

Trucking in Georgia: Freight Performance Measures

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Center

Report 10-16
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16. Abstract

This report provides a review of the recent literature on the development of truck freight performance measures, and specifically measures that can assist the Georgia Department of Transportation in assessing, and in tracking from year to year, how well the state's freight highways supports trucking movements within the state.

An efficient trucking sector is essential to Georgia's economic prosperity, while the recent and projected growth in long haul truck miles of travel is going to place a growing burden on the State's highways, in terms of both pavement maintenance and repair costs, and congestion-induced traffic delays. Such delays can prove costly to the trucking companies themselves, as well as to the companies whose ship and also the customers who receive the goods they are carrying. Planning effectively for such trucking activity requires measurement and tracking of current and future system performance. Measuring transportation system performance on a periodic basis offers at two important benefits to planners and policy makers. First, it provides quantitative evidence of how well the system is performing and whether travel conditions have been improving or getting worse over time. Second, it offers useful benchmarks against which the success of the transportation planning process can be assessed, and possible re-directed where a particular trajectory needs adjustment. The performance measures reviewed in this report support a quantitative analysis of long-haul truck freight movements within the state, and are specifically meant for assessments of the performance of high volume truck freight highway (principally Interstate) corridors.

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Executive Summary

This report provides a review of the recent literature on the development of truck freight performance measures, and specifically measures that can assist the Georgia Department of Transportation in assessing, and in tracking from year to year, how well the state's freight highways supports trucking movements within the state. Project activities were based on the following four step exploratory process:

Task 1: Review the latest information on truck freight performance metrics (Chapter2)
Task 2: Assess the availability and quality of existing data sources (Chapter 3)
Task 3: Generate example truck performance metrics from existing data sources (Chapter 4)
Task 4: Document findings, including identification of promising new data sources for use in performance measurement (Chapter 5)

An efficient trucking sector is essential to Georgia's economic prosperity, while the recent and projected growth in long haul truck miles of travel is going to place a growing burden on the State's highways, in terms of both pavement maintenance and repair costs, and congestion-induced traffic delays. Such delays can prove costly to the trucking companies themselves, as well as to the companies whose ship and also the customers who receive the goods they are carrying. Planning effectively for such trucking activity requires measurement and tracking of current and future system performance. Measuring transportation system performance on a periodic basis offers at two important benefits to planners and policy makers. First, it provides quantitative evidence of how well the system is performing and whether travel conditions have been improving or getting worse over time. Second, it offers useful benchmarks against which the success of the transportation planning process can be assessed, and possible re-directed where a particular trajectory needs adjustment. The performance measures reviewed in this report support a quantitative analysis of long-haul truck freight movements within the state, and are specifically meant for assessments of the performance of high volume truck freight highway (principally Interstate) corridors.

Based on a review of the recent, and rapidly expanding performance measurement literature, the following seven categories of performance measurement are discussed in Chapter 2:

1. Network Supply
2. Travel Times
3. Travel Safety
4. Energy Security
5. Mobile Source Emissions
6. Monetary Travel Costs
7. Regional Accessibility

Chapter 3 of the report describes the results of a search for data sources with which to estimate promising examples in each of these performance categories. Chapter 4 then applied these data sources to creating a sub-set of truck freight performance measures for the southern section of the I-75 corridor between the cities of Macon and Valdosta. The list of measures experimented with are listed below. Performance measures with a '*' after them were created using existing data sources. Those with a (*) after them were created but would benefit from improved data inputs. All of the measures in the list could be created with some additional data collection or data modeling that was beyond the scope of this present effort. A performance measures template is suggested.

Network Supply (inc. Truck Traffic Volume) PMs:
1. Corridor truck and general traffic volumes on a typical day*
2. Tons of freight moved though the corridor on a typical day (*)
3. Market value of the freight moved through the corridor on a typical day
4. Percentage of corridor miles subject to high levels of congestion on a regular basis*

Truck Travel Time PM:
5. Average truck speeds in the corridor on a typical day*
6. Corridor planning time index*
7. Corridor buffer time index*

Truck Energy Security PMs
8. Gallons of fuel and per mile fuel consumption in the corridor on a typical day*

Truck Mobile Source Emissions PMs
9. Metric tons of carbon dioxide equivalent motor fuel based emissions produced daily in the corridor*
10. Metric tons of US EPA regulated criterion pollutants produced daily in the corridor*

Truck Travel Cost PM:
11. Estimated daily costs of traffic delay in the corridor (*)
12 Estimated cost of travel time variability in the corridor (*)
13. A corridor per mile delay cost index (*)

Truck Safety PM
14. Number of corridor truck-involved traffic accidents annually (*)

Interstate Corridor Accessibility PM:
15. Typical trucks speeds on major truck route connectors

Finally, chapter 5 summarizes the major findings of the report, including a table of both current and future data possibilities for measuring the performance of the State's high volume trucking corridors.

1. Introduction

1.1 Study Background

An efficient trucking sector is essential to Georgia's economic prosperity. However recent and projected growth in trucking activity is placing a growing burden on the State's highways, in terms of both pavement maintenance and repair costs, and congestion-induced traffic delays. One recent forecast suggests a 90% increase in total highway vehicle miles of travel (VMT) on state roads over the period 2003-2035, including a 151% increase in truck VMT over this same period [1]. The latest federal government projections through year 2035 anticipate similar increases in truck traffic on a nationwide basis, including a good deal of truck traffic that links Georgia to other states [2]. The potential for costly delays to freight deliveries due to such traffic growth is obvious, and has led to concerns being voiced by the trucking industry [3] as well as by state Departments of Transportation (DOTs) tasked with maintaining high quality highways in an era of tight fiscal budgets.

To plan effectively for this future growth in truck traffic requires first of all the ability to measure what traffic is out there, and then to be able to assess how effectively it is moving around the state. Effectiveness in this instance includes the ability to move freight quickly and at reasonable dollar cost between freight pickup and drop locations. Addressing this issue, a recent survey of 21 state DOTs, sponsored by the American Association of State Highway and Transportation Officials [4] identifies travel time/speed, on-time service reliability, and access to freight activity locations as key transportation system performance indicators for the future, especially along high volume trucking corridors and within urban areas. As public agencies, state DOTs must also be concerned about the safety of both truckers and of the general public, and about the environmental impacts associated with these truck movements.

The issue addressed below is how best to quantify, and track over time, suitable truck freight performance measures (FPMs). The role of such measures is two-fold. First, they inform and ideally become an integral part of the state's long range freight planning process. Second, they can do useful service as stand-alone indicators that are of interest to a variety of parties, notably elected officials, the trucking industry, and also the general public.

1.2 Study Purpose

The research reported in this paper provides a review of the recent literature on the development of truck freight performance measures (FPMs), and specifically measures that can assist the Georgia Department of Transportation (GDOT) in assessing, and in tracking from year to year, how well the state's highway network supports truck freight movements. Project activities were based on the following four step exploratory process:

Task 1: Review the latest information on truck freight performance metrics
Task 2: Assess the availability and quality of existing data sources
Task 3: Generate example truck performance metrics from existing data sources
Task 4: Document findings, including identification of promising new and emerging data sources for use in performance measurement

The specific focus of the current project is on identifying performance measures applicable *for major trucking corridors* in Georgia, with an emphasis on truck freight mobility and access measures that can usefully inform, and be easily linked to, the GDOT multi-year freight transportation planning process.

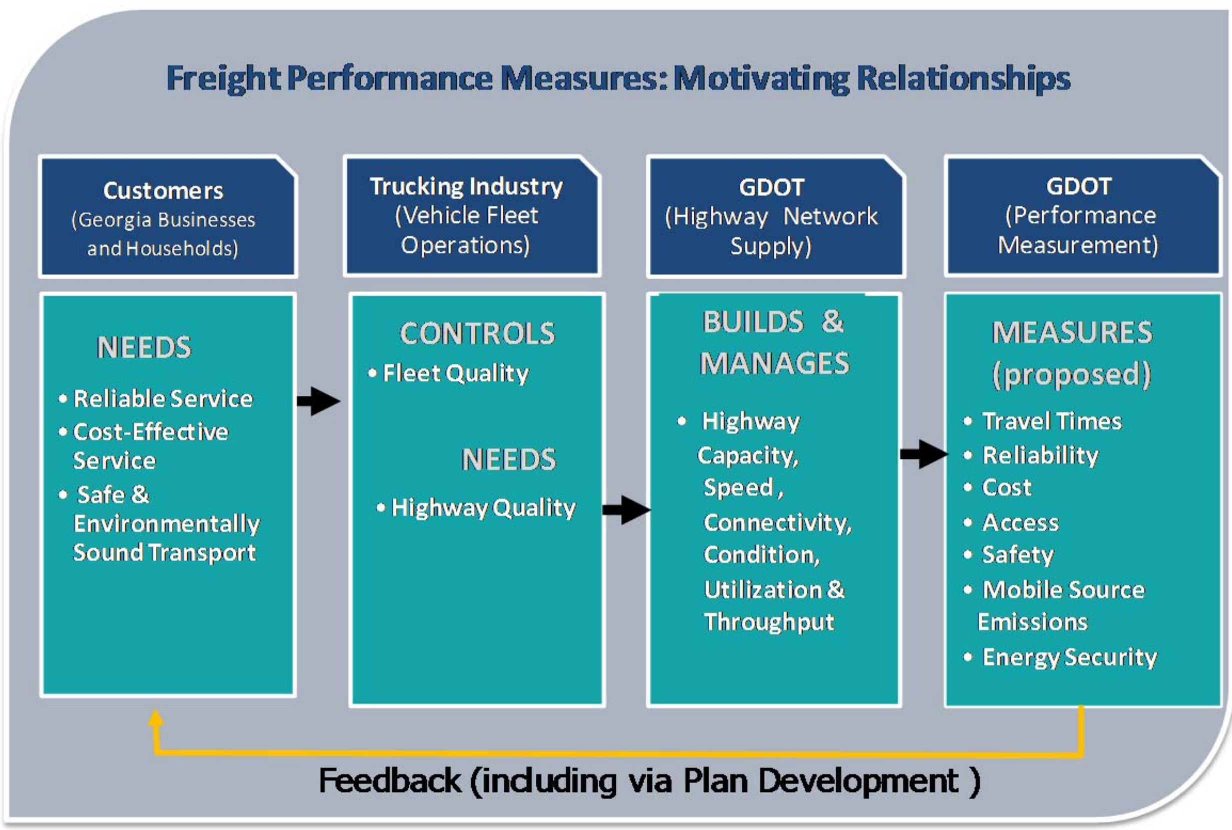

Figure 1. FPM: Motivating Relationships

Figure 1 reflects these interests, viewing Georgia businesses and households as the basic customers being served by better highway performance, supported by a trucking sector that requires a high quality highway network in order to ensure cost-effective and reliably goods deliveries. How well a state's highway network, or a specific freight corridor within that network, is meeting these needs is then determined by the quality of the (private and for-hire) trucking fleets and by the connectivity, carrying capacity, and operating conditions offered by the state's highway network, and notably its ability to safely maintain reasonable highway speeds. The quality of these network attributes in turn determines the performance of the state's highway system by providing fast, cost effective, and reliable access to freight suppliers and freight customers across Georgia, while remaining subject to acceptable levels of travel safety and environmental impact.

The rest of the report is organized as follows. Chapter 2 addresses Task 1 above and provides an up to date review of the literature on truck freight performance measures. In the process a framework is developed for discussing the most popular performance measures, in what is a rapidly evolving field of enquiry at the present time. Chapter 3 addresses Task 2 above, describing the results of a search for useable sources of performance measurement data for Georgia's major trucking highways. Chapter 4 then describes the steps involved constructing a set of truck freight performance measures from these data and presents the results of the empirical analysis. Example performance measures are reported at a) the link (highway facility) and corridor-wide level. Finally, Chapter 5 summarizes the main findings of the research, discusses the strengths and weaknesses of current data sources as aids to performance measurement-based truck corridor planning, and makes some suggestions on how GDOT might proceed based on the use of emerging as well as existing data sources.

2. A Review of the Truck Freight Performance Metrics Literature

2.1 An Overview of What the Papers Say

"Performance-based planning provides a consistent, repeatable, and transparent process for developing and selecting transportation projects and policies." [5]

"Performance measures have become a critical element for many transportation planning activities. Understanding how well a program works or how effective a project is at meeting its goals is necessary to ensure staff is investing in projects and processes that enhance the existing system." [6]

Since the Intermodal Surface Transportation Act of 1991, performance measurement has become an increasingly important part of the long range transportation planning process that states use to develop their infrastructure investment plans [7, 8, 9]. This includes an increased interest in freight system performance [10, 11, 12, 13], making use of the growing availability, and variety, of electronically transmitted data sources for tracking the locations, and determining the speeds of individual vehicles on state roads. Over the past decade this has led to a number of studies by the federal government and others looking into how to use these, largely automated, data sources to measure performance, and how to maintain a database that tracks this performance over time. This includes reports produced for the Transportation Research Board [5, 7, 8, 9, 14, 15, 16, 17], and by the Federal Highway Administration [3, 18, 19, 20, 21], among others [4, 22, 23]. These studies have been supplemented in recent years by a number State DOT directed efforts, including those in Alabama [24], California [25], Minnesota [26, 27], Oregon [28, 29, 30], Texas [10, 31, 32] and Washington [33].

A number of generally supported conclusions can be drawn from this literature, and are used below to guide the development of both an FPM analysis framework as well as selection of specific performance measures. In particular, Schofield and Harrison (2007) offer the following guidelines for determining appropriate FPMs for emerging users, requiring each performance measure to be [10]:

1. Capable of being measured – If data is not currently collected, it should be at least feasible to accomplish.
2. Capable of capturing deficiencies – A proper PM should not measure performance for no reason, but rather diagnose a problem.
3. Capable of measurement over time – Measures should be standardized enough to allow continued collection and time-series comparisons.
4. Capable of being forecast – The most useful PMs will allow planners to solve problems before they occur if current data can be forecast to show future deficiencies, and

5. Easily understood by decision-makers – If the PMs are to make any difference, they must be understandable to decision-makers of any background.

Performance Issues of Interest: While no single performance measurement framework or set of FPMs has yet become common practice, considerable similarity exists across many of the studies reviewed. High on most lists are measures of travel time, (monetary) travel cost, on-time shipment arrival reliability, and ease of access to freight producers and freight markets, including connections to a state's major seaports and airports. Other commonly reported measurement topics, when seen from a State DOT perspective, involve safety, fuel/energy consumption, and environmental (principally airborne emissions) impacts.

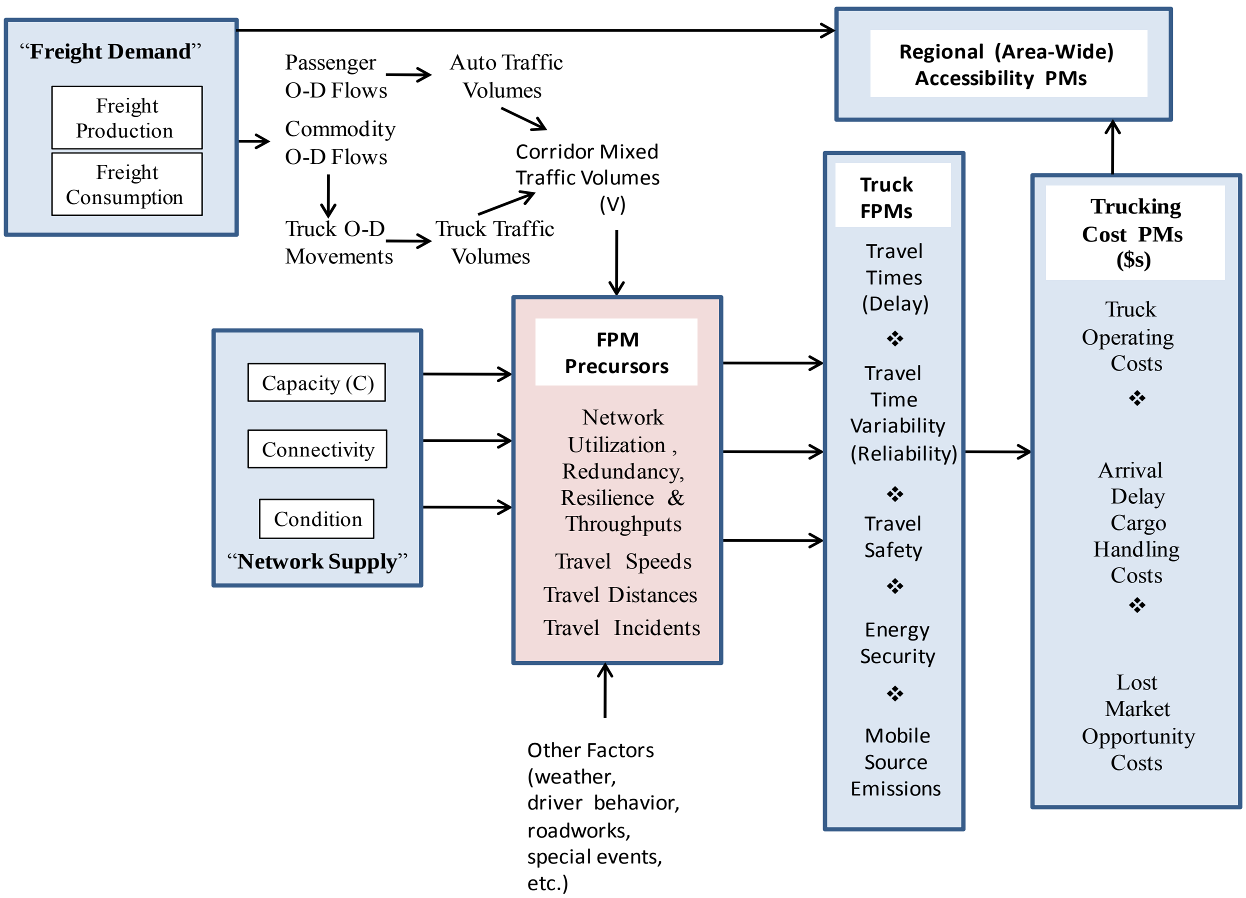

Figure 2. A Framework for Truck Freight Performance Measurement along Major Traffic Corridors

Figure 2 reflects these issues, showing how the state's freight generating and receiving industries generate the demands for origin-to-destination (O-D) patterns of freight movement which result in over the highway truck traffic volumes. These traffic volumes interact with highway network supply characteristics, notable network design capacities, network connectivity, and network condition (pavement quality, effectiveness of road markings, signalization, etc.), in conjunction with other factors such as weather conditions, driver behaviors, road works, and special traffic intensive events, to determine average vehicle speeds and distances traveled, as well as the number of traffic incidents (including accidents that do and don't involve trucks). Additional and important FPM precursors include the level of network utilization, typically measured as the volume/capacity (V/C) ratio, and network (truck traffic volume based) throughputs. With an eye to forecasting network performance into the future, it is also valuable to include measures of network redundancy and resilience in the face of both pre-planned and unexpected network disruptions. Each of these network supply based measures is often listed in the literature as network supply-based PMs. This is largely a semantics issue, and they typically need to be computed in the process of deriving the set of Truck FPMs shown to their right in Figure 2.

Five types of FPM are shown in Figure 2 immediately to the right of these FPM precursors: measures of travel time delay and travel time, travel safety, energy (notably petroleum fuel) security, and mobile source emissions (notably federally regulated criterion pollutants and greenhouse gas emissions).

To the right of this box are a set of monetary cost based truck FPMs, reflecting the effects of the all of the prior FPMs on trucking industry expenditures. Finally, the top right corner box in Figure 2 includes one or more regional accessibility FPMs, which are most usefully constructed, in turn, by combining data on these trucking cost PMs with data on freight production and consumption. These measures can usually be generated by a state's strategic or long-range freight planning process, or more specifically the freight activity forecasting models within it.

Considerable attention is being devoted currently to PMs dealing with travel speeds, and therefore travel times. Delays due to traffic congestion have been increasing in many parts of the national as well as state highway systems, including a spreading of delays along Interstates and other major highways outside metropolitan areas, as well as around major freight terminals, including seaports and major hub airports. It has also been realized that measuring changes in average travel times is not enough to capture the true costs of delay. Just as important are costs incurred due to the day-to-day variability in such times: leading to unreliable arrival times and not only extra driver costs but also extra freight handling and cargo carrying costs. Among other efforts, a major study of the causes, costs, and potential remedies for such day-to-day variability in journey times is currently being undertaken as part of the FHWA's SHRP2 program [15, 26, 34, 35; see Section 2.3).

Within the travel delay literature a significant topic of interest has become that of measuring the effects of recurring versus non-recurring traffic congestion: in part because of their different causality, but also because they may also need to be assigned different monetary costs. While the former is largely reflected in daily peak period V/C ratios, reflecting inadequate road capacity, non-recurring congestion results from a range of unanticipated causes, including accidents, severe weather, traffic work zones, and special high traffic generating events. Both types of delay can be costly, and both can be difficult to avoid. Putting a monetary value on such delays, and the unreliability they cause in delivery times is, along with the access distances the highway network provides to freight sources and markets in the first place, are at the heart of the cause and effect linkage between trucking performance and the profitability of many business activities within a state.

