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PROGRAM

FREIGHT DATA FOR SUPPLY CHAIN ANALYSIS

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16. Abstract

The primary objective of this project is to identify data sources to measure freight fluidity and freight performance. The methodology included literature review, previous experiences assessment, and approaching relevant stakeholders. Based on the importance of freight on economic development, the study proposed a supply chain oriented focus by shifting the unit of measure, from vehicles to commodities. After reviewing and identifying available data sources, the research identified existing data sources and proposed new data components based on a set of basic data elements. The use of the identified data sources was demonstrated through a case study. Recommendations and future research is also explained.

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STRATEGIC RESEARCH PROGRAM

FREIGHT DATA FOR SUPPLY CHAIN ANALYSIS

Final Draft

Date: September 2016

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LIST OF ACRONYMS

ATRI	American Transportation Research Institute
B2B	Business-to-business
BCIS	Border Crossing Information System
BTS	Bureau of Transportation Statistics
ECR	European Congestion Report
FAF	Freight Analysis Framework
FHWA	Federal Highway Administration
FI	Fluidity index
GMT	Goods-miles traveled
GPS	Global positioning system
HPMS	Highway Performance Monitoring System
IMR	Implementation Monitoring Report on Congestion Management Procedures
MAP-21	Moving Ahead for Progress in the 21st Century Act
NCFRP	National Cooperative Freight Research Program
NPMRDS	National Performance Management Research Data Set
O/D	Origin-destination
RITIS	Regional Integrated Transportation Information System
TTI	Texas A&M Transportation Institute
UCR	Urban Congestion Report
VPP	Vehicle Probe Project

EXECUTIVE SUMMARY

Problem: One of the main issues when measuring freight transportation performance is the availability of information. Many times this information is not available or partially available with various levels of disaggregation that do not allow for valuable measures.

Relevance: Measuring freight transportation performance at the supply chain level has recently become an important element in the overall transportation planning practice by federal, state, and local agencies. Information and data to perform measurements is not ready available as it is an innovative way of assessing the performance of the freight transportation system.

Objective: The primary objective of this project is to identify data sources to measure freight transportation performance at the supply chain or product level.

Approach: The methodology included literature review, previous experiences assessment, and approaching relevant stakeholders to obtain detailed information, recent experiences, and future plans.

Findings and contributions: Based on the importance of freight transportation and the relationship to national and regional economic development, the research identifies several potential data sources for freight transportation performance measurement and proposed additional data elements that could be collected to strengthen such measurement. The use of these data sources was exemplified through a case study.

Conclusions: The information that is currently available does not meet the spectrum of required data elements necessary to measure freight transportation performance at the supply chain level. Existing data elements need to be complemented with additional sources, and the information needs to be analyzed to provide a consolidated set of data. This is important because the effort to consolidate information from several sources (some of them new) implies data standardization, system communications, and coordination

Recommendations: It is recommended to consolidate existing data sources and complement them with new identified sources under the new freight performance measurement with a supply chain perspective initiative. Researchers recommend that future research should focus on specifying technical aspects, data attributes, and features of new data sources.

INTRODUCTION

Logistics is a key component of regional and national competiveness and economic development. For instance, the World Bank's Logistics Performance Index 2014 report states, "Improving logistics performance is at the core of the economic growth and competitiveness agenda" (*1*). Policymakers globally recognize the logistics sector as one of the key pillars for development. Countries that have traditionally been international traders, such as the Netherlands, Vietnam, or Indonesia, see "seamless and sustainable logistics as an engine of growth and of integration with global value chains" (*1*).

Many times, this importance is focused on logistics components, such as infrastructure, whose importance for productivity, costs, and economic development is largely documented in the literature (*2, 3, 4, 5*). The importance of freight performance measures lies in the fact that freight transportation is also recognized as a key element of logistics performance—an "inherently crucial component in supporting economic activities as well as providing opportunities for economic development" (*6*).

Freight transportation performance measurement has been gaining more relevance in the United States, as required by the Moving Ahead for Progress in the 21st Century Act (MAP-21) and Fixing America's Surface Transportation (FAST) Act.

The recently established Fixing America's Surface Transportation Act is a five-year legislation designed to improve the nation's surface transportation infrastructure. MAP-21 and FAST became milestones to transform "the policy and programmatic framework for investments to guide the system's growth and development" (*7*), create a "performance-based surface transportation program" (*7*), and "improve the Nation's surface transportation infrastructure, including our roads, bridges, transit systems, and rail transportation network" (*8*).

Freight transportation measurement and the concept of freight fluidity are tightly related. Freight fluidity has been defined as:

> A broad term referring to the characteristics of multimodal supply chains and associated freight networks in a geographic area of interest, where any number of specific modal data elements and performance measures are used to describe the performance (including costs and resiliency) and quantity of freight moved (including commodity value) to inform decision-making. (*9*)

A key concept from the fluidity definition is the idea of measuring performance of multimodal supply chains and associated freight networks. The initial step to provide data for such performance measures is identifying data sources, which feed the specific modal data elements and performance measures.

The most common data elements used by previous and current experiences are: time, time reliability, and cost. There are other elements of data like safety and resilience that have also been part of freight measurement; however, the first three are the most common ones.

The typical freight transportation system performance measures focus on assessing the efficiency of network links and nodes via vehicle throughput. However, this type of measurement does not take into consideration supply chains or commodity products that are handled by the freight transportation system. Classic freight transportation performance measurement makes it difficult to link transportation to economic development. Supply chain and logistics performance are associated with goods or commodities that are produced, transported, and/or consumed in a region, as well as to value-added services or activities that are performed during a specific step in the supply chain that impact the economic development of the region. Therefore, to measure freight performance and its influence on economic development in a region, it is necessary to collect and analyze information at the supply chain level. This innovative approach entails identifying new data sources that can provide information at the supply chain level.

This project reviews current freight performance measurement efforts and identifies data sources to measure freight fluidity to feed a freight performance model. These data sources should provide information in a regular and consistent form to measure performance and changes in the transportation supply chain over time.

To identify these data sources, a set of data elements needs to be defined. Data elements are pieces of information at a general level and are building blocks of more precise calculations or measurements.

This report is organized as follows. First, the report presents a review and analysis of current and previous freight performance measurement experiences focusing on data sources and collection procedures. Then a concise analysis of requirements of these performance measurements in terms of information (i.e., data elements) is presented. After data elements are defined, data sources and collection features are discussed. These data sources consider not only direct primary data but also data in the form of proxies. Thereafter a case study is documented to exemplify the use of some data elements and specific data sources. Finally, conclusions are found at the end of the document.

ANALYSIS OF RECENT FREIGHT PERFORMANCE MEASUREMENT EXPERIENCES

This section presents a concise review of several performance measurement, data collection, and freight data research initiatives. The primary purpose of this review is to identify the most relevant data sources, data elements, and systems used in performance measurement experiences for supply chain analysis. These include:

- National Cooperative Freight Research Program (NCFRP).
- Transport Canada's Fluidity Index (FI).
- I-95 Vehicle Probe Project (VPP).
- Urban Congestion Report (UCR).
- National Performance Management Research Data Set (NPMRDS).
- Regional Integrated Transportation Information System (RITIS).
- Datamyne.
- European Congestion Report (ECR).
- Freight Analysis Framework (FAF).
- Bureau of Transportation Statistics (BTS).

