was also voiced about the lack of providing a value proposition to private companies for obtaining data. A participant stated that the necessary paradigm shift has not yet occurred.

Concluding Remarks

ALISON CONWAY
City College of New York

The TRB Innovations in Freight Data Workshop brought together a diverse group of stakeholders to reflect on the state of the art and the state of the practice for freight data applications. Participants learned about a variety of data sources being employed or tested, including GPS and Bluetooth; in-road, roadside, and onboard sensors; satellite radiology; and crowdsourced information. Through panel discussions, speed presentations, and interactive demonstrations, participants learned about a variety of applications for these data sources for freight modeling, visualization, and real-time operations.

In the breakout sessions, participants had the opportunity to reflect on the advances in freight data presented during the preceding sessions. A number of participants identified the use of artificial intelligence—particularly the integration of machine learning with computer vision and sensors—as a significant advancement to address persistent data gaps. Several participants also noted that real progress has occurred in the scalable integration of both emerging and traditional data sources to produce added value. They noted additional opportunities for integrating multiple sensors to give a more complete picture of freight activity—for example the possible integration of inductive loops with WIM to measure vehicle loading as well as to identify body type.

Participants also identified a number of tangible challenges that remain to be addressed. Given the mismatch between the geography of freight and the reality of jurisdictional boundaries, a lack of standardization is still an obstacle to seamless data integration. While new methods of sharing, storing, and securing data—particularly the use of cloud computing—have eased the technology requirements for individual stakeholders to make their data available, new partnership frameworks that provide real value for all participants and that protect the privacy of sensitive information are still needed. These may be further complicated by financial interests, as participants noted that some agencies are seeking new business models that will allow them to establish revenue streams associated with data. Others suggested that opportunities may exist for better communications between agencies, and even offices within the same agency, who are collecting redundant or overlapping data streams with multiple potential uses.

Many of the advances presented during the workshop focused on the use of new data sources to estimate traditional highway performance measures, whether more quickly, at a lower cost, or with better granularity. Participants identified local commodity flows, e-commerce, and service vehicles as persistent data gaps that remain. A number of participants also noted the need to include air, marine, and rail freight stakeholders in a broader discussion of innovative freight data practices and opportunities. Several individuals across breakout groups suggested that in addition to the incremental improvements in traditional practices already being realized, opportunities exist for a greater paradigm shift away from existing, modally siloed methods of measuring freight. However, they recognized that a key first step would be to define clearly new research questions. Participants noted that understanding the full potential for emerging data to achieve real improvements in freight planning, operations, and visualization would require an ongoing discussion with the freight industry and with technology experts in data science, artificial intelligence, sensor development, and other related fields.

Applications

The presentations and applications at the workshop were a result of a call for applications using recent “big” freight data innovations. Two applications, which demonstrated top innovations in research or practice, were awarded, one for Best New Data Source and one for Best Data Fusion. A description of the applications are presented below.

AWARD WINNERS
BEST NEW DATA SOURCE APPLICATION: TRAINFO

Garreth Rempel
TRAINFO Corp.

TRAINFO is a live railway crossing blockage information system. It provides an immediate notification when a crossing is blocked and predicts when it will clear. TRAINFO was originally developed to help first responders avoid blocked crossings when traveling to and from emergencies. However, this information has been used for many different applications, including many related to transportation engineering and planning.

Information Provided by TRAINFO

TRAINFO provides live and historical railway crossing blockage information. Figure 12 shows a screenshot of an interactive online map that illustrates the type of live information provided.[11] The green icons indicate a crossing is clear, yellow icons indicate that the crossing is predicted to be blocked soon, and red icons indicate the crossing is currently blocked. Clicking on each icon opens a dialogue box that provides a hyperlink to more-detailed live and historical crossing information. Rail lines, shown in red and black, can also be clicked to show the average number of trains per day and other relevant information.

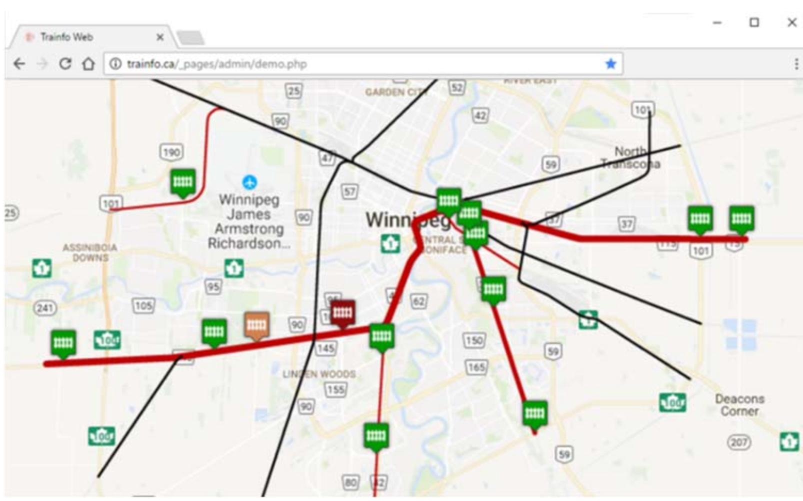

FIGURE 12 Live online map of railway crossing blockages in Winnipeg, Manitoba, Canada.

TRAINFO stores railway crossing information, which is used to produce detailed temporal trends and accurate statistics and is available in file formats such as Excel to facilitate custom analyses. Statistics that can be produced from this information include:

- Number of blockages by hour-of-day, day-of-week, and month;
- Average and maximum blockage duration; and
- Blockage duration by day-of-week.

TRAINFO Application

TRAINFO collects railway crossing blockage data and shares these data with users as shown in Figure 13.

TRAINFO can help reduce congestion, improve safety, and save money through

- Prioritizing infrastructure investments;
- Managing traffic;
- Supporting emergency services;
- Selecting railway crossing improvements;
- Responding to public complaints and inquiries; and
- Reducing collision risk.

Three example applications for prioritizing infrastructure investments, managing traffic, and supporting emergency services are presented in the following sections.

Detect
TRAINFO detects railway-crossing blockages using proprietary trackside sensors installed off rail property. These sensors are low cost, easy to install, require little maintenance, are insensitive to adverse weather, and highly accurate and reliable.

Transmit
TRAINFO uses edge computing and wireless communication to transmit data to secure cloud servers where the data are analyzed.

Analyze
TRAINFO applies patented, machine-learning algorithms to analyze the data. These algorithms confirm a crossing is blocked and predict when the crossing will be cleared and when it will be blocked in the future.

Share
TRAINFO shares information in many digital formats (e.g., XML, JSON, KML) via an application programming interface. This information can be delivered to smartphones, traffic management centers, dispatchers, roadside variable message signs (VMSs), and interactive online maps.

FIGURE 13 Overview of how TRAINFO works.

Example Application 1: Prioritizing Infrastructure Investments

Public agencies are responsible for identifying grade crossings that are candidates for improvements such as grade separation. Prioritizing these improvements is often based on benefit–cost analyses. One of the costs to consider is travel delays caused by blocked railway crossings. TRAINFO can provide the precise time-of-day blockages and exact blockage duration facilitating an innovative approach to measuring travel delay, rather than estimating it. This approach integrates railway crossing blockage data provided by TRAINFO, traffic volume data collected by pneumatic road tubes, and travel time data collected by Bluetooth sensors. As shown in Figure 14, TRAINFO data shows when blockages were causing delays, traffic volume data provides how many vehicles were affected by the delay, and Bluetooth data provides how much delay was experienced by these vehicles.

Table 2 provides a comparison of at-grade crossings in Winnipeg, Manitoba. Compared to the conventional method, the TRAINFO method found that the gate down time per train was more than twice as long, average daily train volumes were similar, more than twice as many vehicles were delayed, and total delay was more than four times longer. This resulted in a travel delay cost that was four times greater, which can significantly affect benefit-cost analyses and infrastructure prioritization decisions. Several crossings were evaluated with similar findings, although the average daily train volume is often much different.

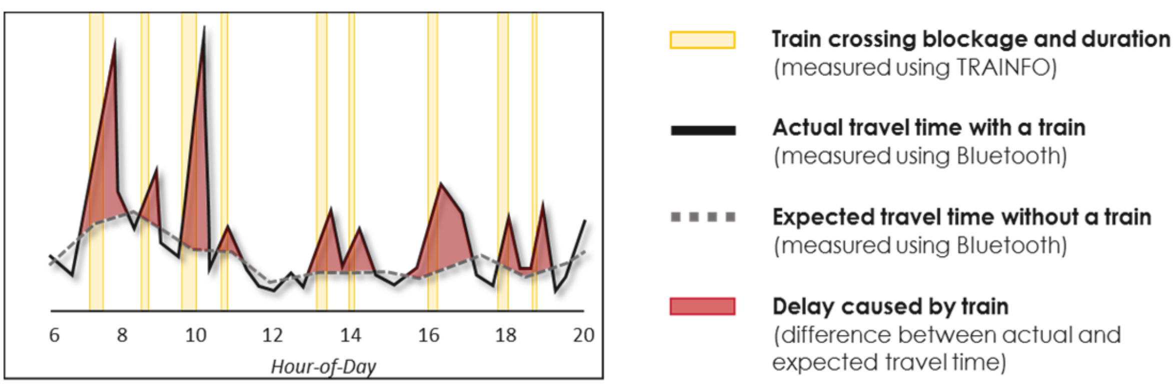

FIGURE 14 TRAINFO approach for measuring travel delay at grade crossings.

TABLE 2 Comparison between conventional and TRAINFO methods for calculating delay.

Metric	Conventional Method	TRAINFO Method	Difference
Gate down time per train (min)	2.7	5.4	+111%
Average daily train volume	35	38.0	+9%
Vehicles delayed per day	1,864	4,277	+129%
Total vehicle-delay per day (h)	53.2	286.6	+437%
Total person-cost per year	$510,000	$2,750,000	+437%

Example Application 2: Managing Traffic

Railway crossing blockages are usually unexpected and often occur with little warning. This unpredictability can cause significant nonrecurring congestion events. Public agencies have limited options for addressing this congestion including grade separation, which is very costly and sometimes infeasible due to land use constraints and other issues, or implementing minor geometric or traffic operations modifications that are low cost but often ineffective. TRAINFO's live railway crossing blockage information and ability to synchronize with roadside VMS facilitates an intermediate approach to mitigating traffic congestion at grade crossings. TRAINFO is working with MORR Transportation Consulting to install Bluetooth sensors along a roadway with a grade crossing and a VMS prior to the crossing. TRAINFO monitors the crossing to determine when it is blocked and Bluetooth sensors monitor TT. These data are wirelessly transmitted and integrated within TRAINFO's cloud server system, known as LeXIS (Level Crossing Information System), which applies proprietary algorithms to calculate and predict expected travel delays due to crossing blockages. This information is wirelessly transmitted to the VMS to alert road users about potential delays. Figure 15 illustrates this approach, which is currently being implemented in Winnipeg, Manitoba.

