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16. Abstract

Federal and state transportation planning and policy has begun to focus on highway performance measurement, balancing goals, performance measures and measurement. The push toward performance measurement first focused on passenger vehicles, largely ignoring the measurement of freight-related (truck) performance. The period since 2000 has seen a handful of DOTs examining broad indicators of efficient freight movement, but as of yet, there was no definitive work in the area until a 2003 FHWA funded project began to look into various freight tracking technologies to develop freight performance measures (FPMs), finally selecting a GPS technology widely adopted by U.S motor carriers. At the time of this study report, the FHWA study worked on data manipulation and graphical representation of highway speeds, but has yet to use the data for alternative performance measures or examine the possibility of using the truck respondents as probe vehicles for real-time ITS applications. The purpose of this report is to develop a set of universal FPMs, as well as looking into various applications, both real-time and long-term planning, for the truck GPS data collected as part of the FHWA study.

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Developing Appropriate Freight Performance Measures for Emerging Users

by

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Research Report SWUTC/07/473700-00073-1

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September 2007

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ABSTRACT

Federal and state transportation planning and policy has begun to focus on highway performance measurement, balancing goals, performance measures and measurement. The push toward performance measurement first focused on passenger vehicles, largely ignoring the measurement of freight-related (truck) performance. The period since 2000 has seen a handful of DOTs examining broad indicators of efficient freight movement, but as of yet, there was no definitive work in the area until a 2003 FHWA funded project began to look into various freight tracking technologies to develop freight performance measures (FPMs), finally selecting a GPS technology widely adopted by U.S motor carriers. At the time of this study report, the FHWA study worked on data manipulation and graphical representation of highway speeds, but has yet to use the data for alternative performance measures or examine the possibility of using the truck respondents as probe vehicles for real-time ITS applications. The purpose of this report is to develop a set of universal FPMs, as well as looking into various applications, both real-time and long-term planning, for the truck GPS data collected as part of the FHWA study.

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EXECUTIVE SUMMARY

Since the early 1990s and the beginning of the emphasis in the U.S. on performance, transportation planning and policy has begun to focus on performance measurement, leading the U.S. to a turning point between creating appropriate goals and performance measures and actually executing them. During this push towards performance measurement, the focus has been on passenger vehicles, largely ignoring the measurement of freight-related performance. In the past several years, a handful of DOTs have begun looking into some broad indicators of properly functioning freight movement, but as of yet, there has been no definitive work in the area.

A 2003 FHWA-funded project began to look into various technologies for tracking freight movement for the use of developing freight performance measures (FPMs), finally settling on GPS units already installed in many motor carrier fleets. Up to this point, the study has extensively worked on data manipulation and some graphical representation of highway speeds, but has yet to make use of the data for alternative performance measures or look into the possibility of using freight locations as probe vehicles for real-time ITS applications. The purpose of this report is to develop a set of universal FPMs, as well as looking into various applications, both real-time and long-term planning, for the truck GPS data currently being collected.

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CHAPTER 1. INTRODUCTION

Since the early 1990s and the beginning of the emphasis in the U.S. on performance, transportation planning and policy has begun to focus on performance measurement. While the move towards performance-based planning is still in its infancy compared to other notable examples abroad, the completion of some major projects recently at the federal level as well as many of the DOTs seems to indicate that the U.S. is at a turning point. Many planning agencies throughout the country are at a stage between completing the planning required to create appropriate goals and performance measures and actually executing them.

During this push towards performance measurement, the focus has been chiefly on passenger vehicles, the transportation infrastructure itself, and economic concerns. While these are all very important indicators of a transportation systems success, one major area that has been largely ignored is the measurement of freight-related performance. More and more studies as of late conclude that among the primary concerns of the motor carrier industry are congestion and reliability of the highway system. Many are looking to toll-roads as the cure-all for these problems, but few have attempted to quantify in any way the specific needs of freight movement. In the past several years, a handful of DOTs, most notably Minnesota and New Jersey, have begun looking into some broad indicators of properly functioning freight movement, but as of yet, there has been no definitive work in the area.

An FHWA-funded project started in 2003 and carried out by the American Transportation Research Institute began to look into various technologies for tracking motor carrier movement in the U.S. for the use of developing freight performance measures, finally settling on GPS units already installed in many motor carrier fleets. The past three years have shown that this data has a wide range of uses very applicable to identifying the failures, successes, and needs of the highway system specifically relating to goods movement.

Up to this point, ATRI has extensively worked on data manipulation and some graphical representation of highway speeds, but has yet to make use of the data for alternative performance measures or look into the possibility of using freight locations as probe vehicles for real-time ITS applications. The purpose of this report is to develop a set of universal freight performance measures, regardless of what technologies are available, as well as looking into various applications, both real-time and long-term planning, for the truck GPS data currently being collected.

CHAPTER 2. PERFORMANCE MEASURES IN THE US AND ABROAD

2.1 History of Performance Measures

Since the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 put an emphasis on performance, performance measures have been at the forefront of transportation policy in the US. The most commonly accepted factors encouraging this trend in planning include:

- A reduction in available resources as compared to current transportation needs,
- A need to get user support for infrastructure investments, facilitated by the easily communicable results of performance measures,
- More timely response to transportation needs, and
- A desire of the customer to increase the accountability of decision-makers involved in public spending. (TRB Proceedings 26)

Most advantages of performance measures boil down to the desire of the users and owners of our transportation system to get more value from their dollars spent. This is possible through the pro-active approach of making good performance measures, properly evaluating them, and inputting this information into the planning process, each of which can be a tricky process. It is generally accepted that performance measures are not a trend, but rather a permanent and integrated part of the planning process that will presumably be used by transportation agencies at all levels.

2.2 Types of Performance Measures

The performance measures used by a given agency should start with an end product in mind. This can include the transportation or community goals of the agency, but can also simply address information needs of the decision makers. Beginning with a goal can help to ensure that a successful change in performance leads to successful completion of the goal. Without a clear definition of objectives, the measurement of performance indicators can be a waste of resources. Figure 2.1 shows the elements of a performance-based planning process, particularly how changing goals, creating performance measures, collecting data, and evaluating can be a cyclical process.

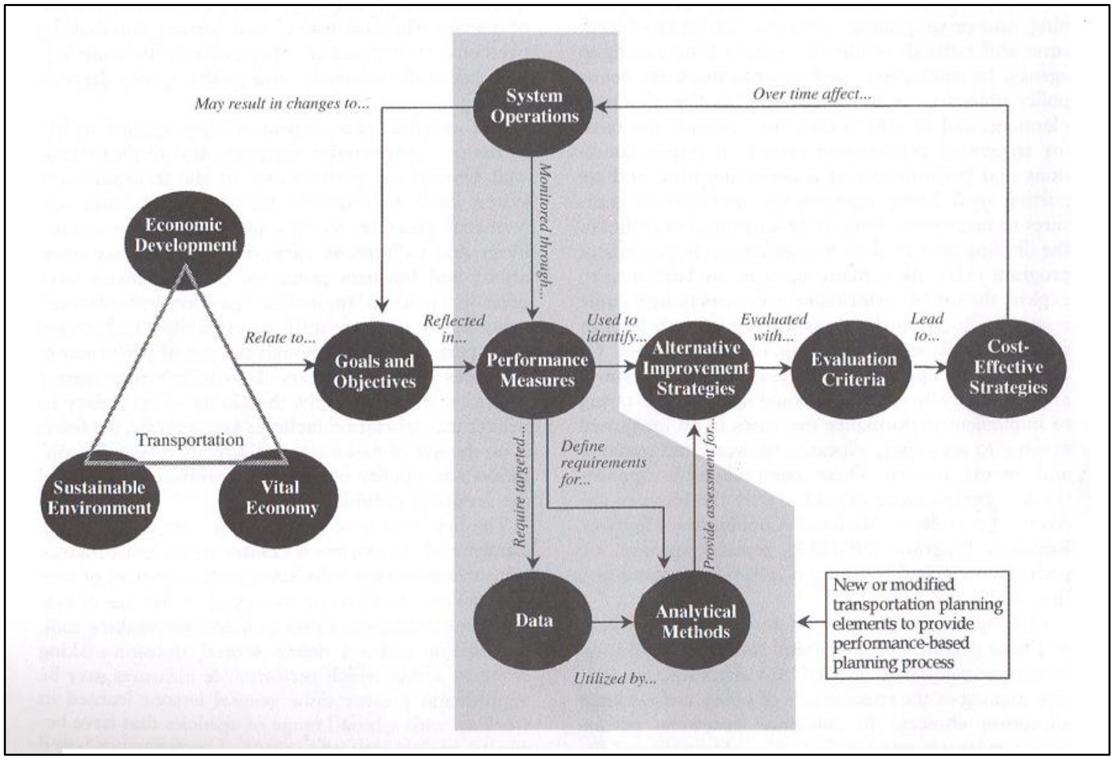


Figure 2.1 Elements of Performance-Based Planning (Cambridge Systematics, Inc., 2000)

Starting with a given set of objectives in mind can lead to a variety of needs, naturally leading to performance measures that fall into a few categories:

- Input: performance measures that relate to the amount of resources spent on a specific problem or in a specific region (e.g., dollars spent to alleviate environmental transportation problems),
- Output: performance measures that relate to physical progress being made in a specific area (e.g., length of pedestrian paths constructed in a given calendar year), and
- Outcome: performance measures focusing on improvement over time (e.g., average delay time on a city network).

It is important that decision makers take all three performance measure types into account to get an accurate picture of resources expended, the immediate result of those expenditures, and the eventual result of the expenditures. Only with all three of these viewpoints can policy makers evaluate the success of their policies and modify them appropriately. Good performance-based planning leads to performance measures that are fluid – constantly changing and improving to meet public needs.

2.3 Specific Advantages of Performance-Based Planning

Given the public-sectors reasons for making a gradual shift to a performance-based planning system, there are some implied advantages to using performance measures. These advantages may or may not be taken full advantage of by the planners and decision makers, which makes it all the more important for these professionals to consider them before the measures are even set. Advantages of performance-based planning are quite widespread, but typically fall into three categories: communication with the public, accountability on the part of the planners to make effective decisions, and an overall improvement on operations.

Communication

As a direct result of making objectives that are explicit and quantifiable, with a focus on progress, communications between decision makers and the general public will naturally occur. The nature of a good performance measure requires that it be easily understandable and measurable, creating new clarity that eases communication on all levels: agency to agency, planner to planner, and agency to the public.

Accountability

Setting specific performance-related goals allows resources within an agency to be focused on problem areas, increasing efficiency on all levels, while also improving the connection between the objectives of decision makers and the objectives of the users of the infrastructure. Overall, this “reflects a shift in agency thinking away from simply output (e.g., “tons of salt applied”) to outcome (e.g., “reduction in ice-related fatalities”)”. (Cambridge, 2000) This focus on objective creates a simple method of tracking whether both long-term and short-term goals are being met and whether resources are being allocated appropriately, resulting in an overall increase in agency accountability.

Operational Improvement

With the clarity of goals produced by this planning process and maintaining these goals over a span of years, evaluating the success of goals over time becomes an easy matter. With better knowledge of the impact of their decisions over time, planners can adjust to accomplish consistent improvement over time, which should be the goal of any agency.

2.4 Important Features for Performance-Based Planning

While the performance-based planning system has been summarized in a variety of ways over the years, which may not have an effect on agencies’ improved understanding or application of the system, most of these outlines are essentially the same in that they generally contain as a minimum these five broad steps: setting the goals of the agency, refining goals into specific objectives, specifying measurable indicators, data collection and evaluation, and the use of the results. Figure 2.2 shows the iterative nature of these five steps and their application to ITS.