Given the relation between freight performance measures and the fluidity concept, some of these initiatives are focused on the freight fluidity concept.

National Cooperative Freight Research Program Publications

The NCFRP program researches and disseminates "timely findings that will inform investment and operations decisions affecting the performance of the freight transportation system" (*10*). By winter 2013–2014, a total of 48 current and completed projects were published (*11*). From these 48, 11 are considered to be of relevance to data sourcing. Table 1 lists the relevant data sourcing projects.

Table 1. NCFRP Projects Highlighting Data Collection Procedures.

Data Collection Procedure	Project No.	Title	Report No.
Literature reviews	Project 11	Current and Future Contributions to Freight Demand in North America	Web-Only Document 4
	Project 15	Understanding Urban Goods Movements	Report 14
	Project 31	Freight Data Sharing Guidebook	Report 25
	Project 47	Implementing the Freight Transportation Data Architecture: Data Element Dictionary	Report 35
Interviews	Project 06	Freight-Demand Modeling to Support Public-Sector Decision Making	Report 8
Mixed reviews, surveys, and interviews	Project 12	Specifications for Freight Transportation Data Architecture	Report 9
Existing databases	Project 03	Performance Measures for Freight Transportation	Report 10
Mixed surveys and databases	Project 20	Guidebook for Developing Subnational Commodity Flow Data	Report 26
Case study analyses	Project 25	Estimating Freight Generation Using Commodity Flow Survey Microdata	Report 19
Mixed case studies and reviews	Project 26	Freight Data Cost Elements	Report 22
Mixed surveys, direct data collection, and agent-based models	Project 39	Making Trucks Count: Innovative Strategies for Obtaining Comprehensive Truck Activity Data	Report 29

NCFRP Project 39 (Report 29) evaluated four strategies of data sourcing. The evaluation was performed in terms of the ability to collect the data and technical, institutional, operational, geographic, and financial issues. From this analysis, researchers considered three strategies as most likely for successful implementation:

- Using global positioning system (GPS) traces to understand trucking activities.
- Re-conceptualizing the Vehicle Inventory and Use Survey.[1]
- Employing agent-based models for freight transportation.

The first strategy translates to traceability or tracking systems, which basically are direct data collection procedures. Nowadays, these procedures are performed with automatic technology and thus fall into the domain of auto identification systems. The second strategy suggests implementing a periodical census defined as part of the economic census. The third strategy switches the paradigm of data collection, or data capture, to data production. However, to

1 The Truck Inventory and Use Survey/Vehicle Inventory and Use Survey series, which was initiated in 1963 and conducted as part of the economic census every five years starting in 1967, ended in 2002 due to financial constraints.

produce these data by modeling, raw data are required. These strategies are discussed later in this document.

In terms of data elements, most of these NCFRP projects deal with time and time reliability data; however, among the 11 relevant projects, three specifically considered costs as follows:

- NCFRP Project 03 (Report 10): *Performance Measures for Freight Transportation*—presents a comprehensive, objective, and consistent set of measures to gauge the performance of the freight transportation system. The set of potential measures was screened on the basis of surveys of public- and private-sector freight stakeholders, finding that private-sector stakeholders were more interested in cost, reliability, and travel time measures. The measures were captured using existing databases as information sources, such as FAF or BTS-Transportation Services Index.
- NCFRP Project 26 (Report 22): *Freight Data Cost Elements*—identifies the specific types of direct freight transportation cost data elements required for public investment, policy, and regulatory decision making, and describes and assesses different strategies for identifying and obtaining these cost data elements.
- NCFRP Project 39 (Report 29): *Making Trucks Count: Innovative Strategies for Obtaining Comprehensive Truck Activity Data*—describes cost of freight movement by truck as one of its data elements.

A detailed description of each of the selected NCFRP projects can be found in the Appendix A-1.

Transport Canada's Fluidity Index

The main purpose of Canada's FI is to evaluate and measure the impact and performance of the strategic gateways and corridors of the country. To evaluate how gateways and strategic trade corridors interact together operationally, a fluidity indicator was developed. Transport Canada's supply chain performance monitoring initiatives support the establishment of key performance indicators to assist government agencies in enhancing visibility and accountability on oversight of key assets. These indicators will ultimately aid Transport Canada in identifying to what extent the Government of Canada's policies and investment in infrastructure are being leveraged and operated to support trade and economic prosperity (*12*).

Transport Canada's fluidity indicator enables Canada to measure its own performance and do comparative analysis within the North American marketplace. The metrics focus on bottlenecks and impediments along major trade corridors, resilience issues, and the competitiveness of Canada's supply chains.

Transport Canada contracted with the Texas A&M Transportation Institute (TTI) to develop and apply the indicators for measuring freight system performance. Researchers created two fluidity indicators using an index approach. One indicator captures average travel time (FI), while the other indicator captures variations in travel time (planning time index). Because freight moves according to both travel time and delivery requirement schedules, and because travel time varies according to mode, the performance measures use a normalizing concept to allow comparisons within a mode and across an entire supply chain (*13*). Total travel times are calculated by adding all modal segments of end-to-end movement. No single data source (or provider) could capture travel time data for the entire container trip; hence, a variety of data exchange partnerships are in place with several stakeholders. For the most part, the method relies on genuine primary data from private-company carriers (*12*).

To calculate the FI, Transport Canada obtains truck GPS travel time data from a third-party provider. Information on approximately 30,000 trucks is provided on a monthly basis (*14*). The data contain a unique identifier, date and time, and geographic coordinates for each satellite observation. The data are used to analyze travel times and trip time reliability between major origin and destinations, as well as at border crossings with the United States (*15*).

The Government of Canada and Transport Canada developed a web-based, multimodal tool, based on the fluidity indicator that measures the performance of individual segments of supply chains in near real time and the end-to-end travel time of freight flows (*16*). Other efforts focused on estimating wait times at border crossings between Canada and the United States and measuring the carbon footprint of freight supply chains. Along with the FI, the data set allows Transport Canada to conduct a variety of analyses of supply chains responding to various disruptions. For example, the immediate and residual impacts of disruptions on the rail network from strikes and weather events have been examined. Information on commodities, travel time, and disruption impact can be examined (*16*).

I-95 Vehicle Probe Project

The I-95 Corridor Coalition is a partnership of transportation agencies, public safety organizations, and other related organizations, from Maine to Florida.

In April 2007, the I-95 Corridor Coalition began a regional traffic monitoring system, VPP, to act as a continuous source of real-time transportation system status information within the corridor.