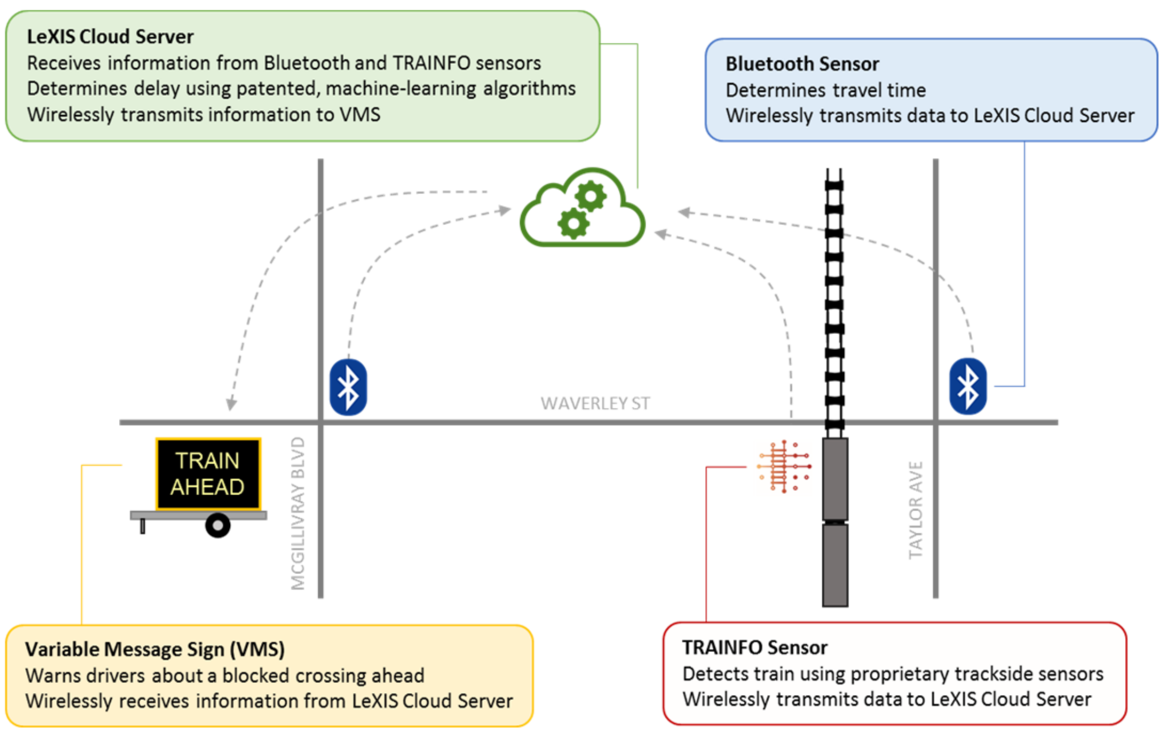

FIGURE 15 TRAINFO approach for mitigating congestion at grade crossings.

Example Application 3: Supporting Emergency Services

Most emergency services departments, such as fire and paramedics, strategically locate their stations to minimize potential delays with railway crossings, among other considerations. However, many of these delays cannot be avoided. TRAINFO's ability to provide advanced warning to emergency vehicle dispatchers and drivers about a blocked crossing can help minimize these delays. TRAINFO worked with the University of Saskatchewan and the City of Saskatoon Fire Department to evaluate the effects TRAINFO could have on dispatch operations. Figure 16 illustrates the results for Saskatoon's downtown fire station. The catchment area for this station is divided by a rail line with seven grade crossings. The shading represents response time where the darkest shade is less than 4 min, the lighter shade is less than 6 min, and the lightest shade is less than 10 min.

Figure 16*a* shows the response time when a train is blocking the crossings and when TRAINFO is not available. The response time across the tracks is reduced and there is a portion of the catchment area where the response time increases to ten minutes directly north of the station. Figure 16*b* shows the response time when a train is blocking the crossings when TRAINFO is available. As indicated, response time reduces north of the tracks substantially.

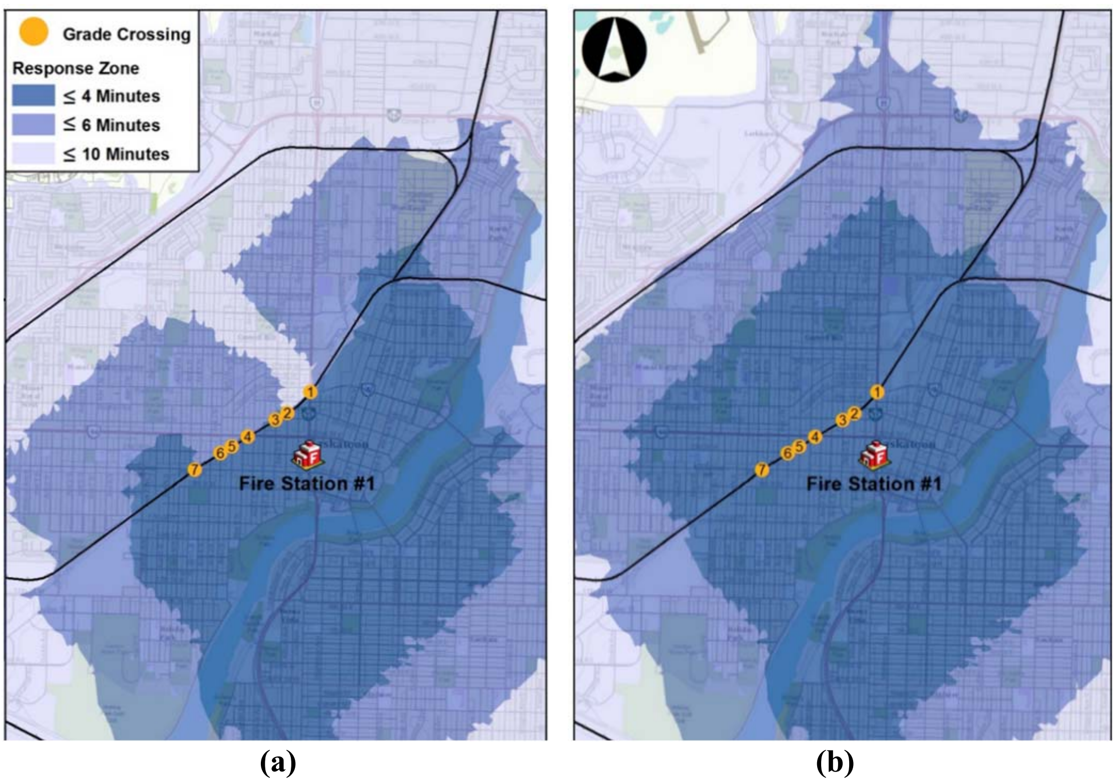

FIGURE 16 Saskatoon Fire Station #1 response time when a train is blocking the crossings: (*a*) without TRAINFO and (*b*) with TRAINFO.

Summary

TRAINFO is a new data source for live and historical railway crossing blockage information. It uses proprietary trackside sensors that are installed off rail property to determine when a crossing is blocked and patented machine-learning algorithms to confirm blockages and predict when the crossing will clear. It then delivers this information to smartphones, roadside VMS, traffic management centers, emergency dispatchers, and others to help reduce congestion, improve safety, and save money. TRAINFO's vision is a world with seamless mobility and no railway crossing fatalities. To support this vision, TRAINFO offers to provide this information to public agencies at no charge at crossings with more than 7,200 vehicles per day and more than 24 trains per day.[12] This offer provides live data for a minimum of 1 year and historical information indefinitely in exchange for sensor installation and power. Sensors typically require 1 h for installation and power consumption is negligible.

BEST DATA FUSION APPLICATION: ADVANCED FREIGHT MODELS AS DATA INTEGRATORS

Five Takeaways from the Megaregional Multimodal Agent-Based Behavioral Freight Model

Vladimir Livshits
Maricopa Association of Governments

This presentation was prepared with assistance from FHWA, Maricopa Association of Governments, Arizona DOT, ATRI, Cambridge Systematics, Inc., CDM Smith, Inc., IHS Global Insight, InfoGroup, Pima Association of Governments, RS&H, Inc., StreetLight Data, Inc., and Walls and Associates, Inc.

The Maricopa Association of Governments (MAG), Arizona DOT, and Pima Association of Governments (PAG) jointly developed a successful proposal for the Round 3 of Strategic Highway Research Program 2 (SHRP 2) C20 Implementation and Technical Assistance Program Grant.[13] The grant funds were designated for a pilot proof of concept study to develop a behavior-based freight model. The proposed scope exceeded the original grant offering and included development of an operational megaregional multimodal agent-based behavioral freight model based on the guidelines identified in the SHRP 2 C20 findings. The model was developed in accordance with the agencies' travel forecasting and planning needs. The behavior based freight model was implemented using R and Java script language.

The Arizona Sun Corridor megaregion is among the fastest-growing megaregions in the country and a freight gateway to the international market. This emphasizes the significant importance of a freight policy analysis tool to the megaregion's decision makers that is consistent with MAG freight flow forecasting needs.

The goal was to develop a megaregional multimodal behavioral freight model. The objectives that were achieved during model development include:

- Improve and expand the knowledge base;

- Develop modeling methods to reflect actual supply chain management practices;
- Develop modeling methods based on sound economic principles;
- Maximize use of freight tools by the public sector for planning and programming; and
- Improve availability and visibility of data between public and private sectors.

The study demonstrated the use of cutting-edge, behavior-based modeling approaches for evaluating freight policy impacts at the regional scale.

Model Design

Figure 17 provides the context for model development and the interactions between data, models, and applications. The model framework has three main layers.

1. Financial–economic layer,
2. Logistics layer, and
3. Transportation layer.

In the economic layer, each node has a certain amount of demand associated with it. In the logistics layer, each node has supply associated with it from the supply chain model. The output from the logistics layer is rolled into the transportation layer via commodity flows and modes of transportation.

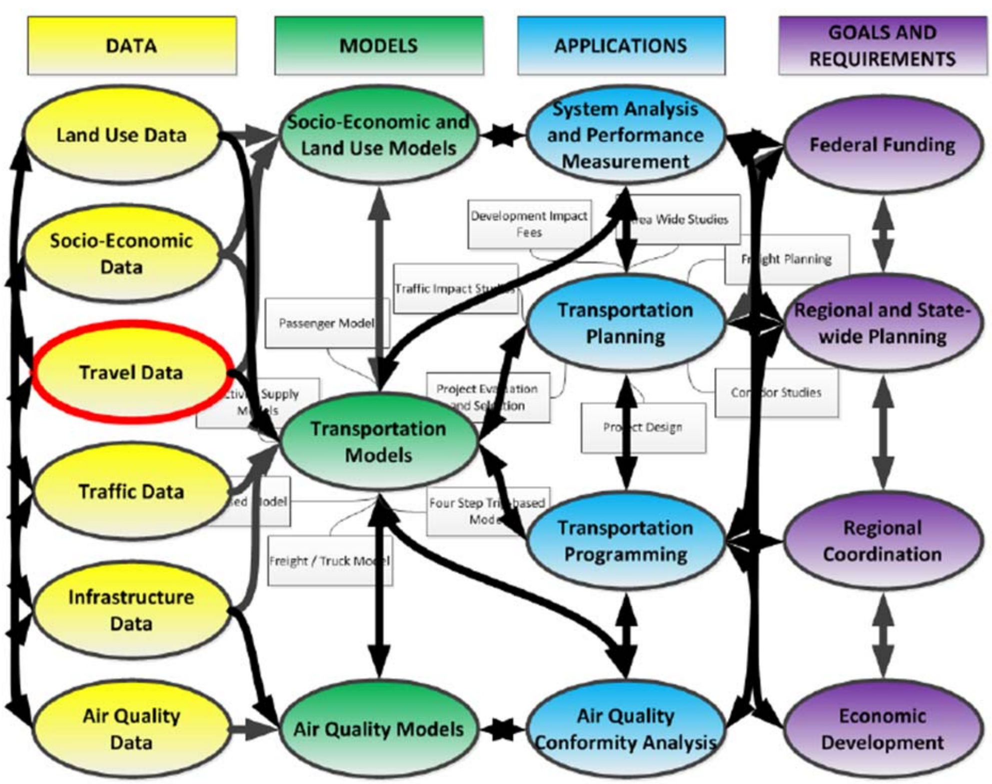

FIGURE 17 Freight model overview.