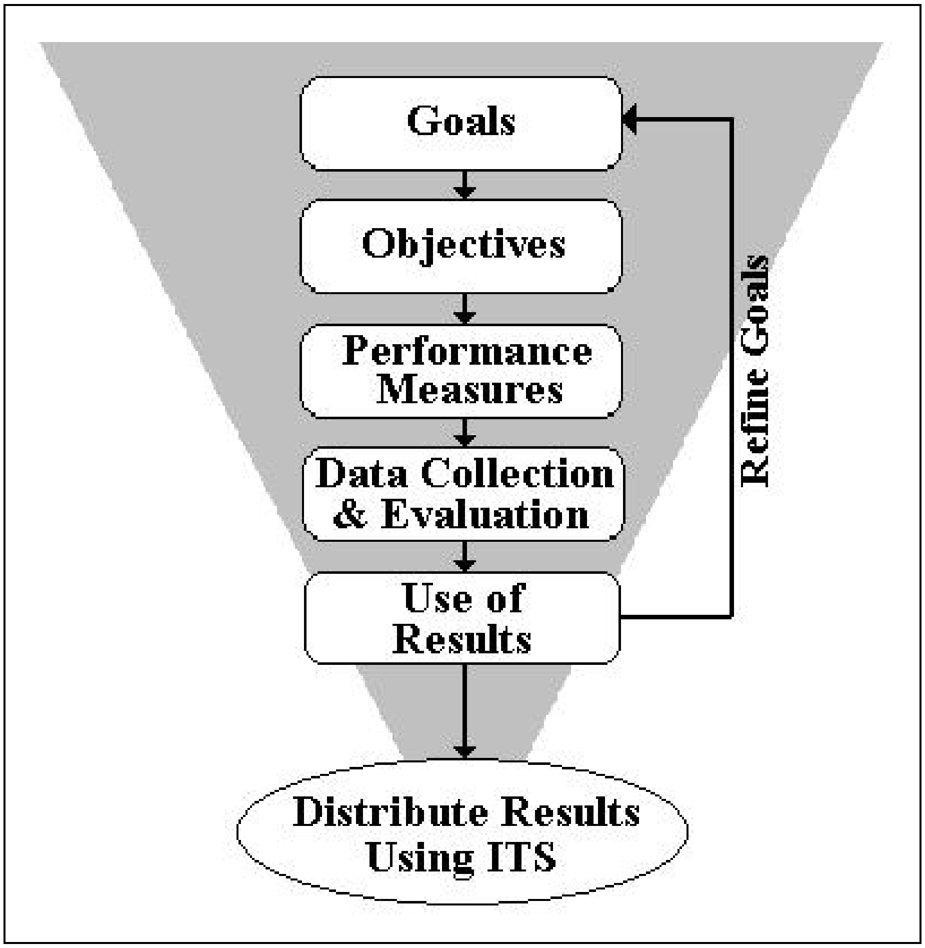


Figure 2.2 Five Steps of Performance-Based Planning

Goals

The goals of a transportation planning agency are generally quite broad. They are also fluid and in a properly working system are based on the results found in the last period of performance-based planning. For example, Transit New Zealand's "Triple Bottom Line" plan focuses on three parts: economy, social aspects, and the environment. These three goals form a framework and vision for the agency to plan around, yet are broad enough to remain flexible and allow change from year to year as necessary.

Objectives

The objectives of an agency should be nothing more than a reflection of the goals with added detail. This makes sure that the objectives, if achieved, will actually have an impact on the overarching goals. For example, in the case of Transit New Zealand, following along with their goal of economic improvements, there could potentially be an objective "Increase economic efficiency of capital projects".

Performance Measures

As objectives are simply more focused versions of the overall goals, performance measures should focus on specifying a measurable indicator of how well the objective is being completed, that could also be usefully fed back into the decision making process. Tracking performance measures that are not linked to a specific objective uses resources that could be better spent elsewhere. There should also always be causality between a performance measure and things that planners can affect. If a problem cannot be solved by tracking performance, than using performance-based planning is not appropriate.

To measure the performance of the hypothetical New Zealand objective above, a proper measure could be "Increase the percentage of capital projects delivered on time and within budget to 90%" within a specific time period. This measure is very specific, very measurable, and can be used to determine if the objective is being accomplished.

Data Collection and Evaluation

A simple, but important question to ask before creating a performance measure is "What are the data requirements and is the collection feasible?" If either the data is not collectible or the required analysis is not possible, there is little to gain from following through with the performance measure.

It is important to think of the evaluation of the collected data as the same step since performance should be evaluated regularly when the data is available. The closer the decision makers can get to real-time data collection and evaluation, the more quickly and efficiently they can respond to problems.

Use of Results

This step in the performance-based planning process is the most open-ended in that it is entirely up to the decision makers to what extent the results of the evaluation are used. It is also probably the most critical step. A failure to take full advantage of the results of performance measurement constitutes a waste of both time and money, so it is therefore of extreme importance that decision makers attempt to take advantage of every facet of utility possible.

One of these facets is the feedback of this information to the decision makers at the front-end of this process, those creating goals and defining performance measures. Only through this constant feedback can the full potential of this planning style be realized, in theory leading to increasingly minute changes and an eventual meeting of our goals. An equally important audience for receiving performance information is the user of the system. This not only helps to increase accountability for decision makers, but also assists the user in making more informed travel decisions.

2.5 Current National and International Performance Measure Practices

A brief study of performance-based planning worldwide shows that there is a large gap between countries and agencies that are changing their transportation planning process to a more proactive approach of using performance measures and those that are still very reactive in responding to transportation problems. Five of the countries that seemed most willing to adapt to this new form of planning are Australia, Canada, England, Japan, and New Zealand, as evidenced by their annual planning reports and outside investigative reports over the past decade. (Transit NZ, 2003; MacDonald, et al, 2004; Geiger, et al, 2005) In this time, the US has begun to shift in the same direction, both at the national and state DOT level, but has as yet not had much time for refining and utilizing performance measures. To get an overview of these more aged and refined international systems, Japan will be used as a case study, as they have highly optimistic goals that they appear to be on track to meet and their linkage of performance measures with ITS is unmatched in the world.

2.6 International PMs: A Japan Case Study

Japan's primary performance measure is congestion, with approximately 750 billion yen ($7 billion US) per year being spent to alleviate the problem. This is a major problem because of the extremely high population density of the country, but the Ministry of Land, Infrastructure, and Transport (MLIT) has fairly optimistic goals set in their performance measures. Between 2003 and 2007, the goal is to reduce time loss due to traffic congestion by 10%.

When determining the level of congestion and time lost in certain segments, several different methods are used, including the road traffic census, visual observation, vehicle detectors, and probe vehicles. The road traffic census is carried out every five years and collects data on road conditions, traffic volumes, and traveling speed, as well as conducting some roadside interviews of drivers on the roads. It can be used as a crude measure of how well roads are operating and in this case, the time delay caused by congestion. The only problem with this census is that it may depend too heavily on drivers' opinions, which may be overly negative when they are being interviewed in the traffic. Generally, these census's cover only the major arterials and freeways on one weekday and one holiday.

Visual observation is not necessarily unreliable, but it can involve a lot of man-hours on the part of the roadside counters, especially for high density sections of road. It consists of traffic counters sitting at stands on the side of the road counting the traffic volume per hour at various road segments at various times of day, sometimes the whole day. Due to the very labor-intensive nature of this work, loop and ultrasonic type vehicle detectors are widely used for traffic counting. Video vehicle detectors are in late development and early use in many parts of Japan. The main advantage of these is that without disrupting any pavement, vehicles can be detected over a very long and wide distance down the road.

The most advanced type of congestion measurement is the use of probe cars, which are beginning to be used widely throughout Japan. Vehicles on the road, often buses or other public vehicles, are equipped with some type of location device to obtain location and time data. The device can be part of a large network of electronic tolling towers, GPS (global positioning systems), or any other type of equipment that can determine a precise location for the vehicles moving in traffic at each time increment. This data is then relayed for data processing and accumulation. With one system of collection, a large array of information can be found, including traffic speed and lost time by congestion. Under the assumption that the probe vehicle accurately portrays the average vehicle and inputting average flows, a total lost time due to congestion can be found.

When a final output of the performance measure is achieved, it can begin to be used for policy evaluation. Often times, with congestion, this can include construction work planning, as it is very important to be aware of the times of day, week, and year when traffic is the most sensitive to negative changes. On a broader scale, however, all performance measures in Japan are evaluated annually, which often reflects directly on the budget and staffing made available to various sections of the government. Sometimes, full funding is only available when performance measures are met. For the most part, the varying performance in different areas shows officials at the MLIT where resources need to be shifted (1). Figure 2.3 shows a chart representing the process of using performance measures to influence policy in Japan.

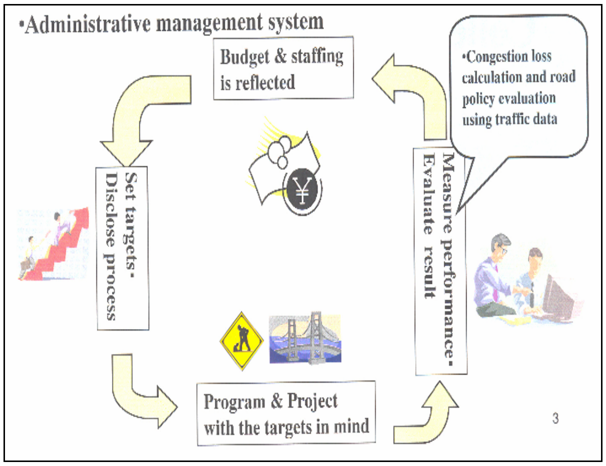


Figure 2.3 Use of performance measures (MLIT).

Probe cars can be a very useful tool in evaluation of performance measures. For example, during or following roadwork, the probe cars can determine its effect on both congestion and accident rates. It can then be decided whether these are at an appropriate or acceptable level. The information provided by the vehicles can allow policy-makers to determine whether their traffic flow goals are being met and to come up with priority plans and budget allotments. After project completion, probe cars are effective in determining the overall benefit provided by a project, which can be associated with a cost-benefit analysis. In 2003, the MLIT began evaluating all programs and projects and rating them with an “outcome index” which takes any number of performance measures into account. None of that would be possible without the development of ITS, especially probe cars (2). Chapter 4 describes the interactions between performance measures and ITS in a properly working performance-based planning system.

CHAPTER 3. FREIGHT-SPECIFIC PERFORMANCE MEASURES

3.1 Overview of US Trucking Industry

The motor carrier industry can be divided into two distinct categories which often share the same goals: private carriers and for-hire carriers. Private carriers transport goods for their own company, while for-hire carriers are separate and contracted by a shipping company to deliver their cargo. Given the intense competitiveness that has always been present in the shipping industry and the increase in technologies of the past several decades, for-hire motor carriers have become increasingly dependent on information technologies of various types to keep up with the competition and remain quality service providers for their customers. Private carriers have never been far behind the initiatives of for-hire carriers and have also implemented technologies of many kinds to not only record the performance of their own fleet and drivers, but also more recently for security reasons.

The common link between for-hire and private motor carriers is the need for both to stick to strict schedules. In the case of private carriers, as the popularity of just-in-time operations has increased, shipping has become more directly linked to demand in the short-term. In order for a just-in-time business plan to work, with its low stock of inventory at places of sales or manufacturing, shipping must be rapid, and even more importantly, reliable. For-hire carriers inherently have the same challenges because their clients have the same challenges. Often with hired shipping companies, deliveries that are not timely can result in penalties for late delivery. Conversely, early delivery can lead to logistical problems when attempting to plan full loads for both directions of a trip. Clearly, reliability is a chief concern in all segments of the shipping industry.

3.1.1 Current Motor Carrier Issues

Even with some of the technological solutions to industry challenges, a number of operational issues persist. While it is not always the responsibility of the state to resolve these issues for the motor carriers, several of the issues relate to problems outside of the carriers' control, but sometimes within the areas of influence of the state or federal departments of transportation. Often these issues could be dealt with by integrating freight performance measures into the planning process, either in the short-term (dynamic FPM use) or long-term (static FPM use).

Several studies over the past few years have looked into the major issues in the motor carrier industry, both from their perspective and from an outside perspective. The Federal Highway Administration supported a study involving a direct survey of fourteen experts in the motor carrier industry asked to rank the top fourteen operational issues in order of importance. The fourteen experts surveyed included some from regional carriers, as well as long-haul carriers and they represented drayage, truckload, and less than truckload carriers (ICF Consulting, 2003). This diversification was meant to give a fairly balanced view of issues within the motor carrier industry, although there was no indication of any weighting of the experts within their carrier niches to properly represent the industry as a whole. Table 3.1 lists the top issues according to these industry experts and their average rank. Many of the top issues, particularly those near the top of the list, are beyond the control of the departments of transportation: rising insurance costs, fuel price volatility, emissions standards. However, some of the concerns are within the realm of issues that can be addressed by performance-based planning with the use of some as yet undetermined data collection methods: urban congestion/travel time reliability and delay at port terminals. The focus of the section "Effective FPMs for Describing Freight Mobility" later in Chapter 3 will be identifying FPMs that may be able to address these issues.

