

# **Freight Fluidity Scale of Analysis**

## **Freight Fluidity Background Paper #2**

for

Transportation Research Board (TRB) Task Force on Development of  
Freight Fluidity Performance Measures, National Academy of Sciences (NAS),  
and the Federal Highway Administration (FHWA)

by

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## Executive Summary

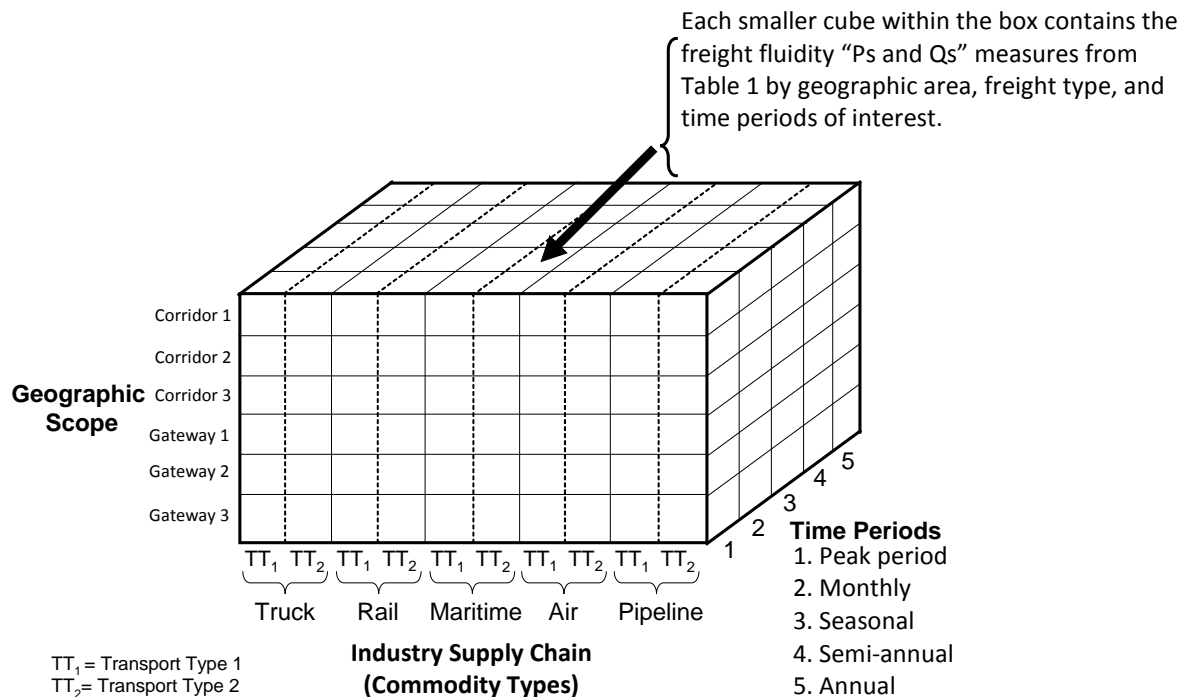
This is the second (2<sup>nd</sup>) of four (4) background papers developed by the Transportation Research Board (TRB) Task Force on Development of Freight Fluidity Performance Measures. The research questions for this paper include:

- At what scale or geography can fluidity measurements be applied?
- What are the options for analyzing corridors and gateways versus analyzing particular supply chains?
- What factors should be considered in determining the level of analysis?

The paper focuses on how to determine the “what” that is analyzed. Suggestions have included looking at key corridors and gateways, aggregated supply chains, regions and megaregions, key industries and commodities, and/or freight sheds. Because fluidity can be measured at these different levels, this paper explores options for different scales/geographies in terms of feasibility, usefulness, and other factors.

The authors conclude with a number of recommendations and considerations related to the scale of freight fluidity analysis, which include the following selected highlights:

- Both spatial (geographic scale) and temporal scale of the analysis are important, and are defined based on the user’s needs.
- Geographic scale is very broad – ranging from local streets to global supply chains, and any “links” or “nodes” in between.
- The “freight box” concept presented in Figure ES-1 provides a useful way to illustrate and understand all spatial and temporal aspects of a desired analysis, and scalable to handle various supply chains, “links,” “nodes,” and time scales.