Review of Freight Data Sources for the Development of a Behavior-Based Freight Model

The project team reviewed data requirements for each layer. A list was compiled of commercially available data as well as public databases with a detailed description of contents. This description included: (1) advantages and deficiencies of each of the datasets; (2) sources and methods used in compiling the datasets, if available; and (3) aggregate statistics of databases where available, including number of records, levels of geography, exclusions from datasets, pricing where applicable and available, contact information where applicable, and periodicity of updates. Data that were used from each source in both the state of the practice and state-of-the-art freight models were documented to identify whether they were candidates for estimation, calibration, or validation of models. Finally, data summaries from each dataset were prepared at a regional level or state level, depending on availability.

Analysis of Datasets Used in the Model Development

Datasets were identified for the development of each submodel based on its specific data needs. MAG acquired or used the following datasets:

- National Establishment Time Series (NETS) data,
- ATRI Truck GPS data,
- StreetLight Truck GPS data,
- IHS Global Insight's TRANSEARCH data, and
- FAF 4.1 data.

Firm Synthesis Model

Firm demographics were modeled using a microsimulation approach for the Phoenix-Tucson megaregion. The model predicts the location, magnitude, and size of firms in the study region based on firmographics. This model uses the NETS database as a seed table. A series of econometric models are estimated to simulate the firm events that consider determinants such as firm internal attributes (size, age, and growth) and external attributes (market area characteristics, transportation costs, agglomeration economies). The simulated results are validated with observed firm demographic trends along with zone-level employment estimated using goodness-of-fit measures.

Supply Chain Model

Supplier selection was modeled using two components: (1) a supplier selection model and evaluation of commodity flows and (2) a transport, mode, and path choice model. The resulting agent-based supply chain and freight transport model uses disaggregate behavior-based logistics and transportation choice models to simulate commodity flows at a firm level. The model considers firms or business establishments as individual decision-making units in the freight transportation system. It assumes that logistics and supply chain decisions are made by business establishments. These logistics decisions include supplier selection, shipment size, and mode choice. Supplier evaluation and selection process is among the most crucial logistics decisions in supply chain management. An agent-based computational economics approach for supplier selection was developed for the modeling supply chains in the MAG–PAG region. The transportation choice model consisted of a nested logit model, which was estimated for freight mode and shipment size choice. Four modes of transportation were considered including truck, rail, air, and parcel (such as U.S. Postal Service, UPS, and other couriers).

Tour-Based Truck Model

The objective of the truck tour model was to develop truck trip chains by industry sector and truck type. These truck trip chains were then grouped into major linkages based on land uses where trucks make stops and the probability of making another stop based on the number of previous stops. The tour-based model generates the number of stops by industry sector, number of stops on a tour, stop purposes, and the location and time of day of stops. Truck GPS data from two different sources ATRI and Streetlight were used for developing tour-based models by truck type.

Integration of Supply-Chain and Tour-Based Models

The supply chain model outputs annual commodity flows in tons by commodity group. The truck tour model produces tours of trucks that travel from an origin of the tour to the destination of the tour including intermediate stops by time period (i.e., average weekday). The legs of the tour, i.e., between each stop of the tour, can be unchained into a trip table by making each leg of the tour into an individual trip between stops. Only truck flows from the supply chain model were used assigned to the highway network, while rail, water and other modes of freight were not assigned to any networks. Truck flows were converted to daily truck tours and trips and integrated with the highway assignment model.

Assignment and Validation

Tour results were converted to an O-D matrix and combined with MAG and PAG travel demand passenger vehicle matrices. These trip matrices were separated for MAG and PAG regions and then assigned separately to the respective highway networks using TransCAD.

Assignment validation was done at two levels of geography; first using a screenline analysis that included major freeways passing through the region and carrying large truck volumes and second comparing summed truck volumes at all locations where observed truck counts were obtained.

Conclusion

This project represents a step forward in behavior-based freight modeling as the project team was able to develop an operational megaregional model. Notable outcomes of this project included:

- Fusion of the discrete freight data sets used in the model;
- Implementation of new modeling approaches (e.g., a firm synthesis model that estimates business population over time and space, implementing the Roth-Peranson algorithm for buyer and supplier matching); and
- Development of visualization tools used to better understand and communicate model output.

Key Takeaways

Five key takeaways were identified as a result of this project.

1. Freight data integration problems are often unstructured problems.
2. Models are natural data integrators—they bring structure into data integration problems.
3. Big data and new agent-based and microsimulation demand models qualitatively change needs and approaches for data integration.
4. Increased fidelity of models (agent-based, microsimulation) leads to merging of models and data.
5. Visualization and analytical tools are a necessity (Figure 18).

HANDS-ON DEMONSTRATIONS

In addition to presentations and the breakout groups, workshop attendees had the opportunity to attend a hands-on demonstration showcasing the latest innovations in vehicle technology.

INSTRUMENTED TRUCK

Jeff Denny
Volvo

Bryan Schmitz
TEC Equipment

Representatives from Volvo and TEC Equipment provided access to and an overview of a 2017 Volvo Tractor.[14] The tractor includes nine onboard computers that monitor emissions, improve fuel efficiency, monitor vehicle and driver performance, and enhance safety. Data are available in real time onboard to the driver and through wireless cellphone service to the carrier and the vehicle manufacturer. For example, 4,500 topical maps are incorporated into the automated manual transmission with digital intelligence to optimize fuel efficiency.

FIGURE 18 Tools and visualizations from the project.

ADVANCES IN GPS APPLICATIONS

Origin–Destination Trip Data for Operations and Planning

Nikola Ivanov
CATT Laboratory

Introduction

Traditional O-D data analysis relies on data collected via transportation surveys, an expensive and tedious process that may not be a true representation of mobility patterns. In addition, by the time the data are collected and processed for use in O-D analysis, it is often outdated and may not provide accurate results. Some of the more modern methods of O-D data collection include Bluetooth reidentification, cellular data collection, aerial photography, and GPS locations. While these methods provide significant improvement over traditional methods, concerns remain about cost, accuracy, and bias.

Summary of Application

This objective of this project was to analyze a newly available O-D data set created by third-party private-sector GPS data providers. The initial research used INRIX O-D data for the state of Maryland for July 2015.[15] This data set shown in Figure 19 included 20 million trips, as well as 1.4 billion waypoints along those trips.

The initial analysis used clustering of trips and noise elimination to identify most used routes between specific O-D pairs to guide freight route choices. In addition, this analysis allowed understanding of most-traveled routes and a crosscheck against available transit service to identify potential transit service improvements that would have a high positive impact on movement of people.

FIGURE 19 Waypoints for trips—1.4 billion total—originating or ending in Maryland.

Another application of this data set included analysis of congestion patterns along routes by time of day and day of week. Using a similar clustering algorithm and associated TT data, the data set identifies congested routes by time of day and day of week as shown in Figure 20, which can be used by freight operators to make route choices based on departure location and time.

As data providers reduce the latency between collection and availability of O-D and the associated waypoint (trajectory) data, opportunities will become available to use these data sets in real-time to guide freight routing to avoid congested routes or incidents and to understand travel patterns of remaining traffic and impacts of re-routing decisions.

Finally, this project looked at traditional O-D matrices using this new data set. The newly developed visualizations shown in Figure 21 allowed users to analyze O-D matrices as well as specific roadway links or routes being used for each O-D pair. In fact, the user was able to select a link or route and find the absolute number or percentage of trips from each origin zone to each destination zone traversing that link or route. This information provides additional insight into travel patterns between different O-D pairs.

VALIDATING THE FLORIDA FREIGHT MODEL WITH TRUCK GPS

Kaveh Shabani
Resource Systems Group, Inc.

Introduction

A major shortcoming of freight forecasting models is the lack of data for calibration and validation. This application used truck GPS data to calibrate and validate an advanced freight forecasting model for the state of Florida. Truck GPS data can be a relatively inexpensive data source for calibration and validation to enhance freight model's forecasting ability. Because

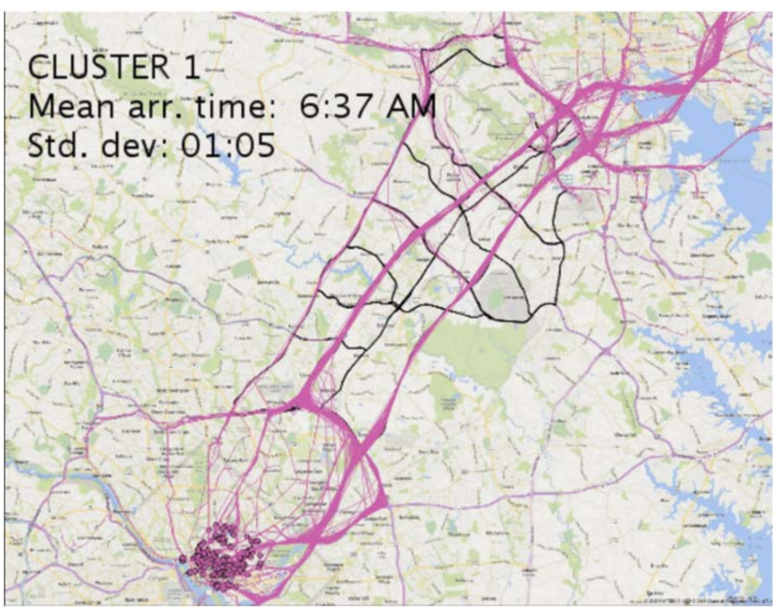

FIGURE 20 Identifying congested routes by time of day and day of week.