Table 3.1 Top Issues of the Motor Carrier Industry

Issue	Average Rank
Rising Insurance Costs	2.6
Hours of service rules changes	3.6
Fuel price volatility	5.4
Urban Congestion/Travel Time Reliability	5.6
New emissions and fuel standards	6.1
Driver waiting and loading times	6.9
Security concerns	7.3
Truck size and weight limits	8.7
Driver turnover	8.7
Ergonomics regulation	9.4
Safety concerns and NAFTA	10.1
Shortage of vehicle mechanics	10.1
Introduction of truck toll roads	10.7
Delays at port terminals	12.4

Another study addressing the issues of the motor carrier industry, but this time from a more outside perspective, was an American Transportation Research Institute (ATRI) study completed by partnering with the Center for Transportation Studies at the University of Minnesota (Donath and Murray, 2005). This study identified a list of nine operating issues for motor carriers that in many ways align with those found by ICF consulting in Table 3.1, although slightly more aggregated. The nine major issues presented in this study are:

- Highway taxes and user fees
- Driver shortages
- Insurance costs
- Fuel price volatility
- Hours of service
- Technology utilization issues
- Congestion and capacity
- Shipper-carrier relationships
- Maintaining a safe industry.

Two areas on which the studies of motor carrier issues continually agree are the issue of congestion/capacity and the related issue of travel reliability. These are also issues where initiatives by the state departments of transportation could assist the motor carrier industry, and some would argue, assist the movement of all traffic by doing so. In the two studies above, congestion was listed in the top nine major issues of one and received a rank of 5.6 in the other, showing the perceived importance of this problem. This perception and the accompanying attitudes of motor carrier industry workers towards congestion have been researched (Golob and Regan, 1999), along with the possible implementation of technologies that could help to alleviate the problem.

The Golob and Regan survey of 1998 of 1200 private and for-hire carriers in California was one of the first of its kind, determining the industry's views on congestion, its effects on their schedules, and possible solutions. The study finds that the increase in fuel and insurance costs, reliability and scheduling problems, and accidents caused by congestion are believed by more than half of the survey participants to have a larger impact than traffic delays alone. About 88 percent of those surveyed said that drivers sometimes or often have to work in congested areas at present, with 85 percent stating that they believe congestion will get worse in the future. Congestion makes just-in-time delivery rather difficult, with 62 percent of drivers saying they sometimes fail to meet schedules due to congestion. On top of all this, there is also a mental health aspect, with many drivers reporting a serious effect on their patience and morale. This could very well apply to motorists in general, not just drivers in the trucking industry.

Given the existing challenges within the trucking industry, two questions remain. The first of these is: what FPMs can be implemented that can help resolve the issues of congestion and reliability? This is a highly debatable question that should be answered using basic performance-based planning steps that are most agreed on across planning agencies. This question will be answered in the section “Effective FPMs for Describing Freight Mobility” later in Chapter 3. The second question is: what technologies need to be implemented to collect data for these FPMs and how could this data best be used for both the short- and long-term? Much of this data is already being collected by carriers on the road, but the sharing of data is not such at the moment that it can be implemented into any performance measures. This and other issues will be discussed later in Chapter 3, in the section “Data Collection Issues for Effective FPMs”.

3.2 Current FPM Practices in the US

Freight performance measures in the US are currently at a very early stage. Many states have made a push to begin looking into FPMs or to begin some data-collection on the scale of what would be required for proper ITS-PM integration. However, the general consensus seems to be that to implement a comprehensive set of FPMs requires far more data-collection capabilities than the states currently possess. This puts most DOTs in a planning stage for FPMs at best. States that have made a notable start towards FPM integration include California (Barber and Grobar, 2001; Jones, 1995), Colorado (Colorado DOT, 2005), Florida (Florida DOT, 1998), and Oregon (Monsere, et al, 2005; Reiff and Gregor, 2005). Individual studies have ranged from port performance in California to more ITS-related studies in Colorado. However, these states have mostly focused on broad goals and objectives, rarely getting to the specifics of performance measures and addressing the data-collection requirements of these FPMs. Two states stand out that have addressed these issues and seem to be on the cusp of implementing some of these measures in a meaningful way: Minnesota and New Jersey.

3.2.1 Minnesota

Of the many states looking into using freight-specific performance measures in the near future, Minnesota is probably the most notable. This is due not just to the amount of information the Mn/DOT has published in recent years about the possibility and early results, but more because of the level of detail they offered in their plans from the very start. This is quite rare at most early stages of performance-based planning, but also necessary to get a quick and effective start.

A 1999 study by the Minnesota Freight Advisory Committee recommended a series of freight-specific performance measures which were much more specific than typical performance measures introduced for development. (Larson and Berndt, 1999) Rather than the typical “decrease highway accidents” recommendation for a safety measure, the MFAC recommended both “Dollar cost of crashes” and “Crash rate per mile traveled by freight mode”. The study broke down possible measures into four categories, the typical transportation, economics, and safety, as well as “Bottlenecks and Impediments”, measuring the impediments to freight traffic. This level of specificity is important to give planning agencies direction on their choice of measures and their relative importance. In addition, proposed measures were broken down into two primary segments, those that could be measured with available data and those that would require further development. This type of segmentation, while often ignored, makes the job of the DOT much simpler by pinpointing the areas where data is currently available but unused, which makes a much stronger case than simply stating all possible performance measures.

From this study, Mn/DOT created five priority outcomes related to freight needs, its “Family of Measures”, leading the way to a full shift to performance-based planning in 2003, following its previously formulated strategic directions:

1. Time/Directness – A predictable travel time for length of trip is maintained so that customer expectations are met.
2. Safety – Incidents and crash rates are minimized to Mn/DOT’s current and potential ability to influence infrastructure and driver behavior.
3. Condition of Infrastructure – An infrastructure that meets customer expectations is maintained.
4. Access/Basic Levels of Service – Services are provided to meet personal travel and shipping needs.
5. Socioeconomics – Balance investments with an evaluation of community values and social impacts.

The 2005 Minnesota Statewide Freight Plan further specified the FPMs, building on data and experience from the first few years of implementation. This document classifies all of the performance measures as:

- “Developmental measures” – a commitment would need to be made to set any targets.
- “Emerging measures” – data is available, but no targets have been set.
- “Mature measures” – data is available and targets have been set.

In the case of the “mature measures”, the targets are specified (e.g. “Percent of rail track-miles with track speeds > 25 mph”), and in the case of the measures with data collected, examples of their performance are given, as in Figure 3.1. This figure shows the time taken to clear the freeway after incidents in urban Minnesota areas. This is taken as a 3-year moving average to help reduce outliers, possibly false indicators, which is a good approach for any performance measure. Data between 1995 and 2003 approximately follows the projection, but data beyond 2003, the start of performance-based planning in Minnesota, should show the effectiveness of Mn/DOT policies related to clearance time.

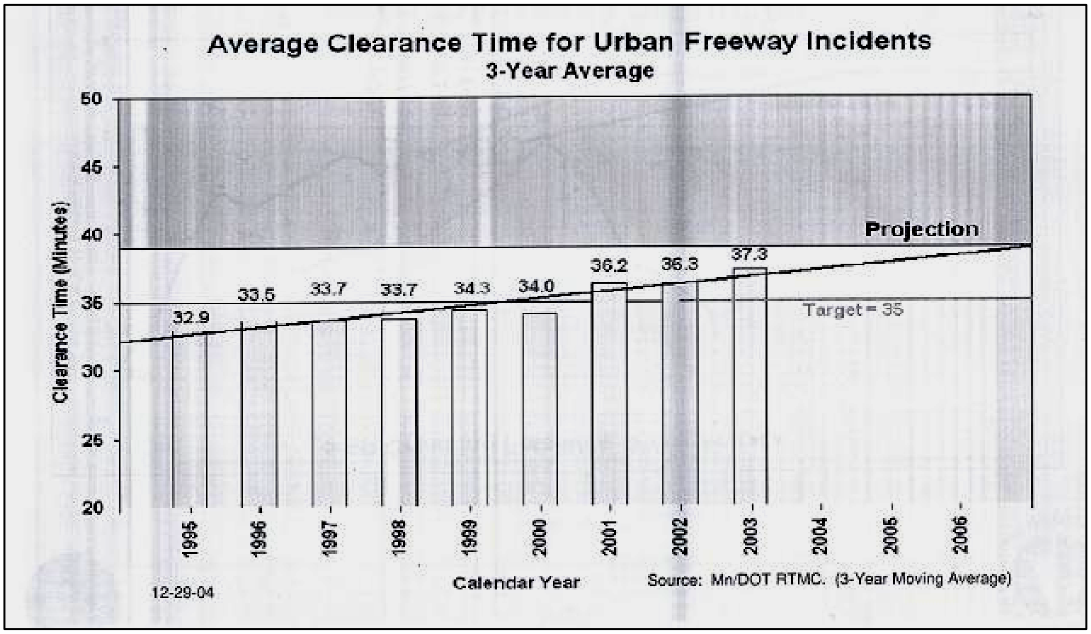


Figure 3.1 Average Clearance Time for Urban Freeway Incidents (Mn/DOT, 2005)

3.2.2 New Jersey

The main feature discussed in New Jersey's freight planning reports (NJIT, 2003) that distinguishes them from the other states is the level of detail with which they have extended their FPMs into the future, an aspect largely ignored by most agencies in the early stages of performance-based planning. Planning performance measures over a long time period and not just using a single flat goal makes the measures more dynamic and effective over time. Simply using a single-value goal discourages later evaluation and changing of the goal which may be beneficial and implies a complete knowledge that may seem like a silver bullet answer to the problem for future planners.

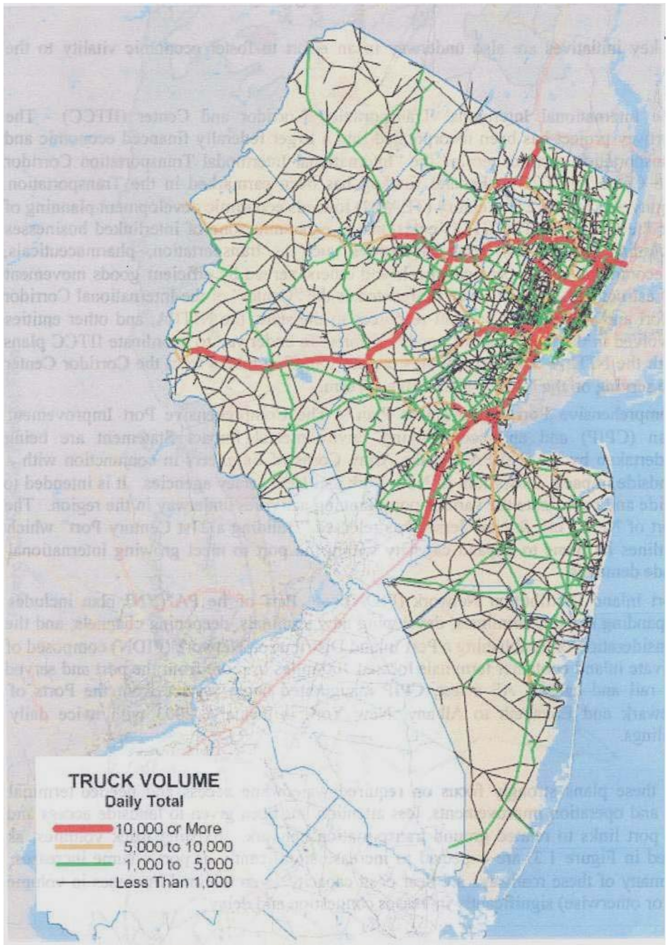


Figure 3.2 New Jersey Truck Volumes

In developing FPMs, NJIT sets its first goal as identifying current indicators of performance in the state and any data collection that is currently undertaken but unused; a common occurrence in planning at all levels. Figure 3.2 shows the current truck traffic on New Jersey highways. This is fairly simple data to collect, but is largely ignored or calculated as a predetermined percentage of passenger volume; a very inaccurate estimate for many corridors. The importance of this data collection is extremely important to performance-based planning, as it can lead to the determination of traffic density. This system of estimating truck volume by demand modeling is far better than the alternative of not using any data at all, but a preferable system would be collecting data on truck traffic directly, without the effort of manual counts. The possibility of acquiring this data through the sharing of information already on-board most motor carrier fleets will be discussed further in Chapter 4.

In what appears to be the current standard of organizing performance measures, NJIT lists its suggested FPMs in eight broad categories and from there determined potential indicators of each category, data and data collection needs for the indicators, current and future levels of the indicator where data is available, performance goals, and current and future needs to meet performance goals. This is the most straight-forward and common sense method of organizing FPMs and will be taken into account when recommending new FPMs to a state planning organization, given data constraints, in the section, “Recommendations for Effective FPMs in Texas”.