**Figure ES-1. Expanded Freight Box for Varied Freight Modes of the Supply Chain**

- A systems approach should be applied to capture the performance of all modes and supply chains.
- There is a need for the fluidity tool to focus initially on the areas of highest initial interest and use rather than trying to meet the needs of all users immediately as shown in Table ES-1.
- The fluidity tool must be created with spatial/temporal flexibility (and expandability) to handle the more common uses initially with an eye toward future expansion as it becomes clearer how industry will use the tool.

**Table ES-1. Typical Jurisdictions and Uses with Associated Analyses Scales**

<b>Agency Jurisdiction (Examples)</b>	<b>Typical Geographic Analysis Scale</b>	<b>Typical Temporal Analysis Scale</b>	<b>Frequency of Analysis Updates</b>	<b>Example Use Case Question(s)</b>
International (World Bank, Private Corporations)	Megaregion to global	Monthly, seasonal, annual	Seasonal, Annual	How is the global supply chain operating? How is the country's overall logistics operating? Are my client's suppliers receiving goods in a timely manner?
Federal (FHWA, Chamber of Commerce)	National Highway System (NHS) – national; Global; Borders (gateways), interconnectors	Annual	Annual	Where are there bottlenecks in NHS continuity and/or connectivity? Where are delays in imports/ exports?
Megaregion (MPO, COG, Chamber of Commerce)	Regional or even global	Seasonal, Annual	Seasonal, Annual	How does my region compete in comparison to peers/competitive regions?
State (DOT)	Interstate and regional	Peak periods, monthly, annual	Monthly, annual	How are corridors on the state freight plan operating? How well are border crossings and ports operating?
Local (MPO, city, county, Chamber of Commerce)	Urban area and/or specific roadways	Peak periods,	Seasonal, annual	Where are specific freight bottlenecks on Main Street?

The shading indicates the possible geographic scale range of a beta (initial) freight fluidity measurement system – regional, national and borders/interconnectors.

## What is Freight Fluidity?

The transportation system is complex. It includes travelers and carriers using a variety of modes to make a multitude of trips. Understanding freight movement with an eye toward performance management requires multi-modal data and supply chain information for informed decision-making on the freight network.

The concept of a “fluidity indicator” was first popularized by Transport Canada to evaluate the performance of trade corridors and multi-modal supply chains. For Transport Canada’s applications, the fluidity indicator measures total transit time and travel time reliability of goods along defined supply chains (1). The Texas A&M Transportation Institute (TTI) provided early technical assistance to Transport Canada to develop and test fluidity measures and demonstrate them along a supply chain, which is documented elsewhere (2).

In a recent presentation, Mr. Louis-Paul Tardif of Transport Canada - who is credited with coining the phrase “Freight Fluidity” - stated that “the fluidity indicator provides evidence-based information to assess and analyze the efficiency of supply chains and assists Transport Canada’s work in identifying constraints in the transportation system” (3).

For the purposes of this paper, “freight fluidity” refers to the performance of transportation supply chains and freight networks. “Freight fluidity” can be a measure of the performance of a supply chain using a single mode or multiple modes of freight transportation. “Freight fluidity” can also be a measure of the performance of a freight network or freight corridor serving many supply chains.

In current U.S. parlance, **“freight fluidity” focuses on transportation supply chain performance measurement (SCPM)**; that is, the measurement of travel time, travel-time reliability and cost of moving freight shipments from end-to-end of a supply chain.

The following definition was previously put forth to define freight fluidity by researchers at the Texas A&M Transportation Institute, working in concert with University of Maryland researchers to implement Freight Fluidity in Maryland and sponsored by the Maryland State Highway Administration.

*“Freight Fluidity’ is a broad term referring to the characteristics of multi-modal 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”  
(adapted from reference 4)*

This longer definition is provided here because it provides a more detailed perspective on freight fluidity, one that touches upon the importance of the scale of freight fluidity – the focus of this paper. This definition highlights that how “fluid” the freight network is can be captured by quantifying performance (including resiliency) and quantity of freight moved. The detailed elements of the definition are described further in Table 1. The “geographic area” over which these elements are monitored could be a specific route (e.g., roadway, rail line, drayage line), supply chain (combination of routes and transload “nodes”), urban area(s), statewide, regional, and even global.