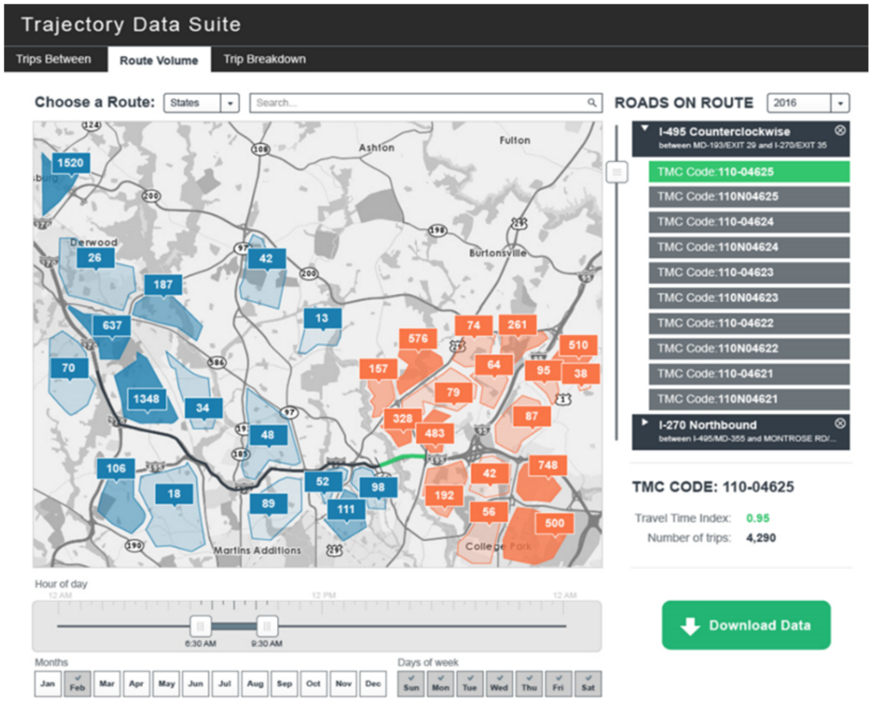

FIGURE 21 Trip O-Ds traversing a specific link or corridor.

trucks account for the majority of freight flows in the United States, truck trips and TT validation is key in assessing the valididty of a statewide freight model. Use of more-robust and -reliable truck trip data that provides O-D, speed and TT information for truck movements improve the accuracy of freight models and subsequently improves freight planning for regions. The truck GPS data and a validated freight model can be used to assess deficiencies in the freight network and evaluation of future alternatives. Policy decisions and project evaluation are dependent on reliable and robust modeling tools that are adequately validated.

Summary of Application

This project adapted and used ATRI truck GPS data to calibrate and validate the Florida advanced supply-chain freight model as part of a research project for Florida DOT. The raw GPS data were processed by the University of South Florida to develop truck trip tables and O-D TTs. Truck trip tables generated from ATRI's raw data were fused with observed truck traffic counts at over 500 locations within and outside Florida, using an O-D matrix estimation procedure to adjust for consistency with observed truck traffic volumes. The use of ATRI data in the model was twofold. Truck trip tables were used (1) to validate the freight model and (2) for comparison with model trip table output to support calibration of truck trips distribution and adjustments to the region-to-region truck movements reported in the FAF. Truck TTs were also used to validate–adjust truck TTs and speeds used in the model.

A majority of freight models typically use truck counts and WIM data to validate truck trip table output. These data sources have limitations that the ATRI or other truck GPS data can resolve. For instance, they do not include information regarding the O-D of truck trips, and thus, cannot be used to validate truck trips to–from a zone. They also do not include average TTs to validate modeled TTs. Application of GPS truck data for validating freight models will benefit public and private stakeholders by supporting more accurate models which are validated against reliable truck movements data.

IDENTIFYING AND RANKING TEXAS' MOST CONGESTED TRUCK SEGMENTS

Bill Eisele
Texas A&M Transportation Institute

Introduction

The Texas A&M Transportation Institute produces an annual listing of the 100 Most Congested Roadways in Texas for the Texas DOT. The 100 roadways are ranked by the measure of annual hours of delay per mile. The most congested roadways for trucks are also ranked using the measure of annual hours of truck delay per mile.[16] Production of the ranked list includes the merging of two large datasets:

- Private-company crowdsourced speed dataset, and
- Traffic volumes from the Texas DOT roadway inventory.

Researchers generate performance measures that capture "total magnitude" (hours of delay, hours of truck delay, delay per mile) and "individual" traveler measures [TT index, planning time index (PTI)]. These measures are used to inform problem areas for trucks on the Texas roadway system, and they can be used to begin the discussion about possible solutions.

Summary of Application

The appeal of the ranked list is identifying problem areas with quantitative information. Statewide there are 9,600 mi monitored in the effort. Figure 22 shows a simple example from Houston and how these data allow the creation of graphics that allow the comparison of truck delay (left side of Figure 22) with traffic conditions for "all vehicles" (right side of Figure 22).

PATH-BASED FREIGHT RELIABILITY USING GPS DATA

Sabyasachee Mishra, Mihalis M. Golias, Santosh Bhattarai, and Afrid Sarker
University of Memphis

Introduction

TT and travel time reliability (TTR) for trucks are different from autos primarily for three reasons. First, trucks do not necessarily travel on the same lanes as autos. Second, the posted speeds for trucks are different from autos. Third, certain segments are restricted for truck travel

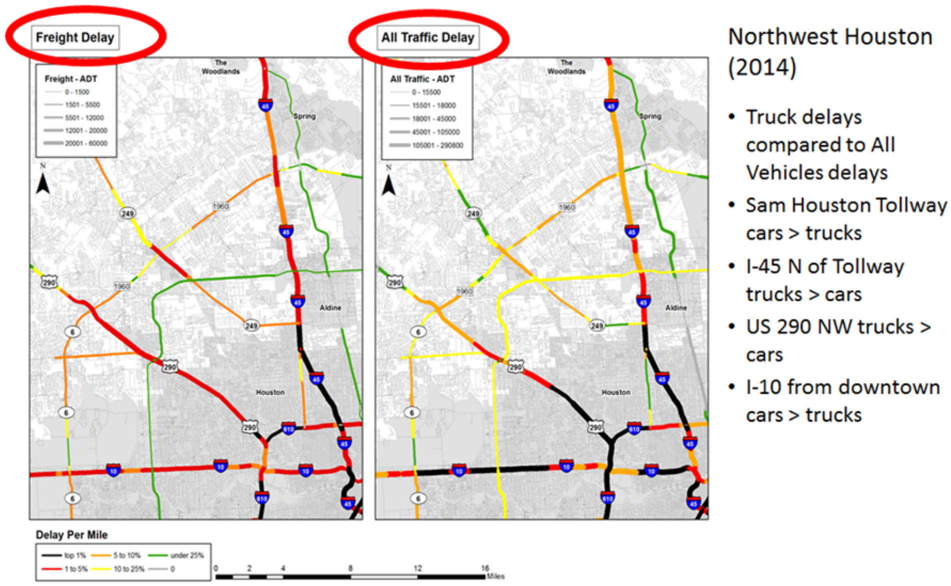

FIGURE 22 Comparison of "truck delay" (*left*) and "all-vehicle delay" (*right*) in northwest Houston.

because of height restriction or urbanization. The goal of this research is to find TT and TTR in a network for recurring and nonrecurring congestion and to identify relationships of various roadway geometry, traffic exposure, crash characteristics, weather patterns on TT and TTR. Availability of truck GPS data offers significant promise as instantaneous vehicle speeds are available along with vehicle position. Using truck GPS data along with roadway network characteristics related to other nonrecurring events it is possible to create a hybrid data set and to obtain truck TT and TRR.

Study Area and Data

In this study, 8 weeks of truck GPS data were used for Shelby County, Tennessee. Figure 23 shows 1 day of truck GPS data on the FAF network. Shortest paths on the FAF network are determined based on off-peak period travel time. Each hour of travel time observation on these paths is later conflated with crash and roadway characteristics. The distance between O-D is restricted to 40 mi to account for the marginal effect of congestion on travel time.

Initial Results

TTR is defined as the inverse of the standard deviation of TT, although other measures, such as 95th percentile, PTI, buffer index (BI), or coefficient of variation, can also be used. Figure 24 shows TTR by time of day. TTR is lower in the a.m. and p.m. peak periods with a.m. peak having the lowest TTR among all time periods. Figure 25 shows travel time variation by congestion type and trip length. Travel times increases with increasing congestion and trip length, although nonlinearly. Similarly, travel time for nonrecurring congestion is highest. While recurring congestion is the expected delay caused by high volume of vehicles at peak period, nonrecurring congestion is the delay caused due to crashes, work zones, inclement weather conditions, and more, and is more unreliable.

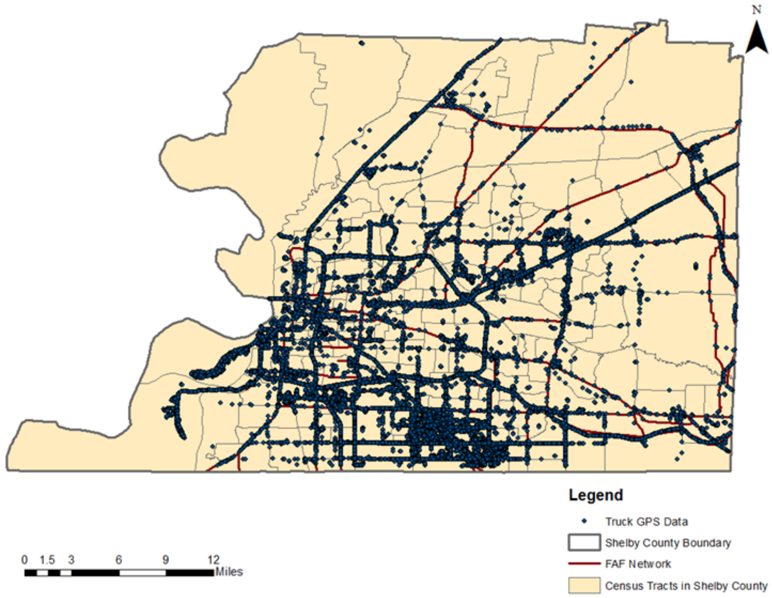

FIGURE 23 Truck GPS data locations on FAF network in Shelby County for June 10, 2014.

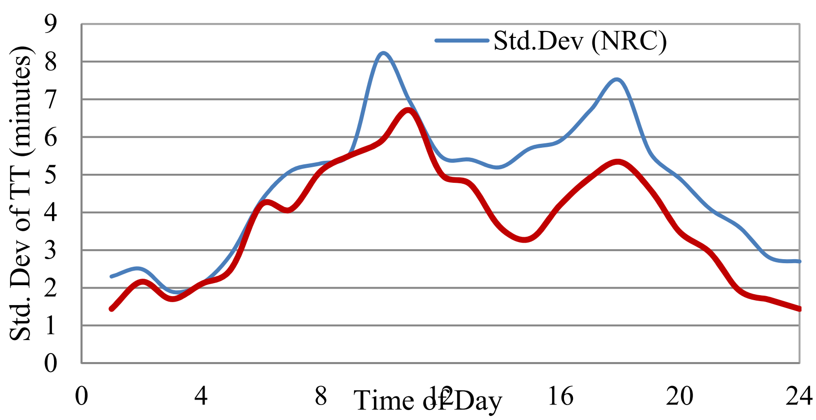

FIGURE 24 Standard deviation of TT over time of day for nonrecurring and recurring congestion.