The NJIT recommended indicators fall mostly into these categories, similar in some areas to the current and recommended PMs of Minnesota:

- Average Travel Time Measures – Congestion delay
- Private Sector Cost Measures – Fuel Costs Per Mile, Insurance Costs
- Public Impact Measures – Freight-related Accident Rates, Emissions
- Economic Impact Measures – Value of Transportation Goods, Impact of Transportation Investments to Regional Economy
- Transportation Industry Productivity Measures – Vehicle Miles Traveled, System Performance (by survey), Average Haul Length

3.3 Characteristics of Effective FPMs for Describing Freight Mobility

The main challenges of performance measures of all types are fairly similar and certainly apply to performance measures designed specifically for freight movement. One basic concern is developing a performance measure that is simple and intuitive enough that data collection is possible and that the data can be used to represent something real and controllable. Both of these issues are integral since without data collection, the performance measure is not measurable and without proper representation, the performance measure will not be useful to users. Without taking both of these criteria into account before creating performance measures, the planners risk wasting their efforts on a good idea that is destined to fail.

Developing performance measures that will affect the private sector is even more problematic in that the state must understand the basic business models of the motor carriers in order to understand the changes that will occur in freight mobility. At the FHWA National Freight Transportation Workshop of 2000, a representative of the Oregon Department of Transportation briefly discussed the challenges inherent in developing performance measures.

"Using performance measures to identify transportation improvements can be an example of a public sector activity in which private sector participants lose interest over time. Performance measures that sound good conceptually often are problematic to implement because the data needed for measures are not available, are available but difficult or expensive to obtain, or are not reported regularly enough to be useful. Muddling through efforts to develop and implement performance measures can be intensely arduous for public sector staff, and even more so for private sector representatives trying to help through service on advisory committee. Keeping the effort simple is excellent advice but not always easy to follow. ODOT continues to seek the proper balance between meaningful and easy to measure performance standards and criteria." (Streff, 2000)

One of the main purposes of developing freight performance measures is the base assumption that providing users of the highway system with information will alter their decisions related to transportation. This change in decisions and behavior would likely occur mostly in route choice, since for motor carriers, choosing the faster route can make the difference between a late delivery and an on-time delivery. This is even more relevant for intercity trips than intracity trips. In a 2003 study by the National Cooperative Highway Research Program (Shaw, 2003), it was found that motor carriers performing intercity deliveries are more prone to change itineraries if they are made aware of traffic conditions such as increased travel times or decreased operating speeds. This supports the idea that congestion, especially on intercity corridors such as I-10 and I-35 in the Texas triangle area, could be impacted by the distribution of information detailing the travel times on multiple corridors at various times of the day. Among the issues still to be resolved are how this data could be collected and how it can be distributed to users, freight or otherwise, of the highway network.

3.4 Recommendations for Effective FPMs in Texas

"The data-collection needs for implementing a comprehensive set of overall ITS performance measures far exceeds the data-collection capabilities within the state. As a result, the latest efforts focus on measures that are easily achievable and measurable." (Colorado DOT, 2005)

When determining appropriate performance measures of any kind, in this case FPMs, it is important to ask the questions that have been stressed throughout this paper: Is it possible to collect data to support the performance measure? Would the results of the measure be useful to users or policy-makers? Is there a goal or level of successful performance? If the answer to any of these questions is no, the measure in question will most likely not be a successful PM.

This paper will address possible FPMs of any type that would benefit users or planners, but will go into the most detail with measures that are possible using data that could be shared from motor carrier fleets. This GPS data simply includes the position of each unit and its coordinates, but could be immensely useful to planners in maintaining a variety of measures. As obvious as it may seem, a freight performance measure is simply a performance measure related to freight and should therefore follow all the basic guidelines when creating performance measures.

For this study, basic guidelines were followed for determining appropriate FPMs for emerging users, requiring each PM to be:

- Capable of being measured – If data is not currently collected, it should be at least feasible to accomplish,
- Capable of capturing deficiencies – A proper PM should not measure performance for no reason, but rather diagnose a problem,
- Capable of measurement over time – Measures should be standardized enough to allow continued collection and time-series comparisons,
- 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 easily understood by both decision-makers – If the FPMs are to make any difference, they must be understandable to decision-makers of any background.

3.4.1 Relating 5 Steps of Performance-Based Planning to FPMs

As determined in the section "Important Features for Performance-Based Planning" in Chapter 2, there are five major steps to the performance-based planning process: setting goals, determining objectives, specifying performance measures and indicators, collecting data and the use of the results, which can take a variety of forms. These steps are completely applicable to freight performance measure planning at any level, particularly for emerging users of FPMs.

The goals of any freight performance plan should be quite broad and are generally applicable to most planning agencies. Assuming performance measures have been used in the past, these goals will be an improvement over the last year's goals, based on the measured findings, in a constantly changing, iterative process. For freight, the two goals are fairly straightforward: ensure that the transportation system allows freight carriers to transport goods efficiently and minimize the impacts associated with freight movement. These goals form a framework and vision for the agency to plan objectives around. For many agencies, these objectives will form five PM categories: travel time, reliability, economic issues, public impact, and infrastructure concerns.

Table 3.2 Suggested Freight Performance Measures for an Emerging User

Category	Potential Indicators
Travel Time	Intercity Travel Times Average Speed on Freeways, by Route and Time of Day Major City Congestion Levels Compared to Other Metro Areas Volume/Capacity of All Vehicles on Freeway Segments
Reliability	Deviation of Travel Times or Speeds from the Average Density of Nonrecurring Delays Portion of On-Time Motor Carrier Arrivals
Economic	State Transportation Investment vs. Gross State Product
Public Impact	Emissions Freight Related Accident Rates
Infrastructure	Pavement and Bridge Quality Delay at Border Crossings

Table 3.2 defines twelve freight performance measures/indicators that would be of importance to emerging FPM users. Each is elaborated on in terms of reasoning and data needs, but specific targets are not set as these are largely dependent on the current state of performance and the priorities of the planners for the planning area. Note that a commonly cited category, “Industry Productivity”, was left out. This is based on the requirement of good PMs to be capable of affecting a change over time. The assumption is that there is little a planner can do to increase industry productivity. The motor carrier industry is affected by supply and demand. Planners can only affect the ability of the industry to supply and this is best done by concentrating on the inadequacies of the highway system.

Travel Time

Intercity travel time is a very critical measure and a dominant issue among shippers who are concerned with reliability. (ICF Consulting, 2003) Since freight shipment is mostly intercity, a state should be very concerned with minimizing the intercity travel time between its own cities. GPS time and position data, if made available to planners, could easily be used to find the average travel time from city to city at any time of day or day of week. If such information was available, the logical step would be to not limit data collection, but create a real-time series of data. Performance targets could be set in a variety of ways, but one reasonable method would be describing travel times as a percentage of those experienced under free flow conditions, with 100% being ideal.

Average speeds of motor carriers on freeway segments of any size would also be a very significant measure and probably the most direct indicator of the overall performance of the highway system for shippers. This would also be easily calculable using vendor GPS data, preferably in real-time if there is any possibility of this information being passed on to the users in the system. A performance target of a single speed could be used for each corridor, but a simpler and more meaningful method is to use a percentage of free flow speeds, generally the speed limit, rounding down to 100% for any trucks exceeding it. This is based on the assumption that trucks will not travel below the speed limit if there is no congestion holding them back; a fairly safe assumption.

A comparison of congestion levels compared to other metropolitan areas, most likely as a percentile, is an easily achievable FPM, with data available. The report *Urban Road Congestion* by the Texas Transportation Institute includes annual congestion indexes and for more than 70 major metropolitan areas. Although the reporting tends to lag two to three years behind measurement, it is an important indicator of a city's performance and a large carrier survey found that 82% of respondents believe congestion is at least a somewhat serious problem for their business (Golob and Regan, 1998).

The ratio of highway volume compared to capacity is a well accepted means of measuring the performance of a highway for all users. This method and data do not need to be updated for freight-specific travel. Assuming there are no truck-only lanes, the volume occupying the freeway during peak hours is just as important to trucks as it is to passenger vehicles.

Reliability

Despite the importance of reliability to the trucking industry, there is no accepted standard for measuring reliability. The deviation of truck travel times on highway segments from the average is an important indicator of the reliability of the highway. No additional data would need to be collected over that used for intercity travel time or average motor carrier speeds, only additional manipulation of the data. The simplest possible performance target for this indicator would be the travel time which corresponds to one standard deviation above the average travel time over a segment. The goal would be to minimize this Travel Time Reliability (TTR) value over time. A similar reliability standard would be an Average Speed Reliability (ASR) over any chosen highway segments. While indices like the Texas Transportation Institute's (TTI) Buffer Index can be useful, it could also be argued that standard deviation is both the simplest and most universal measure of reliability.

For example, the following would calculate the Average Speed Reliability on a designated segment of highway over an entire week-long period:

$$ASR_n = \sqrt{\frac{\sum_{i=1}^{N}(Speed_i - AvgSpeed)^2}{N-1}}$$

Where N = # of trucks passing through highway segment n in a given study time

$Speed_i$ = the speed of truck i as it travels the segment

AvgSpeed = the average of all $Speed_i$ terms

Nonrecurring delays, those taking place outside of normal peak congestion times, have as yet remained quite difficult to track. This is unfortunate, since these delays are among the leading reasons for highway unreliability. With GPS data being collected from motor carrier fleets, however, this could change. Real-time data collection and analyzing could make time-varying congestion on highway segments very well defined. With these peaks defined, any additional spike can be deemed and recorded a nonrecurring delay, which most commonly occur during accidents and extreme weather conditions.

The portion of motor carrier movements arriving on-time is the most accurate indicator of the reliability of a highway system, although it cannot be determined from any easily obtainable data. While many shippers track this information themselves to minimize penalty fees, retrieving this sensitive information would be difficult. Similar to the Golob and Regan survey of 1998 stating that 62 percent and 27 percent of drivers sometimes or often/very often fail to meet schedules, a survey of this kind could be administrated on an annual basis, determining whether any efforts made to improve reliability have been effective.

Economic Measures

A common concern of the freight sector is whether the capital investment in transportation, particularly highways, is keeping up with the economic growth of the state or nation. This is a fair concern considering that much of that growth may be linked to freight shipment. Although there may be a time lag, transportation spending information should be readily available. As a comparison with a state’s domestic product, this could be a simple but useful tool for relating the growth of both. It may be valuable for a planning agency to create a PM and recommend to decision-makers that transportation funding keep pace with the growing economy.

Public Impact Measures

Air quality issues are important to the public, especially in areas where these issues have been ignored in the past. Federal regulations also require attention to air quality conformity and emissions. Creating a FPM and setting performance targets such as tons of pollutants per ton-mile or vehicle-mile can help bring attention to an emissions problem while it's still young. With the accurate count of truck traffic and speeds available using truck GPS data, models such as MOBILE can be employed on highway segments to determine problem areas.

Freight related accidents are a concern for both social and economic reasons. It is important to measure this data and try to minimize the impact of trucks on the highway, possibly by their separation from other vehicles. Tracking these accidents over specific highway segments requires accident data already collected, but aggregated spatially, to give planners the knowledge of dangerous areas to focus on. The most effective performance target would likely be either incidents or fatalities per million ton-miles, possibly both.

Infrastructure Measures

Pavement and bridge quality data throughout many states largely exists in various forms such as the Pavement Management System and Bridge Management System. Setting a goal for these quality levels can be extremely important for freight movement on an operational level and is also linked to fleet maintenance costs and safety. Performance targets for this measure would be most reasonable as an A to F level of service.

Although delay at border crossings could be viewed as simply a component of total delay, it is an important enough component, especially in border states such as Texas, to be measured separately. With a drastic increase in Mexico-US trade traffic due to NAFTA (US Customs Service, 2004), wait times at the border are continuing to increase dramatically. Traditional modeling techniques do not capture this information, nor do traditional delay reducing techniques affect this portion of delay. The obvious performance target would be average delay per truck at each border crossing, but such data does not as yet exist. New forms of data collection, perhaps GPS positioning data, would need to be implemented to determine the time between a truck entering the queue and crossing the border.

After determining the performance measures needed to meet your objectives, it is important to establish the currents and future needs to meet those goals. Although it seems like common sense, NJIT put these needs into a simple equation that is important to keep in mind during all stages of performance-based planning to keep focused on stated goals:

Needs = Goals - Performance

3.5 Data Collection Issues for Effective FPMs

In many cases, when freight is involved, data is collected, used in the short-term and discarded. Often this data is only used by the motor carrier and no one else. While this makes sense in a solitary business setting, it is a huge waste of resources. The data being collected everyday by motor carriers, vendor GPS data reporting both time and position at regular intervals, could solve many of the data collection problems that would be faced when trying to implement the FPMs in Table 3.2.