How Performance Measures Are Being Used: It is important to understand the uses to which performance measures are going to be put, and for who they are being developed. Two broad areas of PM application have emerged over the past decade or so:

- PMs that are used to inform (and also subsequently be generated from) a state or region's strategic or long range freight planning process.
- PMs that are used, and developed specifically to inform not only transportation planners, but also policy-makers, the trucking industry, and the general public about current operating conditions , as well as potential future problems that ought to be addressed in a quantifiable and systematic manner.

The FPMs reviewed in this paper are for the most part applicable to both uses, although their method of presentation may differ between the two categories: with the need to develop easily understood visuals of performance, and especially of performance improvement or deterioration over time, an important sub-topic within the PM literature.

Qualitative & Quantitative Approaches to Measurement: A third generally supported observation from the PM literature is that in order to develop useful freight PMs, it is necessary to involve those most affected by current conditions: the trucking industry, major shippers and receivers of freight, and other local or regional agencies involved in supporting these freight agents. One increasingly mentioned aspect of this involvement is the use of trucking company satisfaction surveys: as a compliment to and guidance for the more quantitative, data intensive statistical assessments of system-wide or corridor specific performance now being carried out by a growing list of state DOTs (and upon which this present R&D effort is focused).

Spatial Contexts: A fourth issue running through the FPM literature as it pertains to state DOT responsibilities is the level of geographic or regional specificity that such measures should deal in. At least four levels of spatial analysis are reported on: facility specific, including network link or segment specific measures, corridor specific measures, area-wide measures, and network-wide (i.e. statewide) measures. A good deal of the literature to date focuses on the performance of highway corridors that contain high volumes of truck traffic. This makes sense in terms of the impact that possible improvement strategies can have on overall network performance, while also making use of data sources, principally data on truck counts and operating speeds that are often missing at the present time for lower functional class roads. In doing so, however, there appears to be the realization that ultimately it is the performance of the entire network that needs to be captured, since many delays en route occur at or near the start or end of a truck trip: increasingly referred to in the literature as the “first and last mile” problem. Recognizing this issue means identifying the source (= origination) and market (= destination) locations from and to which trucks using a particular corridor are tied. This in turn means developing suitable origin-to-destination (O-D) truck movement matrices in order to capture the significance of delays along major trucking corridors that may carry a significant volume of non-local, including out-of-state and through state O-D movements. Procedures for defining suitable traffic analysis regions associated with high volume truck freight corridors are therefore an important part of the discussions below.

Temporal Contexts: There are also a number of recurring issues associated with the temporal as well as spatial dimensions of the FPM problem. At the root of these issues is not only the use to which a particular PM is being put, but also who is most interested in, or affected by, the particular condition being investigated. For freight planning purposes a year by year treatment of network performance seems most appropriate, one that is updated on an annual basis. However, given the considerable variation in both truck traffic volumes and associated travel speeds across different seasons or months of the year, days of the week, and hours of the day, a number of different measures need to be considered. A strong interest in traffic congestion-induced delays suggests the use of peak hour or peak period measurements – although daily truck traffic peaking often occurs at different hours to that caused by commuters and other passenger traffic. Differences between typical weekday and weekend day traffic operations are also being investigated by some DOTs.

Data Requirements: FPM data requirements can be significant, and are an important limitation on what can be successfully measured and tracked over time. In addition to in-the-pavement traffic counters, including speed and vehicle class detecting loop counters, a number of comparatively new data sources are now being used by state traffic engineers. Global Positioning System (GPS) satellites, cellular telephones, aerial photographs, transponder and active radio frequency identification (RFID) technologies are all now being used for tracking and reporting truck movements (see Table 1 below).

GPS tracking of individual truck movements appears to be a very promising approach, in part because it is can provide data on door-to-door truck movements over a period of days or weeks: data that otherwise would be too expensive to collect by means of surveys. Of particular note in this regard are the joint efforts, beginning in 2003, by the Federal Highway Administration (FHWA) and the American Transportation Research Institute (ATRI) to use GPS technology to provide nationwide tracking of truck movements on U.S. major freight corridors [11, 36, 37, 38, 39] producing an invaluable source of truck speed and route selection data.

Specific sources of Georgia traffic data and their potential value for truck freight performance measurement are reviewed in Chapter 3 of this report.

Table 1. Traffic Data Collection Technologies

Data Technology	Description
Loop Detector	A magnetic loop installed on or in the pavement that detects vehicles based on a disruption in the electromagnetic field. May be used to determine the speeds and axle spacings of vehicles on a corridor.
Automatic Traffic Recorder	A permanent, fixed, traffic counter located on major highways and interstates throughout Georgia. Traffic counts are obtained by the Georgia Department of Transportation.
Video Detection System Traffic Camera	Fixed cameras located every third of a mile along major interstates and highways displaying black and white images. VDS cameras can be used to determine corridor density as well as travel time, speed, and vehicle counts. VDS cameras are operated by the Atlanta Transportation Management Center.
Closed Circuit Television Camera	Pan-tilt-zoom cameras that display color feeds on major Interstates and other highways. In Atlanta, CCTV cameras are operated by the Atlanta Transportation Management Center.
Weigh-In-Motion	Weigh-in-motion (WIM) centers can be used to determine truck counts through a corridor. Truck weigh stations are located along interstate highways. As trucks pass through the WIM station, trucks fitted with transponders can be tracked and counted, allowing information on travel time to be deduced as successive WIM centers are traversed.
Global Position System	Devices used within trucks. GPS devices can be tracked and used to determine route choice as well as speed and travel time. ATRI/FHWA provide access to Interstate GPS data for Georgia and U.S.
Radio Frequency Identification Tag	Small plastic identification tags that can be mounted in vehicles. Tags are read by radio frequency as vehicles passes through a data collector. Data obtained through RFID tags can be used to determine truck speeds along a corridor and the unique ID also allows for identification of route choice across a system.
Aerial Traffic Monitoring	Traffic monitoring by fly-over aircraft, including small aeroplanes and heilcopters equipped with time lapse photography and/or videocameras. Data can be used to identify weaving of traffic through bottlenecks as well as snapshots of truck size mix along major highways. Excellent presentation graphics are an additonal benefit. Data has been collected in the past for Atlanta and other Georgia metro regions.

Classification of Freight Performance Measures: Using the FPM framework provided in Figure 2 above, specific examples of the most popular FPMs are reviewed below under the following headings:

1. Network Supply PMs
   - Network Extent and Condition
   - Network Utilization
   - Network Throughputs (Traffic Volumes)
   - Network Redundancy
   - Network Resiliency
   - First and Last Mile Connectivity

2. Travel Time PMs
   - Mean Travel Times
   - Travel Delays
   - On-Time Variability
3. Travel Safety PMs
   - Truck Accident Rates
   - Hazmat Incident Rates
4. Energy Security PMs
   - Average Fuel Savings
5. Mobile Source Emissions PMs
   - Criteria Pollutants
   - Greenhouse Gas Emissions
6. Monetary Travel Cost PMs
   - Delay Costs
   - On-Time Unreliability Costs
7. Regional Accessibility PMs
   - Activity Weighted Accessibility

Each of the above FPMs need to be collected over a period of a number of years, in order to monitor the direction in which highway performance is moving. Ideally, these same data and measures might also be used, on the basis of the resulting time series data, to predict the future trends in such performance. With the comparatively recent emergence of interest in FPMs, in conjunction with the emergence of GPS tracking and other forms of IT-based data collection, this promises to be an area of growing interest to researchers as well as planners over the next few years. Examples of recent studies that are either proposing or already using specific measures are listed in the references at the end of this paper. Most attention has been given to the category of measures dealing with speed and truck traffic volumes, notably those associated with a specific corridor or stretch of highway of interest. These measures also play an important role in each of the other measurement categories.

2.2 Network Supply Performance Measures

2.2.1 Network Extent and Condition

Area-wide or corridor-wide measures of network extent include:

1. The number and percentage of network miles (and/or lane-miles) of highway suitable for use by trucks of different sizes (e.g. trucks over 26,000 pounds gross vehicle weight)
2. The number and percentage of network miles (lane miles) of designated truck routes.

Useful measures of network condition include:

3. Number and percentage of bridges that meet good and poor structural condition targets on popular truck routes
4. Ice and snow removal clearance times on popular truck routes.

Measures that combine mileage with pavement condition may also be useful to track, for example:

5. Pavement condition weighted heavy truck miles, given as:

($\sum_{\text{network links in corridor}}$ Heavy truck supporting network miles * pavement condition) /($\sum_{\text{network links in corridor}}$ Heavy truck supporting network miles * ideal pavement condition)

2.2.2 Network Utilization

The most commonly used measure of highway system utilization is the (V/C) ratio, i.e.

$$U=(V/C) \tag{1}$$

where V = a highway section's average daily or peak-hour traffic volume, and C = the section's hourly design volume or 'capacity'. This can be computed for a highway segment, a multi-section highway corridor, or on a multi-section, multi-highway, area-wide basis. Highway section-specific U values can be put on a per mileage basis for corridor or area- wide averaging purposes. *GIS mapping of section specific U values helps to identify current of potential future traffic bottlenecks.* However, with the advent of truck speed data, such a mapping may be less useful for general presentation purposes (to the public or to non-technical decision-makers) than direct average speed mapping. Alternatively, for the purposes of display, U can also be portrayed as a measure of congestion:

6. Network Congestion Index = (V/C)

For example, the Pima Association of Governments (PAG) based in Tucson, Arizona, use a pie chart to show congestion levels in the area based on the following definitions: [1]

- V/C Ratio greater than 1.0 = Severe Congestion
- V/C Ratio of 0.75 to 1.0 = Heavy Congestion
- V/C Ratio of 0.5 to 0.74 = Moderate Congestion
- V/C Ratio of less than 0.5 = Low or No Congestion

[1] http://www.pagnet.org/RegionalData/TravelDataandForecasting/TransportationSystemPerformanceMeasures/VolumetoCapacityRatios/tabid/457/Default.aspx

An alternative way to look at such disruptions to normal flow is to measure the loss of truck traffic throughput due to high V/C ratios or long duration traffic incidents, implying a loss of network throughput (see Figure 3). Substituting a highway's design capacity for the pre-disruption traffic volume, the California DOT [25] interprets the traffic volume below the red line in Figure 3 as a loss of network "productivity":

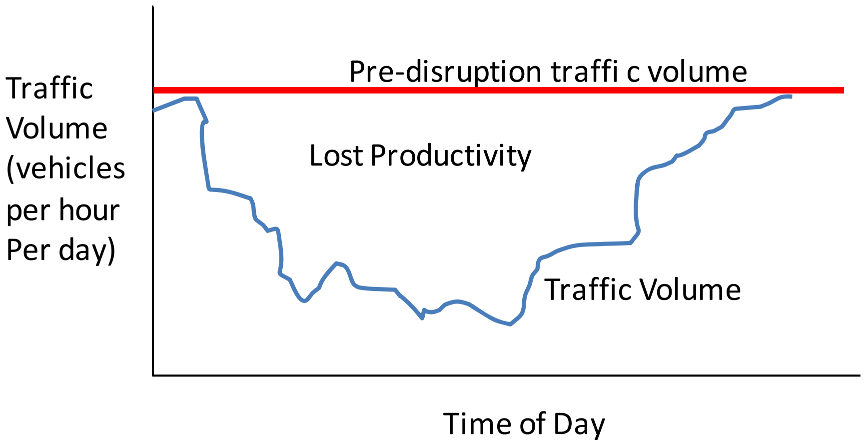

Figure 3. Traffic Volume Lost To A Network Disruption Or Recurrent High Congestion. (Based on [25])

The principal value of this approach may be as a visual aid. Related to this issue is the following readily computed measure:

7. Annual Number of Lost Lane Miles of Highway Capacity Along Popular Truck Routes

2.2.3 Network Throughputs (Traffic Volumes)

The following truck freight volume or 'throughput' measures are useful both as stand-alone performance measures as well as basic inputs to many of the travel time and cost measures described below. Measures can be highway section, corridor, or area-based based:

8. Annual or Average Annual Daily Number of Truck Trips, in Aggregate, or by Vehicle Truck Size Class
9. Annual or Average Annual Daily Truck Miles of Travel, in Aggregate, or by Vehicle Size Class
10. Annual or Average Annual Daily Truck Ton-Miles of Travel, in Aggregate, or by Commodity Class

where vehicle size classes are usually the 13 size classes used by the FHWA and states to collect, for example, Highway Performance Monitoring System (HPMS) truck counts; and where commodity classes may be the 43 2-digit commodity classes used by the US Census Bureau's quinquennial Commodity Flow Surveys and by the FHWA's Freight Analysis Framework (see Chapter 3).

2.2.4 Network Redundancy

Redundancy in transportation network terms refers to having sufficient back-up options should a section of the network become unusable for transportation for a significant length of time. Redundancy measures may be used to guide infrastructure investments that protect against long term traffic disruptions, allowing economic activity to continue without too high an additional transportation cost. This usually means having one or more alternative routes available and offering a travel time and cost similar to the best route usually taken. They can be especially useful in rural areas, where the highway network is relatively sparse, where there are a limited number of medium or high volume highways suitable for heavy or combination truck use, and/or where frequent use by heavy trucks is not a good idea from the standpoint of pavement wear and tear. While this topic is widely discussed in the transportation network literature, and is closely tied to network security issues (see [40], for example) there is not to date a well established method for deriving such redundancy in a quantitative way. Example measures include the following:

11. Absolute or Percentage Difference in the Truck Travel Distances or Travel Times of the First and Second Best Distinct Routes
12. Number of Distinct Routes Available to Trucks (of a given size class) within a given Percentage Distance or Time Increase over the Shortest or Fastest Route.

Among the issues that need to be dealt with is the definition of distinctively different routes. For example, two routes sharing 80% or more of the same highways may not be distinct enough to offer much support for overcoming network disruptions within a region. For high traffic corridor based studies (such as this current one) this issue has two facets. First, there may or may not be a reasonably parallel alternative to the main corridor highway (e.g. Interstate). Second, the redundancy issue may be one associated with the options for accessing and egressing the main highway. In all cases it is important to also recognize that some trucks may not have access to all roads, due to bridge heights, vehicle turning radius, or hazardous transport restrictions. When considered over a full year, and for a multi-county geographic area, it may also suffice to have time series data on the travel time measures discussed in Section 2.3 below, since these will capture the extra time required to negotiate long duration network outages. However, pro-active planning may require more attention to this network robustness issue, especially for already heavily trafficked truck corridors.

Finally, from GDOT's perspective, the use of alternative freight modes, notably rail transport, may offer a good deal of redundancy in carrying capacity. However, this multimodal issue is not considered part of the current project activity.

2.2.5 Network Resiliency

Related to the concept of connectivity is the concept of resiliency. If alternative routes around a location-specific loss of highway connectivity occur, then an important measure of performance is how well the affected link deals with and recovers from the temporary loss of capacity. And even when other routes exist, trucks can easily be caught up in a long traffic queue should an incident occur quickly. Resiliency measures are used to understand vulnerabilities in transportation networks, and can be defined as the capacity of a network to absorb the impacts of a disruption [41]. One means proposed for measuring the resiliency of specific routes to a major disruption is the resiliency triangle [41, 42]. Figure 4 shows this idea:

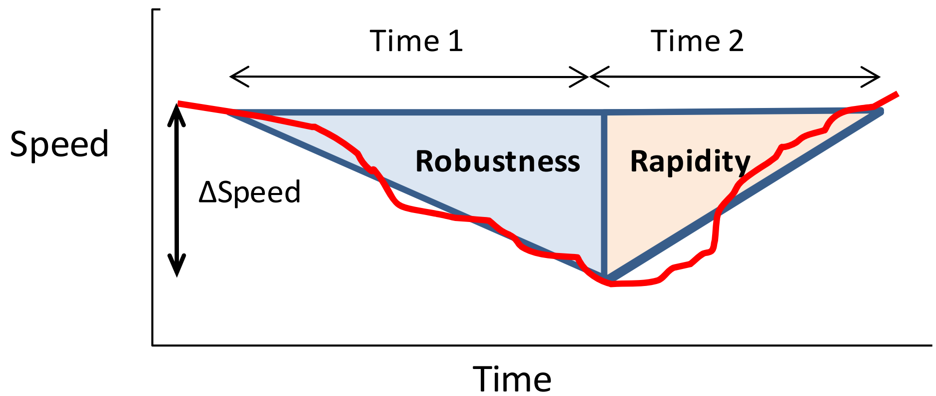

Figure 4. A Resiliency Triangle (Extreme Weather Event) (Based on [41])

The red line shown in Figure 4 represents a tracking of vehicle speeds over time through an incident. Adapting concepts from the disaster management literature (see [43], for example), the incident here is a bad weather event, and its duration consists of 'time 1' in which speeds slow to their minimum, and 'time 2' as they start to recover, finally getting back to pre-incidence traffic speeds. The duration of the first time period is taken here to measure the robustness of the network to handle the adverse conditions, while that of the second time period represents the rapidity with which the traffic stream recovers from the worst case (i.e. slowest speed) condition after the incident is over. Following Adams, et al (2008) robustness is here measured as (ΔSpeed/Time1) and rapidity by (ΔSpeed/Time2) [41]. Different types of incidents produce differently shaped triangles. For example, a sudden event might have a very rapid speed decline, followed by a much more gradual recovery period. A work zone induced disruption to regular traffic flow may offer yet another temporal profile. A potential use of this concept in a planning context is to measure the number and duration of incidents over the course of a year, or season, perhaps reporting the robustness and rapidity results separately and in combination, for each major type of incident and/or by highway functional class, i.e.

13. Network Resiliency Measure = $(\sum_{\text{incidents}}$ incident duration $)$ / number of incidents

2.2.6 First and Last Mile Connectivity

The draft Georgia Department of Transportation Statewide Strategic Transportation Plan for 2010-2030 (pp. 11) describes this issue as follows:

"Though the Interstates, the state highway network, the ports, the Class 1 rail assets, and the airports are powerful economic assets, they lose that value if congestion on the local and regional arterial grid prevents people or shippers from reaching their final destination efficiently. The same principle applies in rural areas where bridge weight capacity can be an issue, particularly for freight. The MPOs and counties should be full partners with the state in identifying these bottlenecks and in designing an end-to-end solution that moves people and freight efficiently to and from the airports, state and interstate networks, and other major transportation hubs." [44]

FPMs that have been suggested to help a state to assess its progress in this area really span a number of other categories of PM discussed in the paper, and include the following:

14. Average Truck Travel Speeds on Popular Local and Arterial Truck Routes
15. Number and/or Percentage of Bridges that Cannot Be Used by Trucks over a given Gross Vehicle Weight.
16. Local and Arterial Volume/Capacity Ratios on Popular Truck Connectors To Major Highways
17. Average and Worst Case Delays in Truck Access to Freight Terminals and Port Areas.

To these we could add:

18. Over the Road Circuity Involved in Reaching a Major Truck Highway = Actual highway distance traveled (in miles) from start or end point of a truck trip to the major highway / Straight line distance to the major highway.

For general consumption this sort of measure may be better reported as additional local miles needed to access a major truck highway. A variant on this idea, data permitting, could compare the miles actually driven with the miles that would have been driven had all local bridges been in good repair. However, the data demands on such measures can become quite significant, as some means of generating these alternative routes is required, such as use of the routing software found today in many GIS packages.

2.3 Travel Time Performance Measures

Delays en route can be costly to shippers and their customers, as well as to for-hire trucking firms tasked with getting the goods delivered on-time and at reasonable, and typically pre-delivery negotiated cost. Additional time often means additional costs in terms labor, fuel and other vehicle costs, while unanticipated delays in delivery can lead to labor and other logistics costs on the destination end of a trip. Data on travel times, to date usually collected using loop counters or, increasingly, GPS technology in the form of spot or link specific driving speeds, is therefore a key input to performance measurement, along with data on truck traffic volumes.

2.3.1 Mean Travel Times

An obvious truck based performance measure is travel time, the time it takes to get from a specific location to another. The key measure here is origin-to-destination (O-D) time, although getting such O-D times for a large enough sample of door-to-door truck movements for planning purposes is currently problematic for reasons of both expense and confidentiality. For major freight corridor level planning, especially if the corridor is essentially an Interstate highway route, it will usually be possible to derive speed and volume measures for all or part of the main highway. Extending these measures to actual door-to-door truck trips has been problematic, although this may change as more studies use GPS tracking of individual vehicles from their pickup to drop-off locations (see McCormack et al, 2010 [38]; also see Short, 2010, who describes the tracking of truck movements across the nation, in a joint FHWA/ATRI project that is drawing on hundreds of thousands of trucks for its data [45]). Useful measures besides average travel times are peak and –off-peak average times, differentiated by weekdays and weekends, and also seasonally. Often these times may need to be derived from reported truck operating speeds, averaged over a large number of trucks passing over site specific traffic counters, or based on repeated sampling of truck speeds along short (e.g. 3-mile) sections of highway using GPS technology, from which mean travel times can be derived, i.e.

19. Mean Travel Time (in minutes) = $\sum_{i=1,N}$ [$(1/S_i)$ * Dist]/ N

where S_i = the speed in miles per minute of truck i; Dist = the distance in miles of the monitored highway section, corridor, or O-D route), and N = the number of trucks passing over the highway.