The VPP was aimed at collecting and evaluating real-time, travel time, and speed data for approximately 1,500 miles of freeways and 1,000 miles of arterials in New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and North Carolina. At its conclusion in summer 2014, live data were being provided by INRIX for over 40,000 centerline miles of roadways in 10 states, including nearly 8,000 miles of freeways (*17*). Data were evaluated for quality control by the University of Maryland using Bluetooth readers. The primary source of the INRIX data was GPS-equipped fleet vehicles.

The VPP is now moving forward with a traffic probe data marketplace. Three vendors (HERE, INRIX, and TomTom) were selected by a team of the I-95 Coalition members to provide data under a new contract. This structure gives agencies the opportunity to select the vendor that best suits their individual needs at a cost that was negotiated for the corridor. As part of this new contract, the data are still subjected to rigorous validation for reliability. In addition, all data, regardless of vendor, are available to each of the participating agencies, providing a truly shared effort.

According to the I-95 Corridor Coalition website, currently 10 of the 16 states in the Corridor Coalition are receiving and using real-time data from the VPP Suite as the source for their Advanced Traveler Information System (*18*).

The National Performance Management Research Data Set

The NPMRDS historical traffic speed data set covers the entire National Highway System. It includes observed measurements (collected 24 hours a day) and provides the user with average travel times in five-minute intervals in three ways: freight trucks, passenger vehicles, and all vehicles (*19*).

NPMRDS in turn, relies on the American Transportation Research Institute (ATRI) as trusted 3rd party for freight data, which is formed of over 600,000 truck probes, collecting GPS data for 3 billion position points a year of primarily long-haul trucks on the interstates, capturing a decent amount of other trucks (*19*). Specifically, the data represent a strong truck sample (approximately 30 percent of registered Class 6, 7, and 8 trucks). However, short haul, drayage and delivery are less represented and offer no commodity information (*19*).

Urban Congestion Report

The main focus of the UCR is reducing congestion growth through better highway system management.

This program began in March 2002 when the Federal Highway Administration (FHWA) commissioned a leading firm to establish an urban congestion reporting capability using data provided by intelligent transportation system roadway sensors from the largest instrumented cities in the nation.

The UCR communicates and summarizes, on a quarterly and annual basis, performance measures that are aggregated nationally (and by urban area). Since 2014, the UCR program has been operated as a cooperative effort between TTI and FHWA, developing congestion and reliability measures for U.S. metropolitan areas with over 1 million in population (the metropolitan boundaries are defined as metropolitan statistical areas—geographic entities delineated by the Office of Management and Budget for use by federal statistical agencies in collecting, tabulating, and publishing federal statistics [*20*]), using vehicle probe-based travel time data from FHWA's NPMRDS. Thus, the current number of metropolitan areas being reported is 52. Also, more complete roadway coverage within the metropolitan areas has been implemented, and the Highway Performance Monitoring System (HPMS) volume database is used to weight performance indices by vehicle-miles of travel. The primary measures presented by UCR are congested hours, travel time index, and planning time index (*21*).

Because of the quarterly performance statistics evaluated by the UCR, a 12-month trailing average of monthly free-flow speeds for the performance measure calculations is used.

UCR information comes from different data sets and systems. Specifically, travel times/speeds come from NPMRDS, while traffic counts and road inventory data come from HPMS.

The Regional Integrated Transportation Information System

RITIS is an automated data sharing, dissemination, and archiving system that includes many performance measure, dashboard, and visual analytics tools that help agencies to gain situational awareness, measure performance, and communicate information between agencies and to the public (*19*). RITIS consolidates, standardizes, and fuses disparate data sources and systems into a platform for use by a wide range of users and applications (*22*). RITIS is hosted by CATT Lab, a user-focused research and development laboratory at the University Of Maryland.

RITIS consolidates data from various sources, state agencies, device manufacturers, and 3rd party data providers such as HERE, INRIX and TomTom data (*22*). HERE is a multifaceted company providing mapping data, technologies, and services to the automotive, consumer, and enterprise sectors. INRIX is also a private initiative who provides historical, real-time traffic information, traffic forecasts, travel times, travel time polygons, and traffic count to businesses and individuals in 40 countries. TomTom NV produces navigation and mapping products as core business. TomTom is headquartered in Amsterdam.

Datamyne

Datamyne is a private initiative founded in 1992 and since then became a top-ranked provider of international trade data (*23*). The data set is drive by U.S. trade with more than 230 markets worldwide.

Datamyne data are extracted from import and export manifests and customs clearances documents (*23*). Manifests yield details of each shipment: parties to the transaction, logistics, cargo descriptions, and volumes. The data are then enhanced with additional information, including calculated values of incoming shipments. Datamyne's data cover 100 percent of U.S. waterborne imports and approximately 94 percent of U.S. containerized exports.

European Congestion Report

The ECR is based on the analysis of a large number of real vehicle speeds that have been measured on each road link and the application of algorithms that allows for the estimation of congestion indicators for specific types of roads during selected time periods.

During 2008 and 2009, large amounts of data on speed measurements from vehicle navigation systems on European roads were collected as an initiative of the European Commission. This information gives a highly accurate and representative vision of the driving conditions of the European road network in different periods of the day, and can be compared to speed estimations in a variety of flow conditions. As a result, indicators of congestion for different time periods can be measured and compared across road links (highways), regions, and countries (*19*).

The data used (over 1 trillion records) represent relevant information on real speed from in-vehicle navigation systems for different time periods and allow measurement and monitoring of road congestion across the European Union.

To analyze the collected data, road links are clustered in groups of speed-time intervals over a 24-hour period. Each road link has a specific speed profile assigned per day of the week. The average speed on a specific link during a certain time period can be compared to the speed estimated for the link during free-flow conditions or against selected threshold values.

These data allow a direct mapping of recurrent road congestion in Europe, offering a flexible framework of analysis. Modifying the selected period of time can limit the estimation on specific peak hours or extend it to wider periods (e.g., three hours, six hours, or even a whole day).

The ECR has now evolved to become part of the Implementation Monitoring Report on Congestion Management Procedures (IMR)—first published in January 2015. While the ECR focuses on the question of whether actual congestion has occurred at interconnecting points in the European Union, the IMR focuses on the question of whether the congestion management procedure provisions have been implemented and what their effects have been. The IMR relies mostly on data gathered from the ECR and case studies from each congestion report of the European members, affiliates, and non-members (e.g., Spain's congestion report, United Kingdom's congestion report), as well as case studies provided by the Agency for the Cooperation of Energy Regulators and national regulatory authorities (*24*).

Freight Analysis Framework

The objective of FAF is to integrate data from many sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. FAF also provides information on import and export flows (*25*).

FAF uses data from the Commodity Flow Survey (CFS) and international trade data from the Census Bureau. The CFS is the primary source of national and state-level data on domestic freight shipments by American establishments in mining, manufacturing, wholesale, auxiliaries, and selected retail and services trade industries (*26*). FAF incorporates data from agriculture, extraction, utility, construction, service, and other sectors (*27*). The CFS information is collected every 5 years. Based on the CFS, the FAF has a base year and forecasts, but not continuous data.