**Table 1. The Components of Freight Fluidity: Mind Your Freight Network “Ps and Qs!”  
(Adapted from Reference 4)**

Components	Description	Selected Suggested Measures/Considerations <sup>1</sup>
Performance (“Ps”)	How well are the links/nodes and network operating? Where are there bottlenecks in the supply chain or freight network?	<ul style="list-style-type: none"> <li>● Mobility (e.g., travel time, total delay, delay per mile, travel time index)</li> <li>● Reliability (e.g., planning time index)</li> <li>● Costs<sup>2</sup> (associated with delay, unreliability, wasted fuel)</li> </ul>
	How well do supply chains and the system (infrastructure, users, agencies) react to disruptions (i.e., how resilient is the system)?	Resiliency <sup>3</sup> (or risk) has 4 aspects: <ul style="list-style-type: none"> <li>● Robustness (ability to withstand disruption, measured in time)</li> <li>● Rapidity (time to respond and recover)</li> <li>● Redundancy (alternate route [capacity] availability/access within a certain travel time)</li> <li>● Resourcefulness (ability and time to mobilize needed resources)</li> </ul>
Quantity (“Qs”)	How much freight is moved (and where)?	<ul style="list-style-type: none"> <li>● Volume (e.g., # of trucks, railcars, twenty-foot equivalent units [TEUs])</li> <li>● Weight (e.g., pounds, tonnage)</li> <li>● Commodity Value<sup>2</sup></li> </ul>

<sup>1</sup>These are selected measures and considerations. These measures are ideally obtained by mode and by commodity for complete supply chain and freight network evaluation. The measures are described in further detail in the text.

<sup>2</sup>Costs in the “performance” component and value in the “quantity” component capture the economic impact of freight fluidity. Methods to capture these economic values are documented elsewhere (5-7).

<sup>3</sup>Resiliency (or risk) is an element of the “performance” component because current system resiliency is inherently captured in measures of mobility, reliability and associated costs. Note that the “4 Rs” (robustness, rapidity, redundancy, resourcefulness) of resiliency can typically be expressed in time, and hence, delay and associated cost measures. Resiliency is included in the freight fluidity framework here because it is critical for efficient goods movement during system disruptions. Evaluating and improving transportation system resiliency during disruptions serves to better understand and improve performance during challenging times of goods movement.

Some clarification of the selected suggested measures from Table 1 is needed. The travel time index mobility measure is defined as the ratio of the travel time during the peak period and the travel time during uncongested conditions. A value of 1.20 indicates that a trip that takes 30 minutes on average during uncongested conditions will take 36 minutes during the peak period (5). The planning time index reliability measure is defined as the ratio of the 95<sup>th</sup> percentile travel time during the peak period and the travel time during uncongested conditions. It represents the amount of extra time travelers must plan to ensure they are on time for important trips. A PTI of 2.00 indicates a 30-minute uncongested trip takes more than 60 minutes (30 x 2.00) only one day per month (5).

Table 1 includes costs in the “performance” component and the value in the “quantity” component to capture economic impact. Methods such as TTI’s *Urban Mobility Scorecard* capture costs of congestion due to wasted time and fuel due to congestion. The authors recommend similar methods for estimating congestion costs for freight fluidity. One way to estimate commodity values is the use of existing datasets such as FHWA’s Freight Analysis Framework (FAF). The costs of unreliability are particularly impactful on the freight community, especially for just-in-time trucking operations. Because unreliability impacts different sectors, business practices, inventory, logistics and operations, etc. in varied ways,

there is no universal agreed-upon methodology or “factor” to estimate the financial impact of unreliability.

Table 2 breaks down the phrases of the Maryland freight fluidity definition from page 4 into components for scoping questions that the analyst can use to better understand how freight fluidity is best applied to their specific application. The issue of “scale of analysis” – the subject of this background paper – is implicit to all of the scoping questions highlighted in Table 2.

The second row of Table 2 specifically mentions geographic scale of the analysis. Many of the subsequent definition phrases (e.g., network performance, quantify of freight moved, etc.) also have a temporal scale component. The question of “scale of analysis” is two-fold – spatial (geographical) and temporal (peaks, all day, seasonal, etc.).