2.3.2 Travel Delay-Based Measures

A useful performance measure is one that compares such mean travel times to either free flow (i.e. light traffic) or posted speed limit times, i.e.

20. Travel Time Index = mean travel rate (minutes per mile)/ free flow travel rate (minutes per mile)

Travel time delays due to congestion, for whatever reasons, can be summed over all truck trips within a given time period using the same travel time or speed data, by similarly relating delay to a baseline of free-flow speeds and times, i.e.

21. Travel Delay Index (in minutes) = (Mean Travel Time – Free Flow Travel Time) x N

where N again = the number of trucks passing over the highway (i.e. truck volume).

The following travel speed index also offers a useful, and readily understood way to track the growth of traffic congestion over time on a single highway, as well as compare congestion levels across different highway sections, and is perhaps easier to explain to the general use than, for example, volume/design capacity, or v/c measures:

22. Congestion (Speed) Index = percentage of vehicle (truck) speeds less than an acceptable speed threshold

Although the following two variations on this idea may prove more appealing as performance measures:

23. Congestion (Duration) Index = how long (how many hours) on an average day do congested conditions exist
24. Congestion (Extent) Index = how much of the corridor or regional road network operates under congested conditions

2.3.3 On-Time Reliability Measures

The empirical evidence from recent shipper surveys, as well as the subsequent modeling of demand for different types of right service indicate that time-based reliability and other quality of service factors play an important role in choice of carrier and freight supplier (and in some instances in the choice of mode) mode/supplier selection, and that level of service characteristics such as service reliability are often as or more important than freight rate [46]. A reliable freight service is one that consistently delivers goods to customers on-time, with an "ideal" one making on-time deliveries all of the time. Doing so in the case of trucking service depends heavily on consistency in en-route highway travel times. The opposite of such consistency is variability in travel times, and it is the measurement of this variability that currently offers the most practical method for estimating the effects of highway network performance on service reliability. Taking this approach, *reliability* is used in this paper to refer to the level of consistency or dependability in a trucking service's travel times, as measured from day to day and/or within different times of day [35]: while *variability* refers to the amount of inconsistency in highway operating conditions [47].

The principal causes of hour-to-hour and day-to-day variability in travel times are well known, if sometimes difficult to forecast accurately [27, 48]:

- Traffic incidents
- Traffic work zones
- Adverse weather conditions
- Fluctuations in travel demand
- Special traffic-intensive events,
- Poorly synchronized traffic control devices , and
- Inadequate roadway capacity

The first six of these factors interact with and are influenced by the last factor, the basic design capacity of a roadway, whether measuring variability in times from hour-to-hour or from day-to-day. For this present study the focus is on the day-to-day variability in truck travel times, with most truck trips completing their within state deliveries over the course of a single day. However, understanding how the range of travel speeds vary at different hours of the day, and notably how they differ during peak versus off-peak periods, also has value as a performance measure: since a good deal of truck traffic may be able to avoid peak travel times, while some of it may not.

Seasonal variations in travel times are also quite common on many highways, such as those carrying high volumes of summer tourist traffic, or carrying trucks loaded with seasonally harvested agricultural products. Identifying these seasonal differences in both freight and passenger traffic demand can also prove useful for tracking the performance of a specific highway section or corridor over a number of years.

The two most common methods for quantifying this variability in travel times are to derive the standard deviation (= the square root of the variance)[2] in vehicle travel times over a period of time, and to estimate the 95th percentile travel time over the same number of observations. In practice, these "observations" are typically travel speeds, although GPS tracking can now be used to follow a truck for a period of time and geo-locate its starting and ending points to derive an observed travel time for a given stretch of road.

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[2] The standard deviation in a sample of i=1,2… n of vehicle travel times can be computed as:

$$s_{N-1} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2} \ .$$

The following are frequently cited travel time *reliability* measures from the recent literature, based on measuring the standard deviation, or using the 95th percentile travel time or similar measures of delay [see, for example, references 26, 35, 45, 48, 49, 50, 51, 52]:

25. The 95th Percentile Travel Time Index = the travel time at or below which a truck can expected to cover the distance of interest 95% of the time[3]
26. Percentage On-Time Index = Percent of travel times < (1.X * Mean Travel Time)
27. Coefficient of Variation = standard deviation of travel time/mean travel time
28. Planning Time Index = 95th percentile travel time / free-flow (or posted speed limit) travel time
29. Buffer Index (%) =[(95th percentile travel time - mean travel time) / mean travel time] *100
30. Misery Index = (mean of the top X% of travel times/ mean travel time) – 1

Lomax et al (2003) offer the following index, calculated as a ratio of the difference in the upper and lower 95% travel time confidence intervals between the peak period and the off-peak period, i.e.

31. Variability Index = $\dfrac{\textit{Difference in peak - period confidence intervals (=Upper 95\% value - Lower 95\% value)}}{\textit{Difference in off - peak period confidence intervals (=Upper 95\% value - Lower 95\% value)}}$

The interval differences here represent two standard deviations above and below the mean, which in peak periods is usually larger than in off-peak periods, so that the index will have values greater than 1.0. The index may prove useful in corridors where a significant difference exists in travel time variability over the course of a typical travel day. The complexity of the index may render it unsuitable for the non-technical readers, however.

Each of these measures can be applied to a specific link or section of highway, to a multi-link corridor, or to an O-D pair.[4] Where several (i = 1,2,.n) highway sections make up an O-D route or corridor, or where variability in travel times is required over several time periods, indices need to be averaged by using the VMT on each section or in each time period as follows [50]:

$$\text{Average Index Value} = \sum_{i=1,n} (\text{Index Value n} * VMT\text{n}) / \sum_{i=1,n} VMT\text{n}$$

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[3] Put another way, only 5% of the time are reported truck travel times above the 95th percentile value. Some studies have used the 90th percentile time.

[4] Given that truck travel speeds and not travel times are what is usually measured by GPS tracking, in-road loops etc., multi-link performance measures such as the buffer index can be derived by substituting *travel rates* for travel times, where a travel rate is here simply a measured speed, usually expressed in minutes per mile, and offering a highway link length-neutral surrogate for time variation (Lomax et al, 2003).

Each index measures something a little different from the others. For example, the *planning time index* indicates how much additional time needs to be allocated under worse case conditions compared to the ideal or free-flow travel time. This implies making an allowance for both anticipated and unanticipated (e.g. incidence based) congestion. The b*uffer index,* in contrast, expresses the amount of extra time, as a percentage, needed to be on time for 95 percent of trips (e.g., based on being late for work on one day out of the typical 20-work-day month). As such it appears more suited to capturing the effects on unanticipated, non-recurring delays [52]. The evocatively named *misery index* measures the length of delay of only the worst trips, and this metric is computed by subtracting the average travel rate from the upper x% (where x= 10, 15 or 20 percent) of travel rates. This yields the time difference, as a proportion, between the average trip and the slowest x% percent of reported travel times. With no consensus on which measure to use for a given purpose or situation at the present time, most recent studies have chosen to compute two or more of these indices, revealing generally high levels of correlation between them. Margiotta (2009) reports that each of the most popular travel reliability indices (Buffer index, planning time index, 95th percentile travel time index) appear to be predictable as a function of the basic Travel Time Index, and that some success has been had (root mean square errors of around 20%) in predicting both the mean TTI and the 95th Percentile TTI as a function of traffic volume to capacity ratios, incident-based highway lane-hours lost, and adverse weather conditions (hours with rainfall > 0.05 inches) [35].

A 2009 Report on Transport Analysis Guidance issued by the United Kingdom Department of Transport [53] recommends the following approach to forecasts the 'Coefficient of Variation' (= measure #27 above) in travel times, based on distance (d) and the Travel Time Index (TTI: or measure # 2 above) for each origin to destination flow in an urban area. The Coefficient of Variation (CV) here is the ratio of the standard deviation (SD) of travel time to the mean travel time (Tm), and it is estimated by an equation of the form:

$$CV = \beta 1 * TTI^{\beta 2} * d^{-\beta 3} = (SD/Tm) * (Tm/Tf)^{\beta 2} * d^{-\beta 3} \quad (2)$$

where the TTI = the ratio of the mean travel time (Tm) to the free flow travel time (Tf) on the roads in the data sample. This also means that, if a suitable statistical relationship can be developed, we can rearrange the above equation to forecast the standard deviation of travel time using data on mean travel time and O-D distance (or corridor distance).

A challenge for such forecasts is the difficulty of separating out recurring from non-recurring forms of delay, especially when trying to process large volumes of hour-by-hour traffic speed and volume data over a large number of days or weeks. Doing so entails keeping track of work zone based lane closures, reported traffic incidents, special traffic events, and prevailing weather conditions, all of which are otherwise potentially lost in the recurring day-to-day levels of traffic congestion. However, for multi-year forecasting purposes, as required of long-range freight plans or large infrastructure projects (e.g. truck-only lane proposals, adding lanes to portions of designated truck routes), this may not be too much of a drawback, unless long term disruptions to flow lasting a few weeks at a time are involved (and cannot be easily identified and extracted from the dataset). At issue here is whether to accept an averaging out of such variability over time, as part of the performance monitoring process: or to develop more detailed cause-effect relationships between variability and the above discussed factors, and then use these results to either extrapolate, or to factor up or down, the statistical results from simpler cross-sectional regression model-based predictions of travel time variability.

2.4 Travel Safety Performance Measures

2.4.1 Truck Accident Rates

Traffic incidents are a major cause of en route delay, and those involving trucks can have costs in terms of extra labor time, even when no personal injuries or significant vehicle damages are sustained. Given the difficulty of modeling the statistical likelihood of highway accidents (and the even more challenging task of determining cause-and-effect statistics) , suitable FPMs benefit from simplicity of presentation, and require a time series covering multiple years of data in order to begin to identify real trends in the frequency of crashes along any significant stretch of highway. Both all-traffic and truck-inclusive accident rates are useful in corridor analysis: the former because they identify the frequency with which trucks are likely to be delayed en route, the latter because they identify both the potential for significant, unexpected delivery costs as well as potentially much longer delay times associated with on-the-scene accident reporting.

A focus on high volume trucking corridors suggests the following FPMs, which may be applied to a corridor's major highway, or to all highways within a corridor, including local access and egress links, over which significant truck traffic is operating, and usually represent annual statistics [5, 22,]:

32. Number Of Truck-Inclusive Traffic Accidents Per Year (by Truck Size Class)
33. Truck Accident Rate = Number Of Accidents Involving A Truck Per Million Truck Miles Of Truck Travel (by Truck Size Class)
34. Truck Ton-Mile Accident Rate = Number Of Accidents Involving A Truck Per Million Truck Ton–Miles Of Travel (by Truck Size Class)

Averaging accident rates over a number of consecutive years may also be prudent, given the random nature of such occurrences over a short period of time. A three-year running average crash rate may be useful here, for example. Given the often very different route lengths and load sizes associated with different truck types, a distinction in rates between truck classes can also prove useful for estimating the costs of en route delays as well as vehicle repair/replacement and cargo replacement costs. If the average speed data on truck travel times supplied by ATRI are used, these costs are in principle included in the overall travel time cost estimates described in Section 2.7. However, this may underestimate the costs of unexpected, long delays that close sections of highway for one or more hours at a time. Some means of separating out these long duration incidents from other forms of delays may therefore be worth pursuing.

2.4.2 Hazmat Incident Rates

A special class of traffic accidents that involve trucks are those involving hazardous materials (hazmat) transport. Among the FPMs proposed in the literature are the following:

35. Number and Duration Of Hazmat Truck Spills Per Year
36. Number Of Hazmat Spills Per Hazmat Truck Mile (Per Year)

2.5 Energy Security Performance Measures

The principal energy performance measure of interest is the average miles per gallon, or MPG, that trucks experience on the state's highways. This difference considerable across truck classes, with some of the longer and heavier single unit as well as combination trucks operating at relatively low fuel efficiencies.

37. Average Annual MPG = Average Annual Miles Per Gallon For Trucks Operating in a Given Vehicle Size Class

By tracking mpg's over time, a useful FPM, especially if network speed improvements as well as more fuel efficient trucks support higher fuel efficiencies, is the total increase in fuel saved due to more efficient fleet operations, measured from year to year as:

38. Annual Fuel Savings Measure = Total diesel equivalent gallons of fuel used this year, summed over annual truck miles operated in the state - Total diesel equivalent gallons of fuel that would have been used in a previous year summed over the same number of annual truck miles, but based on that year's average mpg.

Truck classes may be rather broad or as detailed as available data will allow. An important distinction between tractor-trailers and single unit trucks should be made, as the former tend to operate much longer O-D trip lengths, and may include through state trucks. These speed- and vehicle class-based MPG rates are also an important input to the truck operating cost FPMs discussed in section 2.7.

Fuel consumption rates per ton of freight moved have also been suggested as a performance measure, but would involve a more involved set of calculations and, given current data sources, some assumptions to be made about average payloads by truck class.

2.6 Mobile Source Emissions Performance Measures

The most common forms of environmental impact assessments applied to truck movements are directed at air pollution, in the form of the 'criteria pollutants' ozone, particulate matter nitrogen oxides, lead, sulfur dioxide and carbon monoxide, as well as the principal greenhouse gases (GHGs) carbon dioxide, nitrous oxide and methane. For each pollutant a useful FPM is:

39. Average Annual Emissions Rate = Emissions per Vehicle Mile for Trucks in a given Vehicle Size Class

Where GHGs are concerned these rates are most usefully multiplied by the global warming factors, in order to turn them into carbon dioxide equivalent (CO2e) emissions rates. Similar to the energy savings measure described above, we can then also compute a series of emissions specific FPMs:

40. Annual Emissions Savings Measure = Total emissions produced this year, summed over annual truck miles operated in the state - Total emissions produced in a previous year, summed over the same number of annual truck miles, but based on that year's average emissions rate.

2.7 Monetary Travel Cost Performance Measures

2.7.1 Monetary Costs of Delay

From the perspective of economic theory avoidable time spent traveling is a nonproductive activity against which there is an opportunity cost. Working time lost due to delays in delivery is a good example of this, and may include additional driver wages and costs associated with additional cargo handling time. It may also include difficult to quantify but potentially costly losses in receiver or shipper sales revenues due to failure to provide time-sensitive goods for sale. The Georgia DOT's draft Statewide Strategic Transportation Plan for 2010-2030 identifies the following three components of *supply chain costs*, based on the monetary costs that shippers actually measure [44]:

- the direct cost of shipping = the cost of fuel, the truck, and hiring the driver;
- the direct inventory cost = the capital "carrying cost" associated with having the inventory on a truck; and
- the obsolescence cost = the value at risk from depreciating inventory

The Strategic Plan notes that "Congestion in a corridor drives up all three components. The size of each component varies highly by commodity type, but for higher value containerized freight, delay can cost up to $50-75 per hour." [44, pp. 61-62]. Few studies have been able to shed light on these last two costs to date. Most of the statistically robust research to this point has focused on the effects of labor, fuel and other vehicle operation and maintenance costs, evaluated on as per mile or per hour basis. A common approach to placing a dollar cost on any extra time spent in travel is to assess the value of such time in terms of the hours lost multiplied by some fraction (or all) of the gross hourly wage of the workers (e.g. truck drivers) concerned, including worker's compensation and other fringe benefits paid for by employers. Recent ATRI studies have used truck speed data from its FHWA supported GPS tracking research to estimate an average marginal truck operating cost of just over $83 per hour, or $1.73 per truck mile, but with specialized carrier types having somewhat higher costs per mile, followed by less than truckload, and truckload carriers [11, 38, 39]. These costs include the following, with driver wages, fuel, and truck/trailer lease or purchase costs among the more expensive cost components:

- Vehicle Based:
  - Fuel-Oil Costs
  - Truck/Trailer Costs
  - Repairs and Maintenance
  - Fuel Taxes
  - Truck Insurance Premiums
  - Tires
  - Licensing
  - Tolls

- Driver Based:
  - Driver Pay
  - Driver Benefits
  - Driver Bonus Payments

Wheeler (2010) provides a recent review of this and other truck freight value of time studies [54]. The range of possible values reported is rather large, depending on study approach as well as type of vehicle, type of carriage (i.e. private versus for-hire, truckload versus less-than truckload), and nature of the cargo/commodities being moved: from as low as $20 per hour on the lower end, to over $190 per hour associated with time delay cost in congested traffic conditions. *This suggests considerable value could be derived from associating specific truck movement delay costs (and the travel time variability costs discussed below) with the type(s) of commodities moving through a truck corridor.* This in turn raises the challenge of using O-D commodity flow data in concert with route/corridor specific truck volume and speed data. The biggest stumbling block to doing so is the availability of suitable data sources.

Finally, note that the costs of traffic incidents are also covered to a large extent (although not entirely) in the truck insurance premiums listed above. Tracking the change in such insurance premiums over time has been suggested as one way of monitoring truck safety costs within a state. Hagler Bailly Services, Inc. (2000) also identified cargo insurance rate changes as a potentially valuable performance indicator since they follow the value of loss-and-damage claims, providing a surrogate measure of quality of trucking service [18].

Based on this literature, the following cost based FPMs suggest themselves as candidates to be tracked over time:

41. Direct Shipping Delay Costs = the extra dollar costs per truck-mile or per ton-mile due to delay
42. Total Logistics Delay Costs = the sum of extra direct shipping, inventory carrying, and cargo obsolescence costs per truck-mile or per ton-mile due to delay

2.7.2 Monetary Costs Associated with Travel Time Variability

Putting a dollar value on service reliability, and hence for practical planning purposes on the value of variability in truck travel times, proves even more challenging. A review of work on this topic in the United States, European Union, and elsewhere, by Grant-Muller and Laird (2006) notes that:

"At this point in time there is still uncertainty as to what the value of reliability is for both personal and freight related travel. However, there can be no doubt, given the qualitative and increasing quantitative evidence, that these values can be significant and large." [55]

In considering how to quantify travel time variability costs incurred on sections of US freeways (by general traffic) as a result of non-recurring incidents, Cohen and Southworth (1999) present two different approaches to assigning a user benefit (cost) to more (less) reliable travel times [56]. In the first approach, an additional cost of travel is assigned directly to a measure of trip time variability, i.e.:

$$C = a_1 * T + a_2 * Var(T) + a_3 * M \qquad (3)$$

where C equals the expected cost of a trip, and $a1$, $a2$, and $a3$ are parameters that reflect travelers' relative dislike of, respectively, trip time T, a measure of trip time variability $Var(T)$, (the standard deviation, SD, was used), and a monetary travel cost, M. The ratio of ($a2/a1$) provides a useful measure of the relative importance of changes in travel time variability versus changes in total trip time. The ratio of ($a2/a3$), often termed a *reliability ratio*, allows a monetary cost to be assigned to the importance of such variability, i.e.

Reliability Ratio (Travel Time) = Value of SD of Travel Time / Value of Travel Time (4)

a variant on which is the following [53]:

Reliability Ratio (Lateness) = Value of SD of Lateness / Value of Lateness (5)

Such measures offer a useful link to a state's freight infrastructure planning process. For example, if we have a proposed capacity expansion to a heavily trucked highway corridor, we can estimate the travel time delay reduction benefits of such an improvement by using the traditional "rule of a half", ROH, surplus measure as follows:

$$\text{ROH Benefit} = -\Delta(SD) * [(V2 - V1)/2] * VOR \quad (6)$$

where V1 and V2 = the before and after improvement truck traffic volumes, and VOR = the value of improved reliability, given by multiplying the value of truck travel time by the reliability ratio as given by equation (3) above.

To date only limited work on quantifying the monetary value of travel time reliability in trucking has been done in the United States. The issue is clearly a universal one where freight movement is concerned. Grant-Muller and Laird's (2006) review of European studies reports evidence for a travel time reliability ratio of 1.2 for commercial truck traffic (versus 0.8 for automobile traffic) [55]. However, given the above described wide range of truck freight values of time, a wide range of values should probably be expected for the reliability ratio. In the United Kingdom, Fowkes (2007) develops a measure of journey time 'spread' to capture the monetary value of truck journey time variability, defined in his case as the difference between the earliest arrival time and the 98% arrival time [57]. He suggests using a value for spread, expressible in cents per mile per ton shipped, of 2 times that of the value of journey time, for both bulk and non-bulk cargos. Wigan et al (2000), in Australia, using different metrics (reliability equated to % on late arrivals) found similarly high values placed on on-time delivery reliability by freight shippers [58].

In an alternative approach, Cohen and Southworth (1999) instead assign an additional cost of travel to that part of a trip in which delays caused by congestion occur [56]:

$$C = a_1 * T + a_2 * f[T_c] + a_3 * M \quad (7)$$

where T=total expected travel time, $f[Tc]$ = a function of the time spent in traffic congestion, M=monetary cost of travel, and $a1$, $a2$, $a3$ are again estimated model parameters. Two alternative specifications for $f[Tc]$ are identified in the literature. The first sets $f(Tc)$ equal to the percentage of the trip time spent in congestion, while the second model uses the number of minutes spent in congestion directly. The approach based on their second equation has the practical advantage of linking directly computable measures of the location and duration of congestion, using in-vehicle and along-the-highway sensor systems, to suitable valuation of travelers' (e.g. a trucker's) dissatisfaction with unexpected en route delays. The objective once again is to provide a method for quantifying the benefits associated with improved system reliability that can also make use of data that can be routinely collected with the deployment of (real time) regional traffic monitoring systems.