An issue currently making this form of data difficult to obtain is somewhat political and a natural result of motor carrier competition. Many of the larger carriers, which have several units from their fleet operating on a single corridor at any given time, can already accomplish some of the goals outlined in this paper without state support. For these carriers to give away the data they are already collecting, they might gain a significant amount of useful information on route congestion from the data of other carriers, but the smaller carriers will inevitably gain more. This would result in the larger carriers giving up a significant market advantage, which would be understandably unappealing to them. Therefore, any attempt by the state to provide information to all motor carriers will lessen the amount of control the larger carriers have over travel information and greatly alter the nature of competition between the carriers. What any planning organization must appreciate is that this information is beneficial to all users of the interstate system, both freight carriers and passenger vehicles, and the increase in overall efficiency may be worth creating some incentive for larger carriers to share their information. As one study stated, shippers in the Minnesota area have urged Mn/DOT to share performance data with them, believing that "good information flow will build support for transportation investment and will help balance the interests of shippers and the traveling public". (Larson and Berndt, 1999) Incentives for motor carrier companies, such as reduced tolls, are always a possibility, but what planning agencies should focus on is letting shippers know that information sharing works both ways and can be cyclical and symbiotic; any information that motor carriers can provide could be helpful to the agency, the shippers themselves, and the general public.

Assuming this information is acquired, the next step is implementation, both for helping the users on the highway system, passenger and commercial, and helping planners make more informed decisions. Chapter 4 goes into depth on the implementation of FPMs mostly via ITS technologies.

Chapter 4. FPM Implementation and ITS

The GPS data available from motor carrier fleets and presumably used for freight performance measurement potential has two separate uses: the inherent policy-changing potential that the information has in the hands of planners and real-time transmission of highway data. The latter could come in the form of transmission to the users via signing or some form of wireless technology (cell phone/internet/on-board computer) for more informed everyday decision-making. It could also be communicated to traffic management centers for real-time reporting of highway incidents involving nonrecurring delays. The basis of much of this data use is the assumption that the speed of trucks collecting GPS data represents trucks as a whole, but also represents passenger vehicles as probe vehicles. This is based on the assumption that a truck traveling below the speed limit is not doing it by choice, but rather by a force of nature or congestion, the same conditions that would lower the speed of a passenger vehicle. This chapter discussed many of the technologies that could allow for this feedback-based FPM implementation.

4.1 Current US and International ITS Trends

Over the past several decades, there have been a massive amount of new technologies implemented for transportation feedback to the user. This new ITS use is apparent in many US cities, but even more so abroad. The following two case studies demonstrate the future of ITS in implementing performance measures in a real-time, user-friendly manner.

4.1.1 US ITS Innovation: GPS Tolling in Seattle, Washington

In comparison to the many ITS technologies in use abroad in other first-world countries, the US has been somewhat hesitant to implement change on the highway system. This may be caused by a leaning towards simplicity and systems that have been proven to work well over years, but along with the shift towards performance-based planning and tolling, there appears to be another shift in the US towards the use of ITS technologies for various purposes.

The Puget Sound region of Seattle, Washington, where annually more than $1.5 billion is wasted in congestion-related delays, is currently running live tests of GPS-based tolling on highways in the region. This is based on their problem of inadequate funding, common to most planning agencies, necessitating some form of tolling in the future to either control demand, pay for increased capacity, or likely a combination of the two.

The test study uses Siemens onboard GPS units similar to the Qualcomm units used in the motor carrier industry, but with the necessity for much smaller updating times. In all, the study encompasses 400 vehicles using 6,000 links, which would be expanded greatly if the tolling moved beyond the test phase. This will also serve as a test for the eventual system, which is planned to include congestion-based pricing, as an incentive for drivers to vary their schedules and drive outside peak hours and on highways of lesser demand. Not only will the test determine the feasibility of this style of pricing in the area, if the households are a representative sample, it could also lead to the acquisition of the value of travel time to Puget Sound drivers, the price elasticities essential for any variable pricing strategy.

This test represents a move towards a system that transportation experts have been awaiting for years: a time when each vehicle can be held fiscally accountable for the time that it is on the road and the impact that this has on all users. This is a move towards a fairness in pricing that has been unprecedented in this country to this point, with the additional benefit of an easy system of tracking the highway use and collecting payment.

The benefits of in-vehicle GPS-based tolling go well beyond the advantages of congestion-based pricing on the highways. With GPS data collection units updating on a regular basis, every vehicle on the road could collect performance data, eliminating the need for probe vehicles. While freight-specific data is still required for FPMs, perhaps the more logical way to collect it would be through a tolling plan similar to the test in Puget Sound, not the more proprietary data collection occurring only for motor carriers.

4.1.2 International ITS Trends: A Case Study in Japan

The future of ITS in Japan, as the MLIT sees it, is Smartway, a “next-generation” road that will supposedly combine the areas of communication and transportation (two areas which are already related, at least in theory) into a single entity. They hope to do this by the incorporation of road-to-vehicle communication systems in all vehicles, different types of road sensors, a totally fiber optic network, etc. The goal of all this, as in all countries with a transportation system, is to ensure safety, make road transport safer, and have minimal effects on the environment.

Eventually, the MLIT foresees the computerization of all road transport and Smartway will simply act as the infrastructure to support it. This infrastructure is in three components:

1. Communication devices such as dedicated short range communication (DSRC) for use in communicating with electronic toll collection antennas;
2. Data storage devices like GIS, probe car data, and road communication standard;
3. Information network devices to be placed in the infrastructure such as fiber optic cable, sensors, and information provision devices.

The main objective of DSRC devices is allowing no-stop toll collection via electronic toll collection (ETC) antennas. The main difference between DSRC and forms of automatic toll collection used in other parts of the world (such as the E-ZPass system used widely in the U.S.) is that DSRC devices have both transmitters and receivers, as do the ETC antennas. This system has been shown to be more reliable than having only a transmitter in the vehicle and receiver in the ETC tower. Also, since DSRC equipment is generally sold together with an in-vehicle monitor, it leaves possibilities for a variety of other ITS services. ETC on-board equipment is currently installed in over 1.75 million vehicles, accounting for 11.5% of all vehicles using toll expressways, with projections to reach 70% by the end of 2007. (MLIT, 2004)

Besides its use for ETC, on-board equipment (OBE) has a viable use for automatic parking charges, where communication devices could be located in parking structures or simply in parking meters or lots, automatically deducting money based on time in the parking space. DSRC systems currently in use in parking structures, using ETC equipment, have reduced gate congestion simply by automatically opening the gate based on an ETC ID number. This idea of automatic charging of fees on the ETC has led to other ITS services. In 2003, Japan began the implementation of automatic ETC charging at gas pumps and car washes. These services are popular among drivers and are quick to spread due to their simplification of everyday tasks.

An ITS system currently in early use is using probe cars for monitoring “precise traffic flow, traffic behaviors, positions, vehicle behaviors, and meteorological and natural states”. Probe cars have so far been, but are not limited to, public vehicles including buses and police cars. The experience that Japan has in successful use of probe vehicles could be very useful to the US if GPS data from motor carriers is to be used in the future. In Japan, there is a possibility that this responsibility could move to private users, such as taxis or everyday vehicles, with incentives such as no tolling. The system, which collects continuous data from the probe car in space and time, could not only give current information about road congestion, but also be used to predict peak travel times and durations. A side benefit of this is that when all buses in a system are used as probe cars, electronic bus location systems can be installed (and are currently in place in some Japanese cities) at bus stops to show users the current location of buses and the approximate time until the next bus arrives (MLIT, 2003).

Like most other developed countries, Japan is actively updating its road GIS (geographical information system) databases. The goal is to get all possible road and infrastructure data onto electronic maps that will be far more precise than the current vehicle navigation systems. Not only could this data be accessible to drivers for navigation, but it would also be very useful in application with probe cars, efficient road management and road administration services. Road GIS has broad potential for use in dealing with disasters. Not only could a GIS system determine optimum evacuation routes bases on affected areas and locations, it could also be used to predict areas of future damage. The private-sector market related to GIS is expected to grow dramatically in the next five years, as people become more aware of its potential.

Fiber-optic networks are essentially the backbone of ITS technologies in Japan's future. The MLIT is currently constructing "information BOX", a small tube next to major roadways that will contain the optical fiber network. Approximately 8,000 miles of information BOX are planned, with room in the tubes to contain fiber cables of private sector companies, reducing some of the cost to the government. This network will be used for transmitting the data for the ITS systems planned – including probe car, GIS, and tolling data – and sending the data to a planning organization or user via display boards, OBE, or the internet. (MLIT, 2003) This information infrastructure will be essential in the future, when ITS applications will require much more data transfer. The US could learn from the ITS experience of Japan and update its own fiber optic infrastructure before real-time data transfer becomes a problem.

4.2 ITS Implementation for FPMs in Texas: User Benefits

There are many of features that make Texas different from the rest of the country and world, not the least of which is the distances between cities and the upcoming trend of increased toll road use on a massive scale throughout the state. As toll road use spreads throughout the country, what could set Texas apart and make it more effective is providing a real service to the traveler or trucker for the fee they are paying. Many services could be possible through ITS use, particularly the use of probe vehicles and its many benefits.

A major benefit to the users of a highway system is dynamic signing. Although this is already in place in some parts of Texas, most dynamic signing is currently based on more estimation than actual data. Through the use of probe vehicles, whether they are motor carriers, vehicles with onboard GPS, or vehicles using a Radio Frequency Identification (RFID) tag for tolling, exact real time data could be displayed overhead for all users of the highway, displaying the most timely routes at any given moment, the required travel time, upcoming accidents and bottlenecks, or any similar valuable information.

The collection and application of truck location data could be similar to an application now widely used in Japanese for their buses: bus location systems (Figure 4.1) that show the location of all buses in the area or in some

Figure 4.1 Bus Location System

cases, the entire city. Along with this, the arrival time of each bus to the stop is given. This system is currently in use in 41 Japanese cities in conjunction with a probe vehicle program, where the buses are the probe vehicles. Not only has this system increased bus ridership in the cities, it has also been used in support of performance measures such as lost time due to traffic congestion. The system uses 118 buses and the monthly cost for all of the communications is $7,500 (MLIT, 2004). It is easy to imagine this technology being implemented in the US to give real-time information on the highway about travel times for various routes.

One solution to the problem of data collection in the US, while also providing real time information to the user could be OBE, currently in use in Japan is vehicle information and communication system (VICS), which were installed in 7.2 million vehicles in 2003 and are forecasted to spread to almost all vehicles within the next two decades. (MLIT, 2003) Even if, for privacy reasons, this equipment could not be used to collect data on vehicle locations, the data collected and analyzed from trucks as probes of the system could be used to display information to all OBE users. This system allows drivers to obtain information on navigation in image, voice, and text format through their OBE via transmitters on the side or above the road. Besides standard travel time information, this can also include weather and accident updates. When the equipment is used for data display alone, not for collection, this is known as a push-type message delivery.

The goal of ITS should be that one day, as soon as possible, drivers, vehicles, and the roadway will act as one entity, with ITS systems acting as the glue that holds this entity together. This setup would allow each user to make the appropriate decision for minimizing their own delay, while simultaneously creating the best possible equilibrium of the entire network. This seemingly optimistic goal is completely achievable with our current capabilities for data collection and use. The only thing lacking is a framework for putting the two together.