Bureau of Transportation Statistics

The BTS mission is to create, manage, and share transportation statistical knowledge with public and private transportation communities and the nation (*28*).

BTS collects data from different sources through several programs. BTS's freight major sources are: the intermodal transportation database, which includes data from BTS/Census Commodity Flow Survey; the national transportation Atlas Database, which is a set of nationwide geographic databases of transportation facilities, transportation networks, and associated infrastructure; and Statistics on Performance and Impacts of the Nation's Transportation Systems (*28*). BTS also provides summary statistics for incoming crossings at the U.S.-Canadian and the U.S.-Mexican border at the port level. Incoming crossing data are available for trucks, trains, containers, buses, personal vehicles, passengers, and pedestrians. Border crossing data are collected at border ports by U.S. Customs and Border Protection (*29*).

Summary of Freight Performance Measurement Experiences

Based on the analysis of previous experiences in measuring transportation performance, it is clear that some measurements provide information for investment decision making, while others focus on trade competitiveness. Nevertheless, all of them cover most modes of data collection. The NCFRP projects demonstrate that there are several potential sources of freight-related data, including interviews, surveys, databases, and case studies. For the most part, Transport Canada's FI "…relies on genuine primary data from private sector carriers supplied on a voluntary basis" (*12*), and on GPS travel time data from a third-party provider. The VPP data are gathered from GPS-equipped fleet vehicles, the UCR acquires roadway travel time data from NPMRDS, which in turn relies on ATRI for freight data. RITIS retrieves data from 3rd party providers such as HERE, INRIX, and TomTom. Datamyne collects data from manifests and customs clearances. ECR gathers data from vehicle navigation systems on European roads. FAF uses the CFS and international trade data as the main components of data sourcing. The BTS's freight information includes the intermodal transportation and national transportation databases, and statistics from the Nation's Transportation Systems.

Many of these data collection techniques may be relevant for freight transportation performance or fluidity measurements. However, some may not be operationally feasible or adequate for regular and consistent availability.

Note that the list of reviewed experiences includes programs (e.g., VPP, systems; RITIS, data consolidation sources and companies; FAF-CFS, Datamyne). Nevertheless this array of experiences generally used four main or basic data elements to measure freight transportation performance. These basic data elements are:

- Time.
- Time reliability.
- Cost.
- Volume.

Table 2 shows the data sources of each experience reviewed to each of these basic data elements.

Table 2. Previous Experiences-Basic Data Elements Sources.

<table>
<tr><th rowspan="2">Experience/ Initiative</th><th colspan="4">Basic Data Element</th></tr>
<tr><th>Time</th><th>Time reliabili ty</th><th>Cost</th><th>Volume</th></tr>
<tr><td>NCFRP</td><td colspan="4">GPS traces, interviews, surveys, databases, and case studies</td></tr>
<tr><td>Transport Canada’s Freight Fluidity</td><td colspan="2">GPS data for trucks and railway company information for rail</td><td>N/A</td><td>N/A</td></tr>
<tr><td>VPP</td><td colspan="3">GPS from equipped fleet vehicles and Bluetooth anonymous emissions from Bluetooth equipped accessories in passing vehicles</td><td>N/A</td></tr>
<tr><td>UCR</td><td colspan="2">Travel times/speeds in come from NPMRDS, traffic counts, and road inventory data come from HPMS</td><td>N/A</td><td>N/A</td></tr>
<tr><td>NPMRDS</td><td>ATRI</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>RITIS</td><td>3rd party providers (HERE, INRIX, and TomTom)</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Datamyne</td><td>Manifests and customs clearances documents</td><td>N/A</td><td>N/A</td><td>Manifests and customs clearances documents</td></tr>
<tr><td>ECR</td><td>In-vehicle navigation systems for different time periods</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>FAF</td><td>CFS and international trade data</td><td>N/A</td><td>N/A</td><td>CFS and international trade data</td></tr>
<tr><td>BTS</td><td>N/A</td><td>N/A</td><td>N/A</td><td>CFS, FAF, intermodal transportation and national transportation databases, and statistics from the Nation’s Transportation Systems</td></tr>
</table>

Time, time reliability, and cost data elements are the focus of further analysis presented in the next section. Also, researchers define more detailed data elements required to measure freight transportation performance.

As part of this project, a workshop via webinar was organized to share information from various data providers. TTI researchers presented findings from the research and other speakers were invited to present their experiences. The list of invited speakers included:

- Chandra Bondzie, FHWA.
- Nicole Katsikides, Maryland Department of Transportation.
- Andrew Carter, Transport Canada.
- Gary Carlin, INRIX.
- Aetius Rossa, Data Myne.

A copy of the workshop agenda and presentations is presented in Appendix A-2.

ANALYSIS OF DATA SOURCES

In this section, the considerations that need to be made for transportation improvement are the basis to define the needed data elements. Consequently, appropriate data sources are identified based on previous and current experiences.

One of the most important considerations is that transport-related government agencies, with the responsibility of deciding where to invest public funds and shape public policy, aim at providing economic development. Nevertheless, sometimes the best use of resources and public policy to achieve economic development is not clear. This is mostly due to the lack of visibility of the impacts and relations between transportation and economic development. This visibility is constrained by the information the data provide, which is defined by the unit of measurement (typically vehicle).

The mere fact that time, reliability, and cost are measured in vehicles prevents analysts from having a clear view of what is important for this new approach of measuring freight transportation performance, which is the freight or goods throughput. Measurement by goods is important to companies' competitiveness because goods are the value asset for economic growth. A private company's performance is measured by the amount of goods sold and how efficient those goods are delivered to market. Even service-oriented companies, such as transportation or logistics companies, ultimately depend on the amount of goods they serve and how efficient they are handled. From this perspective, vehicles are just the means for handling freight, and government agencies need to have a clear map of the goods being moved in their region and, more importantly, the role that the region plays in the goods supply chain.

Requirement Analysis and Data Elements

As mentioned previously, measuring freight transportation performance is critical for identifying potential system improvements to increase competitiveness and economic growth. To measure the freight transportation system's performance, it is first important to define information (i.e., data element) requirements and sources of that information. To do so, basic data elements (also called main indicators) were retrieved from previous experiences and will determine the final list of proposed data elements. The unit of measurement of these basic data elements is then modified given the supply chain perspective of the system performance measurement. Then, volume of goods is proposed as an additional data element.

Basic Data Elements

Common to most reviewed initiatives included in this report, fluidity measurement has been performed considering four basic data elements or primary indicators, which are the building blocks for more detail data elements, indicators, and measures. These four basic data elements are:

- *Travel Time.* Travel time is important because it is a measure of average conditions, it can reference average speeds or can go one step further and relate these average speeds to some benchmark figure (typically free-flow speeds) and tells one how much longer, on average, travel times are during congestion compared to during light traffic.