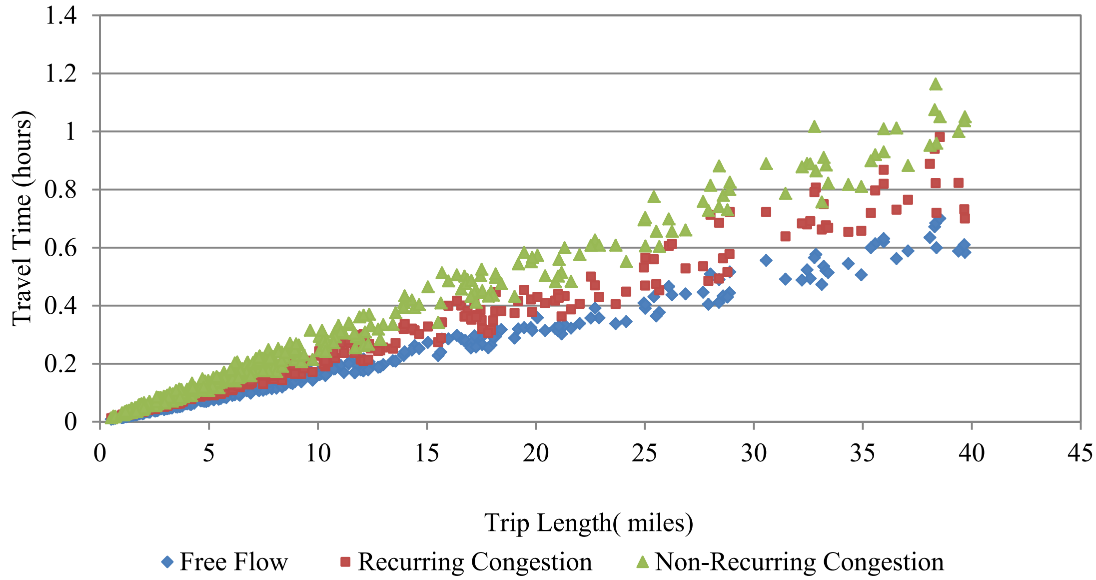

FIGURE 25 TT with trip length by congestion type.

Summary

The findings of this study can offer insight into truck TT and TTR considering ideal, recurring and nonrecurring truck travel conditions between O-D pairs over the road network, which can assist in transportation planning and decision making. Based on initial results, TTR is inversely proportional to volume-to-capacity ratio (VCR), i.e., travel time is less reliable for higher VCR and vice versa. Further, weekend TTR is higher when compared to weekday TTR.

More than roadway characteristics, crash characteristics play a significant role in TTR. Initial results suggest that the number of crashes occurring on the path and number of vehicles involved in the crash result in six to seven times higher unreliability during the p.m. peak period. Crash severity is another major factor and initial results indicated that severe injury crashes result in TTR is more than a twice as unreliable than for injury crashes. Additional research could include developing econometric models to understand the causality of truck TT and TTR with functional class, facility type, crash type, severity, number of vehicles involved, and other characteristics. These econometric models can be beneficial for prediction of truck TT and TTR using GPS data and to augment transportation planning and traffic operations.

MAP MATCHING TRUCK GPS DATA: HARNESSING OPEN-SOURCE SOFTWARE

Sarah Hernandez, Pedro Camargo, Shuyao Hong, and Vladimir Livshits
Veitch Lister

Introduction

In the United States, passively collected, nationwide truck GPS data has become a valuable source of freight data for planning studies and performance measurement. As large streams of truck GPS data become ubiquitous, special analysis tools are needed to uncover their real value. In its raw form, truck GPS data consists of time-stamped latitude–longitude positions grouped by anonymous truck IDs. When mapping GPS positions to network links based on the closest link, the sparseness of GPS positions, e.g., time between successive positions, results in a disconnected sequence of links. This is the standard approach for map matching. To perform detailed analysis such as select link analysis or trajectory visualization, GPS position data has to be transformed from raw positions to route trajectories, i.e., sequences of links comprising continuous paths traversed by each truck with their corresponding timestamps on each of the nodes. A critical challenge persists in performing this transformation. Matching GPS positions to the transportation network can be complex given dense networks or complicated geometries and most commercial GIS software packages do not have the capability of recreating routes from pings. These challenges are addressed in this work through the development of open-source programming tools.

Summary of Application

Using open-source programs, a set of tools and techniques were developed to transform low-frequency truck GPS data available from commercial sources into complete trajectories on the network. This approach, referred to as enhanced map matching, follows a two-step procedure: (1) stop identification and (2) route reconstruction. The algorithms are implemented in Python and are available through GitHub.[17] Advanced visualization techniques are possible once raw position data are transformed into truck trajectories. Java's Leaflet library was used to develop several visualizations including link-based heat maps shown in Figure 26 and animations of truck movements shown in Figure 27.

ATRI FREIGHT PERFORMANCE MEASURES DATABASE

Dan Murray
ATRI

Introduction

ATRI's Freight Performance Measures (FPM) database has been used by 32 state DOTs and 47 MPOs to develop practical freight planning tools built on the validity and reliability of real-world

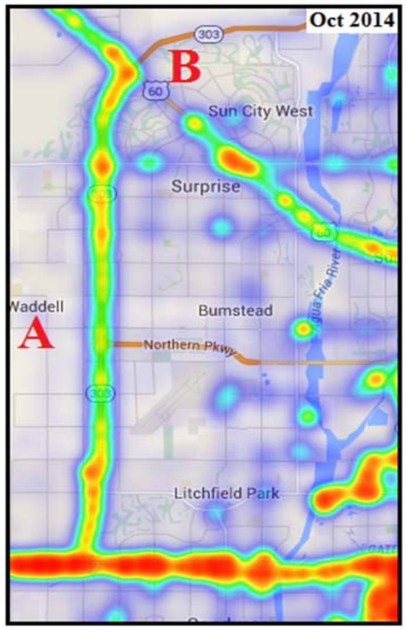

FIGURE 26 Heat maps.

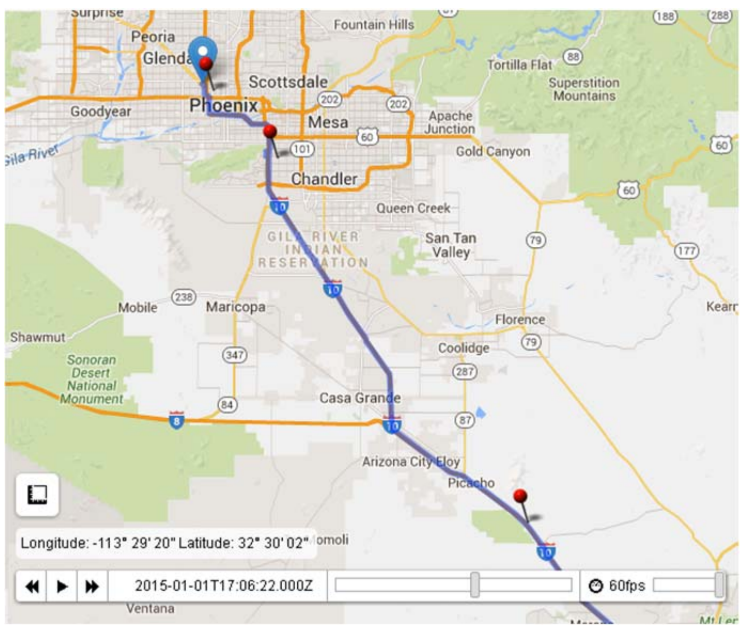

FIGURE 27 Truck trajectory animation.

freight data. The FPM data has been used to calibrate existing freight flow and truck trip models, develop truck trip networks with highly granular O-D matrices, and has been used in performance monitoring programs including the National Performance Management Research Data Set (NPMRDS) and border crossing travel time initiatives with U.S. DOT and U.S. Customs and Border Protection. Because it is the only truck GPS database that has static IDs, it has been and can be used to develop long-term truck flow movement analyses. Its role in freight and transportation planning has enabled a secondary cottage industry for other GPS data providers and GPS data visualization companies.

Summary of Application

ATRI's FPM data obtains and processes nearly 700,000 freight trucks, based on GPS position data. The FPM program is both the largest in North America and is the only truck GPS database supported–endorsed by the freight industry. This industry endorsement ensures both the stability and long-term viability of the FPM program. The data are used as an input to other models and software programs, and has been successfully synthesized with other data such as CFS–FAF, operational cost data, etc., to calibrate existing freight data sets as well as develop new data-based products and services. One example of this is the annual Truck Bottleneck Report which has resulted in and justified multiple new investment activities including the reconstruction of the Chicago Circle Interchange.[18]

The FPM data has created a new standard for freight planning inputs, and is now a permanent data feed for dozens of local, state, and national agencies. It is also the primary data source for the U.S. DOT's Freight Index Dashboard and related indixes including border crossings, intermodal, and TTR.[19] Most recently, the Maricopa–Phoenix MPO developed an economic development tool that provides 3-D visualization of the truck flows. This new visualization tool is now being recreated and used by multiple MPOs for freight planning and economic analyses.

INTERACTIVE DEMONSTRATIONS

In place of a traditional poster session, a series of applications were presented on large flat-screens during an interactive demonstration session. Participants interacted directly with presenters and the applications. Expanded abstracts describing the applications are presented below.

PORT DRAYAGE MOBILE APPLICATIONS

Taso Zografos
ZDEVCO

Dan Smith
Tioga

Introduction

DrayLink and DrayQ are two new innovative mobile applications designed for the drayage–freight goods movement industry to help improve the process for moving containerized cargo or freight all-kinds landside. These mobile apps were designed specifically for, and in partnership with, the intermodal drayage–freight goods movement industry. Both of these mobile apps use a combination of Bluetooth, Wi-Fi, and GPS technologies to collect traffic data in and around ports, intermodal terminals, and freight goods movement corridors. Data are collected, processed, correlated, and disseminated to show only the most useful information to the drayage freight goods movement community. One of the basic primary services is the determination of port–intermodal facility truck traffic congestion and queuing times. These two applications offer practitioners source of detailed, real-time, and archived truck street wait time and terminal turn time information for port stakeholders.

Summary of Applications

DrayQ provides real-time estimates of drayage truck turn-around times at ports and terminal yards. This includes street wait times to enter a container terminal yard, terminal turn time calculated from entry to exit, combined aggregate wait time, and even the trend of that wait time. Drivers can use the app to determine the optimum time to enter a terminal and reduce the time spent in congestion. It will assist dispatchers or shippers to optimize schedules and improve customer expectations. DrayLink is an easy-to-use mobile application that allows the drayage community to dispatch, track, and record the movement of containers from pick up to delivery. It provides real benefits for all stakeholders, including drivers, dispatch companies, shippers, freight forwarders, BCOs, and terminal operators to help improve the ground transport of containerized freight.

DrayQ and DrayLink are currently deployed and in use at three West Coast ports (Oakland, California, and Seattle and Tacoma, Washington), with several other ports nationwide and internationally expressing interest in its deployment as well.[20,21] These two mobile applications are currently commercially available off-the-shelf technology and easy to download from the Google Play and Apple Stores, they can be easily adopted and broadly used and replicated.

PHILLY FREIGHT FINDER

Michael Ruane
Delaware Valley Regional Planning Commission

Introduction

Philly Freight Finder is a product of the Delaware Valley Regional Planning Commission (DVRPC), the MPO for the greater Philadelphia region. This program identifies freight transportation facilities and trends in the region. Philly Freight Finder represents a true public–private partnership made possible by the members and friends of DVRPC’s freight advisory committee, the Delaware Valley Goods Movement Task Force.

Philly Freight Finder is a data platform that integrates disparate data sources into a series of tools and visualizations that tell a story about the freight system. This framework is intended to improve access to freight facility and activity data throughout the region to improve planning, economic development, and public awareness about freight in the greater Philadelphia region. The current system uses 23 unique data sources both internally developed and externally sourced.