**Table 2. Investigating Key Aspects of the Freight Fluidity Definition  
(Adapted from Reference 4)**

<b>Freight Fluidity Definition Phrase</b>	<b>Scoping Questions for Analyst to Ask</b>
“...multi-modal...”	What freight modes are included?
“...geographic area of interest...”	What is the geographic scale?
“...specific modal data elements...”	What are types of data elements going into the analysis?
“...network performance...”	What network performance measures are needed? How well are the links/nodes and network operating? Where are the bottlenecks in the system?
“...quantity of freight moved...”	How much (volume, weight, value) freight is moved (and where)?
“...resiliency...”	How well does the system react to disruptions?
“...to inform decision-making.”	What decisions do you plan to make with the freight fluidity network characteristics? What is appropriate study scale, measures and study scope to ensure you can impact these decisions with the results?

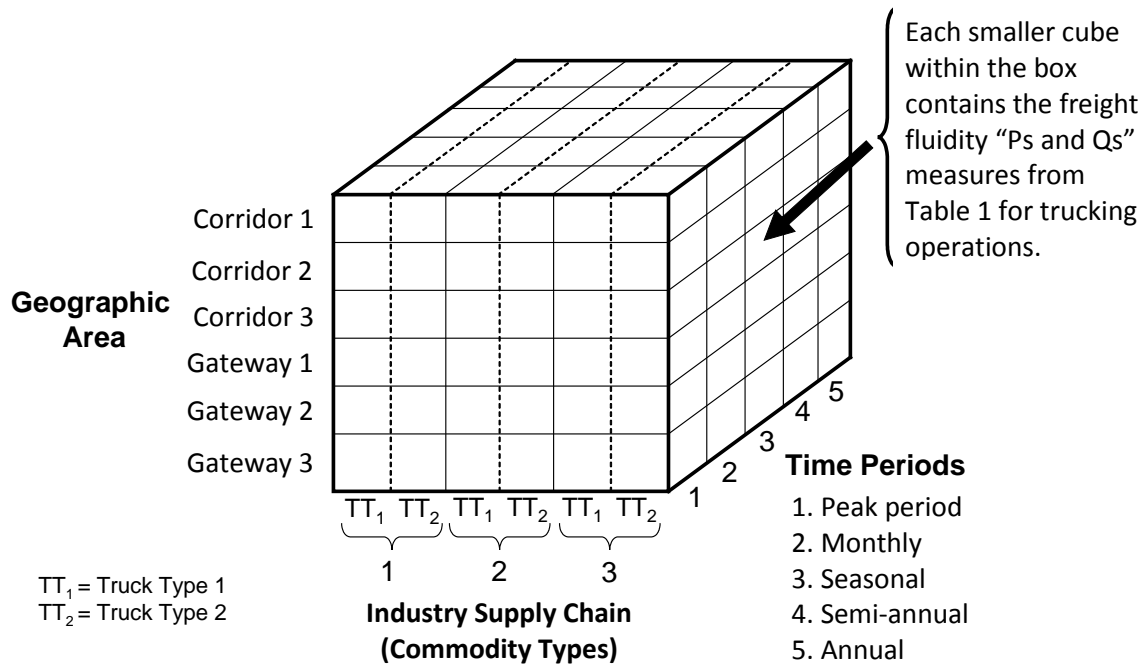
**Fluidity Scale**

The specific spatial and temporal scales of analyses are best defined through consideration of the specific freight application. Before this paper discusses specific applications and related scales, the authors provide an illustration that can better represent the relationship to analysis scale and the performance measures that might be produced through a freight fluidity measurement system.

To better illustrate the concept of freight mobility and reliability, in 2010 researchers at TTI published the “freight box” illustration presented in Figure 1. As a box in three-dimensions, the three axes of the relationship for trucks are 1) geographic area, 2) commodity type and 3) time period. These axes directly relate to, and visually illustrate, the three critical issues under consideration; specifically, where is the area under study? (geographic area axis), what are the time periods of interest? (time periods axis), and what type of trucks are of interest? (commodity types axis). The freight box captures all elements of freight fluidity discussed earlier in Table 1.