- *Travel Time Reliability.* The concept of travel time reliability refers to how consistent travel conditions are from day-to-day. This is related to the concept of travel quality, which contributes to smooth and predict travel conditions. Traffic professionals have come to recognize the importance of travel time reliability because it better quantifies the benefits of traffic management and operation activities than simple averages.
- *Cost.* Cost is commonly used as primary criteria for measuring performance. Therefore, the importance of this basic data element is straightforward since it is a major factor of economic feasibility.
- *Volume.* Volume provides information on the amount of goods handled between and origin and destination point throughout the transportation network. Volume includes measurement by weight (tons) and value by commodity type. This data element delivers the supply chain focus by helping understand how fluid supply chains are.

Travel time and cost data elements are originally referred to in the I-95 Corridor Coalition's VPP, while travel time reliability is used by the UCR and the I-95 Corridor Coalition's VPP. Some volume information has been identified in previous experiences (Datamyne, FAF), with some constraints on the data resolution and update periodicity.

Volume of goods as *basic* data element is critical to measure transportation supply chain performance. This is conceived as supply chain level data and would allow decision makers to identify the role that the region plays in the supply chain. It could be consumption, distribution, manufacturing, storage, or simply point of connection. This information provides decision makers with tools to define public investment and policy to increase local company competitiveness—ultimately positively impacting economic development.

Proposed Data Elements

With the four basic data elements: time, time reliability, cost and goods volume, decisions regarding shifting or enhancing the role of a region in a specific commodity supply chain could be more assertively made. Also, investment on infrastructure, or the creation of incentives for private investment attraction to the region, could be more swiftly and accurately performed.

Nevertheless the information provided by these basic data elements may not be as detailed as needed for more specific decisions. Also, as mentioned in the previous section, there are many data sources that can be used for feeding freight performance measurement; however, these data sources do not provide all required elements for complete measurement. Therefore, an expanded set of data elements is proposed to complement based on experiences and literature review. This expanded set of data elements is based on previous work by Samimi et al. (*30*) and the NCFRP Project 39: *Making Trucks Count: Innovative Strategies for Obtaining Comprehensive Truck Activity Data*.

Merging these documented literature experiences, and using goods or commodity as the measurement unit, researchers deemed the following four categories and data elements to be adequate for transportation supply chain performance measurement:

1. Business establishments:
    - Number of businesses—by commodity group.
    - Type of business—by commodity group.
    - Volume of goods handled/traded—by commodity group per business.
    - Value of goods handled/traded—by commodity group per business.

Data elements under the business establishment category provide information on the actual situation of market and supply chain. This information allows an eventual mapping of supply chain value-adding activities in the region by assessing volume and value of goods per commodity group and business type.

2. Shipments and supply chains:
    - Goods-miles traveled (GMT): Measure of the goods volume transported per distance unit (mile), within a specific geographic area over a given period of time in tons/mile by commodity group.
    - Ton-miles: Total weight of the entire shipment multiplied by the mileage traveled by the shipment by commodity group.
    - Value-miles: Market value of shipments multiplied by the mileage traveled by the shipment by commodity group.
    - Shipment lead time: Speed of order delivery, from order shipping until delivery, by commodity group.

These data elements are the core of goods movement, since they relate volume and distance traveled. Specifically, GMT could yield indicators of goods transportation density, while ton-miles and value-miles offer transportation throughput in terms of goods volume and value in a given region within a certain period of time. Shipment lead time complements supply chain information with the time it takes to deliver a shipment. Lead time also includes waiting time, cargo consolidation, inspections, or other operations related to shipment delivery.

3. Freight transportation networks:
    - Transportation cost: Cost of freight movement by shipment by commodity group.
    - Shipment transportation speed: Velocity of a shipment transportation by commodity group and by transportation mode.

These data elements address mainly transportation efficiency in terms of cost and speed.

4. Zone-to-zone freight flows:
    - Origin-destination (O/D) flows: Start and end points for a particular shipment, per commodity group.

O/D flows would show directions and could help identify regions with supply, transformation, and consumption activities.

These proposed data elements cover all initial data types—time, time reliability, goods cost and goods volume—providing key information for freight performance measurement with a supply chain scope, and thus answering questions related to the regional supply chain role, public investment, and policy making.

Table 3 provides a summary of the data elements, including their individual purpose or use, and its relation with the four basic data elements-travel time, travel time reliability, cost, and volume. First column specifies the concepts on which data elements are constructed. These concepts, taken from Samimi et al. (*30*), framed the information needed for supply chain oriented freight transportation assessment.

Table 3. Data Element Use and Basic Data Element Relation.

Category	Data Element	Use	Basic Data Element Relation
Business establishments	Number of businesses	Supply chain/Market assessment: Provides information on supply capacity and/or market size	Volume
	Type of business	Supply chain/Market assessment: Provides information on supply chain activity	
	Volume of goods handled/traded	Supply chain/Market assessment: Provides information on the magnitude of flows	
	Value of goods handled/traded	Supply chain/Market assessment: Provides information on the value of flows	
Shipments and supply chains	GMT: Goods volume transported per distance unit (tons/mile)	Infrastructure use/Supply chain assessment: Provides information on the density of infrastructure use by goods flows	
	Ton-Miles: Total weight of the entire shipment multiplied by the mileage traveled by the shipment	Infrastructure use/Supply chain assessment: Provides information on the magnitude of infrastructure use by goods flows (volume), and information on commodities transportation length	
	Value-Miles: Market value of shipments multiplied by the mileage traveled by the shipment	Infrastructure use/Supply chain assessment: Provides information on the magnitude of infrastructure use by goods flows (value) and information on commodities transportation length	
	Shipment lead time: From order shipping till delivery	Supply chain assessment: Provides information of delivery speed considering transportation and waiting time, cargo consolidation, inspections, or other operations related to shipment delivery.	Travel Time/ Travel Time Reliability
The freight transportation networks	Transportation Cost: Cost of freight movement by shipment	Infrastructure design assessment: Provides information on the cost of transportation	Cost

	Shipments Transportation Speed: Velocity of a shipment transportation	Infrastructure design assessment: Provides information on the time of transportation	Travel Time/ Travel Time Reliability
Zone-to-zone freight flows	O/D Flows: The start and end points for a particular shipment	Supply chain/Market assessment: Provides information on flows directions and supply, transformation, and consumption areas	Travel Time/ Cost/ Travel Time Reliability/Volume

Data Sources

Based on the previously defined data elements, this subsection analyzes potential data sources from previous experiences, other available data sources, and additional alternative data sources and proposes nonconventional data sources along with new data generation. This analysis is based on the features these data need to possess in order to provide appropriate information. These features are known as attributes.

Data Attributes

The constraints that prevent analysts from using some data sources are in the form of required data attributes. Among these attributes is the type of unit measure and the query filter or classification (e.g., goods are not available as unit measure, and commodity group is not available as query filter or classification). For instance, currently, there are data sources that can provide the volume of goods handled, but not by commodity group and by business. Some other data elements have no viable data source, such as shipment lead time. Another important feature to consider in data sources is how often the information is updated. Most of these data sources are static. For instance, the FAF is updated every four to five years (2012 is the most recent). Also, geographic resolution plays an important role in data attributes since the type of geographic grouping determines economic or market assessment in supply chain analysis. Table 4 summarizes the required data attributes and the type of information per data element.