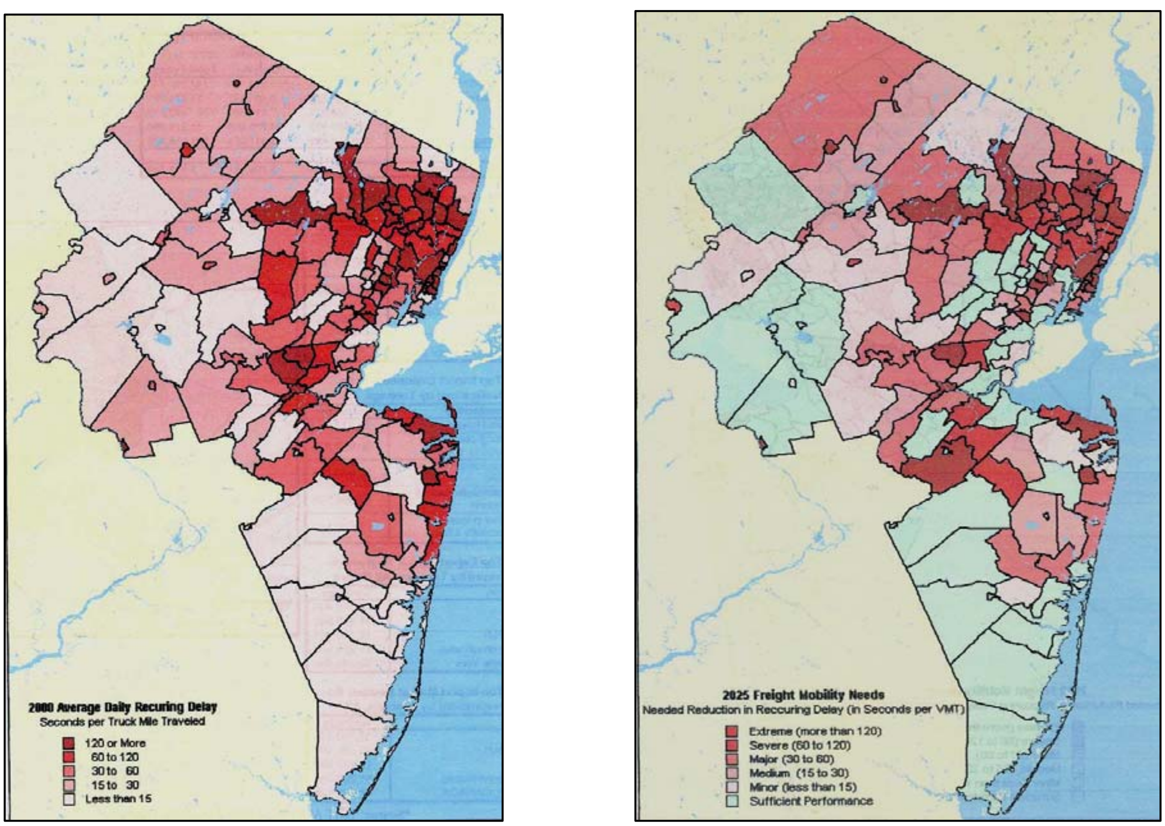
4.3 ITS Implementation for FPMs in Texas: Planning Benefits

The opposite of the push-type message delivery described above is pull-type message delivery, which allows the vehicles to transmit information to receivers, making it possible to accumulate congestion and road condition information. This technology could turn every vehicle on the road into a data collector, eliminating the necessity for probe vehicles or data sampling, while simultaneously eliminating any delay between incidents and response units knowledge of the incident. This pull-type message delivery also makes internet access available while on the road, enabling the acquisition of information such as weather alerts. Slightly further into the future, this on-board equipment will be the basis for Japan’s planned Advanced Cruise-Assist

Highway System Services. This will be a system of driverless automobile travel which will rely on communication from vehicle to vehicle and from vehicle to road and according to the MLIT; it could be in use as early as 2010. (MLIT, 2004)

Aside from these data collection related issues, any type of vehicle location information from push-type delivery in passenger cars to GPS locations from motor carriers can be used extensively in performance-based planning and specifically in maintaining and using FPMs. Performance data is not particularly useful to planners if it cannot be displayed in a way that is intuitive, which is where the use of GIS packages can be useful. With real time information from vehicles, databases can be constantly updated and fed into GIS applications, giving a minute by minute view of the performance of a highway system. This is incredibly useful for determining bottlenecks and accidents, but can also be helpful in spatially visualizing congestion as it changes throughout the day.

Another use of GIS packages in FPM planning is determining trends over a course of years that could then be used for forecasting measures into the future. Figure 4.2a shows a GIS-based representation of average delay in areas of New Jersey. This is a fairly straight forward application of delay data that could be collected from motor carriers either by area or by segment of highway. Representing the data so graphically makes problem areas more visible



Figures 4.2a. and 4.2b.GIS Representation of NJ Delay at Present and Projected (NJIT, 2003)

for planners, toll road operators and system users. Figure 4.2b shows a similar delay representation, but forecasted into a future year, 2025. This forecasting can be done not only by analyzing demand, but also by interpolating from delay data from the past. This aggregation of annual data, more than any other method, can be used to determine future needs in the area to meet FPM goals.

Figure 4.3 shows the simplest possible method for planners to determine what areas or segments need investment to meet goals, representing the Needs = Goals – Performance equation stated earlier. This is the real purpose and future of FPMs because this result can show very accurately the problem areas not meeting PM goals and creates a plan for decision makers to focus their attention.

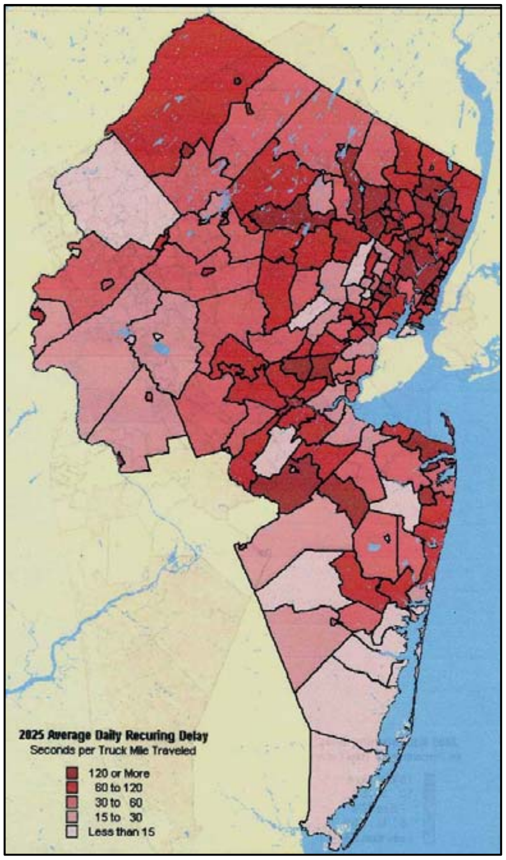


Figure 4.3 GIS Representation of NJ Future Mobility Needs (NJIT, 2003)

Chapter 5. ATRI 2004: A Case Study in Truck GPS Data Use

In line with the current shift of the U.S. towards performance-based planning and a focus on freight, the Federal Highway Administration (FHWA) entered into partnership in 2002 with the American Transportation Research Institute (ATRI) to develop methods to measure the performance of freight movement, with the goal of facilitating more efficient goods movement. Measuring freight performance will represent an improvement in local, state, and federal agency planning in their ability to identify and deal with freight-specific problems.

While the ATRI study, "Developing Real-Time Performance Measures in Freight Significant Corridors" (ATRI, 2003), did not ignore other modes, it mostly focused on the trucking industry, based on the fact that trucking represents an 87% modal share in the U.S. (ATA, 2004)

5.1 Data Collection Techniques

The first step in the alpha test of the project was locating a small number of the most freight significant corridors in the country. Through an ATRI partnership with QualComm, a technology provider, GPS reports from trucks in major cities were found to determine the most highly trafficked truck cities. These cities were then compared to corridors identified in the Cambridge Systematics report "Evaluation of Performance Measurement: Travel Times in Freight-Significant Corridors Phase 1 Final Report" to yield five corridors for further study. After a sixth corridor in British Columbia was added to study cross-border mobility initiatives, the six selected corridors were:

- Houston – Dallas via I-45
- Indianapolis – Chicago(Gary) via I-65
- Houston – San Antonio via I-10
- St. Louis – Kansas City via I-70
- Phoenix – San Bernardino via I-10
- I-5 in British Columbia and Washington State

A variety of data collection technologies were considered for the study, some of which have been discussed within this report. Satellite tracking is accomplished through the onboard GPS units described in detail previously, offering the best service in rural areas. Terrestrial tracking involves the use of cellular technology, providing good metropolitan coverage, but inadequate intercity coverage on certain corridors. Hybrid tracking systems incorporate pieces from each of the previous two technologies, most likely using terrestrial tracking for urban areas and satellite tracking for intercity regions. A fourth technology is on-board computer tracking, which has no connectivity to outside systems, making it very difficult to process the data and relate it to specific highway segments. Fixed site systems mostly related to electronic toll collection systems such as EZ pass. While this is an inexpensive alternative since the infrastructure is already available, at the moment it is very limited in availability. Of these five alternatives, satellite tracking was chosen as the most suitable positioning alternative, as it appropriate for use in intercity data collection.

Within the technology categories, there are two data collection capabilities available: Data Burst Technology and Continuous Flow Technology. Data Burst Technology allows for "near real-time" vehicle movement information through the sending of data packets and regular time intervals. Continuous Flow Technology constantly transfers data to the system in actual real-time. One of the limitations of the currently available GPS satellite tracking systems in trucks is a 60 minute delay between readings on each truck, making any real-time FPMs difficult or impossible to institute. This problem will be discussed further in Section 5.5, "Suggestions for Further Work and Future Application of Data".

5.2 Data Manipulation

The data available to ATRI from the collector is accessible only in very large text files with one line for each time any individual truck in the corridors specified are "pinged". This pinging means the GPS unit was contacted either because of regularly timed polling or human-controlled polling for any number of reasons. Each line of data contains the truck ID of the pinged vehicle, the date and time of the data point, the latitudinal and longitudinal coordinates of the truck location, and which highway the truck was on. There are a number of problems associated with the form that the data arrives in.

One problem is the accuracy of the GPS system. Each data entry has a location that is accurate to within ¼ of a mile. Over long periods of time, this is not a problem, and with large aggregations of data, it tends to make little difference. However, for two data points of the same truck very close in time, the inaccuracy could result in some very deceiving data, even occasionally resulting in two data points showing movement in the opposite direction of actual movement. For this reason, ATRI has made a practice of dropping any two fields that are less than 15 minutes apart. Another possible drawback of this slight inaccuracy is that while the data was collected with a buffer intended to exclude highway frontage roads, this is not guaranteed. Inclusion of frontage roads could give very skewed results, particularly in times of high congestion.

Another problem with the data is that stoppages that are not the result of a failure of the highway system are difficult to separate from those that are. A truck stopping for fuel or for a rest break can appear as a very slow-moving vehicle after data analysis. The solution tested by ATRI is dropping data points with very little distance traveled between two data points compared to other trucks on the same highway over the same time period. This appears to be a successful solution, although a lot of care needs to be taken to do this properly. Given the current data collection methods, no one solution could completely take care of the problem. It will always be inherently possible to eliminate low speeds resulting from non-recurring delay while trying to eliminate those resulting from error. The current practice of eliminating those data points with speeds below one standard deviation may be successful in broadly examining average speeds, but this is not appropriate if the data will be used to measure variance and reliability of the highway network.

One of the most important implementations of ATRI in the manipulation of this data is the development of their “snapping algorithm”. This algorithm was implemented through a program which took the precise coordinates of truck location, albeit with some degree of error, and associated each to the nearest highway marker. This is necessary if the data is to be used graphically, which is one of the key goals of FPM development. Along with this snapping process, the program converts truck-specific IDs to a random identifier unique to each truck, which makes the truck positions anonymous and unidentifiable with any specific motor carrier company. Realistically, this anonymity is essential in acquiring any information on truck location

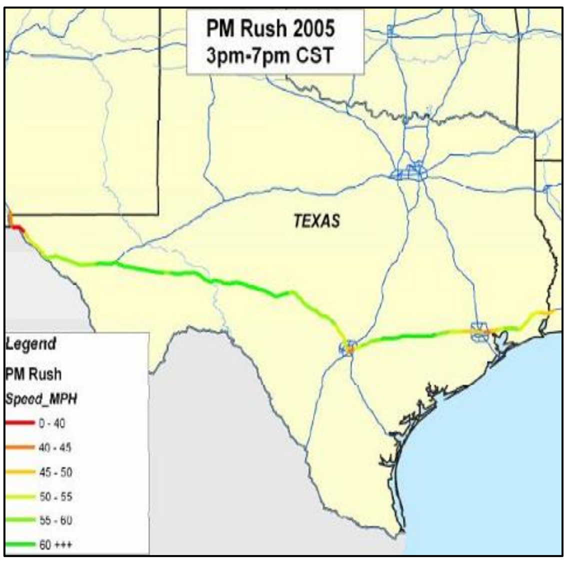
5.3 ATRI Suggested FPMs

There are many potential uses for the GPS data collected for the study, but ATRI began by focusing mainly on average speeds. This was accomplished using the simple algorithm of finding two data points with the same truck ID, finding the distance traveled by subtracting mile markers and dividing by the elapsed time. Since no non-speed measures are considered, all data points not corresponding to two unique positions of a single truck are eliminated.