### Geographic Area

The first axis along the left-side of Figure 1 is the geographic area. Geographic area is certainly a key consideration of truck mobility and reliability. The transportation system naturally includes industry supply chains, bottlenecks, corridors, and/or gateways where freight mobility and reliability are critical for economic vitality. The geographic level of the analysis could be more aggregated as well—statewide, regional, or even global.



**Figure 1. Freight Box Conceptual Framework Applied to Trucks  
(Adapted from Reference 7)**

### Commodity Type

The type of commodity being transported (and associated value), and delayed in congestion, has economic implications. The axis along the bottom of the freight box is commodity type. Commodity types are typically identified per the Standard Classification of Transported Goods (SCTG). Three commodity types and two truck types (size) are illustrated in Figure 1 though more can be tracked in the freight fluidity application. If the geographic area is a specific supply chain to analyze, the commodity type will be driven by the selected industry supply chain.

### ***Time Periods***

Trucking operations and freight movements in general, are sensitive to congestion levels or supply chain disruptions that change over time. The third axis incorporates the temporal aspects of goods movement by truck. The time periods illustrated in Figure 1 are peak period, monthly, seasonal, semi-annual, and annual. Another example for the time period axis in Figure 1 are for a specific day (e.g., typical morning and afternoon peak periods as well as the off peak periods between the peak periods).

### ***Freight Box Contents***

Now that there is an understanding of the axes, what is in the box itself? As illustrated in Figure 1, each smaller cube within the larger box contains information about the “Ps and Qs” (Performance and Quantity measures) (see Table 1). This includes mobility, reliability, quantity, and resiliency information by geographic area, commodity type, and time period for trucking operations.

One could take this a step further for performance management and consider that for each geographic area of interest, there could be a box populated with “target” cubes that incorporate local goals and establish targets for the “Ps and Qs.” In concept, there would also be a freight box of “observed” cubes for each geographic area of interest. This cube would include the field observation of these trucking metrics. The two boxes (target and observed) could then be compared to identify where operation is satisfactory or unsatisfactory.

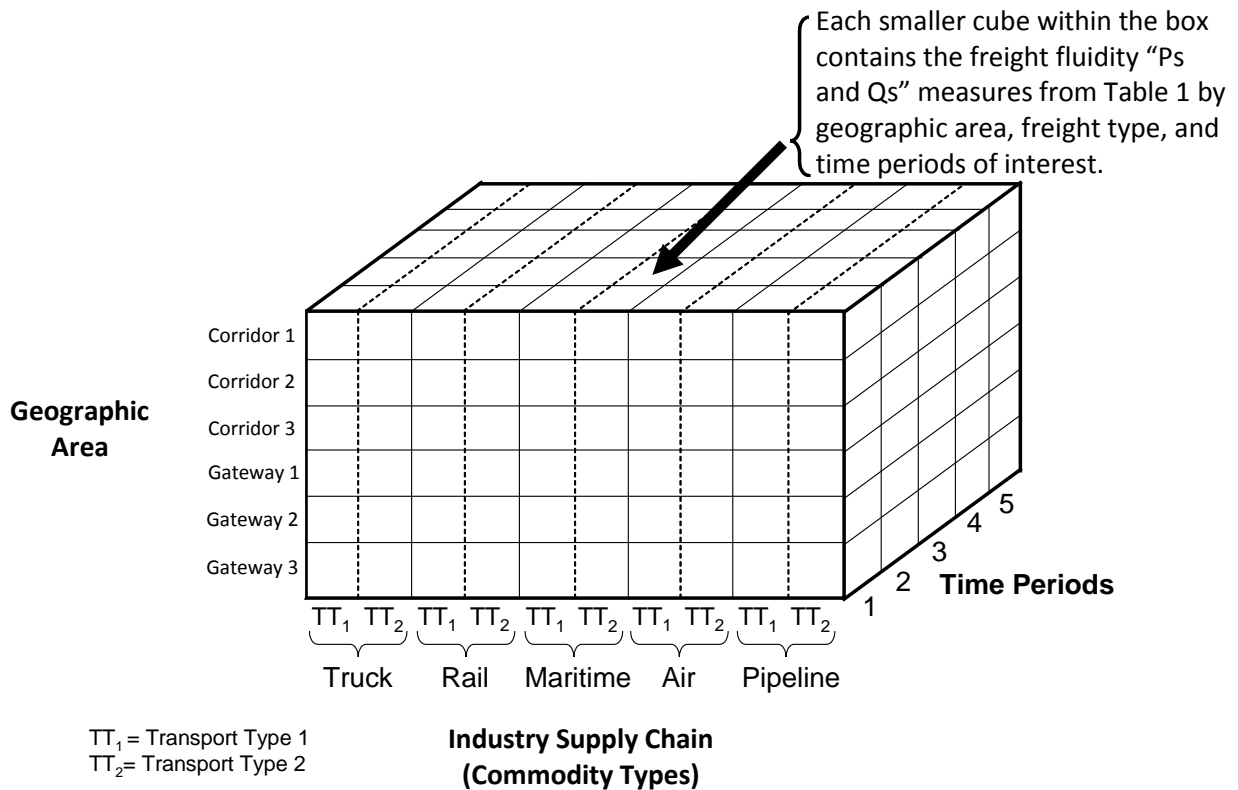
This framework applied to freight fluidity also has geographic scalability. A freight box can be developed for key supply chains, bottleneck locations, gateways, and/or corridors. Theoretically, portions of a state or region could have their own freight box containing cubes with freight mobility and reliability targets.