Table 4. Summary of Data Element Attributes and Information Type.

		Data Attributes	
DATA Element	**Information type**	**Data type**	**Grouping**
Number of businesses	Market size	Integer number	Per goods family
Type of business	Market type/Supply Chain Activity	Categorical variable	
Volume of goods handled/traded	Supply chain size	Real number	Per goods family per business
Value of goods handled/traded	Market value	Currency	
GMT: Measure of the goods volume transported per distance unit (mile)	Density of the transport operation	Real number	Per goods family
Ton-Miles: Total weight of the entire shipment multiplied by the mileage traveled by the shipment	Volume throughput of goods		
Value-Miles: Market value of shipments multiplied by the mileage traveled by the shipment	Value throughput of goods	Currency	
Shipment lead time: From order shipping till delivery	Delivery time	Time	
Transportation Cost: Cost of freight movement by shipment	Cost incurred in the transportation operation	Currency	
Shipments Transportation Speed: Velocity of a shipment transportation	Travel time	Time	Per goods family, per transportation mode
O/D Flows: The start and end points for a particular shipment	Route	Volume	Per goods family

As far as data collection periodicity, yearly updates are desirable. Meanwhile most methods could easily be performed annually, there are exception such as census, which cannot realistically be implemented with this frequency. Thus, some information may have a lag of three to five years due to this operational constraint.

Geographic resolution, on the other hand, may well be achieved at zip code level that would allow aggregation by different types of groups to assess economic activities in specific areas within regions.

Data Collection and Data Organization Methods

Most of the methods identified in previous experiences, including interviews, surveys, databases, and case studies, provide limited information in terms of goods handled. This also includes high-tech methods such as navigation systems. This limitation is due to the nature of the data collection technology that is used, where the objective is vehicle volume estimation rather than goods movement.

Freight Analysis Framework

One of the most relevant data sources identified in the literature review is FAF. FAF is product oriented, meaning that it provides movement information by commodity. However, the FAF has some shortcomings since it is not developed to estimate flows accurately for local regions/individual routes nor to estimate temporal variations in freight flows. It also does not include effects of capacity limitation or forecast future capacity expansion. FAF developers acknowledge that "local data collection/simulation is still key" (*19*). Additionally, the CFS, on which the FAF is based, does not cover some industry sectors in sufficient detail.

Business-to-Business

Some private-sector companies are able to provide data that can be used to better understand how goods are traversing a multimodal freight system. These data are collected through tracking sales, purchasing, shipping, and/or delivering transactions of goods. For instance, Quetica, a private company providing consultancy and financial supply chain solution services,[2] collects bill of lading information from many Fortune 500 companies that are aggregated into their data sets, which enables them to provide routing from standard routing models. The latter is a type of business-to-business (B2B) data along with B2B payment data that could be useful for assessing different freight transportation behaviors.

Census

Based on findings from NCFRP Project 39 (Report 29), the idea of implementing a periodical census as additional part of the existing economic census could be of benefit if the approach and content are expanded to cover supply chain performance information. The new survey could be part of the quinquennial economic census.

Networks

Another strategy from NCFRP Project 39 (Report 29) is employing an agent-based model that switches from data collection, or data capture, to data production (e.g., data that are the outcome of model simulations). This strategy could be implemented through new methods, such as the developed network-based model. The network-based model establishes a strategic partners' network, with the proper technological infrastructure across the target geography. Also, a competence and incentive scheme is applied to comply with the compromise of keeping the data updated as stipulated in the operational rules of the system.

2 See http://www.quetica.com/.

Proxy Data

An additional strategy is inferring information based on proxy variables. This model identifies available data through existing information systems (e.g., IRS, national statistics) to further conduct correlation studies of information like taxes, operative expenses, etc., in which the target data can be inferred (but are not directly available). As an example, from a correlation index and/or a linear/nonlinear factor, unavailable transportation costs can be inferred from fuel costs. Most of the information that could be used as a proxy is required by law; therefore, it is being updated frequently.

Metadata

As it was highlighted in the previous data attributes section, required data need to be classified, grouped, or sorted by specific criteria (e.g., volume of goods handled, grouped by commodity and by business type). The latter may seem simple, but becomes more complex as the amount of data increases. Therefore data organization tools may be needed. Metadata is helpful at these data organization tasks; it is structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource. Therefore metadata facilitates discovering relevant information as it helps organize electronic resources, facilitate interoperability and legacy resource integration, provide digital identification, and support archiving and preservation (*31*). It is colloquially called "data about data" or information about information and as more data sources become involved, with larger data sets, in the freight supply chain analysis the need for metadata will become more pressing.

Proposed Data Sources

Based on the previously described data collection methods, new data sources and in some cases more than one for each of the proposed data elements are suggested. Specifically, an additional supply-chain-oriented census for volume and value of goods complemented with proxy (tax) data is proposed. Also, complementing FAF information, B2B private transactional information is suggested as additional information source. The census provides a large sample closer to the entire target data population, statistically known as universe. However, it is not practically feasible to perform as frequent as would be desire for continuous data update. B2B, on the other hand, is very flexible on periodicity, but usually B2B samples are comparably far smaller and segmented (i.e., focused on a specific type of business or commodity). The mix of these new sources would give the periodicity and accuracy needed for a continuous supply chain analysis.

Table 5 shows the data sources pertaining to each proposed data element. Under column named "Available," the currently available sources are listed. These readily available data sources could be used immediately for analysis purposes. However, as mentioned before, they may not be sufficient in terms of the required information attributes, and for the depth and scope of the analysis it is pursued. The pertinence of new data sources, to each data element, is depicted under the column, "Proposed (data source)." In some cases, there is more than one source for a single element, meaning that even though all of them are pertinent, a single one of them may not be sufficient in terms of data completeness, information continuity, or updating. Specifically, economic census provides enough information to depict the first two business establishment data elements (i.e., number and type of business); however, additional input from a supply-chain-oriented economic census or surveys would be needed to complete volume or value of goods per commodity group-business type combinations (*32*). This information could also be extracted and complemented from tax data because value is related to tax and volume. Such additional census could also provide information on shipment lead time, shipment transportation speed, and shipment origin-destination, all by commodity group. The FAF, on the other hand, could provide information on the number of miles that goods are being transported and the overall value, complementing other shipment transportation speed and O/D data (*19*). B2B transactional information could be useful to complement GMT, tonnage, value-miles, and transportation costs. Also in Table 5, the specific provider of these data sources is identified at the column "Data Provider (Name)."

Table 5. Data Elements—Source Matrix.