A useful dollar cost based FPM can be derived from the above as follows. First, for a given route or corridor, and over a given time period, compute the Reliability Ratio given by equation (4) above. i.e., compute (Value of SD of Travel Time / Value of Travel Time). Then select a parameter value for this ratio from the literature and estimate total travel time delay costs as:

43. Per Mile Delay Cost Index = (Estimated Per Mile Travel Time Costs for the Corridor / Per Mile Corridor Travel Time Costs at Free Flow Travel Speeds)

where Estimated Per Mile Travel Time Costs for Corridor =

[(Mean Truck Travel Time *VOT) + (SD of Travel Time * VOR)]/ Corridor Length in Miles

where SD = Standard Deviation of Travel Time (minutes); VOT = Value of Travel Time ($/minute); and VOR = VOT * Reliability Ratio ($/minute)

and

Travel Time Costs Per Mile at Free Flow Travel Speeds = (Free Flow Truck Travel Time for the Corridor *VOT) / Corridor Length in Miles

and where there is assumed to be no or minimal variability in travel times along the corridor at free flow speeds.

2.8 Regional/Area-Based Accessibility Measures

The ease of access with which a truck can get from one place to another, such as from a shipper's production site to a customer's factory, is generally measured in terms of the journey time and monetary cost (or the freight rate) between the two places. Simply keeping what is a very long list of such connections and their travel times or delivery costs for all the origin-destination (O-D) pairs of interest has limited value to planners and decision makers unless it can be summarized in an efficient and meaningful way. Regional or area-based accessibility indices serve this function, and there is a long history of such indices in the planning literature. Among the most popular indices for transportation planning purposes are measures that weight the importance of specific O-D pairs on the basis of the volume of traffic between them. Commonly used measures include the following:

44. Demand Weighted Average Travel Time = $\sum_{j=1,J} V_{ij} * T_{ij}$ (8)

45. Demand Weighted Average (Generalized) Travel Cost = $\sum_{j=1,J} V_{ij} * C_{ij}$ (9)

46. Gravity Model Based Travel Time Index = $\sum_{j=1,J} V_{ij} * \text{Function}(T_{ij}, \beta)$ (10)

47. Gravity Model Based Travel Cost Index = $\sum_{j=1,J} V_{ij} * \text{Function}(C_{ij}, \underline{\lambda})$ (11)

for V_{ij} = the number of truck trips between origin location i and destination location j; and where T_{ij} = i-to-j travel time and C_{ij} = i-to-j travel cost. Here C_{ij} could be the average i-to-j freight rate, in dollars per unit (per ton, per pallet, etc.), or it could be given in generalized time costs plus freight rate dollars by using an equation such as (1) above, i.e.

$$C_{ij} = (a_1/a_3) * T_{ij} + (a_2/a_3) * V(T_{ij}) + a_3 * M_{ij} \quad (12)$$

where M_{ij} = the average monetary cost of an i-to-j truck delivery, in dollars. By dividing travel time and its variability through by a_3 in this manner, we have a generalized cost of freight delivery in dollar terms. This is a common approach to use in planning models, where the a_1, a_2 and a_3 parameter values are usually derived from the calibration of an inter-regional, or area-wide freight flows (trip distribution) model.

These measures include trucks getting onto the highway from more local, typically lower volume roads, as well as trucks leaving it to get to a final destination. This in turn requires detailed knowledge of truck i-to-j, origin-to-destination (O-D) movements. Such data is rarely available, without first simulating such O-D flows with the help of transportation planning model software. Complicating the issue is the fact that all of the State's major Interstate corridors carry a great deal of external truck traffic: trucks coming into and leaving, as well as simply passing through the State. As a result, each high volume traffic corridor has its own mix of local, non-local within-state, in- out- and through state truck traffic to deal with. While the travel time and travel time reliability based performance measures discussed above can be used to assess how speedily a particular highway is handling specific O-D movements, they do not offer a transparent view of just how connected any part of a State is to one or more of its major Interstate corridors. Accomplishing this requires a means of representing "door-to-door" O-D movements, which usually means developing a set of traffic analysis zone (TAZ) to zone truck flow matrices: including local TAZ as well as rest-of-state and out-of-state TAZ. The effect of a specific corridor's performance on such flows can then be tested by examining what effects higher or lower travel speeds in the corridor have on overall, multi-TAZ accessibility. This is usually the purview of the statewide or regional transportation planning model. However, the simpler to compute measures such as demand weighted travel times (measure # 44 above) can also be developed outside such a model as needed. The issue of first and last mile connectivity (cf. Section 2.2.6) is closely linked to this issue, suggesting that it be included in some form within a State's FPM framework.

3. An Assessment of the Availability and Quality of Current Data Sources

3.1 Introduction

This chapter of the report describes the contents of a number of data sources identified as being useful for deriving truck freight performance measures for the state's high volume truck freight highway corridors. These are measures that could use current or "on the horizon" data sources to track performance from year to year --- while also offering valuable insights into emerging traffic conditions that warrant consideration in the strategic freight planning process.

Ideally, a dataset that contains representative samples of origin-to-destination truck movements and operating speeds by truck configuration, cargo size, and commodity class, by hour of the day and day of the week would go a long way to meeting most performance measurement needs. Such a dataset would also support fuel consumption and air pollutant emissions tracking, as well as allow the derivation of estimated vehicle fleet operating costs. The variability in the O-to-D travel times could be used to assess on time reliability and its associated monetary costs. Data on the locations, frequency, and severity of truck related crashes would further compliment this information. In practice, current traffic volume and speed data is collected in a number of ways, by GDOT and others, but is limited by the number and geographic coverage offered by roadside traffic counters, weigh in motion stations, aerial photographs, and limit-in-size samples of GPS-tracker enabled truck fleets (cf. Table 1).

Of the various data elements required, vehicle speed data continues to evolve rapidly thanks to the growing coverage afforded by individual vehicle-based GPS tracking, supplemented by onboard transponders and improved in-pavement traffic loops. However, our current inability to measure traffic volumes in a similarly continuous manner, across the entire statewide highway network, continues to pose problems for performance measurement. This means either interpolating between traffic count /traffic speed capturing sites, or basing assessments on broader regional measures that combine information from a number of different links and routes within a corridor or other sub-state region. In doing so the need to maintain a consistency across traffic reporting sites over space as well as time is important to effective trend analysis if regional or statewide measures are required. Less easy to establish is the spatial sampling frame or frames, required to ensure representative trends in performance that don't either miss important routes or types of commodity transported, or over-sample activity sites that are of interest to GDOT and other planners and engineers for reasons other than freight plan development or performance assessment. Finally, establishing consistency in reporting detail is another challenge to be met when different data sources, each of which were developed for different purposes initially, need to be combined within a single performance measure.

3.2 Data on Truck Traffic Volumes

3.2.1 Georgia DOT Traffic Count Data

Georgia DOT collects a great deal of traffic data, much of it on a daily, and also an hourly basis, This includes truck counts and their speeds from many automated traffic recorder (ATR) locations throughout the state. This data is reported in a number of forms on the GDOT website[5], including:

***Georgia STARS Traffic Data*:** GDOT's State Traffic and Reporting Statistics, or STARS, system provides Annual Average Daily Traffic (AADT) counts collected from permanent and portable traffic collection devices throughout the state for many segments of Georgia's State Highway System.

***Georgia's TPAS Traffic Data*:** GDOT's Traffic Polling and Analysis System (TPAS) provides 24-hour traffic data collected 24/7, 365 days a year from permanent traffic collection devices (ATRs) throughout the state for Georgia's State Highway System.

ATR Traffic Data Reports: This dataset includes AADT (Average Annual Daily Traffic) counts plus weekday, weekend and average daily truck percentages for some 159 traffic counters spread across the state. Daily average traffic counts for each day of the week and month of the year are also provided for each counter site, as are annual summaries of peak hour traffic count percentages by hour of the day, by highway class, and by truck type based on number of axles, for the years 2007, 2008 and 2009.

***Annual Traffic Counts*:** This data series provides either single direction or combined two-way AADT counts and truck percentages for a sample of highway links throughout the state.

After discussions about this data with staff in Georgia DOT's Office of Transportation Data in Chamblee, GA, a computer run was made by that office to produce the following dataset for the test corridor selected for the project (i.e. the I-75 corridor from the I-75/I-475 junction just south of Macon, GA to the Georgia/Florida State Line near Valdosta, GA: see Chapter 4):

Traffic Volumes Data (2008 – 2010):
County Name and FIPS Code
Route #
Site #
Date (Day)
Direction of Travel

[5] http://www.dot.state.ga.us/statistics/Pages/default.aspx

Vehicle Counts for Vehicle Classes 1 through 15
Total Daily Traffic Volume
Total Daily Truck Volume
Peak Traffic Hour
Description of Counter Location

Traffic Speed Data: (2008 January – April) and 2010 (July – December):
County Name and FIPS Code
Route #
Site #
Date (Day)
Direction of Travel
Vehicle Class Counts for Classes 1 through 15
Total Daily Traffic Volume
Number of Observations in 11 different speed bins, arranged in 5 mph intervals
(Bin 1 = 35 – 40 mph; Bin 11 = 85 – 90 mph).
Minimum Speed
Maximum Speed
Average Speed
Description of Counter Location

Potential Uses for FPM Purposes: This is the only source of data the project team could identify containing truck volumes and speeds by detailed vehicle types, with counting devices placed on the state's major truck highways. This vehicle class information allows aggregations for truck volume and truck speed estimation purposes into single-unit trucks (classes 5, 6, and 7), and combination trucks (classes 8 through 14). Where highway speeds are also captured by GDOT counters this dataset also provides insights into how easily trucks are moving over many highway segments both on and off the Interstate system. Not all counter sites are used each year, however, and so filtering of sites to a subset of those represented consistently over time is necessary in order to derive a regional time series of these truck class volumes (and speeds) for performance tracking purposes.

3.2.2 FAF3 Truck Volume Data

In July of 2010 FHWA released its Freight Analysis Framework, Version 3 (FAF3) national, multimodal commodity flows database.[6] A subsequent update, FAF3.1 was also released in October 2010, with a further update on the way. This database includes an assignment of truck flows to major truck routes on the US highway network. Both a base year 2007 and a forecast

[6] Available on-line at http://cta-gis.ornl.gov/faf/Default.aspx

year 2040 set of annually averaged daily truck traffic (AADTT) flows are reported on the public domain network dataset [59, 60]. In addition, a series of annual provisional updates are being produced which move these 2007 link flow forecasts forward, beginning with year 2009.

The underlying data for these AADTT estimates comes from an elaborate data modeling process that starts with a set of aggregate annual O-D commodity movements that are broken down spatially into a large number of detailed location-to-location O-D flows. These O-D flows are converted from tons shipped into an estimated number of truck trips based on a commodity class specific ton-to-truck matching process. In doing so, the conversion of commodity flows from tons to truck trips involves the following five steps [60]:

- Identifying a set of primary truck configurations and major truck body types
- Allocating commodities across the truck configurations and body types most commonly used to transport them, also taking into consideration trip length.
- Estimating average payloads by truck configuration
- Converting the commodity tons into an equivalent number of trucks
- Estimating the number of empty truck trips associated with these commodity shipments, based on empty truck percentages reported by truck configuration and body type.[7]

The truck configurations and body types used in this process are shown in Tables 2a and 2b below, with separate allocations were done for each of five distance ranges (using ranges of 0-50, 51-100, 101-200, 201-500 and > 500 miles). A separate empty load factor was also developed for each of these 5 x 9 truck configuration x 9 truck body types.

Table 2a. FAF3 Truck Configurations

Group	Abbreviation	Description
1	SU	Single Unit Trucks
2	TT	Truck plus Trailer Combinations
3	CS	Tractor plus Semitrailer Combinations
4	DBL	Tractor plus Double Trailer Combinations
5	TPT	Tractor plus Triple Trailer Combinations

This process uses the 43 FAF3 commodity classes shown in Table 3. These are the same 2-digit Standard Classification of Transported Goods (SCTG) codes used by the U.S. Census Bureau to compile the 2007 U.S. Commodity Flow Survey.[8]

[7] Based on data reported by the US census Bureau's 2002 Vehicle Inventory and Use survey (VIUS).
[8] http://www.census.gov/svsd/www/cfsdat/cfs071200.pdf

Table 2b. FAF3 Truck-Body Types

Body	Truck Fleet	Description
1	37.72%	Dry Van
2	24.37%	Flat Bed
3	14.73%	Bulk
4	8.15%	Reefer
5	7.97%	Tank
6	2.12%	Logging
7	1.70%	Livestock
8	0.91%	Automobile
9	2.33%	Other

Table 3. FAF3 Commodity Classes

Index	Description	Index	Description
1	Live animals and live fish	23	Chemical products and preparations
2	Cereal grains	24	Plastics and rubber
3	Other agricultural products	25	Logs and other wood in the rough
4	Animal feed	26	Wood products
5	Meat/seafood	27	Pulp, newsprint, paper, and paperboard
6	Milled grain products	28	Paper or paperboard articles
7	Other foodstuffs	29	Printed products
8	Alcoholic beverages	30	Textiles and leather
9	Tobacco products	31	Nonmetallic mineral products
10	Building stone	32	Base metal in primary or finished forms
11	Natural sands	33	Articles of base metal
12	Gravel and crushed stone	34	Machinery
13	Nonmetallic minerals	35	Electronic and electrical equipment
14	Metallic ores and concentrates	36	Motorized and other vehicles
15	Coal	37	Transportation equipment
16	Crude Petroleum	38	Precision instruments and apparatus
17	Gasoline and aviation turbine fuel	39	Furniture
18	Fuel oils	40	Miscellaneous manufactured products
19	Coal and petroleum products	41	Waste and scrap
20	Basic chemicals	42	Commodity unknown
21	Pharmaceutical products	43	Mixed freight
22	Fertilizers		

Truck trips are assigned to specific highway links and routes using off-the-shelf stochastic user equilibrium traffic assignment software.[9] In doing so the process makes use of a variety of data sources, including county business patterns data, data on the geographical location of freight inter-modal terminals, and data on the locations of some 18,000 truck related warehouse and distribution centers spread across the continental United States to disaggregate FAF3's rather broad traffic analysis zone-based Os and Ds down to a large number of within-zone traffic generation and attraction nodes. A multi-step procedure developed specifically for the purpose selects and adjusts dynamically the assignment of truck trips to these node-specific traffic generators, until the resulting link-assigned flow volumes are closely comparable to the link specific truck volumes (AADTTs) reported by FHWA's Highway Performance Monitoring System (HPMS). [10] The reader is directed to Battelle (2011) for further details [60].

Table 4 lists the network link specific data elements provided by the FAF3 dataset. This data can be downloaded from the following FHWA sponsored website:

http://cta-gis.ornl.gov/faf/networkdata.aspx

Note that the link speed and delay estimates are 'model-derived' and not based on actual data. The link volumes, however, are put through a validation process that adjusts values to reflect the volumes reported to FHWA by GDOT and other state DOTs to via annual HPMS protocols.

Potential Uses for FPM purposes: A strength of the FAF3 traffic volume dataset is its spatially continuous coverage of the State's major trucking highways, including both its truck freight AADTTs, along with its estimated mixed passenger plus freight (auto plus truck) AADTs. Both base year (2007) and year 2040 forecast link volumes are provided, with annual updates planned for 2009 on, until the next complete FAF update (which will be based on a 2012 US Commodity Flow Survey). Another potential benefit is the inclusion of a spatially continuous set of volume/capacity ratio estimates for these same truck favored links and routes: although these ratios need verification, and most likely modifications, if they are to match GDOT reported traffic capacity and volume estimates. While the FAF3 truck freight flow estimates are synthetic, they are tied to empirically grounded HPMS traffic reported estimates. The flow estimates are generated principally to support federally focused strategic planning activities. As such they have

[9] Specifically, an assignment routing contained in Caliper Corporation's TransCad GIS-based transportation planning software package was used.

[10] "A computer model is developed that dynamically adjusts the location of the nodes as well as share of freight (factor) associated to each of the virtual node using a set of constraints that are function of (i) geographical location of truck related warehouse and distribution centers (18,000 geo-locations); (ii) county business pattern; (iii) adjacent link traffic volume for candidate virtual node; (iv) highway functional classes connected to the virtual node; (v) freight intermodal geo-locations." See Alam,(2010, page 7). This adjustment process helps the traffic assignment route to develop truck volumes that are "comparable with the link specific ground truth truck flows established from HPMS". The HPMS, or Highway Performance Monitoring System data used for validation here is provided to FHWA annually by GDOT.

Table 4. FAF3 Highway Network Traffic Assignment Database: Data Dictionary

Attribute	Domain Type	Description
ID	Integer	Unique identifier to link with FAF network arc
Version	Character	Used for maintaining consistency across data files containing alternate releases of the FAF.
AADT07	Integer	HPMS annual average daily traffic for year 2007, derived from HPMS 2008 database. Volume/day/route
AADTT07	Integer	Year 2007 Truck Volume estimated using a combination of HPMS 2008 database, State truck percentage, and functional class specific defaults. Volume/day/route
FAF07	Integer	FAF 3.1 long distance truck volume estimated based on the FAF 3.1 Origin-Destination truck tonnage and includes empty trucks. Volume/day/route
NONFAF07	Integer	Local truck traffic that is not part of FAF 3.11 O-D database. Volume/day/route
AADT40	Integer	Year 2040 forecast Annual Average Traffic Volume estimated using the HPMS 20 year growth factors and projected to future using linear growth. Volume/day/route
AADTT40	Integer	Forecast Annual Average Truck Volume estimated using the HPMS 20 year growth factors and projected to future using linear growth. Volume/day/route
FAF40	Integer	Year 2040 FAF 3.1 long distance truck volume estimated based on the forecasted FAF 3.1 Origin-Destination truck tonnage and includes empty trucks. Volume/day/route
NONFAF40	Integer	Year 2040 Local truck traffic that is not part of FAF 3.11 O-D database. Volume/day/route
CAP07	Integer	Link specific peak capacity estimated using the procedures outlined in HCM 2000 and the arc geometry provided in 2008 HPMS database. Volume/hour/route
SF07	Integer	Estimated service flow using the procedures outlined in HCM 2000 and arc geometry, FAF truck, non-FAF truck and passenger volume. Volume/hour/route
VCR07	Real	2007 estimated volume to capacity ratio, estimated by dividing SF07 with CAP07. Unit less
SPEED07	Real	2007 estimated peak period link speed, estimated using the procedures outlined in HCM 2000 and the arc geometry provided in 2008 HPMS database. miles/hour
DELAY07	Real	2007 estimated peak period link delay, estimated using the procedures outlined in HCM 2000 and the arc geometry provided in 2008 HPMS database. In hours
CAP40	Integer	Link specific peak capacity estimated using the procedures outlined in HCM 2000. Volume/hour/route
VCR40	Real	2040 estimated volume to capacity ratio, estimated by dividing SF40 with CAP40. Unit less
SPEED40	Real	2040 estimated peak period link speed, estimated using the procedures outlined in HCM 2000. Miles/hour
DELAY40	Real	2040 estimated peak period link delay, estimated using the procedures outlined in HCM 2000. In hours

value to a state's strategic planning activities where the estimates can be verified as being reasonable by other state-specific data sources, notably its truck traffic counts.

While these long distance truck movements begin with a set of commodity trades, commodity specific breakdowns are not provided as part of FAF3's highway network assignments. This prevents its use for the purpose of attributing a commodity based dollar value to O-D or route specific traffic delays. To produce such estimates currently requires more spatially detailed O-D estimation of within, into, out of, and through state commodity flows.

3.3 Data on Truck Travel Speeds

3.3.1 GDOT Traffic Speed Data

GDOT traffic speed data are collected under the traffic count programs reviewed in Section 3.2.1 above. These are roadside traffic detector based speeds, and as such represent snapshots of vehicle speeds at selected points along those highways being polled by GDOT in a given year.

3.3.2 ATRI Truck Speed Data

This data is made available under the Freight Performance Measurement Initiative, started in 2003, a contractual relationship between the Federal Highway Administration and the American Transportation Research Institute (ATRI). ATRI has contractual arrangements and nondisclosure agreement with vendors for data. The data is GPS based and it measuring travel times and speeds on the U.S. highway system. On a typical month data is collected nationwide for some 500,000 trucks equipped with GPS and satellite equipment, moving over 25 significant interstate highways that have significant freight movement volumes. This includes movements along most of Georgia's Interstate corridors. This data is accessed, with ATRI permission, via its FPMWeb tool. Data on individual truck trip speeds are combined into a single database of average speeds by assigning these trips and their corresponding operational speeds to three-mile segments. Data elements reported include average truck speed for each segment, broken down by direction of travel, hour of the day, day of the week, and month of the year. GIS mapping of these speeds is made possible by linking start and end points of each 3-mile highway section to geo-locations along a highway network database also provided by ATRI.