Summary of Application

Philly Freight Finder was developed internally by DVRPC using open-source technologies.[22] This tool is a compilation of data, GIS, and web technology providing a flexible environment for growth and enhancements over time. The application is maintained with regular updates and development of new tools to meet changing demands of the agency and region.

The application provides a series of tools for users to explore various components of the region's rich freight system as outlined below.

- Freight Network Map. The Freight Network map provides identification details, activity, and capacity information for over 350 individual components representing 20 unique types of freight transportation facilities from the following categories: highway, aviation, maritime, energy, freight centers, and community.
- Maritime Indicators Tool. The port system of the Delaware Valley is a critical component of the economy and freight transportation system. Measuring and communicating the performance of this system is a priority. The maritime activity tool can be broken out into three distinct components; annual indicators, vessel activity by terminal, and maritime activity over time.
- Highway Performance Tool. An efficient highway system is integral to the freight economy and transportation system. This tool was designed to make full use of the NPMRDS dataset to illustrate two performance measures for the network throughout the day. Tracking this performance across the network throughout the day helps the region in meeting goals of the FAST Act.
- County Profile Tool. The DVRPC's primary planning partners are our eight county and four city members. The County Profile Tool was developed to better facilitate the sharing of freight activity and economic activity data with these partners. The tool visualizes details about the county network as well as domestic trade by commodity and trading partner helping to provide vital information to counties as they add freight components to their county plans.

EMERGING TRUCK DATA COLLECTION TECHNOLOGIES FROM NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM 49

Donald Ludlow and Vivek Sakhrani
CPCS

Introduction

A number of trends such as growth in e-commerce and expected growth in truck travel are exacerbating long-standing urban and metropolitan challenges. At the same time, the rapid explosion of new truck freight data sources is creating significant opportunities for more effective and targeted planning and operation of roadways, particularly in urban and metropolitan areas.

Summary

The objective of the NCFRP Project 49, Understanding and Using New Data Sources to Address Urban and Metropolitan Freight Challenges is to develop guidance for public agencies that

(1) provides understanding of the rapidly emerging data being collected or processed; (2) outlines approaches, methods, and analytical techniques that enable decision making; and (3) identifies and categorizes the use of current and emerging freight data sources for urban and metropolitan freight management strategies.[23]

As of the date of this publication, this research has identified five urban and metropolitan challenges that new data sources can address:

- Urban and metropolitan congestion;
- Last-mile access;
- Last 50-ft access;
- Truck parking; and
- Land use.

A number of fixed-point, mobile, and records-based data sources are being leveraged to address these challenges through procedures such as data fusion, cloud storage, and interactive visualization. This research associates data sources with their value for addressing these challenges.

The possibilities created by as-a-service business models such as data-as-a-service, software-as-a-service, and insight-as-a-service can change the way agencies acquire, analyze, and use the rapidly growing sources of big data to inform decisions. Case vignettes developed through this research illustrate how agencies are using analytical approaches and business models to address the urban and metropolitan challenges listed above.

ESTIMATING LOGISTICS ACTIVITY POTENTIAL

Seckin Ozkul
University of South Florida

Introduction

LAC (Logistic Activity Center) is a term designated to refer to freight facilities such as larger warehouses, inland ports, and intermodal logistics centers (ILCs). To help guide appropriate investments for successful LAC development, this research focused on the determination of optimized location criteria for LAC development potential.

Summary of Application

The methodology involved generating suitable criteria using variables such as distance from major freight generators like cargo airports, seaports, and intermodal yards; proximity to major roadways; utility availability; and land cost. Once these criteria were finalized, a heat map was generated for the study area to depict LAC development potential of sites ranked from very high to minimal. Land areas that are designated as undevelopable, such as state parks or wetlands, were removed.

The final heat map was compared to locations of existing warehouses over 25,000 ft^2 gross floor area in the Tampa Bay region. These warehouses were clustered in the high heat zones for LAC development potential, thus validating the approach that was implemented. Additionally, analysis results of truck tours obtained using disaggregate level ATRI GPS data were overlaid on the final heat map and many of these tours occurred between–over major heat zones.

Land use and current classification of existing vacant lands were overlaid on the heat map to identify LAC compatible parcels that are currently available for development. Resulting parcels were reviewed in 3-D using Google Earth and the most recent aerial imagery to determine acceptability. Finally, roadway corridors containing clusters of LAC potential locations were highlighted to provide additional information to inform freight infrastructure funding allocations for the Florida DOT District 7 Office.

In addition to supplying guidance to Florida DOT's freight infrastructure funding allocations, results of this study can be used by major LAC development firms, site selectors, and real estate investors to support freight planning and decisions about freight-related investments.

SOFTWARE TOOL TO SUPPORT THE PROCESSING AND ANALYSIS OF TRUCKS' WEIGH-IN-MOTION DATA

Zubair Ghafoor
CDM Smith

Introduction

CDM Smith developed a tool to process and analyze WIM data as part of a study for the FHWA involving highway revenue forecasting. This tool is designed to use a consistent set of rules to classify trucks based on their axle weights and spacing. In addition to classification, it also provides a weight distribution for each class using 5,000-lb increments. The tool's output is a state-level summary of WIM data in the form of self-contained Excel reports, which can be used to perform various analyses at state or national level.

Summary of Application

WIM data are collected by states using sensors installed in the pavement. Depending on the vendor, states may have variations in the classification algorithms embedded within their equipment. From a national-level analysis standpoint, a common criterion for truck classification is important. FHWA uses the standard 13-class system for most reporting and analysis. Another classification system used by FHWA for cost allocation purposes is based on the FHWA Highway Cost Allocation Study (HCAS) and includes 20 vehicle classes. The HCAS classification includes further breakdown of trucks based on number of axles and vehicle configuration. As part of another study, FHWA developed a set of rules to identify approximately 38 different types of vehicles using WIM data.[24] These rules are generally referred to as LTPP (long-term pavement performance) rules. For use in this tool, the LTPP rules were modified to represent HCAS classifications.

The tool reads the WIM data containing number of axles, axle spacing, and weight of each axle. For each WIM data record, a class is determined and the appropriate weight bin is identified based on the gross vehicle weight. The tool was developed to require minimal user intervention and benefits from a file-naming hierarchy available in the WIM data files, which contain weight data files in state-specific folders. Each state's WIM data are processed and automatically placed in a state-specific tab of a predesigned spreadsheet. The report includes graphs and tabulations of WIM data based on the standard 13-class and HCAS classification system. The weight distribution can be generated based on a user-selected classification system, which provides additional flexibility.

The tool was used to process large quantities of WIM data for the years 2013–2015, which included almost a billion records. The simple design and standard Windows desktop platform facilitated running this on a cloud-server. Using Citrix-based connectivity, users were also able to access the tool from a smartphone, which greatly enhanced user experience. Being a work in progress, this tool may be enhanced further depending on the needs of the project or to add more analytical functionality to support general use.

ITTS REGIONAL FREIGHT DATA PLATFORM

Bruce Lambert
ITTS

Introduction

The Institute for Trade and Transportation Studies, funded by nine state DOTs, is developing a state freight planning datamart–template using databases, dashboards and other reports to aid states in examining freight transportation needs.

States are now required to develop state freight plans under the FAST Act.[25] Using the required and recommended elements listed, ITTS has developed a data mart in Tableau using some of these recommended databases, as well as other data elements, to provide a quick initial draft of a state or freight project plan.

Once the data mart–freight planning template is completed, ITTS will train the member states on how to use the data mart for various freight studies.

Summary of Application

The project seeks to create a data warehouse for state DOTs to study freight traffic both regionally and nationally. The goal is to develop a data mart that could be used in planning applications, while providing the training necessary to member states to use the information for other freight or planning purposes.

SRF MAPPER AND SRF SIMULATOR

Justin Bishop
University of Cambridge, U.K.

Introduction

The Centre for Sustainable Road Freight (SRF) Mapper and SRF Simulator comprise part of a decision-making toolbox enabling road freight operators to quantify the impact on fuel use from technology interventions and changes to driver behavior and logistic operations.

Summary of Application

The SRF Mapper and SRF Simulator use data provided by the Android-based SRF Logger that connects to the vehicle FMS port via Bluetooth. Data are transferred to remote servers continuously over the mobile phone network. The Logger is more flexible than a conventional telematics system because it logs data at the speed reported by the vehicle (at least 1 Hz) and can exploit the large Bluetooth capacity of the phone to connect to other sensors around the vehicle.

The SRF Mapper employs a data-driven approach to extract the likely vehicle configuration, such as effective drag (C_dA), rolling resistance, and transmission control. This includes the effective gear ratio (mapping of engine speed to wheel speed) and the engine speeds at which each gear shifts up and down. Engine maps of fuel use and emissions are synthesized from the observed FMS data. For example, Figure 28 shows the engine map of a DAF Euro 6 articulated truck at 28.7 t. The vehicle model reproduces fuel use accurately on a per second basis, resulting in simulated cumulative fuel within 9.2% of the observed value.

Simulation accuracy is improved by integrating data from multiple trips, across different drivers, routes and vehicle masses into composite maps. A combined fuel use map for the DAF Euro 6 in Figure 28 reproduced trip-level fuel use over the training cycle to within 2.8% of observed.

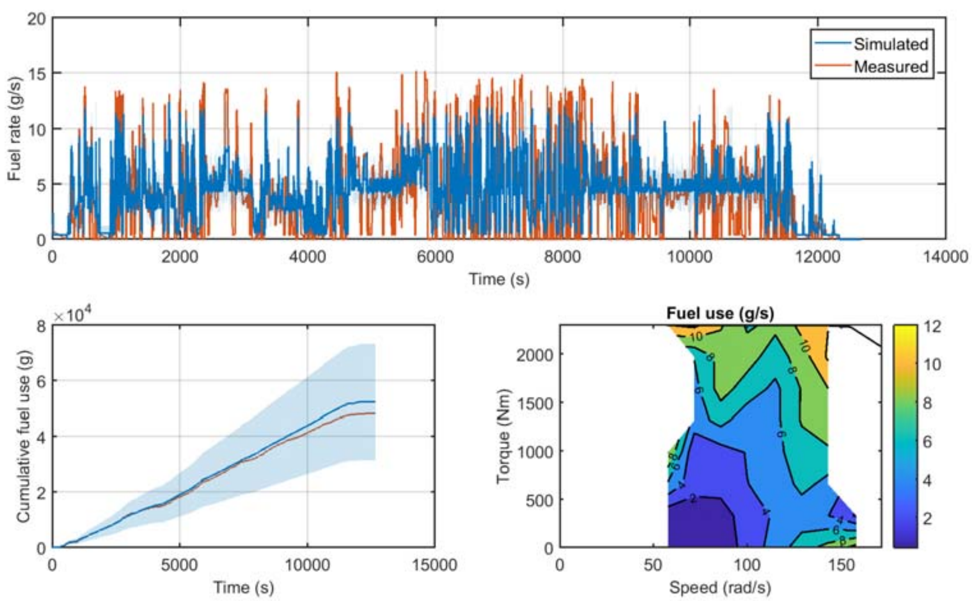

FIGURE 28 Validation of vehicle model of DAF Euro 6 articulated lorry at 28.7 t. Simulated (blue) and observed (orange) fuel use per second (*top*). Cumulative simulated and observed fuel use (*bottom left*). Engine map of fuel use (*bottom right*).