<table>
<tr><th rowspan="2">Data Element</th><th colspan="2">Data Source</th><th rowspan="2">Data Provider (Name)</th></tr>
<tr><th>Available</th><th>Proposed</th></tr>
<tr><td>Number of businesses</td><td colspan="2">Economic Census</td><td rowspan="2">State Data Centers Establishment Data</td></tr>
<tr><td>Type of business</td><td colspan="2">Economic Census</td></tr>
<tr><td>Volume of goods handled/traded</td><td rowspan="2">Not Identified</td><td rowspan="2">Additional Census/Tax Data/B2B Data</td><td>Datamyne</td></tr>
<tr><td>Value of goods handled/traded</td><td>Datamyne</td></tr>
<tr><td>GMT</td><td colspan="2" rowspan="3">CFS/FAF/B2B Data</td><td rowspan="3">FAF/Quetica, Datamyne</td></tr>
<tr><td>Ton-Miles</td></tr>
<tr><td>Value-Miles</td></tr>
<tr><td>Shipment lead time</td><td rowspan="2">B2B Data</td><td rowspan="2">Additional Census/B2B Data</td><td>HERE, INRIX</td></tr>
<tr><td>Transportation Cost</td><td>Quetica</td></tr>
<tr><td>Shipments Transportation Speed</td><td>FAF (Estimated)/B2B Data</td><td>FAF/B2B Data</td><td>FAF/HERE, INRIX</td></tr>
<tr><td>O/D Flows</td><td colspan="2">CFS/FAF/B2B Data</td><td>FAF/INRIX, Quetica, Datamyne/BTS</td></tr>
</table>

Confidentiality is a major concern because this information would need to be considered public to enhance its benefits. Therefore, no individual business information should be disclosed.

Because of the level of detail of the data needed, and the specific features of the proposed data sources, a perfect match of data resolution–data source capability is complex. Therefore, a workshop to discuss proposed data collection ideas is suggested as part of the next steps in the definition of data elements and data sources. This workshop would include major stakeholders such as third-party logistics providers, government agencies, and private-sector companies, manufacturers, and distributors.

At this point, it is not advisable to propose data collection procedures because such procedures depend on the specific agreed-upon measurements that will be developed. Additionally, indexes and consequently the performance model would largely depend on the feedback and data element confirmation from the workshop, and the specific uses of the freight performance measures.

Case Study

In order to illustrate and perform an initial practical assessment of the data elements concept and their sources developed in the initial tasks of this project, the research team has collected and analyzed data from private and public sources to develop a concise case study. This case study focuses on illustrating the use of data elements on specific measures providing an approximation of the use and potential implementation of the data elements and their information sources.

The corridor analyzed starts at San Luis Potosí, Mexico, and ends at Nashville, Tennessee. The entire route was split in three segments (Figure 1):

- Segment 1: Travel segment in México.
- Segment 2: Border crossing at Nuevo Laredo-Laredo.
- Segment 3: Travel segment in the U.S.

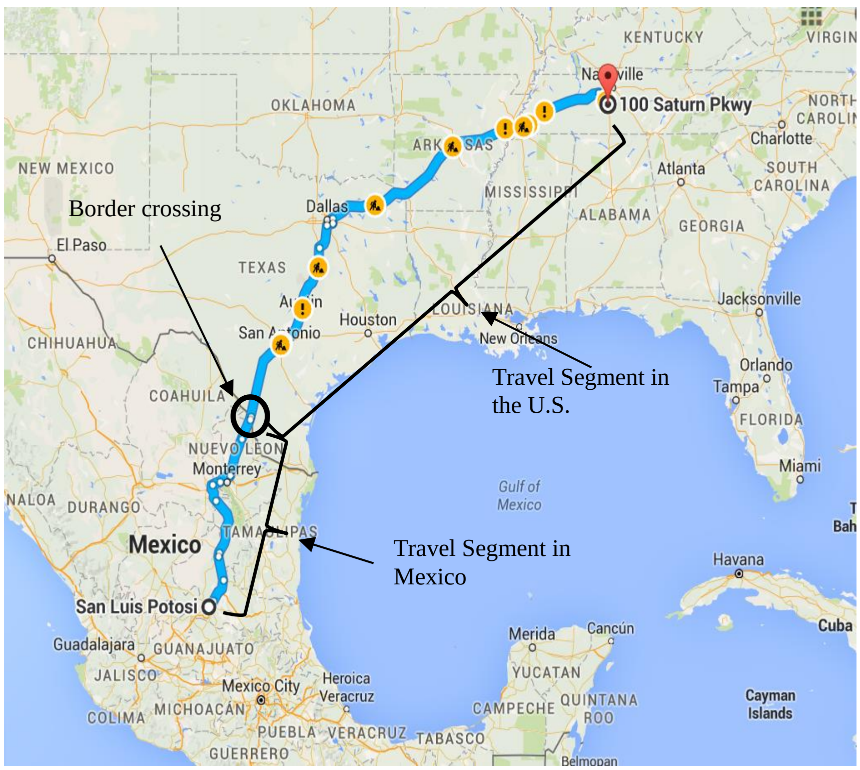

Figure 1. Case Study 1's Corridor and Road Segment.

The case study uses available information to obtain travel and cost data. Costs and transportation rates were obtained from transportation associations published information, while distance and time were obtained from INRIX in the United States side and from the Border Crossing Information System (BCIS). In the case of the segment in Mexico, traveling information was not available, so a sampling data collection was performed using Google Maps.[3]

3 *©2016 GOOGLE*

This example illustrates a reliability specific measure. Reliability is generally a measure of consistency on transportation time. This is an important element for planning, since most negative impacts on operations come from unexpected variability, which result in low customer service and higher costs. For the latter, calculations such as the standard deviation are necessary. On the other hand, speeds are needed to calculate free-flow; this is described in detailed in the index definition later in the document.

Table 6 indicates the sources of the data per input variable and the type of source according to previous descriptions.

Table 6. Case Study's Input Data Sources.

Input Variable	Source	Source Type
Total Travel Cost (Estimated)	Transportation associations	B2B
Average Actual travel time	BCIS for border segment and INRIX for long segments of the trip	State Data Centers Data/B2B
Length of the network segment used for transportation	Google Maps/INRIX	B2B
Maximum speed allowed (by regulation), in the network segment	Estimated using Google Maps	N/A
Std. Deviation Actual travel time	BCIS/INRIX	State Data Centers Data/B2B
Std. Deviation Length over Maximum Speed	Google Maps/INRIX/Estimated	B2B
Average Length over Maximum Speed	Google Maps/INRIX/Estimated	B2B
Average Actual travel cost	Transportation associations	B2B

In this case study, the following data elements were used:

- O/D flows: Start and end points for a particular truck trip.
- Vehicle speed: Velocity of a shipment transportation.
- Transportation cost: Cost of freight movement by truck.

After updating historic data based on inflation and performing prorating operations, the following input data were calculated (Table 7).

Table 7. Case Study's Input Data Values.