Throughout the alpha and beta tests of the study, it is assumed that due to the standard hourly polling of trucks, a 50-mile minimum segmentation of the highway is necessary. This reasoning is accurate for single trucks, but with large amounts of data, calculating average speeds, at least relative from one segment to another, would be possible over much shorter intervals. Since the publishing of the last paper on this study, ATRI has begun to use smaller segments, down to 10 miles and looking into as low as single mile segments. This is a very important point since gaining useful planning information at a 50-mile scale would not be extremely useful.

Since the end of the beta-testing phase of this project, the data collection has extended to 25 corridors over the entire year of 2005. Together with the segmentation of data into smaller highway intervals, this has enabled the use of GIS software for the visualization of average speeds on a scale not previously possible. While ATRI has yet to propose any specific FPMs, the maps they have begun to produce showing speeds in various situations clearly show the usefulness of this information.

The simplest way to look at speeds on a corridor is to show average speeds on individual segments by time of day. Figures 5.1a and 5.1b show the average speeds calculated by ATRI on segments of highway in Texas at two different times of the day, one for midday, when trucks on the highway segments are flowing at approximately free flow speeds and the other at the PM rush hour.



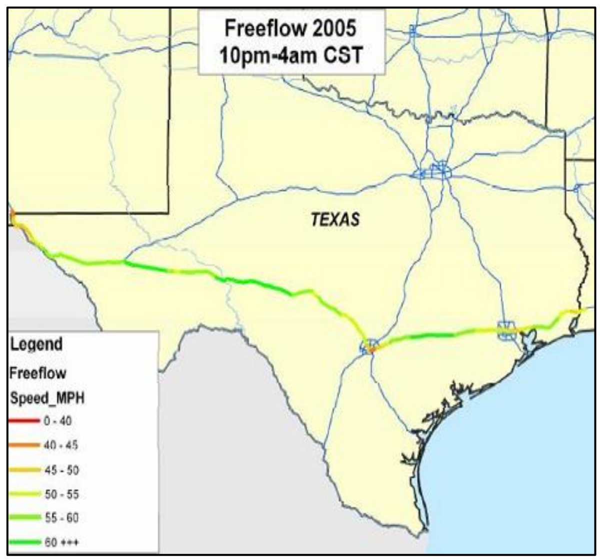


Fig 5.1a&b Free flow and PM Highway Speeds (ATRI)

As expected, most intercity stretches of highway are relatively unaffected by rush hours, the largest congestion effects occurring in segments lying near or within major cities. As this technology progresses and obtains more robust data sets, these maps could be produced for each hour of each day, possibly self-updating for real-time use via internet, highway display, or simply for planning and performance measurement use. Throughout the brief span of analysis that this data has seen, it has already shown its usefulness in non-recurring delay and disaster purposes, particularly in pinpointing bottlenecks.

Figures 5.2a, 5.2b, and 5.2c show the “Texas triangle” area of the Texas highway system on September 20th, 21st and 22nd, respectively and the ATRI-calculated average speeds on each highway segment. These dates correspond to the days immediately after the Hurricane Rita

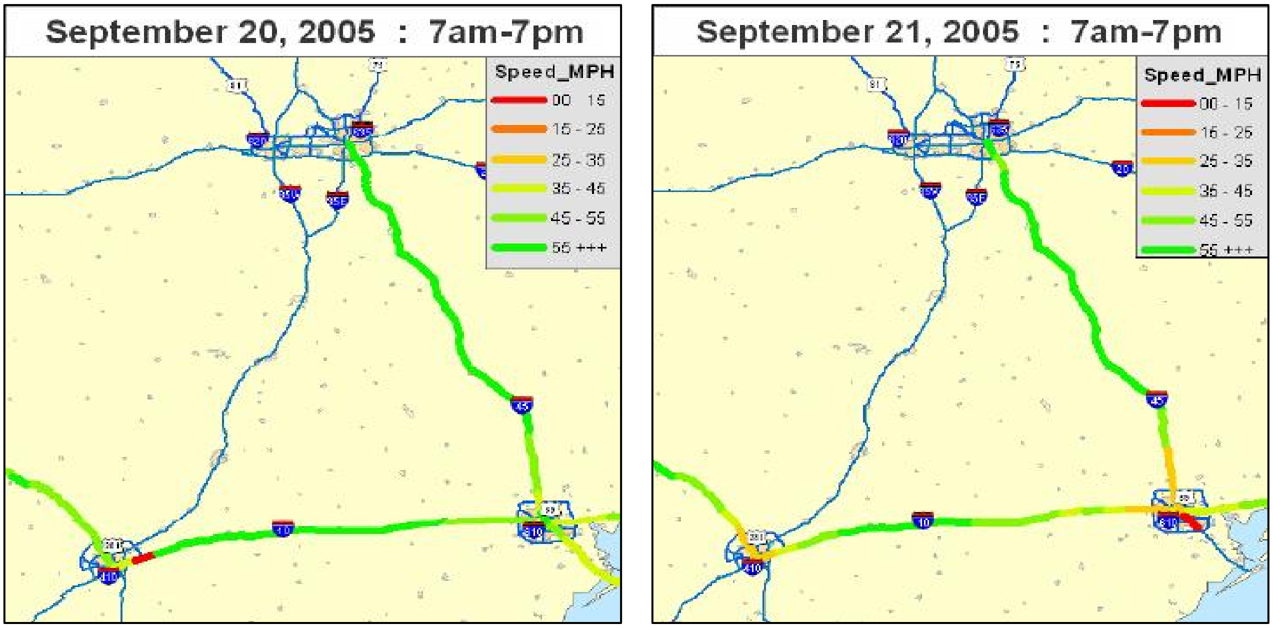


Fig 5.2a&b Disaster Related Congestion (ATRI)

evacuation was announced. During this period, certain bottleneck sections of the highways were almost at a standstill.

While most of this research has focused on average speeds, some reliability measures are underway, mainly focusing on the TTI Buffer Index along entire state segments of each highway. This work provides a decent state-to-state comparison of travel time reliability, but as yet has provided no comparison on a smaller scale for the use of state planning organizations.

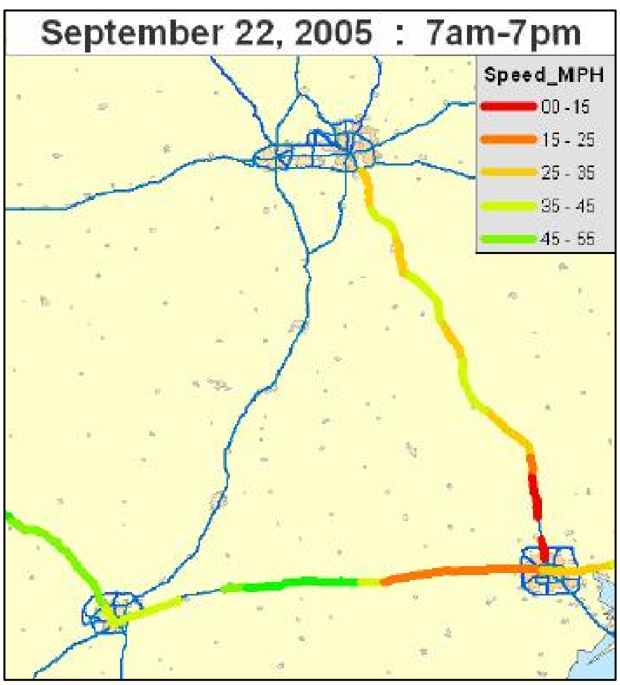


Fig 5.2c. Disaster Related Congestion (ATRI)

5.4 Utilization of the ATRI Data in a Texas Case Study

For two days in mid-April 2006, Jeffrey Short with ATRI visited Austin to collaborate on new ideas for the application of the GPS truck data into freight performance measures, specifically related to Texas highways as a case study. While this time was quite brief, many ideas for potential future work with the data and possible measures were created. In addition to this, one application in particular, finding an hourly volume of traffic throughout the day, was looked at in detail, ending in preliminary results and explicit ideas of where to take the idea in the future.

The typical distribution of total traffic throughout an average day is quite similar from city to city. There are two major peaks, one in the AM and one in the PM rush hour, where a broad assumption can be made that in either one of those hours, 10% of total daily traffic volume occurs. It is also very well known that the PM peak tends to sustain volume longer than the AM peak both before and after the highest hour. Also, in terms of total traffic, the night-time volumes are a small percentage of total volume. Often metropolitan areas complete their own studies of hourly trip distribution to be more exact in pinpointing the patterns of their city. Figure 5.4 shows a very typical 24-hour trip distribution for Austin, Texas.

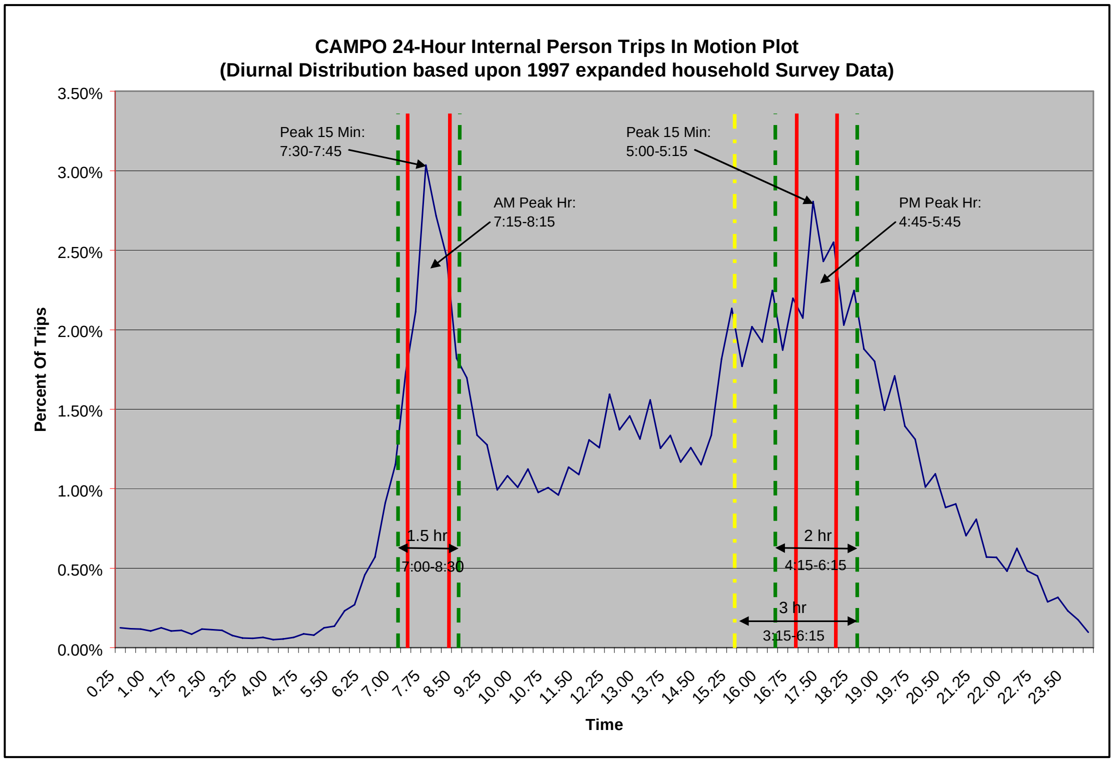


Figure 5.4 A 24-Hour Traffic Volume Distribution of Austin, TX (CAMPO)

Often, for city or region-wide planning purposes, truck traffic volume calculations are very over-simplified. In many cases, on highways, a simple percentage of total traffic is assumed to be truck traffic at all times. This is generally based on very broad observations and while it may be accurate to assume a percentage over the time-frame of an entire day, it is not intuitive to assume that the decisions and priorities of trucking companies will be the same as passenger vehicles. In the past, the reasoning for using this simplified information has been a lack of required information for proper truck volume estimates, yet it would be quite valuable to regional mobility planners for determining accurate truck travel patterns in their models. This could also be very valuable to future investors in toll roads that consider congestion or time-of-day pricing, since current projections tend to be based on inaccurate assumptions.