Potential Uses for FPM Purposes: The ATRI truck speed dataset accessible with its FPMWeb tool covers the majority of the State's Interstate system. It offers the benefit of continuous spatial coverage of representative truck speeds over many of the state's major trucking corridors. From this database average highway space mean speeds can be determined. By analyzing these average hourly, peak period, or daily truck speeds across different days in the year a measures of travel time variability can also be derived for each 3 mile highway segment. These segments, or links, can be conflated (i.e. matched) to links in other highway networks such as the FAF3 network or other statewide, strategic planning network, and average speeds determined for these segments also. Determining travel time variability is more problematic, however. While a reasonable approximation may be gained by taking the square root of the sum of a limited number of sequential ATRI link variances, the use of this approach to obtain travel time variability-based FPMs for the entire length of a multi-link Interstate corridor requires some research. In the general case, it cannot be assumed that sequential link variances are independent of each other [61, 62].[11] While this may not present too big a problem for relatively low volume rural Interstates (see Taylor, 2009 [61]), such as the corridor we study below (cf. Chapter 4 of this report), more accurate measures of route specific travel time variability may need to be based on the individual truck speeds collected from vehicles traversing multiple consecutive network links. Of note, ATRI also now collects individual truck speeds using GPS tracking on many of the state's major off-Interstate truck routes.

3.4. Other Possible Sources of Truck Traffic Volume and Speed Data

In recent years GDOT has also made use of aerial photography of metropolitan traffic activity taken by Skycomp fly-over small aircraft[12]. GDOT is also listed on the INRIX traffic monitoring data site[13] as a participant in the I-95 Corridor Coalition effort to develop and disseminate real-time data on traffic flow conditions for long distance truck as well as passenger flow vehicles.

3.5 Traffic Safety Data Sources

3.5.1 GDOT Crash Analysis, Statistics and Information (CASI) Data

The Georgia Department of Motor Vehicle Safety (DMVS) is the state agency responsible for recording and maintaining motor vehicle crash data. It is the only data source for motor vehicle crashes that is consistent from county to county and year to year. GDOT combines data from the DMVS with its traffic volume (i.e. traffic count expanded) data to publishes a great deal of information on traffic incidents within the state, including regional as well as statewide incident rates. Much of this data can be found on its Crash Analysis, Statistics and Information (CASI) system website.[14] This includes data on the number of crashes, with a breakdown according to whether a crash involved property damage only (PDO), fatal, and non-fatal injury. Data

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[11] If successive link travel times are correlated, as is often the case in highly trafficked urban corridors, then the total variance, s_T^2, may be much larger, i.e. $s_T^2 = \sum_{i=1}^{n} s_i^2 + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} r_{ij} s_i s_j$ where s_i and s_j are the standard deviations on travel time on two corridor links i an j, and r_{ij} is the correlation between them. If not accounted for during plan assessment this may lead to an overestimate of the benefits of a particular link speed improvement scenario.

[12] http://www.skycomp.com/Atlanta/HTML_Slides/

[13] http://inrix.com/publicsector.asp#compliance

[14] http://www.dot.state.ga.us/statistics/CrashData/Pages/casi.aspx

presented in the CASI Notebook lists these incidents by pickup truck, panel truck, single unit and tractor-trailer trucks, tractor-only, twin-tractor trailer, logging trucks, and logging tractor-trailers among other vehicle classes, and which together are reported as "large truck" incidents . (The Georgia DMVS defines large trucks as Large Trucks' as trucks of at least 10,000 pounds).

3.5.2 Fatal Accident Reporting System (FARS) Data

GDOT also supplies data to National Highway Traffic Safety Administration's Fatal Accident Reporting System, or FARS [63].[15] This is a rich set of data from which to draw information, and NHTSA has created an historic data series by combining states' data from previous years into a single data reporting format. An initial download of time series data for years 1999 to 2009 provides the beginnings of a time-series assessment of incident frequencies.[16]

Such data selection is made easier using the FARS data on-line data query tool located at:

http://www-fars.nhtsa.dot.gov/QueryTool/QuerySection/SelectFields.aspx

including a selection of records associated with "Large Trucks Related" incidents.[17] Since crashes can be identified by their geographic coordinates and down to the hour/minute there is no significant difficulty in aggregating crash statistics to specific corridors or sub-regions.

3.5.3 Hazardous Materials (HAZMAT) Truck Movement Data

While data on hazmat movements is collected by local governments, this information is not typically pulled together by state DOTs. Carrier reporting programs also currently limit public access to data that is aggregated to national, broad regional or at best statewide totals, with limited breakdowns on the basis of commodities carried even at these crude levels of geography. The intelligent information technology-based CVISN[18] program within the Federal Motor Carrier Safety Administration (FMCSA) promotes electronic reporting and certification of hazmat shipments by highway, while FMCSA also maintains a National Hazmat Routing Registry (NHMRR) that lists Designated, Preferred and Hazmat Restricted highway routes.[19]

[15] http://www.nhtsa.gov/FARS

[16] Of note, this database is currently undergoing an overall that will put both the non-fatal injury crash data collected under the National Automotive Sampling System General Estimates System (NASS GES) and FARS data into alignment with the Model Minimum Uniform Crash Criteria (MMUCC), the guideline now used by nearly all States to develop their crash report forms and databases.

[17] This same website can also be used to produce a variety of county specific as well as statewide highway safety performance measures, including county mappings and statistics of large truck related accidents for years 2005 through 2009 showing annual number of fatalities and fatalities per 100,000 population.

[18] http://www.fmcsa.dot.gov/facts-research/cvisn/index.htm

[19] http://www.fmcsa.dot.gov/safety-security/hazmat/national-hazmat-Route.aspx

However, there appears to be no database that reports the frequency with which these routes are followed by hazmat trucks. No federally supported database could be identified that captures truck hazmat movements at any level of geographic and commodity class-specific detail below that of the very broad (123) US Commodity Flow Survey regions. Given the limited availability of detailed hazmat transportation data, it will be difficult to generate flow matrices of annual tons shipped by specific O-Ds at levels of geographic specificity below the state-to-state level, or to capture network link-specific hazmat truck movements for the state as a whole. In the case of hazardous chemicals shipments, such as flows of chlorine, even where accurate data on production and consumption exists, it is not always clear from available data sources how much production actually moves between specific O-D pairs without collecting or seeking access to detailed company specific records. Similarly, while spent nuclear waste shipments are carefully controlled by and coordinated with the U.S. Department of Energy's Office of Civilian Radioactive Waste Management, limited information on these movements is made available in the public domain.[20]

3.6 Energy and Mobile Source Emissions Data

US EPA's MOVES2010a (Motor Vehicle Emission Simulator) software package (the in development replacement for EPA's MOBILE6 software often used by State DOTSs and MPOs) can be used to estimate fuel consumption, criteria pollutants, greenhouse gas emissions and mobile source air toxics (MSATs) from gasoline, diesel, and alternatively fueled trucks.[21] Highway condition and performance related factors that can be modeled for their effects on emissions rates include speed, acceleration and grade, which interact with factors such as truck type, truck age, loaded weight, and altitude and ambient weather conditions. Both GREET, and the GHGenius[22] software packages can also be used to estimate greenhouse gas and criterion emissions associated with alternative vehicle classes and fuel types, although both have limited data by truck class. US EPA's Smartway green trucking program also offers software and useful information on truck operating characteristics, criterion pollutants, air toxins, and greenhouse gas emissions associated with truck operations.[23]

If data can be obtained on average truck speeds, such as the data obtained from GPS tracking of individual vehicles, then useful estimates of speed-impacted, and therefore also congestion-impacted truck emissions and fuel consumption can be derived using the MOVES software, or using estimates such as those reported in Oak Ridge National Laboratory's Transportation Energy Data Book (Chapter 5).[24]

[20] http://ocrwm.doe.gov/feis_2/index.htm
[21] http://www.epa.gov/otaq/models/moves/index.htm
[22] http://www.ghgenius.ca/
[23] http://www.epa.gov/smartway/index.htm
[24] http://cta.ornl.gov/data/download29.shtm

3.7 Truck Transportation (Monetary) Costs Data

The literature on per hour truck operating and logistics costs, reviewed in Section 2.7 above, can be used to develop a range of monetary cost estimates associated with miles traveled and with any en-route travel time delays, as well as any travel time uncertainty penalties. Since these costs are known to vary considerably by truck type and class of commodity carried, a representative range of cost estimates may need to be used based on the relative proportion of truck miles of travel assigned to specific vehicle classes (for example, using GDOT classification count data: cf. Section 3.2.1), possibly using data from FAF3 on the approximate proportion of truck miles or truck ton-miles associated with different classes of commodity movements within the state. Current data sources may only be able to support broad corridor, sub-state region or statewide average cost estimates.

3.8 Data Sources for Measuring Regional Accessibility

Since they incorporate data elements from different data sources, measures of regional accessibility present perhaps some challenging data requirements for FPM development. Ideally, this includes data on:

- the locations and daily or annual volumes of goods moved out of and into truck freight generators and attractors, broken down by commodity class; and
- highway route specific trip lengths and travel times, plus (as needed) suitably derived and applied data on freight rates and/or the dollar value of travel time delays and travel time variability.

3.8.1. Data on Significant Truck Freight Generators and Attractors

A popular option for generating statewide origin-destination-commodity (O-D-C) annual or daily freight flow matrices has been to purchase the Transearch® Truck Commodity Flows database. This is an annually updated, commercially available dataset developed and sold by IHS/Global Insight.[25] This dataset is listed among the data sources under consideration for the use in the next Georgia Statewide Freight and Logistics Plan [64]. The database provides U.S. county-level freight-movement data by commodity group and mode of transportation, combining primary shipment data obtained from 22 of the nation's largest freight carriers with information from public sources such as the FAF and US Commodity Flow Surveys, and is accompanied with 30-year forecasts that are consistent with a set of the company's macro-economic forecasts that are used by a number of federal agencies. Its' principal interest to the present project is the spatial disaggregation of O-D flows at or roughly consistent with the level of US counties, making it easier to relate flows in specific commodity classes to at least the state's major freight highways.

[25] http://www.ihsglobalinsight.com/ProductsServices/ProductDetail2322.htm

A second option for identifying significant truck generators and attractors within a corridor or sub-state region may also be to use ATRI data to identify those locations where significant numbers of GPS tracked trucks originate and terminate each day, captured over all days in a given year or season within the year. This approach may offer a second and potentially cost-effective application of the same data source described above to capture over-the-highway route selections and operating speeds.

For any corridor study a key question that also needs to be answered is what geographic area, and therefore which truck freight traffic generators and attractors, should be "polled" in order to identify the important first and last mile access issues associated with any high volume trucking corridor. Within a statewide freight plan this is often handled by defining freight traffic generation/attraction analysis zones, or freight TAZs, in a hierarchical manner. For example, Georgia counties may offer one level of TAZ, while TAZs outside Georgia may be multi-county regions, large metropolitan areas (e.g. FAF3 metro areas) or entire states. Greater, freight facility specific detail can often be added, especially if a specific corridor is being assessed. Example facilities include major seaports and large freight airports, and truck-rail intermodal terminals.

3.8.2 Data on O-D Specific Truck Freight Transportation and Logistics Costs

Section 2.7 above provides a review of the monetary costs of extra in-transit travel time and the costs associated with variability (i.e. unreliability) in these delivery times. To the extent feasible existing data on O-D truck travel times should be obtained linking the selected set of O-D pair within a region, or linking these truck freight Os and Ds to the major Interstate route(s) that define a study corridor. This may initially require a sub-sampling of the speeds obtained from existing pavement loop traffic detectors or from other traffic monitoring devices located on/along major truck routes. GPS tracking of truck speeds along non-Interstate routes, such as those derived from ATRI data, are also a possible option here.

3.9 Summary of Available Data Sources

Combining data from the above described sources requires that a suitable level of spatial, truck configuration and commodity class detail be created and maintained. While not all performance measures need to contain the same level of detail, a consistent treatment of the major data elements, notably traffic volumes and speeds, will help the planning and reporting process. Based on current data availability, especially the partial network coverage of truck trip volumes and the limited amount of spatially explicit data linking truck types to commodities being carried, some performance measures that are ideally route or O-D based may need to be regional or corridor-wide in nature, at least initially.

4. Candidate High Volume Trucking Corridor Performance Measures: Some Empirical Tests

4.1 Introduction: I-75 Test Corridor

This chapter describes the construction of a number of the truck freight performance measures reviewed in Chapter 2, and making use of data extracted from the various data sources described in Chapter 3 of this report. Based on Georgia DOT planning staff input, the largely rural I-75 Corridor between Macon and Valdosta, the latter city lying on the Georgia-Florida border, was been selected as the test application. The Federal Highway Administration has designated this stretch of I-75 to be a significant portion of one of the nation's busiest freight corridors, carrying more than 8,500 trucks (bi-directionally) each day[26]. Figure 5 shows the section of I-75 used in the analysis. The results are not meant to be definitive, the purpose here being to see how far current data sources could be used to support some of the more popular performance measures from the recent literature, based on a reasonable level of effort: and in the process to identify any significant data gaps. This empirical part of the study is limited here to the analysis of traffic conditions and truck movements along the southern portion of Interstate-75. Broader regional measures, including conditions on popular truck routes leading to and from the Interstate are also discussed but not quantified in this report.

Based on the results of the Chapter 2 and 3 reviews, the following rural Interstate highway-based performance measures were considered for measurement, where a * after a performance measure indicates that it could be computed relatively easily with current data sources, and a (*) after a measure indicates that an estimate was made as part of this study, but some of the data input to it warrant improvement:

Network Supply (inc. Truck Traffic Volume) PMs:
1. Corridor truck and general traffic volumes on a typical day*
2. Tons of freight moved though the corridor on a typical day (*)
3. Market value of the freight moved through the corridor on a typical day
4. Percentage of corridor miles subject to high levels of congestion on a regular basis*

Truck Travel Time PM:
5. Average truck speeds in the corridor on a typical day*
6. Corridor planning time index*
7. Corridor buffer time index*

Truck Energy Security PMs
8. Gallons of fuel and per mile fuel consumption in the corridor on a typical day*

Truck Mobile Source Emissions PMs
9. Metric tons of carbon dioxide equivalent motor fuel based emissions produced daily

[26] http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/major.htm

in the corridor*

10. Metric tons of US EPA regulated criterion pollutants produced daily in the corridor*

Truck Travel Cost PM:

11. Estimated daily costs of traffic delay in the corridor (*)

12. Estimated daily cost of travel time variability in the corridor (*)

13. A corridor per mile delay cost index (*)

Truck Safety PM

14. Number of corridor truck-involved traffic accidents annually (*)

Interstate Corridor Accessibility PM:

15. Typical trucks speeds on major truck route connectors.

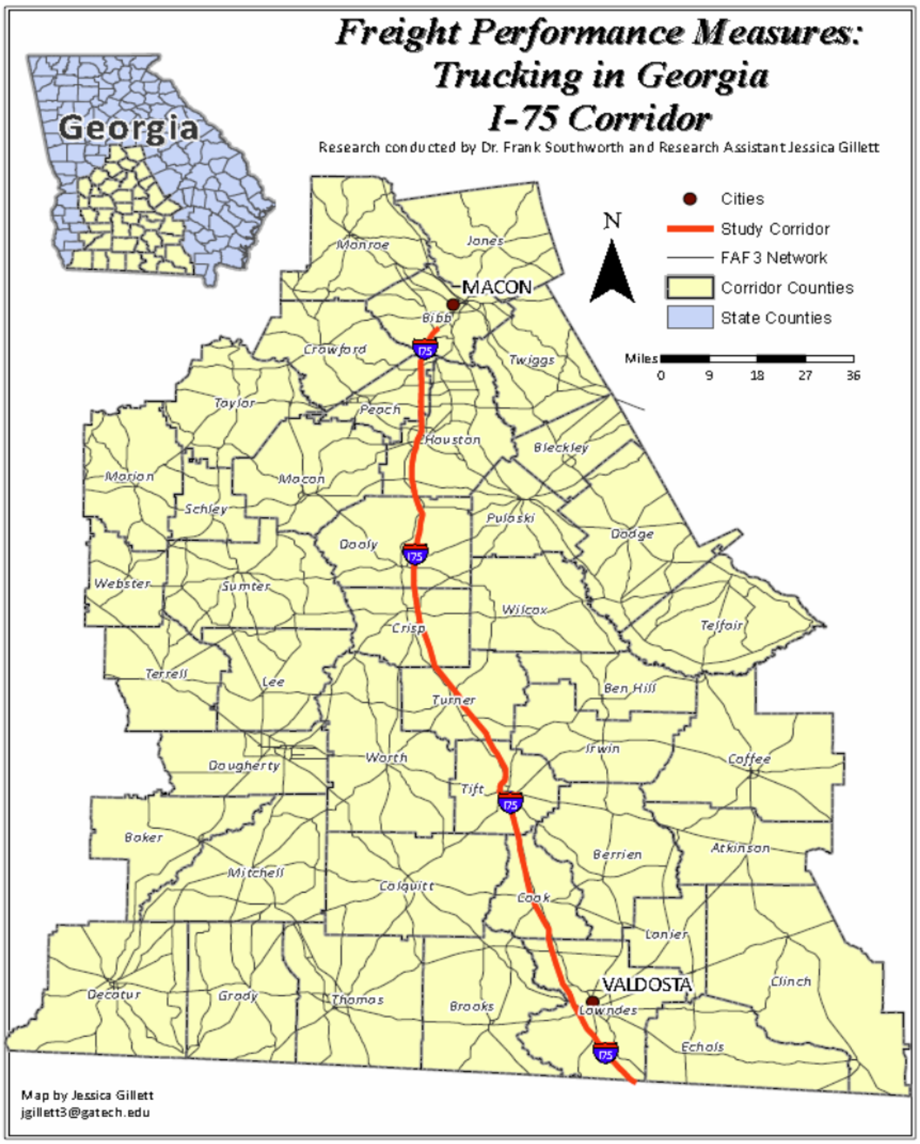


Figure 5. The I-75 Test Corridor, south of Macon, Georgia

A series of both network link (i.e. highway section or facility) specific and corridor-wide measures were developed, the latter often, but not always, the results of summing or averaging over the link –specific measures produced. Not all performance measures listed above could be generated satisfactorily due to limitations on current data sources. The identification of these data gaps was one of the main objectives of the project.

4.2 Example Link Performance Measures

Tables 5a and 5b contain a set of link specific, northbound and southbound truck traffic performance measures generated from this process. The rest of this section discusses the construction of each of these measures in more detail, moving from left to right across the data columns shown in these tables.

Figure 6 shows the major steps required to construct the example performance measures.