Description	Units	SEGMENT 1	SEGMENT 2	SEGMENT 3
Total Travel Cost (Estimated)	$	$1,537		
Average Actual travel time	Minutes	473.96	49.00	1,007.85
Length of the network segment used for transportation	Miles	448.01	0.63	1,093.00
Maximum speed allowed (by regulation), in the network segment	MPH	68.35	5.00	67.00
Std. Deviation Actual travel time	Real Number	29.44	28.00	22.06
Std. Deviation Length over Maximum Speed	Real Number	0.42	0.00	4.99
Average Length over Maximum Speed	Hours	2.56	0.04	6.31
Average Actual travel cost	$	$ 445.96	$ 3.09	$ 1,087.99

From these data, travel time, travel time reliability, and travel cost indices were calculated. These indices were defined as:

$$\boldsymbol{Travel\ Time\ Index} = \frac{Average\ Actual\ Travel\ Time}{Free{-}Flow\ Travel\ Time} \quad (1)$$

$$\boldsymbol{Travel\ Time\ Reliability\ Index} = \frac{Actual\ Travel\ Time\ Coefficient\ of\ Variation}{Free{-}Flow\ Travel\ Time\ Coefficient\ of\ Variation} \quad (2)$$

$$\boldsymbol{Travel\ Cost\ Index} = \frac{Average\ Actual\ Travel\ Cost}{Standardized\ Travel\ Cost} \quad (3)$$

Where:
Free-flow travel time = the ratio[4] of the length of the infrastructure used for transportation and maximum speeds allowed (by regulation), along the used length in the network segment.
Coefficient of variation = standard deviation ⁄ mean.
Actual travel cost = summation of actual travel transportation costs retrieved from companies.

4 The network segment length needs to be divided by the maximum speed allowed, which is usually—and is assumed to be—given in mph, to obtain the portion of, or the number of, hour(s) needed to cover the network segment length. Then it will need to be multiplied by 60 to obtain the number of minutes needed to cover the segment length at maximum speed allowed, namely free flow.

Standardized travel cost = summation of *estimated* fuel, maintenance, personnel, tolls, and transportation tax costs by link or network segment.

Table 8 lists the calculated values of these indices.

Table 8. Indices Values and Interpretation.

Index	Segment 1	Segment 2	Segment 3
Travel Time Index	1.21	6.53	1.03
Travel Time Reliability Index	0.38	5.79	0.03
Travel Cost Index	0.29	0.00	0.71
Travel Cost Index/Distance	1.01	0.06	1.01
Travel Cost Index/Time	0.88	4.99	1.01

The indices values may be interpreted in the following way:

- Travel time index indicates how fast is the vehicle traveling when compared to free-flow; in the example, the vehicle is traveling 0.2 faster than free-flow for segment one, 5.53 times faster in segment 2, and practically have the same travel time for segment 3.
- Travel time reliability index shows that the variation of travel time is less than free-flow variation in segments 1 and 3 and larger in segment 2 by 4.7 times the variation of free-flow
- Travel cost of segments 1 and 3 represents 29 percent and 71 percent of travel cost of total distance (O-D), and is practically negligible in segment 2.
- The ratio of cost to distance of the segment is equal to the ratio of total cost to distance for segments 1 and 3, and is also negligible in segment 2.
- The ratio of cost to time of segment 1 is less than the ratio of total cost to time. For segment 3 is practically the same; however for segment 2 the ratio is very high when compared to total cost to time.

These indices can be used primarily as measurements of congestion level and traffic regulations compliance, measurements of travel time uniformity or consistency, and assessments of cost contribution of the network segment to total travel cost and network segment's cost proportions to distance and time. Decisions related to these indices may range from transportation efficiency, safety, infrastructure capacity, service level risk, traffic regulations, operational inefficiencies, and unnecessary costs identification.

One of the most important results of the case study, is the fact that even for a small instance - such as this case study, information from several data sources needs to be put together to get seamless data for freight performance measures. This indeed is one of the challenges of the data source initiative.

CONCLUSION

What has been proposed in this document is a set of data elements that are building blocks of precise freight transportation measurements. Some of these elements can be used directly, For example, GMT may indicate product transportation density by itself, but for investment of infrastructure planning, it would have to be related to capacity to become an index.

The definition of particular measures needs to be based on specific decision-making applications. However, researchers believe that the proposed small set of data elements would provide enough information for new supply chain and logistics performance measurements of a region.

The innovative supply chain focus indicates measuring by product family or commodity group, and considering transportation as one important part of the broader supply chain concept, which includes several other areas –e.g. marketing, planning, manufacturing, inventory, etc.[5] the typical measuring experiences, are performed with vehicles as the unit of measure, which, while being a good proxy of the amount of freight movement, is not the target unit under a supply chain scope. A more adequate unit measure for supply chain measurements is goods, which tends to be reported in different subunits (e.g., volume, cost, price).

New data sources were proposed for the product approach, such as supply-chain-oriented economic census that would provide value of goods per commodity group per business, and new B2B transactional information, which could be used to complement GMT, ton and value-miles. The proposed data sources were selected based on information gaps identified in previous experiences, as well as a result of the workshop organized during this project where data elements and corresponding data sources were discussed and presented to practitioners and users, as well as to data providers.

[5] http://lcm.csa.iisc.ernet.in/scm/supply_chain_intro.html

Table 9 summarizes the general available and proposed data sources for each of the four data elements.

Table 9. Available and Proposed Data Source per Basic Data Element.

Basic Data Element	DATA SOURCE Available	DATA SOURCE Proposed
Travel Time	1.-Highway Monitoring Systems (GPS Data). 2.-B2B Information.	1.-Highway Monitoring Systems (GPS Data). 2.-B2B Information.
Travel Time Reliability		
Cost	B2B Information.	1.-Supply chain oriented census as part of the economic census. 2.-Tax data. 3.- B2B information.
Volume of goods	1.-CFS. 2.-FAF. 3.-Economic Census.	1.-Supply chain oriented census as part of the economic census. 2.-Tax data. 3.- FAF.

The census provides a large sample but it is not practically feasible to perform frequent enough for continuous data update. B2B is highly periodic but smaller in samples and with narrower scope (i.e., focused on a specific type of business or commodity). The ideal situation would be to have a single source to provide large sampling with high periodicity, but researchers acknowledge this would require significant level of resources.

Even though the new proposed set of data sources would allegedly complete the spectrum of needed information, there is still a major issue: data are not consolidated into a single data set/single source. The case study shows that data consolidation is one of the most important aspects of freight performance measurements. The latter arises since no single source can currently provide sufficient data for freight analysis. In fact, even when consolidating several identified data sources, some assumptions need to be made in order to estimate some variables of the performance measurement. This issue is important because the effort to consolidate information from several sources (some of them new) implies data standardization, system communications, and coordination. The latter represents a major challenge in the implementation phase.

Further steps should consider data generation initiatives following the requirements for freight-supply chain-performance. These data generation initiatives should also include adequate data consolidation tools. The latter would allow a complete and deep freight performance measurement with a supply chain perspective.

Researchers recommend that future research focus on detailing characteristics and features of new data sources. The detail should include technical aspects and data attributes. Also, specific measurements, indices, or indicators will need to be proposed in order to have a complete freight performance measurement system.

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