The framework shown in Figure 1 provides flexibility in analysis. For example, analyses could be categorized by industry (agriculture), large region (e.g., Midwest), or urban area. The framework is also flexible in that it incorporates improved datasets and broader analysis in the future. For example, if commodity information is not readily available, the “commodity types” axis might simply be “trucks” and “passenger cars” in the most basic sense. All trucks could be aggregated, and future adaptations of the methodology could include commodity types and truck size as more data become available. Similarly, there might only be interest in one or two of the time periods, and a shorter time scale can be used. In the development of the initial national freight fluidity measurement system, it is likely that additional datasets can be incorporated as data matures.

### ***Considering All Freight Modes and Intermodal Facilities***

While the discussion above has focused on urban trucks, Figure 2 shows the expansion of the freight box concept to all freight modes – a critical consideration because freight fluidity measurement systems should cover multiple modes. This includes truck, rail, maritime, air, and pipeline. The geographic scope and time period axes remain as before. In this illustration, the third axis is changed to include all freight modes along the bottom of Figure 2. While in Figure 1, truck type was used to represent the size of the truck, Figure 2 uses “transport type” to represent the “size” of the freight component used (e.g., double-stacking of rail, container ship size, cargo airplane size, pipe size).





**Figure 2. Expanded Freight Box for Varied Freight Modes of the Supply Chain  
(Adapted from Reference 7)**

In concept, the framework would apply in a similar manner as illustrated previously for trucks. Each cube within the box contains freight mobility and reliability information by geographic area, freight component, and time period. As before, the information in each cell can be a measured value or a target value based upon goals and objectives of the region(s) and community or communities. These can then be compared to observed conditions to identify needs.

This framework (and freight fluidity application) could easily be expanded to intermodal facilities, distribution centers, borders, or ports. The analysis could be disaggregated to the container level to assess mobility and reliability through intermodal facilities or supply chains at international gateways. For example, by removing the “Air” and “Pipeline” freight components from Figure 2, one could construct a freight box for an international supply chain that contains 3 corridors and 3 gateways using modes of truck, rail and maritime.

Certainly each freight mode or logistical structure would require a unique analysis and associated models. The different freight modes have unique operations and capacity constraints. Freight modes can be aggregated together by commodity value or tonnage or other appropriate value to obtain an aggregate index value for all freight in the area of interest. An example of this is shown elsewhere (10).

### ***Analyzing Corridors and Gateways versus Analyzing Particular Supply Chains***

Supply chains are directly related to industrial sectors, and this could be any step in the supply chain from raw materials, to production and distribution of final products. Supply chains are linked to economic development in a particular region where any step in the supply chain takes place. The freight fluidity analysis should not be viewed as an option of analyzing specific industry supply chains, corridors or gateways, rather the “Freight Box” concept is scalable allowing the visualization and fluidity analysis to be catered to any specific need (i.e., an analysis of an industry supply chain made up of several corridors and gateways, or an analysis of a particular gateway in the network irrespective of supply chains).