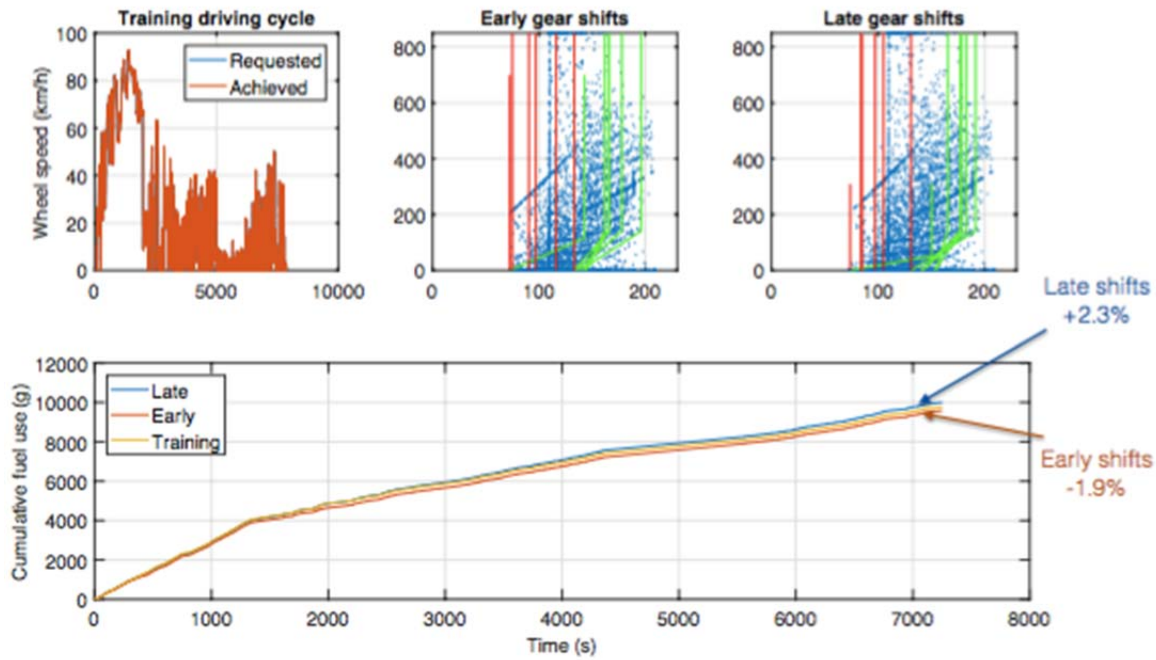

FIGURE 29 Quantifying influence of driver behavior on fuel use of DAF Euro 6 rigid lorry at 11.2 t. Target (blue) and achieved (orange) speed over the requested driving cycle (*top left*). Gear shift envelopes for each gear with early shifting, where green lines represent the engine speed to shift up, red lines represent the engine speed to shift down, and blue dots are the observed data from the SRF Logger (*top middle*). Gear shift envelopes for late shifts (*top right*). Cumulative fuel use under early, late, and base case shift regimes (*bottom*).

The SRF Mapper provides an internally consistent powertrain model of an operator's vehicles validated using its own operation. The vehicle configuration, transmission control and engine maps (Figure 29) form the basis of the SRF Simulator as the framework in which the impact of technological, behavioral, and logistics interventions can be quantified. Examples of technology interventions include reducing rolling resistance with better tires or reducing aerodynamic drag with side skirts and teardrop trailers. The influence of the driver can be quantified by comparing the engine speeds at which upshifts occur as shown by the vertical green lines in Figure 29. Moreover, the impact of driver style can be quantified by observing gearshift behavior both across drivers and before and after training. Figure 29 illustrates that late gearshifts used 2.3% more fuel than the base case, while 1.9% less fuel was used with early shifts. Wider impacts on the logistic operation are quantified by changes to the driving cycle, which can represent a different route, the introduction of multiple drops or a shift in the time of day of operation.

Notes

1. Details about the California Freight Mobility Plan can be found at http://www.dot .ca.gov/hq/tpp/offices/ogm/california_freight_mobility_plan.html.
2. Details about the California Sustainable Freight Action Plan can be found at http:/ /www.casustainablefreight.org/.
3. For example, Heimdal, North Dakota in 2015.
4. Data obtained from IHS/Polk (https://www.ihs.com/products/automotive-market-data -analysis.html).
5. Data obtained from the IRP Clearinghouse (http://www.irponline.org/).
6. More information about FMS is available at https://its.mit.edu/future-mobility-sensing.
7. More information about VIIRS is available at https://jointmission.gsfc.nasa.gov/viirs.html.
8. TAMS is accessible at http://freight.its.uci.edu/tams/.
9. Comtrade is available at https://comtrade.un.org/.
10. More information about the Center is available at http://cwee.ucdavis.edu/.
11. Map can be accessed at www.TRAINFO.ca under "Demo."
12. Additional information is available at contact@TRAINFO.ca.
13. More information about the grant is available at https://www.azmag.gov/information _services/shrp2-expediting-project-delivery-grant.asp.
14. Additional information about the VNL series trailers is available at https://www.volvo trucks.us/-/media/vtna/files/shared/trucks/3872vnlbrochure832.pdf.
15. http://inrix.com/.
16. More details about the analysis, methodology, and results are available at https://mobility.tamu.edu/texas-most-congested-roadways/.
17. https://github.com/pedrocamargo/map_matching.
18. http://atri-online.org/2017/01/17/2017-top-100-truck-bottleneck-list/.
19. https://ops.fhwa.dot.gov/freight/freight_analysis/perform_meas/fpmdata/fei2015.htm.
20. More information is available at http://www.drayq.com/.
21. More information is available at https://www.draylink.com/DLWebApp/.
22. More information is available at www.dvrpc.org/webmaps/phillyfreightfinder.
23. http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3593.
24. FHWA Publication No. FHWA-HRT-13-091 is available at https://ntl.bts.gov/lib /61000/61500/61552/13091.pdf.
25. For specific information on what should be in a state freight plan, consult the Federal Register Notice, Vol. 81, No. 199 / Friday, October 14, 2016, page 71185.

APPENDIX A

List of Abbreviations and Acronyms

ATRI	American Transportation Research Institute
BCO	beneficial cargo owners
C_dA	effective drag
CARB	California Air Resources Board
CA-VIUS	California Vehicle Inventory and Use Survey
CFMP	California Freight Mobility Plan
CFS	Commodity Flow Survey
DOT	department of transportation
DVRPC	Delaware Valley Regional Planning Commission
FAF	Freight Analysis Framework
FAST ACT	Fixing America's Surface Transportation Act
FHWA	Federal Highway Administration
FMS	fleet management system
FMS	future mobility sensing
FPM	freight performance measures
GIS	geographic information system
GO-Biz	California's Governor's Office of Business and Economic Development
GPS	Global Positioning System
HCAS	Highway Cost Allocation Study
ID	identification number
ILD	inductive loop detector
LAC	Logistic Activity Center
LTPP	long-term pavement performance
MAG	Maricopa Association of Governments
MAP21	Moving Ahead for Progress in the 21st Century Act
MARAD	Maritime Administration
MPO	metropolitan planning organization
NCFRP	National Cooperative Freight Research Program
NETS	National Establishment Time Series
NPMRDS	National Performance Management Research Data Set
OBD	Onboard diagnostics
OBIZ	Office of Business Enterprise
O-D	Origin–destination
PAG	Pima Association of Governments
PTI	planning time index
SHRP2	Second Strategic Highway Research Program
SRF	sustainable road freight
STIP	state transportation improvement plan
TAMS	Truck Activity Monitoring System
TRB	Transportation Research Board

TT	travel time
TTI	Texas A&M Transportation Institute
TTR	travel time reliability
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
U.S. DOT	U.S. Department of Transportation
UW	University of Washington
VCR	volume-to-capacity ratio
VIIRS	Visible Infrared Imaging Radiometer Suite
VIP	Video Image Processing
VIUS	Vehicle Inventory and Use Survey
VMS	variable message sign
WIM	weigh-in-motion

APPENDIX B

List of Attendees

Emmanuel Aggreh
Caltrans
Sacramento, CA
Emmanuel.aggreh@dot.ca.gov

Mahmoud Ahmadi
Iteris
Santa Ana, CA
mahmadi@iteris.com

Kome Ajise
Caltrans
Sacramento, CA
kome.ajise@dot.ca.gov

Koti Allu
University of California, Irvine
Irvine, CA
kallu@uci.edu

Ashley Arax
Air Resources Board
Sacramento, CA
ashley.arax@arb.ca.gov

Scott Babcock
Transportation Research Board
Washington, D.C.
SBabcock@nas.edu

Mark Berndt
Quetica
Ham Lake, MN
mark.berndt@quetica.com

Justin Bishop
University of Cambridge
Cambridge, United Kingdom
jdkb2@cam.ac.uk

Michael Bomba
University of North Texas
Austin, TX
michael.bomba@unt.edu

Chandra Bondzie
FHWA Freight Management and Operations
Washington, D.C.
chandra.bondzie@dot.gov

James Brogan
Cambridge Systematics, Inc.
Los Angeles, CA
jbrogan@camsys.com

Travis Brooks
Arkansas State Highway and Transportation Department
Little Rock, AR
travis.brooks@ahtd.ar.gov

Scott Brotemarkle
Transportation Research Board
Washington, D.C.
sbrotemarkle@nas.edu

Dale Brown
U.S. Army Corps of Engineers, Waterborne Commerce Statistics Center
New Orleans, LA
Dale.Brown@usace.army.mil

Steve Brown
Fehr & Peers
Los Angeles, CA
yemi.fp@gmail.com

Joseph Bryan
Parsons Brinckerhoff
Boston, MA
bryanjg@pbworld.com

Ian Butler-Severson
University of New Orleans
New Orleans, LA
imbutle1@uno.edu

Gary Carlin
INRIX, Inc.
Sacramento, CA
gary.carlin@inrix.com

Christina Casgar
San Diego Association of Governments
San Diego, CA
christina.casgar@sandag.org

Nieves Castro
Caltrans
Sacramento, CA
nieves.castro@dot.ca.gov

Chandra Shailesh
California State University
Long Beach Long Beach, CA
shailesh.chandra@csulb.edu

Shih-Miao Chin
Oak Ridge National Laboratory
Knoxville, TN
chins@ornl.gov

Chris Collins
Louisiana Department of Transportation and Development
Baton Rouge, LA
christopher.collins@la.gov

Alison Conway
City College of the City University of New York
New York, NY
aconway@ccny.cuny.edu

Claudio Cunha
University of Sao Paulo
Sao Paulo, Brazil
cbcunha@usp.br

Theresa Dau-Ngo
Port of Long Beach
Long Beach, CA
theresa.dau-ngo@polb.com

Nick Deal
Caltrans
Sacramento, CA
nicholas.deal@dot.ca.gov

Richard A. Dennis
Caltrans
San Bernardino, CA
richard.dennis@dot.ca.gov

Tyler Dick
RailTEC
Urbana, IL
ctdick@illinois.edu

Jing Ding-Mastera
Massachusetts Institute of Technology
Cambridge, MA
dingjing041 O@gmail.com