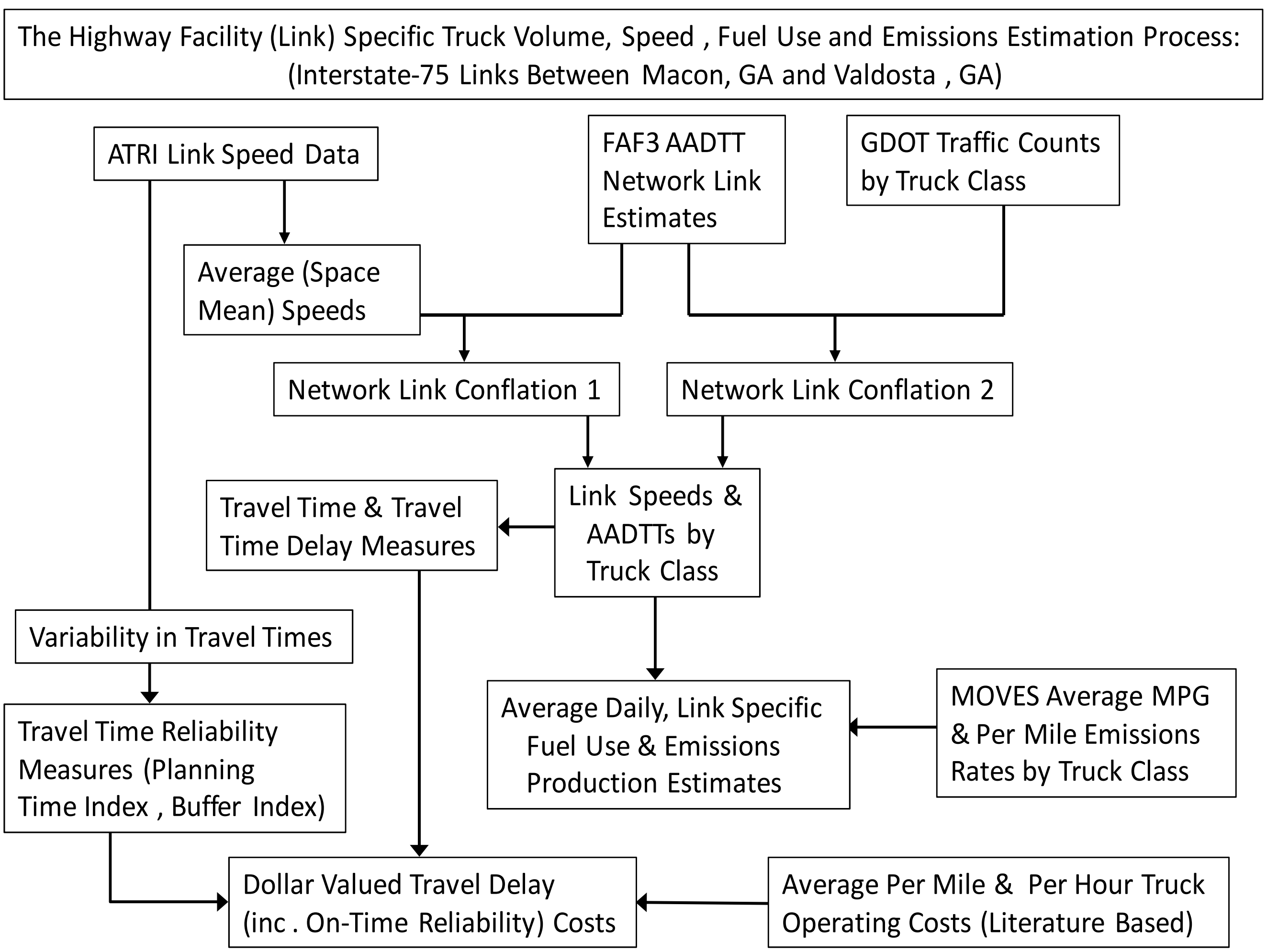


Figure 6. Creation of a Set of FPMs for the southern part of the I-75 Corridor in Georgia

Table 5a. Link Truck Freight Performance Measures for I-75 Corridor, Northbound Traffic

LinkID	Distance (miles)	Total Volume (AADT)	Truck Volume (AADTT)	Single Unit Truck Vol.	Combination Truck Vol.	Average Speed (MPH)	Average Travel Time (mins.)	Free Flow Travel Time (mins.)	95th Percentile Travel Time (mins.)	Total Daily Delay (mins.)	Planning Time Index	Buffer Index	Fuel Use (gallons per day)	Kilograms per day	Average Daily Emissions (grams)				
													Diesel	CO_2E	CO	NO_X	PM_{10}	SO_2	VOC
1	11	18084	4863	775	4085	57.7	11.4	9.4	12.4	9794	1.31	7.9	9437	14734	23482	103922	4610	460	5043
2	5	19606	4687	747	3937	57.1	5.3	4.3	5.6	4543	1.31	6.5	4134	10641	16331	77815	3331	333	3175
3	2	20220	4833	770	4060	57.1	2.1	1.7	2.2	1872	1.30	5.9	1705	9139	13594	68731	2863	286	2406
4	4	20457	4890	779	4107	57.3	4.2	3.4	4.4	3706	1.29	5.4	3451	10483	15943	77301	3282	328	3020
5	7	18444	4408	702	3703	57.7	7.3	6.0	7.7	5655	1.28	5.3	5444	11125	17337	80201	3482	348	3515
6	11	17383	4328	690	3636	58.1	11.4	9.4	12.0	8395	1.27	5.2	8400	13115	20901	92499	4103	410	4488
7	22	18076	4321	689	3629	58.2	22.7	18.9	24.0	16479	1.27	5.9	16770	19108	31513	130104	5975	596	7329
8	1	22538	5387	858	4525	58.0	1.0	0.9	1.1	954	1.28	6.5	950	9504	13945	72328	2978	298	2359
9	2	22133	5290	843	4444	58.2	2.1	1.7	2.2	1833	1.27	5.4	1867	10002	14879	75228	3133	313	2633
10	14	18713	4659	742	3914	58.6	14.3	12.0	15.1	10902	1.26	5.3	11508	15887	25630	110678	4970	496	5669
11	4	18629	4548	542	3998	58.8	4.1	3.4	4.3	2971	1.25	4.9	3291	9518	14306	70943	2981	298	2615
12	2	18530	4524	540	3977	59.0	2.0	1.7	2.1	1441	1.24	4.9	1637	8611	12713	65188	2698	270	2195
13	15	18640	4376	522	3847	58.9	15.3	12.9	16.1	10611	1.25	5.2	11872	13717	21834	96875	4292	429	4674
14	2	22164	4995	596	4391	59.5	2.0	1.7	2.1	1518	1.24	5.7	1807	9507	14036	71972	2978	298	2423
15	1	22174	4997	596	4393	59.4	1.0	0.9	1.1	768	1.25	6.0	904	9038	13205	69034	2832	283	2200
16	8	22304	5445	649	4787	59.9	8.0	6.9	8.6	6298	1.25	6.9	7880	13460	20780	97894	4214	421	4107
17	3	21486	3631	433	3193	60.3	3.0	2.6	3.2	1495	1.25	8.2	1971	7256	10813	54485	2273	227	1925
18	9	21111	5154	615	4531	61.3	8.8	7.7	9.6	5663	1.24	8.6	8391	13228	20533	95722	4141	414	4119
19	1	20904	5104	609	4487	62.0	1.0	0.9	1.0	568	1.20	5.9	923	9231	13486	70506	2892	289	2247
20	5	20985	5124	611	4504	62.2	4.8	4.3	5.1	2736	1.19	6.1	4634	11208	16975	82966	3510	351	3175
21	7	21471	4234	505	3722	63.1	6.7	6.0	7.1	2795	1.18	6.1	5361	10064	15446	73593	3151	315	3003
22	1	21471	5242	625	4608	63.5	0.9	0.9	1.0	459	1.17	6.3	948	9480	13851	72413	2970	297	2308
23	2	24652	6019	718	5291	63.6	1.9	1.7	2.0	1047	1.17	6.2	2177	11455	16912	86722	3589	359	2920
24	2	24361	6220	1642	4570	63.6	1.9	1.7	2.0	1075	1.17	6.1	2042	11518	17481	85092	3607	361	3291
25	4	25552	6525	1722	4794	64.1	3.7	3.4	4.0	2072	1.16	6.3	4285	14817	23178	106428	4637	463	4747
26	5	26583	6788	1792	4987	64.3	4.7	4.3	5.0	2573	1.16	6.7	5572	16838	26633	119657	5269	526	5612
27	3	31211	7970	2104	5855	64.4	2.8	2.6	2.9	1788	1.14	4.8	3925	16428	25354	119511	5143	514	5007
28	6	35401	5834	2569	3224	65.1	5.5	5.1	5.8	2278	1.14	5.7	4993	18530	30747	125338	5794	578	7247

Table 5b. Link Truck Freight Performance Measures for I-75 Corridor, Southbound Traffic

LinkID	Distance (miles)	Total Volume (AADT)	Truck Volume (AADTT)	Single Unit Truck Vol.	Combin-ation Truck Vol.	Average Speed (MPH)	Average Travel Time (mins.)	Free Flow Travel Time (mins.)	95th Percentile Travel Time (mins.)	Total Link Delay (mins.)	Planning Time Index	Buffer Index	Fuel Use (gallons per day)	Kilograms per day	Average Daily Emissions (grams)				
													Diesel	CO_2E	CO	NO_X	PM_{10}	SO_2	VOC
1	11	18108	4908	688	4218	57.3	11.5	9.4	12.4	10240	1.31	7.6	9647	14232	22508	101143	4453	445	4742
2	5	19632	4730	663	4065	57.5	5.2	4.3	5.6	4388	1.30	7.1	4226	10558	16102	77653	3306	331	3075
3	2	20247	4879	683	4193	57.7	2.1	1.7	2.2	1783	1.29	6.4	1743	9259	13724	69862	2901	290	2400
4	4	20483	4935	691	4242	57.9	4.1	3.4	4.4	3552	1.28	5.9	3527	10466	15828	77570	3277	328	2948
5	7	18468	4450	623	3824	58.1	7.2	6.0	7.6	5495	1.27	5.6	5565	10921	16899	79260	3419	342	3361
6	11	17405	4369	612	3755	58.2	11.3	9.4	11.9	8338	1.27	5.3	8587	12667	20034	90026	3964	396	4221
7	22	18099	4361	611	3748	58.3	22.6	18.9	24.0	16425	1.27	6.1	17144	17985	29448	123381	5624	561	6741
8	1	22567	5438	762	4673	59.1	1.0	0.9	1.1	862	1.27	6.9	972	9715	14226	74070	3044	305	2389
9	2	22161	5340	748	4589	58.9	2.0	1.7	2.2	1716	1.26	6.2	1908	10135	15021	76465	3175	318	2627
10	14	18737	4703	659	4042	59.0	14.2	12.0	15.1	10502	1.26	5.9	11764	15206	24345	106765	4757	475	5287
11	4	18488	5102	603	4501	59.3	4.0	3.4	4.3	3161	1.24	5.3	3702	10691	16061	79711	3348	335	2932
12	2	18390	5075	600	4477	59.3	2.0	1.7	2.1	1578	1.25	5.8	1841	9681	14290	73308	3033	303	2465
13	15	18499	4908	580	4331	59.3	15.2	12.9	16.1	11446	1.25	6.0	13356	15355	24424	108505	4804	480	5220
14	2	21996	5603	662	4943	59.3	2.0	1.7	2.1	1733	1.25	5.8	2033	10689	15777	80938	3349	335	2722
15	1	22007	5606	663	4946	59.5	1.0	0.9	1.1	849	1.25	5.9	1017	10168	14853	77672	3186	319	2474
16	8	22135	6109	722	5389	59.7	8.0	6.9	8.6	7205	1.25	6.7	8865	15094	23290	109837	4725	472	4596
17	3	21324	4074	481	3594	60.1	3.0	2.6	3.2	1728	1.24	6.5	2217	8154	12147	61244	2554	255	2160
18	9	20951	5782	683	5101	61.0	8.9	7.7	9.5	6579	1.23	7.2	9439	14830	23005	107369	4642	464	4607
19	1	20746	5725	677	5051	62.1	1.0	0.9	1.0	624	1.19	5.6	1039	10385	15170	79328	3254	326	2527
20	5	20827	5747	679	5071	62.5	4.8	4.3	5.1	2972	1.19	6.0	5213	12583	19049	93183	3940	394	3558
21	7	21309	4749	561	4190	62.8	6.7	6.0	7.0	3275	1.17	5.2	6031	11290	17319	82597	3535	353	3362
22	1	21309	5880	695	5188	63.0	1.0	0.9	1.0	560	1.17	5.2	1067	10665	15580	81474	3342	334	2595
23	2	24465	6751	798	5957	63.3	1.9	1.7	2.0	1229	1.17	5.4	2449	12880	19010	97525	4035	404	3280
24	2	24795	6560	1507	5054	63.4	1.9	1.7	2.0	1168	1.16	5.4	2210	12247	18464	91026	3835	384	3407
25	4	26008	6880	1581	5301	63.7	3.8	3.4	4.0	2334	1.16	5.6	4636	15357	23812	111241	4807	480	4762
26	5	27057	7158	1645	5515	64.1	4.7	4.3	4.9	2822	1.15	5.6	6029	17284	27085	123931	5409	541	5573
27	3	31769	8404	1931	6475	64.5	2.8	2.6	2.9	1857	1.14	4.8	4247	17225	26371	126252	5393	539	5091
28	6	36110	5607	2164	3482	64.8	5.6	5.1	5.8	2326	1.14	5.2	5103	17103	28057	117101	5349	534	6449

A key task was the merging of data from different sources onto a single representation of the study area's highway network. This activity is referred to as "network conflation" in Figure 6, and was carried out by placing the FAF3 national truck network database into geographic information system (GIS) software and moving both ATRI link speed data and GDOT truck traffic volume classification data onto suitable FAF3 links. In the case of the ATRI average truck speed data this meant first of all matching each 3-mile long ATRI highway section to its most appropriate FAF link, then using the ATRI data to generate an average daily space mean speed for that link. GDOT traffic count data, in contrast, is point location specific. Traffic count data for calendar year 2008 was obtained from GDOT for this purpose. With only four such count sites located on the Intestate for which a reasonably full set of truck counts could be obtained, each count site was used to represent the average distribution of that link's AADTT across GDOT defined vehicle classes (i.e. trucks in classes 5 through 14). FAF3 links without a counter were then assigned the same truck class distribution as their nearest GDOT counter link.

Truck, Class Specific, Traffic Volume Measures

A first step in measurement process was to generate a set of link specific truck and total, mixed (i.e. passenger vehicle plus truck) traffic counts. Four GDOT traffic count sites were identified along this stretch of I-75 containing both direction specific (northbound, southbound) total AADT and Truck class specific AADTT values. The project also had access to FAF3 estimated (2007) AADT and AADTT counts, the latter for total truck movements (in both directions). These FAF3 flow estimates are themselves derived from the GDOT truck counts submitted annually to the FHWA's Highway Performance Monitoring System (HPMS) database (see Alam, 2011 [59]), and were found to be generally consistent with the GDOT truck counter volumes assigned to them. For demonstration purposes the GDOT link and truck class specific AADTTs were factored to match these FAF3 link flow estimates. This was done to try to capture the variability in the truck volumes on each section of I-75 as a result of trucks entering or leaving the Interstate at points between the GDOT traffic count sites, using a complete set of FAF3 estimated AADTTS for the entire 159 mile length of the I-75 corridor. (An alternative approach is to spread the GDOT counts across the set of I-75 links without further factoring. However, an increase in the number of counts sites seems warranted in this case).

Figure 7 shows an example of the direction specific (northbound, southbound) truck count distributions applied to these traffic volume estimates. Note that, depending on completeness of counting at such sites, a monthly or quarterly set of such profiles could be developed and used, and matched up to a similarly specified set of monthly space mean truck speed counts using the ATRI dataset discussed below.

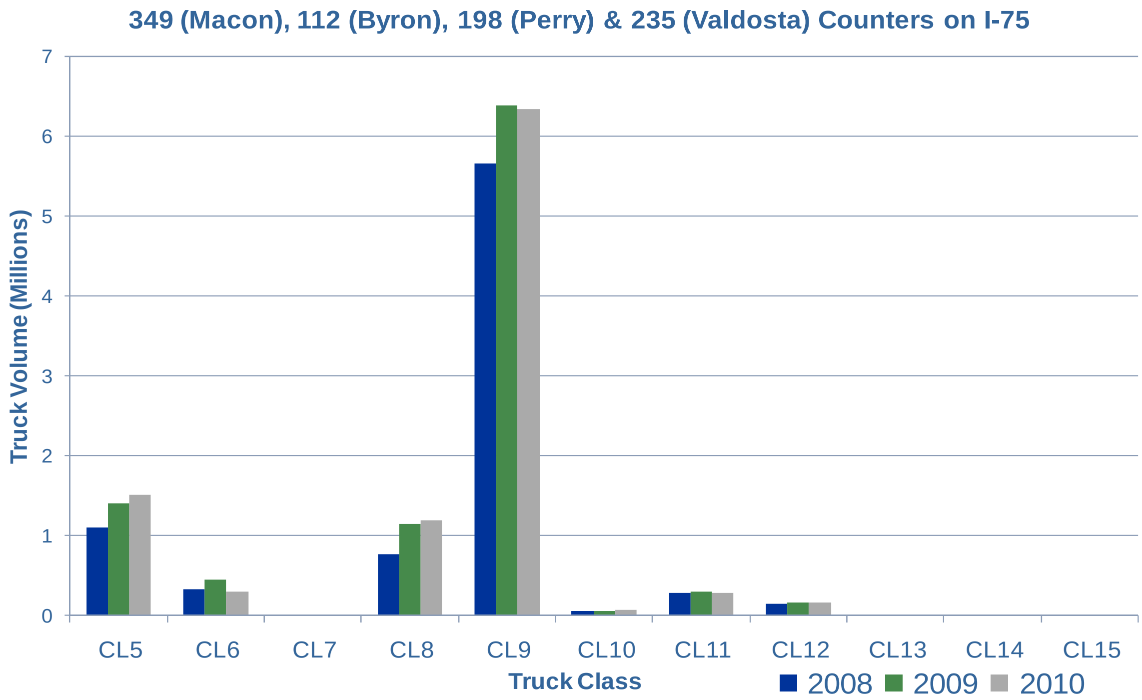


Figure 7. Distribution of Annual Truck Volumes Across Vehicle Classes for the I-75 Corridor 2008-2010 (A Four Count Site Average)

Travel Time Measures

Using the ATRI speed data described in Chapter 3 above, estimates of average link speeds and their resulting travel times were based on averaging over the hourly reported space mean speeds for an entire year. The option exists within the ATRI speed data to average truck speeds on any hour of the day, and/or day of the week basis, either annually, or for a given month or season of the year. However, for this rural Interstate corridor, whether averaged over specific months or specific hours in the day this data yielded similar results to annual averages speeds using all days and hours for the travel corridor, in all instances covering a quite narrow range of speeds with most falling between from 57 to 65 mph.

Figure 8 shows how average hourly truck speeds varied by hour of the day, for four different months worth of truck speed data in 2009. All four months of data show a drop in average speeds around the late morning hours, but with similar, and very narrow ranges between 55 and 65 miles per hour. With the very low average standard deviations for both northbound and southbound average travel times of 3.4 and 3.2 minutes, respectively, average travel times appear to be quite reliable under normal operating conditions.[27] Of course, this result masks the within

[27] However, these estimates of the standard deviation of travel times for the corridor as a whole are necessarily based on the assumption that the variability in hourly travel times is independent between adjacent links. See the discussion in Section 3.2 of this report.

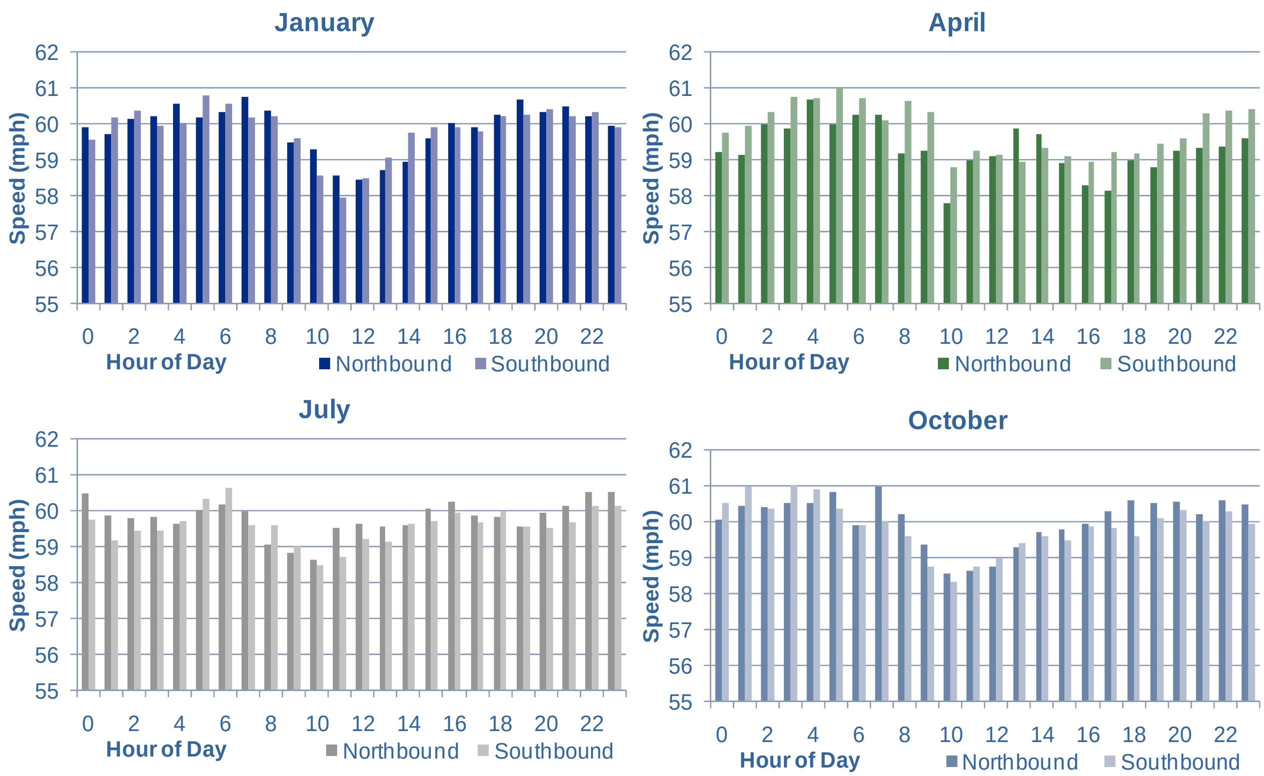


Figure 8. Corridor-Wide Average Hourly Speed Plots for Selected Months

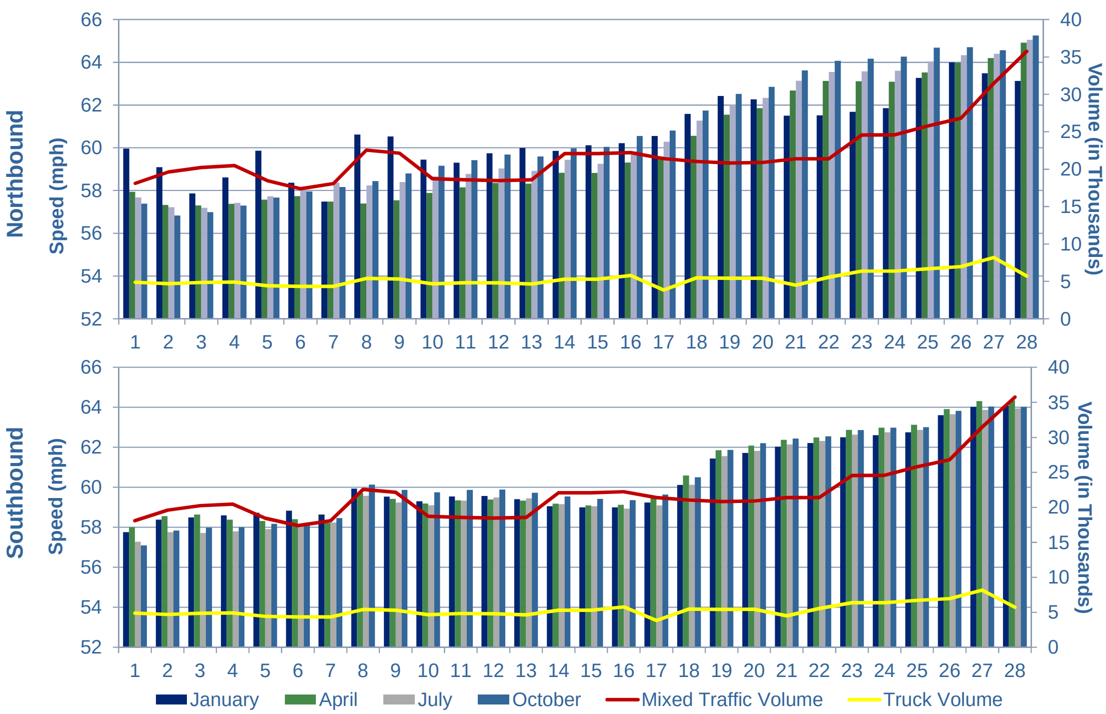


Figure 9. Average Hourly Link Speed Plots for Selected Months

day variability in these hourly times and the speeds they represent. However, barring incidents such as crashes, road works or poor weather conditions, further analysis of the speed data suggests generally reliable travel times throughout the day.