The actual scale of the analysis will be defined by the final goal of the user of the fluidity measures included. For instance, regional development agencies might be interested in a particular supply chain that generates employment in the region. This could be at a corridor level because the supply chain uses the transportation system in a corridor in a region, and/or at the gateway level because the region is in or near an international gateway (maritime port or land port of entry).

It is important to note that the performance of a particular supply chain is influenced by volumes of other commodities that use the particular corridor and gateway, so a systems approach is important. Adding the performance of all supply chains in the corridor or gateway, plus volumes of private vehicles for roadway corridors provides for system analyses.

### **Discussion of Fluidity Scale**

Armed with an understanding of how to define freight fluidity and how to visualize the freight fluidity tool with the aid of the “freight box” concept, this paper turns to considerations for possible applications and related scales of analyses.

Table 3 illustrates potential users of the freight fluidity measurement tool, and the associated scales. A cursory review of Table 3 reveals four (4) takeaways rather quickly:

1. Geographic scale is very broad – from the specific local roadway level to global;
2. There are two aspects of the temporal scale to consider;
  - a. What is the temporal scale of the analysis (as discussed in Figure 1 and Figure 2)?, and
  - b. How often will the freight fluidity analysis be updated?
3. Because the geographic scale is the supply chain – this includes measuring fluidity along the “links” (segments of road, rail, etc.) and also at the “nodes” (transload locations or jurisdictional boundaries); and
4. Because the broad analysis scale shown in Table 3 can be daunting to consider all at once, there is a need to consider what is the “biggest bang for the buck” and focus on that geographic scale for the initial (beta) version of the freight fluidity tool rather than trying to meet the needs of all users immediately (see Table 3 shading).

The key is making the tool flexible for various scales and time periods, irrespective of the specific applications. Applications as we consider them now are only as good as our imaginations. While the authors have great imaginations, they are not so bold to think they have considered everything. There is no doubt that if the freight fluidity measurement tool is rolled out as envisioned, there will be many unanticipated users who will benefit from the tool. Therefore, the recommendation is that the tool be created in a flexible and expandable manner to handle the more common and anticipated industry uses, while planning for future updates after it is observed how varied stakeholders use the tool.

**Table 3. Typical Jurisdictions and Uses with Associated Analyses Scales**

<b>Agency Jurisdiction (Examples)</b>	<b>Typical Geographic Analysis Scale</b>	<b>Typical Temporal Analysis Scale</b>	<b>Frequency of Analysis Updates</b>	<b>Example Use Case Question(s)</b>
International (World Bank, Private Corporations)	Megaregion to global	Monthly, seasonal, annual	Seasonal, Annual	How is the global supply chain operating? How is the country's overall logistics operating? Are my client's suppliers receiving goods in a timely manner?
Federal (FHWA, Chamber of Commerce)	National Highway System (NHS) – national; Global; Borders (gateways), interconnectors	Annual	Annual	Where are there bottlenecks in NHS continuity and/or connectivity? Where are delays in imports/ exports?
Megaregion (MPO, COG, Chamber of Commerce)	Regional or even global	Seasonal, Annual	Seasonal, Annual	How does my region compete in comparison to peers/competitive regions?
State (DOT)	Interstate and regional	Peak periods, monthly, annual	Monthly, annual	How are corridors on the state freight plan operating? How well are border crossings and ports operating?
Local (MPO, city, county, Chamber of Commerce)	Urban area and/or specific roadways	Peak periods,	Seasonal, annual	Where are specific freight bottlenecks on Main Street?

Note: shading indicates the possible geographic scale range of a beta (initial) freight fluidity measurement system – regional, national and borders/interconnectors (i.e., beta version likely excludes international uses given current data availability difficulties and likely excludes specific local roads where disaggregation of commodity flow data is difficult).

## **Recommendations and Considerations**

Beginning with a definition of freight fluidity, this paper describes the scale of analysis anticipated for a freight fluidity measurement system. The paper describes methods to illustrate and better understand typical analysis scales and their implications as it relates to typical applications. In light of this discussion, the paper provides the following recommendations and considerations, organized around the three (3) research questions proposed on page 1 of this document.