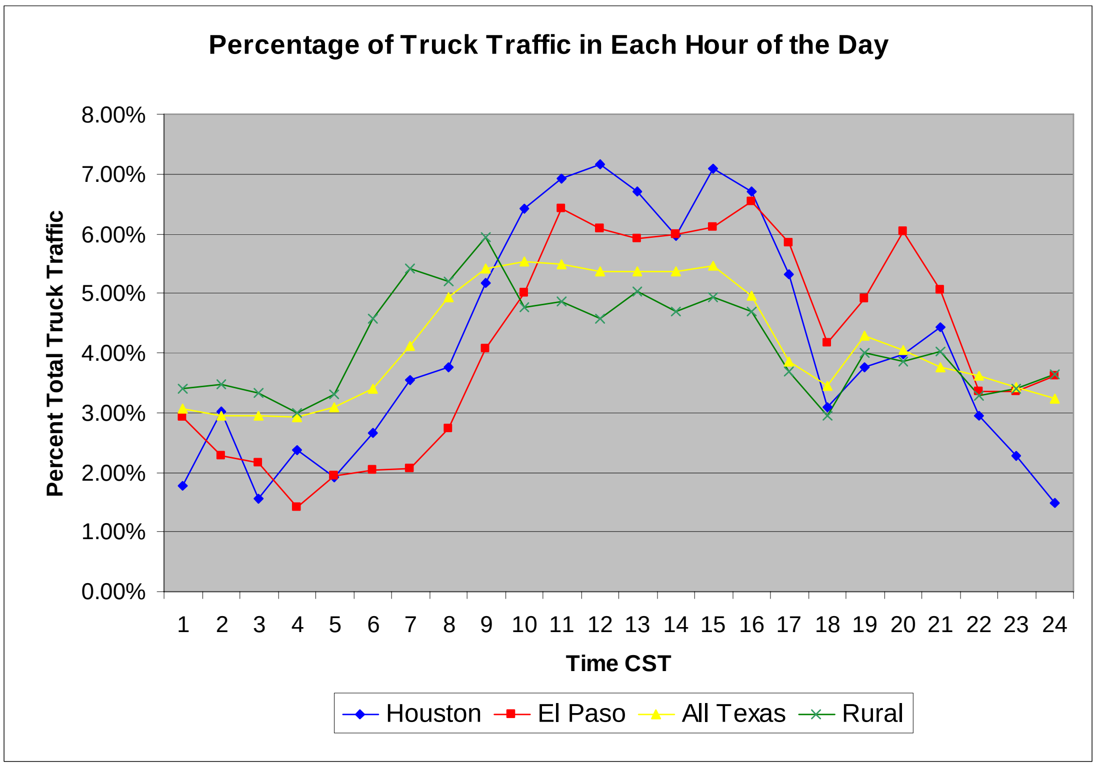


Figure 5.5 Hourly Truck Traffic Distributions Based on GPS data

In this capacity, the GPS data being collected by truck polling would be perfect for filling in lacking information on traffic distributions. Figure 5.5 shows hourly truck traffic distributions based on all 2005 traffic in four areas: a two-mile stretch of I-10 in Houston just east of the outer loops, a two-mile stretch of I-10 in El Paso just east of the border crossing, a 12-mile stretch of I-10 around the rural Texas town of Sonora, and all of I-10 in Texas. These four positions were chosen to contain all of the traffic on the I-10 corridor, which is why positions inside of loop highways were not chosen. Also, they give a good mixture of urban and rural locations as well as El Paso where peak hour congestion is especially problematic due to border crossings.

A lot of conclusions can be made from these graphs. It is immediately apparent that trucks do not simply follow a flat percentage of total vehicle traffic volumes. As expected from companies that have a lot of experience on major highways, the trucks avoid the highways around normal peak periods, instead doing the bulk of travel between the times of 10am and 4pm. This is more noticeable in the urban areas of Houston and El Paso. The stretch of rural highway is much more evenly distributed, not fluctuating as much to time change, as would be expected since rural areas do not encounter the same congestion effects at peak hours. In fact, night-time travel by trucks in rural areas seems to be more than half that of day-time travel volumes, which is unheard of for passenger volumes, in which travel drops drastically at night.

It is important to note that while this estimation can work for percentages of trucks, it in not an accurate truck count, as it only applies to those trucks fitted with GPS units that supplied data for ATRI work and whose data was not eliminated for polling reasons mentioned earlier. However, since each of the four cases studies had thousands of data points over the 24-hour period, it is not a huge stretch to assume that these samples could represent the truck population trends fairly well.

5.5 Suggestions for Further Work and Future Application of Data

Although there have been several years of work by ATRI in developing the data manipulation methods necessary for the GPS truck data and utilizing them to get useful results, the work is only recently moving from a preliminary stage to the kind of testing that should really display the potential of this information. As the project comes into a secondary stage, there are numerous directions that could be followed for future application of the data.

Although extensive speed measurement has been completed and displayed along many of the major US corridors, as in Figures 5.1 and 5.2, there has currently been no display of these speeds as a percentage of the free flow speed for each segment. This is important when focusing on areas that have been shown to have a significant bottleneck even at late night hours. While measuring unweighted average speeds along highway segments can help planners find bottleneck locations, which should be a primary goal of any probe vehicle data collection, until each segment is compared to its free flow speed, it is difficult to determine the current operations of the corridor or any locations of non-recurring delay. This is not a goal that would require any additional changes in data collection or initial manipulation; everything that is needed to accomplish this is currently at the disposal of ATRI.

Currently, there is no effective way to use the GPS data to determine the wait time at the borders, a commonly cited efficiency problem and potentially effective FPM. The main problem that impedes this type of use is the drayage system, where one truck hauls a trailer to the border, a drayage truck hauls it over the border, and a third truck hauls it in the next country. Since each truck could potentially have its own GPS unit, this does not allow for measurement of wait time. However, some fleets do not keep the GPS unit in the front of the truck, but rather in the trailer. This could solve the problem, but currently, there is no differentiation in the data between GPS in the truck and GPS in the trailer. This makes the problem more difficult, but one solution could be the elimination of any data where a truck approaches the border and turns around or with a wait time much larger than the average at the time, implying that the truck has stopped or is out of service. This technique would take a lot of initial data manipulation, but once developed, could be a very accurate and up-to-date display of truck waiting times at the border.

On some large sections of the beta-test corridors, ATRI has looked at one measure of reliability, the TTI buffer index, but only for a corridor across each entire state. While this is a good preliminary step, it does little to show planners and users which individual sections within a state are the most unreliable. With the shrinking of workable highway segments down to ten miles and possibly a single mile in the future, it should be a goal to display and project some form of reliability on these smaller segments. This could be done either by using the buffer index or the ASR, Average Speed Reliability, discussed in Section 3.4 “Recommendations for Effective FPMs in Texas”. This ASR is simply the standard deviation of truck speeds traveling each segment, which is arguably the simplest and most widely understood measure of reliability.

5.5.1 FPM Implementation for Congestion-Based Tolling

As mentioned previously, knowing the travel patterns of trucks in an average 24-hour period could be very useful in determining tolling prices on highway segments. For example, with the current results in Section 5.4 that night-time is somewhat of a down-time for truckers, but not nearly to the extent of passenger travel, there should naturally be a decrease in night-time tolls in any variable-congestion strategy. However, since the trucking industry is less sensitive to time of day than passengers, this price difference should not be nearly as extreme.

Similarly, if real-time operations data becomes a reality, congestion-based pricing could be completely based off of this constantly updating data, not assumptions made at one preliminary point in time. In the case of a tolled bypass being added in an urban area, such as SH-130 in Austin, Texas, truck location data could determine the time savings resulting from taking the bypass as opposed to the main highway through the city. Not only could this time differential be displayed prior to the toll road ramp to promote its use and minimize overall delay, it could also be used real-time in determining an appropriate cost for using the road.

The only other information required for full congestion pricing would be the money value of time for users. While this is fairly well known for passenger vehicles (typically $5-15 per hour for urban commuting), the value of time for motor carriers has always been more elusive, largely because of data sharing issues. If paper or electronic surveys are not well-received, GPS data could be the solution for this as well. At a variety of tested toll levels, the simple toll/non-toll decision of truckers could be used to form a discrete choice model which, when combined with knowledge of travel time, could determine the truckers money value of time. This in turn could be used to calculate an appropriate toll to charge at any congestion level or time of day. Whether using truck-collected data to determine toll prices for trucks is acceptable or even ethical is another matter.

5.5.2 Real-Time ITS Possibilities

The greatest potential of using truck-based GPS units is the possibility of using the trucks as probe vehicles, not just for long-term planning purposes, but for real-time evaluation of traffic as well. The potential uses for this real-time data are explained thoroughly in Chapter 4, but briefly, they include: display of up-to-date travel times on the highway system, opportunities for traffic-normalizing, where overall users in the system can be counted on to make optimal decisions, nearly instantaneous incident location at traffic control centers, and better route-planning for emergency vehicles, among others. The difficulty in accomplishing this is currently the result of data collection processes that update approximately hourly. If real-time ITS applications are to become a reality using truck GPS data, the trucks needs to be pinged continuously and in turn, the data needs to be continuously transferred to whichever agency will be in charge of manipulating it. Beyond that, the data manipulation processes need to already be in place so there is very little lag between data collection and data analysis and display. While this is a lot of initial work, once in place, the system should be fairly self-sustaining and would offer users a service for the increasing fee they will be asked to pay for transportation systems use in the future.

Chapter 6. Summary and Future Work

With the recent lack in funding and increase in urban congestion, resulting in a push towards highway tolling in the U.S., the logical question on many highway users' minds is: what will the benefits of these new toll highways be that will make them worth the cost? A reduction in travel times is implied, but not promised, to toll-road users. This issue is especially important to the motor carrier industry, which is an increasingly competitive industry that must focus on the bottom line above all else. One possible answer to this question could be that the new generation of tolled highways will offer not only ITS interaction on the roads, in any number of forms helpful to the traveler, but also an emphasis on performance measurement, resulting in quick response to the needs of the user.

Up to this point, only a handful of DOTs have responded to these needs by looking into some possible freight-specific performance measures, but no definitive work has yet been completed in this area. A definitive work would include the basic areas of travel time, reliability, public impact, economics, and infrastructure in the form of specific FPMs, as this report does, but would also delve deeply into the best circumstances to implement PMs from each category, very specific goals for each PM, and proper means of projection of these goals into the future.

Currently, most regions with a planning agency determine truck volumes throughout the day, very valuable information for a city, simply by using the measured passenger vehicle distribution and applying a percentage of trucks. This assumption, and many of the freight-related assumptions made by urban or regional transportation agencies, fails to address the fact that the demand for goods is much different than the demand for personal travel. Using the data provided by ATRI, this report determined more realistic distributions of truck traffic throughout a 24-hour period in several areas of Texas; information that could be very useful in urban models distributing individual trips.

Aside from truck trip distribution, there are a number of specific applications for the data that simply require time and data manipulation to complete. Any form of reliability could be calculated for use as an FPM, whether it's the buffer index created at the Texas Transportation Institute or something more simple and universal such as standard deviation. Calculated at one-mile intervals on every major highway in the U.S., this information, along with travel times and average speeds on all corridors, could be extremely helpful in helping decision-makers decide on appropriate uses of transportation funding, based on the hard evidence of bottleneck locations.

The most exciting and promising use of truck location data is the possibility of using the trucks to represent inter-regional probe vehicles, the way many international cities use buses as probe vehicles within the city. Assuming data could be transferred at a high enough rate, this would bring about many real-time uses on the highway system. Travel times on various routes as well as weather and accident information displayed for highway users could turn a city network into a fairly unified system, with travel times on all routes equalized and total delay minimized. This is clearly applicable to disaster situations, where notifying passengers of blockages and optimal routes can save lives. Also, if traffic speeds were constantly updated at a traffic control center, any sudden fluctuation could be easily discernible as non-recurring delay, decreasing accident reaction time significantly.

While the truck GPS data currently being examined by the FHWA and ATRI has many applications, there are also a number of downfalls. There are many privacy issues related to the distribution of this data on a wide scale, bringing about the necessity for some form of incentive for sharing on the part of motor carriers, as well as serious issues in using the data for polling purposes, which the trucking industry would be strongly against. It is also unlikely that their data collection will change from an approximately hourly location polling that suits their needs, yet makes disaggregation into small highway intervals rather difficult and real-time data use impossible.

Although developing further uses of the currently available data is a useful exercise in demonstrating the usefulness of truck location data in creating FPMs, clearly there should also be some thought put into alternative sources of similar data that would not face the same problems associated with truck GPS. GPS studies in passenger cars in Seattle show the possibility of locating a large number of probe vehicles on tolled highways, possibly every vehicle on the highways if it were implemented on a larger scale. Probably the most promising of all technologies for this purpose is RFID (Radio Frequency Identification) chips. This is a very versatile technology that could easily be placed in either toll tags on windshields or the yearly tags on all license plates. With passenger-vehicle/motor-carrier differentiation, this could simultaneously be used for all forms of performance measures as well as making every vehicle on a U.S. highway a probe vehicle, making the days of incorrect travel decisions based on lack of information a thing of the past.

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