Figure 9 shows how average truck speeds varied by corridor link, again based on averaging over average hourly trip speeds sampled during four different months in 2009. With a few exceptions, very similar average link speeds over the course of the year. This figure also shows that daily traffic volumes, which increase as one travels north towards Macon, GA are also associated with the highest average link speeds. While this is a non-intuitive result, it is not an uncommon occurrence on Interstate approaches to urban areas, where traffic levels are still somewhat lower than design capacities. *This result also shows directly the value of performance measurement.* Planning models based on volume/capacity derived travel speeds would miss this relationship. It also demonstrates the very different conditions experienced by trucks on rural Interstate corridors versus more congested urban ones.

The ATRI data was also used to compute estimates of both a 95 percentile averaged hourly link travel time and also the standard deviation of travel time for each link, based on how these averaged hourly travel times varied across hours, days, and months in the year. The results shown in Tables 5a and 5b made use of the entire hour by hour dataset for 2009. Limiting the analysis to specific hours in the day, specific days in the week, and/or to specific months in the year produce very similar results. This may not remain the case, however, as traffic volumes in the corridor increase over time. Presently, however, consistently high average truck speeds on the corridor produced low link specific planning time indices[28] (see Figure 10) and similarly low link specific buffer indices[29] (Figure 11).

While a number of quite low hourly traffic speeds were captured by the ATRI data, suggesting the occurrence of traffic incidents or delays of one form or another, this data was not mined further in the present study. Doing so in the future might be beneficial, but would also benefit significantly from access to individual truck speed traces in order to capture the sort of network resiliency measures discussed on Section 2.2 of this report.

Energy Security and Mobile Source Emissions Measures

Given link specific truck traffic volume estimates (AADTTs) and average speeds, a next step in the process, shown in the bottom right portion of Figure 8, was to make a series of average speed specific runs of EPA's MOVES (latest version 10a) mobile source emissions and fuel use

[28] Derived using equation (28) above. i.e. = [95th percentile travel time / free-flow (or posted speed limit) travel time]

[29] Derived using equation (29) above, i.e. = [95th percentile travel time - mean travel time) / mean travel time] *100

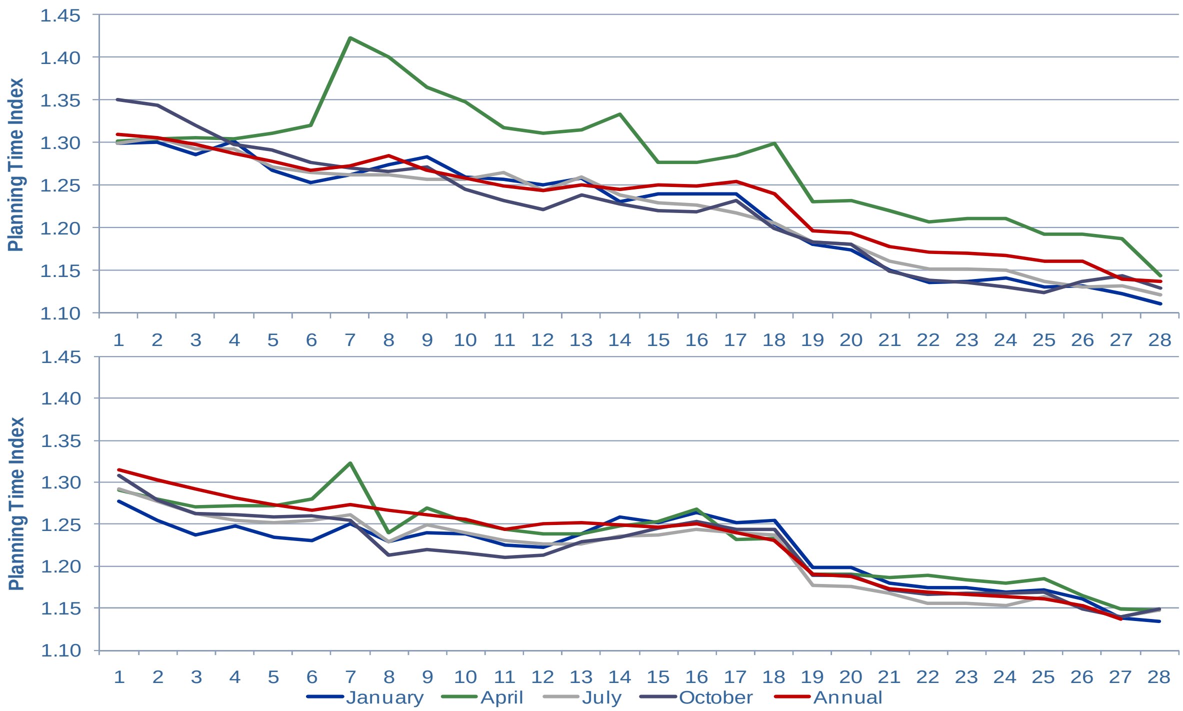


Figure 10. Link Specific Planning Time Indices for the I-75 Corridor: 2009 Speeds

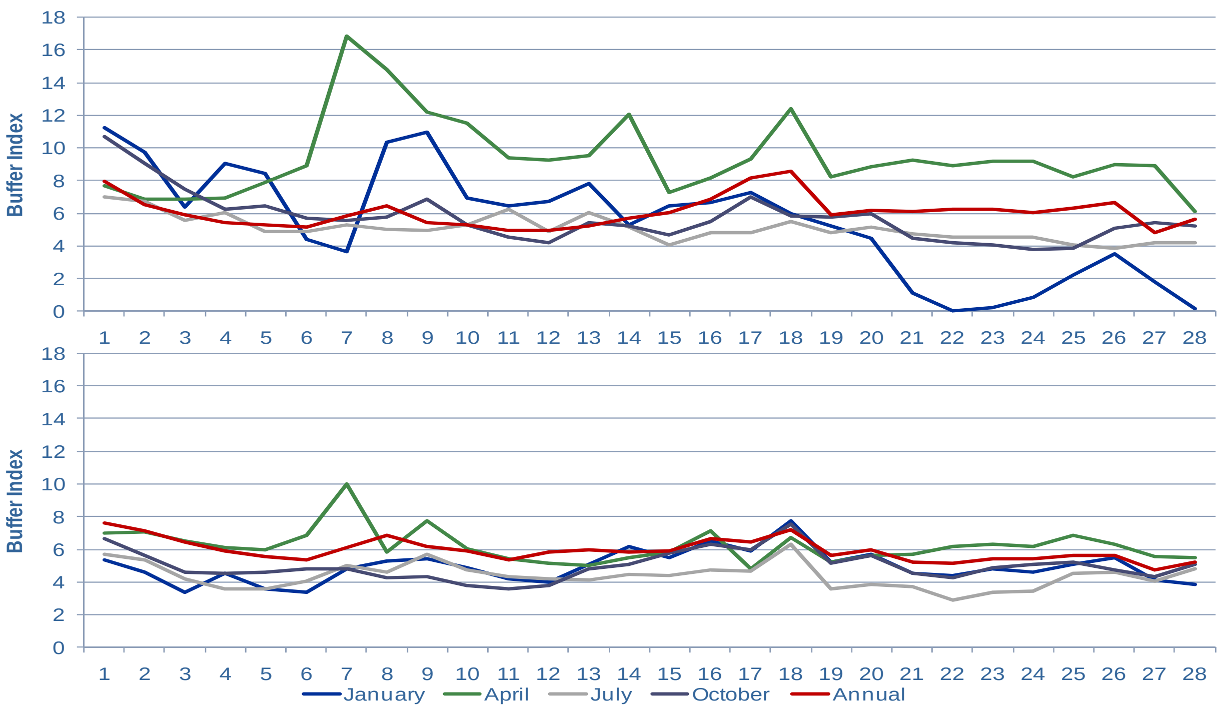


Figure 11. Link Specific Buffer Indices for the I-75 Corridor; 2009 Speeds

estimator. MOVES allows speeds to be generated for a range of vehicle, including truck classes, using 5 mph speed intervals. With a limited range of average daily speeds reported for this rural corridor this simplified to a small number of speed runs, however: using average speeds in the range 52.5 to of 67.5 mpg. In addition to producing speed and vehicle class estimates of gallons of fuel consumed, a large number of different emissions estimates are now provided by the MOVES software. These include the NOx, VOC, CO, SO2, PM 10 and CO2 equivalent emissions estimates reported in Tables 5and 5b.

Unfortunately, MOVES truck classes do not correspond directly to GDOT (or FHWA) truck classes, although a rough crosswalk between the two does exist. For our purposes, and based on the distributions of truck class VMT reported by the I-75 GDOT traffic count sites (cf. Figure 7 above), we generated only two sets of emissions: one for diesel powered "long-haul combination trucks", and the other for diesel powered "long-haul single unit trucks" , weighting each link specific's emissions on the basis of the GDOT reported proportions of truck AADTT assigned to these two truck body classes. As a result the emissions estimates reported for the corridor are heavily weighted towards the "Class 9" 5 axle single trailer tractors (cf. Figure 7) that dominate freight movement on U.S. and Georgia highways. Figure 12 shows how fuel consumption in the corridor mirrors link volume.

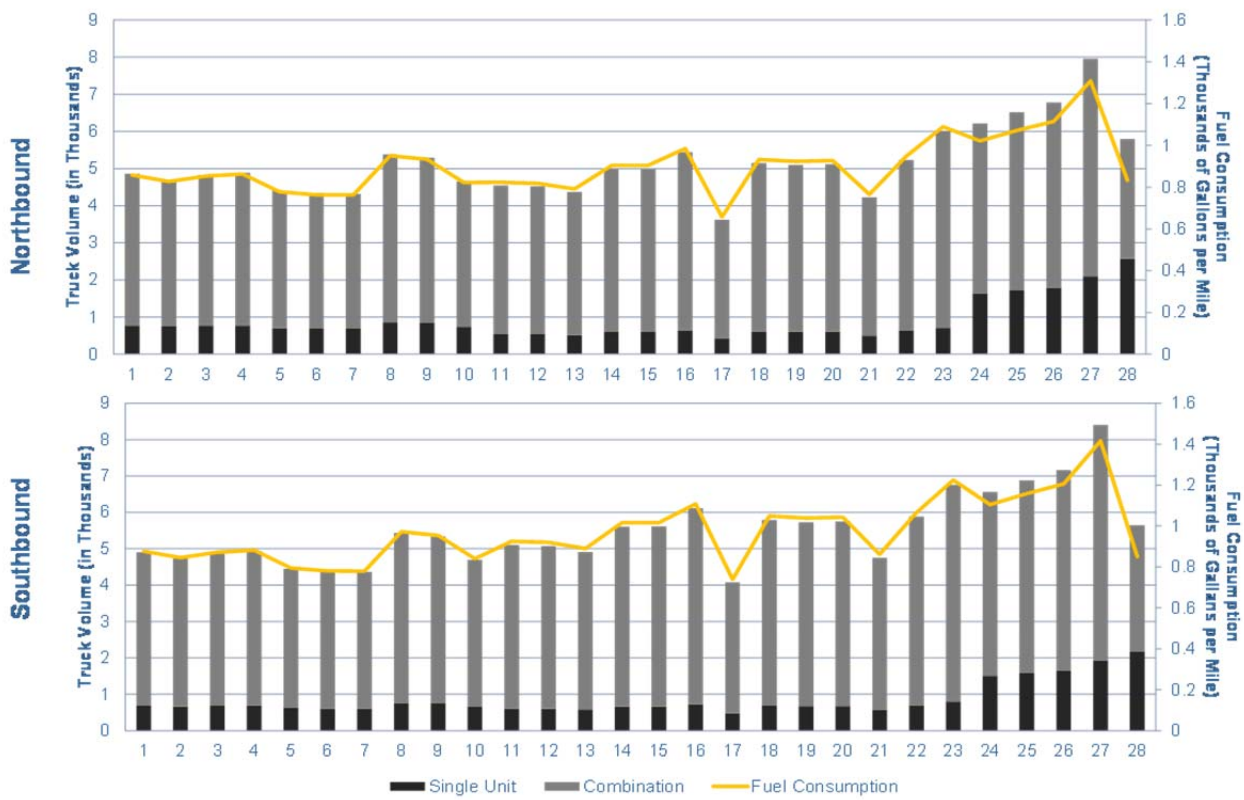


Figure 12. Link Truck Volumes and Fuel Consumption

4.3 Corridor-Wide Performance Measures

An Example Performance Measures Template

Corridor level results are reported in Table 6. This table is arranged in the form of a performance measures template, organized along the lines of Chapter 2 of this report. Only a subset of the measures discussed in chapter 2 could be computed given the data currently available and limitations on project resources. Additional or improved measures are discussed below, and again in Chapter 5 of this report.

Moving from top to bottom of the table, corridor level daily vehicle miles of travel, average daily truck traffic and mixed traffic volumes and average corridor travel times (based on the time it takes a truck to travel from one end of the corridor to the other in a given direction) are based on link distance weighted summations. Total tons shipped of freight up and down the corridor can also be estimated if one assumes an average payload per truck. However, a reasonably accurate estimate requires information of the sort generated by a regional freight planning model, based on the estimation of tons shipped up and down the corridor by commodity class. Using an average payload per truck of 16 tons[30], for example, and multiplying this figure by the VMT weighted average daily truck leads to an estimated 28.6 million tons moved northbound in the corridor each day, and an estimated 32.1 million tons moved in a southbound direction. More carefully derived estimates of tons shipped can be derived by applying truck class specific average payload factors. Data for this purpose can be drawn from the Census Bureau's Vehicle Inventory and Use Survey (VIUS)[31], but only currently with 2002 data until a new VIUS update takes place.

The dollar value of goods shipped can also be estimated using data from FAF3, itself based on the dollar per ton estimates reported by the 2007 U.S. Commodity Flow Survey.[32] However, this first requires that the right mix of commodities be assigned to the corridor. This in turn requires identification of the appropriate set of origin-destination-commodity flows using the corridor. This means either constructing or purchasing a pre-developed set of these O-D-commodity flows, which are commonly derived as part of the freight plan modeling process.[33] A preliminary extraction of these broad regional FAF3 flows for the eastern seaboard states indicates, as expected, a very different product mix moving northbound versus southbound on through the I-75 corridor. Such differences also imply a different cost associated with late delivery of truck

[30] http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/major.htm
[31] http://www.census.gov/svsd/www/cfsdat/cfs071200.pdf
[32] http://www.census.gov/svsd/www/cfsdat/cfs071200.pdf
[33] In doing so an option now exists to tie such estimates to the broader regional flow estimates reported by the FAF3 procedures described in Chapter 3 of this report (see reference [65]).

Table 6. Example Corridor Level Performance Measures Template

		Northbound	Soutbound
Network Supply		*Northbound*	*Soutbound*
Total Corridor Distance (miles)		159	159
Avg. Mixed Traffic Volume (AADT)		20,713	20,735
Avg. Truck Volume (AADTT)		4,890	5,162
Tons of Freight Transported Daily [1]		28,560,000	32,150,000
Corridor Average Daily Vehicle Miles of Travel			
	Total Mixed Traffic	3,293,332	3,296,895
	Single Unit Trucks (CL5-7)	132,513	125,331
	Combination Trucks (CL8-15)	645,032	695,639
	Total Truck VMT	777,545	820,970
Avgerage mixed traffic volume/road capacity ratio (V/C) [2]		0.5268	0.5274
Travel Time PMs		*Northbound*	*Soutbound*
Avg. Speed (miles per hour)		60.3	60.2
Avg. Corridor Travel Time(minutes)		159.9	159.6
95th Percentile Travel Time (minutes)		170	169
Corridor Planning Time Index		1.24	1.24
Corridor Buffer Index		6.07	6.06
Energy Security PMs		*Northbound*	*Soutbound*
Average Daily Fuel Use (Truck-Gallons)		136,278	145,577
	Single Unit (CL5-7)	10,499	9,930
	Combination (CL8-14)	125,779	135,647
Average Daily Truck Miles per Gallon		5.71	5.64
	Single Unit (CL5-7)	12.62	12.62
	Combination (CL8-14)	5.13	5.13
Mobile Source Emission PMs		*Northbound*	*Soutbound*
Average Daily Emissions (grams)			
	CO_2E	337,642,465	352,823,163
	CO	521,837	541,898
	NO_X	2,453,146	2,578,438
	PM_{10}	105,698	110,461
	SO_2	10,565	11,043
	VOC	103,452	105,570
Travel Cost Based PMs		*Northbound*	*Soutbound*
Average Daily Dollar Cost of Delay [3]		$154,752	$160,899
Average Daily Cost of Travel Time Variability [4]		$93,159	$107,486
Corridor Per Mile Delay Cost Index		1.27	1.28
Safety PMs			
Number of Heavy Truck Involved Crashes in the Corridor (2008)			
Number of Crashes Involving Heavy Trucks per Million Truck MIles (2008)			
Number of Heavy Truck Involved Crashes with Fatalities (2008)			5
Average Per Year Heavy Truck Involved Crashes with Fatalities (1999 - 2009)			*10.2*
Number of Crash Fatalities Involving Heavy Trucks per Million Truck MIles (2008)			0.0168

[1] *Based on an average truck payload of 16 tons.* [2] *Based on Peak Hour Design volumes and capacities (see text);*
[3,4] *VOT = $82.69 per hour VOR = $107.15 per hour for a (VOR/VOT)=1.3*

cargos, another area where a set of detailed O-D Commodity flows (e.g. based on county-level flow matrices) could better inform the performance measurement process.

The volume/capacity ratio shown for the corridor is the FAF3 estimated design hour volume (DHV) of a link in 2007, where the DHV for a link 'a' = Va x a K-Factor, and where Va = the AADTT, and the K-Factor = proportion of daily traffic occurring on the link during the peak hour, expressed as a decimal. For design purposes, this represents the proportion of AADT occurring during the 30th highest peak hour of the year.

Average corridor-wide traffic volumes in both the northbound and southbound direction were very similar in 2009, with almost identical average travel times around 159 minutes. Similar average hourly speeds of around 60 mph throughout the corridor were also found during all four seasons of the year (see Table 7). Looking with each of the four months selected for analysis, only northbound movements in April reported any significant and very temporary lowering in average corridor speeds. However, at the level of planning model/analysis inputs this effect washes out when looked at on an average daily basis.

Table 7. Seasonal (Monthly) Travel Time Performance Measures

Travel Time Based Performance Measures	January		April		July		October	
	*N**	*S**	*N*	*S*		*S*	*N*	*S*
Avg. Speed (miles per hour)	60.7	60.4	60.0	60.5	60.4	60.2	60.8	60.5
Avg. Corridor Travel Time(minutes)	159	160	161	160	160	160	159	160
95th Percentile Travel Time (minutes)	168	167	178	170	168	168	169	168
Corridor Planning Time Index	1.23	1.23	1.30	1.25	1.23	1.23	1.24	1.23
Corridor Buffer Index	5.75	4.96	10.25	6.69	5.31	4.60	5.95	5.09

The corridor-wide planning time and buffer indexes shown in Table 6 are also link VMT weighted averages, and as such represent an approximation to more ideal measures based on using actual truck speeds that have been tracked, using GPS or cellular tracking technology, for a sufficiently large sample of individual truck movements within the corridor. Table 7 shows the equivalent planning time and buffer index measures for four specific travel months in 2009.