Paula Dowell
Cambridge Systematics, Inc.
Atlanta, GA
pdowell@camsys.com

Scott Drumm
Port of Portland
Portland, OR
scott.drumm@portofportland.com

James Durako
Illinois Department of Transportation
Springfield, IL
james.durako@illinois.gov

Kelly Eagan
Caltrans
Sacramento, CA
Kelly.Eagan@dot.ca.gov

Bill Eisele
Texas A&M Transportation Institute
College Station, TX
bill-eisele@tamu.edu

Romeo Estrella
Caltrans
Sacramento, CA
Romeo.estrella@dot.ca.gov

Connie Fan
Microsoft
Irvine, CA
cofa@microsoft.com

Chester Ford
U.S. Department of Transportation
Washington, D.C.
chester.ford@dot.gov

Eric Fredericks
Caltrans
Sacramento, CA
eric.fredericks@dot.ca.gov

Ed Fritz
Wyoming Department of Transportation
Cheyenne, WY
ed.fritz@wyo.gov

Zubair Ghafoor
CDM Smith
Lisle, IL
ghafoorzf@cdmsmith.com

Michail Gkolias
University of Memphis
Memphis, TN
mihalisdgolias@gmail.com

Anne Goodchild
University of Washington
Seattle, WA
annegood@u.washington.edu

Daniel Haake
SRF Consulting
Minneapolis, MN
dhaake@srfconsulting.com

Kathleen Hancock
Virginia Tech
Falls Church, VA
hancockk@vt.edu

Jolene Hayes
Cambridge Systematics, Inc.
Los Angeles, CA
jhayes@camsys.com

Sarah Hernandez
University of Arkansas
Fayetteville, AR
sarahvh@uark.edu

Ulises Hernandez Jimenez
The International Council on Clean Transportation
San Francisco, CA
u.hernandez@theicct.org

Nathan Huynh
University of South Carolina
Columbia, SC
huynhn@cec.sc.edu

Ho-Ling Hwang
Oak Ridge National Laboratory
Knoxville, TN
hwanghl@ornl.gov

Sherif Ishak
Louisiana State University
Baton Rouge, LA
sishak@lsu.edu

Barbara Ivanov
Supply Chain Transportation and Logistics Center, University of Washington
Seattle, WA ivanovb@uw.edu

Nikola Ivanov
University of Maryland CATT Lab
College Park, MD
ivanovn@umd.edu

Eric Jessup
Freight Policy Transportation Institute, Washington State University
Pullman, WA
eric.jessup@wsu.edu

Evangelos Kaisar
Florida Atlantic University
Boca Raton, FL
ekaisar@fau.edu

Dan Kopulsky
Caltrans
Los Angeles, CA
dan.kopulsky@dot.ca.gov

Jim Kruse
Texas A&M Transportation Institute
Houston, TX
j-kruse@tamu.edu

Bruce Lambert
ITTS
New Orleans, LA
bruce@ittsresearch.org

Pasi Lautala
Michigan Tech University
Houghton, MI
ptlautal@mtu.edu

Mai Le
Transportation Research Board
Washington, D.C.
MQLe@nas.edu

Chen-Fu Liao
University of Minnesota
Minneapolis, MN
cliao@umn.edu

Vladimir Livshits
Maricopa Association of Governments
Phoenix, AZ
vlivshits@azmag.gov

Hector G. Lopez-Ruiz
KAPSARC
Riyadh, Saudi Arabia
hector.lopez@kapsarc.org

Donald Ludlow
CPCS
Washington, D.C.
dludlow@cpcstrans.com

Andrea Maguire
U.S. Enviromental Protection Agency
Ann Arbor, Ml
maguire.andrea@epa.gov

Nicola Mammes
New York City Department of Transportation
New York, NY
nmammes@dot.nyc.gov

Jose Marquez-Chavez
Caltrans
Sacramento, CA
jose.marquez@dot.ca.gov

Caroline Mays
Texas Department of Transportation
Austin, TX
mary.aparicio@txdot.gov

Edward McCormack
University of Washington
Seattle, WA
edm@uw.edu

Tom McQueen
Georgia Department of Transportation
Atlanta, GA
tmcqueen@dot.ga.gov

Rodrigo Mesa-Arango
Florida Institute of Technology
Melbourne, FL
rmesaarango@fit.edu

Alan Meyers
WSP–Parsons Brinckerhoff
Herndon, VA
meyersap@pbworld.com

Christopher Michael
East-West Gateway Council of Governments
St. Louis, MO
acctpayable@ewgateway.org

Chad Miller
University of Southern Mississippi
Hattiesburg, MS
Chad.r.miller@usm.edu

Michael Miller
Transportation Research Board
Washington, D.C.
mmiller@nas.edu

Bill Mitchel
Microsoft
San Francisco, CA
billm@microsoft.com

Mario Monsreal
Texas A&M Transportation Institute
College Station, TX
m-monsreal@tti.tamu.edu

Heather Monteiro
University of Nevada Las Vegas
Las Vegas, NV
heather.monteiro@unlv.edu

Daniel Morgan
U.S. Department of Transportation
Washington, D.C.
daniel.morgan@dot.gov

William Morgan
Illinois Department of Transportation
Springfield, IL
william.morgan@illinois.gov

Michael Morris
FHWA-CA
Los Angeles, CA
michael.morris@dot.gov

Dan Murray
ATRI
Roseville, MN
dmurray@trucking.org

Evan Murray
U.S. Environmental Protection Agency
SmartWay
Ann Arbor, MI
murray.evan@epa.gov

Vidya Mysore
Federah Highway Administration, OTS,
Resource Center
Atlanta, GA
vidya.mysore@dot.gov

Hau Nguyen
Caltrans
Marysville, CA
hau.nguyen@dot.ca.gov

Val Noronha
Digital Geographic–UCSB
Santa Barbara, CA
noronha@digitalgeographic.com

Thomas O'Brien
California State University, Long Beach
Long Beach, CA
thomas.obrien@csulb.edu

Seckin Ozkul
Center for Urban Transportation Research,
University of South Florida
Tampa, FL sozkul@cutr.usf.edu

Tom Palmerlee
Transportation Research Board
Washington, D.C.
tpalmerlee@nas.edu

Birat Pandey
FHWA Office of Operations
Washington, D.C.
birat.pandey@dot.gov

Marygrace Parker
1-95 Corridor Coalition
Greenwich, NY
mgparker@i95coalition.org

Laura Phillips
Louisiana Department of Transportation and
Development
Baton Rouge, LA laura.phillips@la.gov

Fatemeh Ranaifar
Fehr & Peers
Los Angeles, CA
y.kuku@fehrandpeers.com

Garreth Rempel
TRAINFO Corp.
Winnipeg, MB Canada
Garreth.rempel@trainfo.ca

Stephen Ritchie
University of California
Irvine, CA
sritchie@uci.edu

Keri Robinson
Caltrans
San Diego, CA
Keri.Robinson@dot.ca.gov

Bill Rogers
Transportation Research Board
Washington, D.C.
wrogers@nas.edu

Cory Rogers
CDM Smith
Fairfax, VA
rogerscm@cdmsmith.com

Matthew Roorda
University of Toronto
Toronto, ON Canada
roordam@ecf.utoronto.ca

Michael Ruane
Delaware Valley Regional Planning Commission
Philadelphia, PA
mruane@dvrpc.org

Vivek Sakhrani
CPCS Transcom Inc.
Washington, D.C.
vsakhrani@cpcstrans.com

Katayoun Salamati
SAS Institute
Cary, NC
katy.salamati@sas.com

Douglas Scheffler
U.S. Coast Guard
Washington, D.C.
Douglas.W.Scheffier@uscg.mil

Chris Schmidt
Caltrans
Sacramento, CA
chris.schmidt@dot.ca.gov

Kaveh Shabani
RSG
San Diego, CA
kaveh.shabani@rsginc.com

Sushant Sharma
Texas A&M Transportation Institute
Arlington, TX
s-sharma@tamu.edu

Jeffrey Short
ATRI
Marietta, GA
jshort@trucking.org

Daniel Smith
The Tioga Group, Inc.
Moraga, CA
dsmith@tiogagroup.com

Lynn Soporowski
Kentucky Transportation Cabinet
Frankfort, KY
lynn.soporowski@ky.gov

Rahul Srivastava
Caltrans
Sacramento, CA
rahul.srivastava@dot.ca.gov

Kenneth Steve
U.S. Department of Transportation
Washington, D.C.
kenneth.steve@dot.gov

Bethany Stich
University of New Orleans
New Orleans, LA
bstich@uno.edu

Scott Strelecki
San Diego Association of Governments
San Diego, CA
michelle.posada@sandag.org

Magnus Swahn
Conlogic
Stockholm, Sweden
magnus.swahn@conlogic.se

Chien Sze
U.S. Environmental Protection Agency
Ann Arbor, Ml
sze.chien@epa.gov

Neil Ternowetsky
TRAINFO Corp.
Winnipeg, MB, Canada
Neil.ternowetsky@trainfo.ca

Yeow Chern Tok
UC Irvine–ITS
Irvine, CA
ytok@uci.edu

Kenneth Troup
CDM Smith
Bolton, MA
kefty@comcast.net

Tujague, Amy
U.S. Army Corps of Engineers,
Waterborne Commerce Statistics Center
New Orleans, LA
amy.c.tujague@usace.army.mil

Sharada Vadali
Texas A&M Transportation Institute
College Station; TX
s-vadali@tti.tamu.edu

Isabel Victoria-Jaramillo
Cambridge Systematics, Inc.
Austin, TX
ivictoria@camsys.com

Juan Villa
Texas A&M Transportation Institute
College Station, TX
j-villa@tamu.edu

Chao Wang
Cambridge Systematics, Inc.
Los Angeles , CA
cwang@camsys.com

Yinhai Wang
University of Washington
Seattle, WA
yinhai@uw.edu

Casey Wells
Kentucky Transportation Cabinet
Frankfort, KY
casey.wells@ky.gov

Ronald West
Cambridge Systematics, Inc.
Davis, CA
rwest@camsys.com

Dara Wheeler
Caltrans
Sacramento, CA
dara.wheeler@dot.ca.gov

Chris Wolfe
Environmental Defense Fund
Austin, TX
cwolfe@edf.org

Joel Worrell
Florida Department of Transportation
Tallahassee, FL
Joel.Worrell@dot.state.fl.us

Xing Wu
Lamar University
Beaumont, TX
xing.wu@lamar.edu

Jinghua Xu
Fehr & Peers
Los Angeles, CA
jinghuax@gmail.com

Kirk Zeringue
Louisiana Department of Transportation and
Development/LTRC
Baton Rouge, LA
kirk.zeringue@la.gov

Hong Zhang
Louisiana Department of Transportation and
Development
Baton Rouge, LA hong.zhang@la.gov

Fang Zhao
Singapore-MIT Alliance for Research and
Technology
Singapore, Singapore
fang.zhao@smart.mit.edu

Johanna Zmud
Texas A&M Transportation Institute
Washington, D.C.
j-zmud@tti.tamu.edu

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. C. D. Mote, Jr., is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the National Academies of Sciences, Engineering, and Medicine to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.national-academies.org.**

The **Transportation Research Board** is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to increase the benefits that transportation contributes to society by providing leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied committees, task forces, and panels annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

Learn more about the Transportation Research Board at **www.TRB.org**.

TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001