### ***Geographic Scale***

- Geographic scale is very broad – ranging from Main Street (local streets) to global supply chains (international), and any “links” or “nodes” in between, and
- Any discussion about geographic scale is inherently linked to the transportation application.

### ***Options for Analyzing Corridor and Gateways vs. Specific Supply Chains***

- The “freight box” concept discussed in this paper provides a useful way to illustrate and understand all spatial and temporal aspects of a desired analysis (Figure 1 and Figure 2).
- Based on the definition of freight fluidity presented in this paper, key measures/considerations (freight “Ps and Qs”) are outlined that relate to the performance and quantity components of interest in the freight fluidity tool (Table 1).
- The “freight box” concept is easily applied to the freight fluidity “Ps and Qs” measures, and the analysis of these measures is possible along all geographies of the supply chain and/or at specific locations (gateways, corridors).
- The “cubes” within the freight box can be populated with performance measures of the existing conditions and compared to “target” cubes that incorporate local goals and establish targets for the “Ps and Qs” measures, allowing the observed and targets to be compared to identify where operation is satisfactory or unsatisfactory in the freight network.
- Because the geographic scale is the supply chain – there is a need to measure fluidity along the “links” (segments of road, rail, etc.) and also at the “nodes” (gateways, transload locations or jurisdictional boundaries).
- The freight box concept (Figure 1 and Figure 2) is temporally and geographically scalable to handle various supply chains, “links,” “nodes,” and time scales.
- The freight fluidity measurement tool should likewise be flexible/expandable geographically and temporally.
- The freight box concept can encompass specific supply chains for a fluidity analysis.
- A systems approach should be applied to capture the performance of all modes and supply chains.

### **Factors to Consider in Determining Level of Analysis**

- This paper presents a definition for freight fluidity, and the components of the definition are linked to the scale of analysis (Table 2)'
- Both spatial (geographic scale) and temporal scale of the analysis are important, and are defined based on the user's needs.
- Another important temporal consideration for the fluidity measurement tool is how often users will desire to update results (and the associated implications for data needs and data collection).
- Freight fluidity estimating over all geographic and temporal scales is generally feasible, limited largely only by data limitations – the subject of background paper #3.
- There is a need for the fluidity tool to focus initially on the areas of highest initial interest and use rather than trying to meet the needs of all users immediately (see Table 3 shading).
- The fluidity tool must be created with spatial/temporal flexibility (and expandability) to handle the more common uses initially with an eye toward future expansion as it becomes clearer how industry will use the tool.

### **References**

1. Fluidity Indicator Website, Transport Canada, Available: <https://stats.tc.gc.ca/Fluidity/Login.aspx>. Last Accessed July 3, 2015.
2. Eisele, W.L., L.P. Tardif, J.C. Villa, D.L. Schrank, T.J. Lomax. Evaluating Global Freight Corridor Performance for Canada. In *Inaugural Journal of Transportation of the Institute of Transportation Engineers*. Pages 39-57. Institute of Transportation Engineers. Washington, D.C., March 2011.
3. *Developing Freight Fluidity Performance Measures: Supply Chain Perspective on Freight System Performance*, Transportation Research Circular Number E-C187, Transportation Research Board, Washington, D.C., October 2014.
4. Eisele, W.L., R.M. Juster, K.F. Sadabadi, T. Jacobs, and S. Mahapatra. *Implementing Freight Fluidity in the State of Maryland*. Submitted for Presentation and Publication, Transportation Research Board's 95<sup>th</sup> Annual Meeting, January 2016.
5. Schrank, D.L., B. Eisele, and T.J. Lomax, *2015 Urban Mobility Scorecard*. August 2015. Available: <http://mobility.tamu.edu/ums>.
6. Eisele, W.L., D.L. Schrank, J. Bittner, and G. Larson. Incorporating Urban Area Truck Freight Value into the Urban Mobility Report. *Transportation Research Record 2378*. Washington, D.C., January 2013.
7. Eisele, W.L. and D.L. Schrank. Conceptual Framework and Trucking Application to Estimate the Impact of Congestion on Freight. *Transportation Research Record 2168*. TRB, National Research Council, Washington, D.C., 2010.