Corridor Motor Fuel Consumption and Mobile Source Emissions

The motor fuel consumption and emissions measures shown in Table 6 are also simple summations over the corridor's link specific totals listed in tables 5a and 5b above.

Corridor Travel Cost Measures

Three travel cost PMs are also included in the Table 6 template. The average daily dollar cost due to delay measures the difference between the free-flow travel time on a link (based here on a speed limit of 70 mph) and the average travel time reported for that link, multiplied by that link's truck volume, summed over all links in the corridor. This "lost" time is then multiplied by a value of per hour truck operating costs. A cost of $82.69 per hour was used here (see [39] and the discussion in Section 2.7 above).

The third travel cost measure shown in Table 6 is based on the above two measures (defined in Section 2.7 of this report as measure # 43), i.e.

Per Mile Delay Cost Index = (Estimated Per Mile Travel Time Costs for the Corridor / Per Mile Corridor Travel Time Costs at Free Flow Travel Speeds)

where Estimated Per Mile Travel Time Costs for Corridor = [(Mean Truck Travel Time *VOT) + (SD of Travel Time * VOR)]/ Corridor Length in Miles,

where SD = Standard Deviation of Travel Time (minutes); VOT = Value of Travel Time ($/minute); and VOR = VOT * Reliability Ratio ($/minute)

and

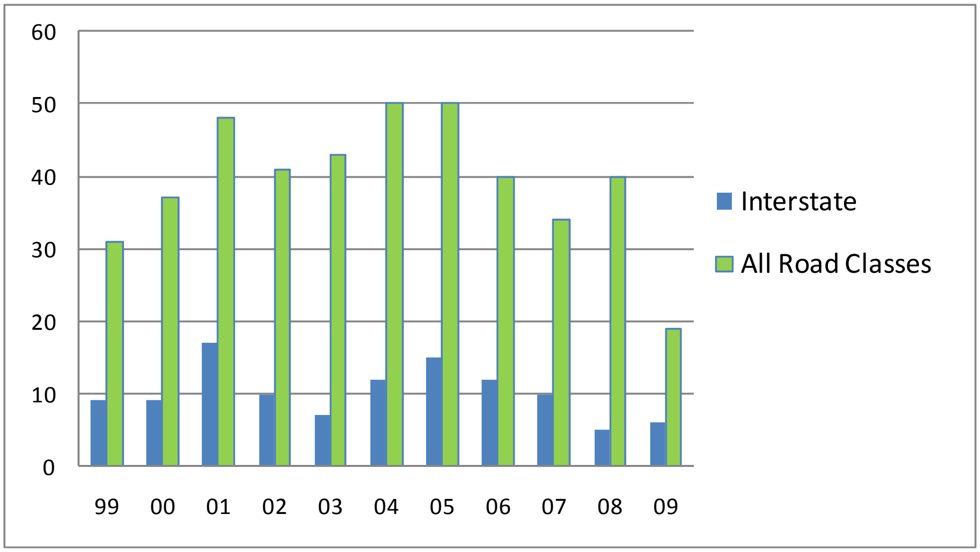
Travel Time Costs Per Mile at Free Flow Travel Speeds = (Free Flow Truck Travel Time for the Corridor *VOT) / Corridor Length in Miles

and where there is assumed to be no or minimal variability in travel times along the corridor at free flow speeds. The standard deviation of corridor travel times was computed by summing the variances of the 28 individual link specific travel times and taking the square root of that sum. This implies no significant correlation between the speeds on adjacent links. This is considered a reasonable assumption given the relatively low levels of hourly congestion on the corridor under typical operating conditions. However, as congestion levels, and V/C ratios, increase within the corridor, this may not be true in the future. Such conditions will then require access to individual truck travel speeds on the corridor, initially to test the assumption of independence being made.

Corridor Safety Measures

A number of Safety PMs are also in the template, and values were computed for those crashes involving one or more fatalities (based on FARS data). Figure 13 shows the temporal incidence of these heavy truck related accidents for both the I-75 highway and also for the non-Interstate highways in the rest of the study corridor.

Both number of incidents, as shown in Figure 13, and number of fatalities (as reported in Table 6) are available. Similar measures covering all truck involved accidents can also be derived on an annual or running average annual basis, using the State's Department of Motor Vehicle Safety CASI database (cf. Section 3.5 above), with truck size and body type breakdowns of the crash data also possible.



Note: Source: FARS data. See NHTSA (2010) and Section 3.5.2.above.

Figure 13. Number of Fatal Accidents Involving Heavy Trucks, 1999-2009

4.4 Regional Truck Accessibility and Mobility PMs

Due to limited time and resources, regional accessibility measures were not developed for the present study. Measures such as those described in Section 2.8 of this report are usually derived as part of a state DOT's freight plan (modeling) process, making use of model-generated commodity flow matrices of the type useful for estimating the value of goods shipped through the corridor. The two principal inputs to the sort of accessibility measures discussed above are 1) a set of truck travel times (and costs), and 2) a set of spatially explicit truck traffic generators and attractors with which to weight the importance of these travel times.

'First and Last Mile" Truck Travel Speeds

A good deal of time can be spent getting to and from Interstate highways, especially if local traffic builds up on low capacity rural roads. In an effort to look at this issue, truck and mixed traffic volume and speed data on non-Interstate highways was obtained from GDOT's traffic data center. Much of this data is indexed at the county level. Using data for the 43 counties highlighted in Figure 5 above, 38 of GDOT's automated traffic recording (ATR) sites were identified as providing both truck and mixed traffic volume data within this study area, mostly in the form of daily mixed traffic (AADT) estimates and the percentage of this traffic made of trucks on both an average weekday and an average weekend day, with sites reporting for only 17 of the 43 counties in 2009, of which with 13 were found in Bibb county (around the city of Macon, GA). Such clustering of traffic count sites is common in other parts of the state, as well as in other states. This data can provide very useful information on broad regional trends in local and arterial truck volumes, and if tracked, truck speeds. Even if truck speed data is not collected, as is currently the case at most of these sites, V/C ratios might be used to approximate them. However, with or without speed recording at most sites, the database's spatial sample is not designed for region-wide planning study purposes, so that average truck speeds for many of the major truck route connectors that feed into the I-75 corridor could not be estimated.

GPS tracking of truck speeds on non-Interstate highways offers one promising solution to this situation, in support of such first and last mile truck access/egress measures, as well as a potentially providing a sound empirical basis for estimating O-D truck times, and hence also truck travel costs, for use in plan (model) development.

Truck Traffic Generators and Attractors

Obtaining sufficient traffic volume data for planning purposes also remains a major spatial sampling challenge, given typical budgets for traffic acquisition, operation and maintenance. As the number of GPS tracked trucks increases, an intriguing possibility may exist here. This involves recording the overnight locations of GPS enabled trucks to identify major truck trip generators and attractors within a corridor or region. If supportable by sufficient sample sizes (and found acceptable to trucking firms supplying the data), such an approach might act as an adjunct to, as well as a means of validation for, the sort of economic activity-based truck trip generation and attraction modeling typically carried out as part of the freight plan development process (as described in [66], for example).

4.5 Reducing PM Template Content for General Use

Table 6 contains a number of measures that may be of less interest/difficult to explain to non-transportation planners and engineers, and as such is most useful as a planning input template. Remembering the fifth general element of a good performance measure introduced at the start of Chapter 2 (page 5) of this report, i.e. that performance measures should be "easily understood by decision-makers", at least two different types of performance measurement presentation may be warranted: one that supports freight planning studies by transportation specialists, and one for more general use by non-transportation specialist decision-makers, the media, and the general public. A possible subset of corridor specific performance measures might be:

1. Number of trucks using the corridor on a typical day
2. Number of tons carried by trucks using the corridor in a typical day
3. Average speed of corridor traffic on a typical day
4. Average daily cost to trucking of traffic delays (congestion)
5. Percentage of corridor subject to congested (e.g. a design hour volume V/C ratio > 0.8)
6. Total fuel used by trucks in the corridor daily or annually
7. Total greenhouse gas (CO_2e), and criterion pollutant emissions produced by trucks in the corridor daily
8. Number of truck related accidents per million truck miles of corridor travel

The data collection challenge is then to track how each of these measures changes, for the better or worse, from year to year. This can be done using simple line graphs to show these year to year trends on a common (e.g. percentage or proportional change) scale.

5. Summary and Conclusions

5.1 Status of Performance Measurement and its Value to Statewide Freight Planning

Measuring transportation system performance on a periodic basis offers at least two important benefits to planners and policy makers. First, it provides quantitative evidence of how well the system is performing and whether travel conditions have been improving or getting worse over time. Second, it offers useful benchmarks against which the success of the transportation planning process can be assessed, and possibly re-directed where a particular trajectory needs adjustment.

The review of latest practices in truck freight performance measurement, as reported in Chapter above, testifies to the growing importance of performance measurement as an ongoing, and necessarily quantitative activity. The review also identifies a rapidly evolving field of activity, both in terms of measurement concepts as well as in the deployment and the scope of the technologies now being used to collect the measurements themselves. These technologies include the increasingly widespread use of GPS satellite, cellular phone tower, video camera, and improved in-pavement counter-enabled tracking of individual vehicle movements, as well as RFID monitoring of on-board cargos and wide-area surveillance of traffic patterns, using variously supported forms of aerial photography. These technologies are changing the way we will collect traffic movement data in the future.

While already enormously valuable for tracking on-going traffic operations, these new information technologies can also be put to use in the multi-year transportation planning process. Doing so effectively, however, requires good areawide, and ideally statewide geographic coverage. While not all roads need be monitored to get an accurate sense of the overall growth, commodity and vehicle class make-up of truck traffic, a sufficiently representative sample set is needed to support a planning process that is strongly dependent on the volume of origin-to-destination (O-D) movements of freight moving within, as well as into and out of the state. In Georgia, as in most (probably all) states in the Union, the development of detailed origin-to-destination truck, and more generally freight, movement matrices is a significant challenge that poses problems for data collection in a time of limited data collection budgets.

5.2 Strengths and Weaknesses of Existing Data Sources (for Plan Oriented Performance Measurement) in Georgia

The performance measures reviewed in this report appear to be well suited to the analysis of long-haul truck freight movements within the state, and to assessments of the performance of high volume truck freight highway (principally, Interstate) corridors. A number of the performance measures reported in the Table 6 example corridor level PM template (cf. page 56) were generated from existing data sources, while others (notably regional accessibility measures) could also be generated as outputs from current freight planning model software. However, all of the measures reviewed could be improved with the creation of more complete datasets. This was not an unexpected result. Much of the traffic monitoring carried out by State DOTs today has to date been geared to site specific monitoring of day to day traffic conditions. And while it has long been recognized that the sum total of this monitoring data offers many possibilities for use in longer range freight movement planning, the needs of planning studies that build their economic assessments around origin-to-destination (O-D) movements of goods between counties or other similarly sized traffic analysis zones typically put a good deal of strain on existing traffic count data.

Table 8 summarizes this study's major conclusions with regard to availability and quality of current FPM data sources, as applied to the performance of high volume trucking corridors in Georgia. The last column of entries suggests some data improvement options. The following paragraphs provide a brief expansion on these findings as they pertain to truck travel speeds, traffic volumes, and truck operating costs.

Truck Speed Data: Perhaps the most immediate benefit from this information technology revolution to date has been a much improved ability to capture vehicle operating speeds. The GPS-based American Transportation Research Institute (ATRI) truck speed data used in this study is a leading example. ATRI is part of the American Trucking Associations Federation. One particular benefit of being able to record vehicle movements and speeds continuously for long periods has been the ability to determine not just average trip travel times, but also the hour to hour and day to day variability in such times, and to the recognition that trip time variability can translate into unreliable, and potentially costly, arrival times. This is an important topic for both trucking firms and for freight planners in the public sector who are trying to support on-time goods deliveries in the face of growing levels of daily mixed passenger and freight traffic congestion.

While the publicly available speed data from the FHWA supported ATRI website used in Chapter 4 of this report was limited for study purposes to pre-averages hourly mean truck speeds for specific three-mile Interstate segments, this data was found to be invaluable in estimating average link specific as well as corridor-level, route specific Interstate speeds that are well suited to planning studies. The ability to experiment with a full calendar years' worth of hourly speed data also made it possible to consider whether hour of the day, day of the week, or month of the year average speeds differ sufficiently to warrant separate evaluation. This data also allowed a set of approximate on-time reliability measures to be derived that appear to be acceptable for use in strategic planning studies. This said, direct access to individual truck tracking data here is highly desirable, especially in trucking corridors experiencing congested traffic conditions.

Table 8. Current and Future Data Possibilities for Measuring the Performance of High Volume Truck Corridors in Georgia

Performance Measures	Quality of Current Data Sources			Areas of Current Use	Areas for Improvement	Possible Solutions
	Good	*Medium*	*Poor*			
Traffic Volumes		X		Estimation of link and route level truck volumes and VMT shares by direction, truck class (also by speed bin in some instances).	Better spatial coverage of major truck trafficked routes. More counters with vehicle class identification capability. Current data gaps limit the creation of a complete time series of truck class specific volumes based on existing count sites.	Increase the number of counter sites, especially on feeder ('first and last mile') routes. Determination and selection of a representative set of off-Interstate traffic counter sites suitable for year to year tracking of truck volume. Possible eventual use of GPS tracking of trucks to better distribute truck count volumes to specific network links.
Travel Times/Travel Speeds	X			GPS reporting of average hourly network link speeds can be used to estimate multi-link corridor average travel times. This data can also can be used to approximate travel time variances on non-congested routes.	Complete O-D truck trip route and speed profiles are needed in order to develop accurate measures of travel time variability. Expansion of tracking to major non-Interstate highway links.	Acquisition of individual truck GPS tracking data. Increased sampling on non-Interstate routes. (This is a relatively new data source, so an historical database will need to be established).
Transportation Costs		X		Used in travel time delay and on-time reliability costs. Good formulas for per mile operating and maintenance costs, but empirical datais hard to obtain for specific truck classes.	Closer linkage of costs to specific truck types and both the class and volume of commodity being carried. There is limited data on cargo carrying costs on specific truck corridors or for specific O-D pairs.	Linkage to freight planning studies that include detailed modeling of O-D commodity flows and their use of specific truck corridors
Energy Security & Mobile Source Emissions	X			EPA MOVES software can be used to generate per mile motor fuel consumption, criterion pollutant and air toxis empssions rates by 5 mph speed intervals and for a number of truck body/size types.	MOVES truck classes are not the same as FHWA or GDOT truck classes.	Develop a crosswalk between the two truck classifications.
Travel Safety	X			Multi-year crash data exists, much of it with detailed geographic specificity for link identification. This includes GDOT's CASI and NHTSB's FARS databases. "Large truck" involved accident rates are possible, as are numbers of hazardous materials involved accidents.	Crash rates by high traffic volume corridors might be developed. The CASI database contains additional truck class details, but they do not match GDOT or FHWA traffic volume classes	GDOT merges the Georgia DMVS dataset on crashes with its annual traffic volume estimate to obtain accident rates per million miles of travel, and per resident, at the county as well as statewide level. Similar results for specific high volume corridors might also be developed, focused on truck-involved incidents.
Corridor Accessibility to High Volume Freight Generators		X		Network accessibility measures are usually generated as part of the strategic/multiyear freight transportation planning process. They are rarely treated as performance measures outside this process.	A closer linkage between empirically derived highway network performance measures and the estimates of travel times and flows in freight planning studies would help to establish a sound plan baseline, as well as track plan projections. The performance of local highway connectors to and from key freight facilities, including the State's major truck-rail terminals, air-, sea- and inland port facilities, warrant regular monitoring in order to forestall costly traffic delays.	Use empirically derived average truck speeds on 'first and last mile' corridor connectors in the freight plan generation process. There may also be a cost effective use of GPS technology here as a means of identifying where large numbers of over-night trucks are parked, prior to commencing the next day's freight movement activity: as either an alternative or an adjunct to current truck trip generation estimation techniques.
(Truck O-D Patterns)		X		Estimates of truck origin-to-destination (O-D) flow patterns are a key component in the State's Strategic Freight Plan.	Aggregate truck O-D flow patterns are well represented in the statewide freight planning process, based on recent roadside truck O-D surveys (not used in this present study). However, the linkage between commodity classes and tonnages moved, and the types and numbers of trucks needed to move them is an on-going challenge for all State DOTs, and this relationship is important to O-D truck forecasts based on forcecasts of economic activity.	Roadside or weight station surveys of truck O-D movements, incorporating cargo (commodity) details. Such data needs to be collected at regular intervals (e.g . every 6 to 8 years) in order to keep up with changes in freight movement patterns. Analytic methods that combine non-intrusive truck counts, the results of truck O-D surveys, and FAF-based estimates of cargo value may be one way to keep down the size, and hence cost of (as well as traffic disruptions caused by) such O-D surveys.

Based on the FHWA/FAF3 projections of Interstate truck traffic growth between now and 2040, major freight corridors such as I-75 will see increasingly high levels of congestion if the historic growth in truck traffic volumes continues. The various travel time variability measures reviewed in Chapter 2 of this report become more difficult to calculate given high serial link speed correlations.

Given individual truck speed profiles, for corridor length movements, or better yet, for specific door-to-door (O-to-D) trips, also allows the investigation of non-recurrent traffic delays. This is an important area for future development with incidence based delay costs becoming more important as corridor traffic volumes continue to grow.

Truck Volume Data: Less well developed to date, but clearly improving over time, is our ability to estimate on-road traffic volumes. While traffic volume measures are also possible from GPS and other in-vehicle tracking devices, much larger sampling is needed to get representative estimates of truck or other vehicle volumes, so that other forms of roadside surveillance equipment are currently preferable. In most rural areas such as the corridor examined in this present study, there are as yet far fewer traffic counters per highway mile than in and around our cities. Where traffic counts were taken continuously and included truck speed ranges as well as truck classification counts, the data was found to be in excellent condition, well maintained and easy to use. The principal data gap here is caused by the limited number of such counters currently, and their need to be used for various monitoring purposes that do not necessarily locate them at sites best suited to O-D truck trip estimation. This is a problem faced by all State DOTs, and comes down to priorities in the use of limited traffic monitoring resources. Many of the counters also do not capture bi-directional speeds or record truck counts by vehicle size/body class, while the mobile versions of the State's traffic counters are often needed to monitor specific locations where new construction, higher incident frequencies, or other site specific, and day to day operational conditions need to be tracked. In Georgia, a three year site rotation scheme has been used for some of these traffic counters. This presents problems for planning studies that require a more even spatial, as well as regular periodic sampling of traffic count sites, on a year to year basis, with coverage of all major roads in order to develop a complete picture of traffic, including truck, movements. This includes the vehicle volumes and speeds on those arterials or local connectors feeding large numbers of trucks onto and off the State's Interstates on a daily basis.

Truck Cost Data: Better disaggregation of truck traffic volumes and truck speeds will provide opportunities to better estimate truck movement costs, and in turn the cost to trucking of delays in transport. As better vehicle speed data becomes available, better fuel cost estimates will result, but these are only one (albeit an important) component of total trucking costs. While there is currently no definitive method for capturing the range of vehicle operating costs by truck size, body type, and type of commodity carried, on a corridor specific basis, the literature contains a number of examples of truck costing models and formulas that might be used. Examples include the software developed by Berwick and Farook (2003) [67], the US DOT's ITIC software [68], and the recent work by ATRI [39]. A significant challenge still to be met is the identification of what sort of freight is moving along specific truck corridors. While the data available from the FHWA's Freight Analysis Framework (FAF) website contains a good deal of data on commodity flows, these annual movements are reported in the form of a 123 x 123 flow matrix for the entire country. As the review of truck cost based performance measures in Chapter 2 point out, not knowing the type of cargo being carried makes it difficult to assess the costs of transport. Some commodities require higher insurance carrying costs than others, while some have steeper penalties on late delivery. Higher costs to transport usually translate into higher freight rates being charged. Any en route delays can therefore mean higher costs to shippers, or lost revenues to trucking firms faced with tight logistics deadlines, and possibly late delivery penalties. Better estimates of the mix of commodities being moved along specific corridors can therefore improve significantly estimates of the cost of travel time delays on such routes.

Truck O-D Data: Finally, while not used directly in this present, corridor-oriented study, Table 8 also lists *Truck O-D Flow Patterns* as a Performance Measure worth tracking, and based for its raw data on a combination of truck volume counts and periodic roadside surveys of trucks traveling on the State's major highways. This is always a challenging data element to obtain for any state DOT. Where data on cargo carried, and specifically data on tonnage and commodity class, is also obtained from such surveys, this data can be used to better match vehicle flows to commodity flows. With forecasts of county specific economic activity often used as the basis for forecasting statewide commodity flows, this linkage between truck O-D movements and commodity O-D movements is an important aspect of statewide freight planning. By tying the sort of truck traffic volume estimates described in this report more closely to these O-D truck movement estimates, and by linking these O-D truck flows to O-D specific commodity flows, a basis exists for a closer linkage between corridor specific truck traffic forecasts and O-D specific economic activity forecasts.

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