MULTI-CRITERIA ASSESSMENT FOR SUPPORTING FREEWAY OPERATIONS AND MANAGEMENT SYSTEMS

by

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ABSTRACT

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Freeway traffic congestion represents an increasing concern for urban areas throughout the United States. In addition, faced with limited roadway expansion alternatives, transportation agencies are considering investment in traffic management centers (TMCs) as a more viable way to operate and manage freeways effectively. The TMCs' responsibilities include monitoring roadway conditions using the various data collection strategies and determining performance measures for freeway operations. At the same time, traffic engineers at the TMCs may react to the traffic congestion problems by implementing operational strategies. In order to provide reliable decision support for TMC freeway operations and management systems, this dissertation aims to examine the factors influencing the TMCs' investment, the effective methods for persuading the public to support TMC deployment, and the legal issues involved with deciding to deploy a TMC. Second, this research presents an innovative approach, using a multi-criteria decision framework for selecting data collection strategies by considering the limitation of data collection strategies and candidate performance measures at the same time.

The multi-criteria decision framework includes establishing a statement of purpose, identifying the alternatives and their criteria, developing a screening approach using the decision makers' priorities, and multi-criteria decision models. This research suggests both qualitative and quantitative criteria that affect the quality of operational performance measures and data collection strategies; these include understanding, measurability, availability, importance, time, cost, accuracy, and reliability. Then, multi-criteria models such as Simple Additive Weight (SAW) and ELECTRE III are used to select the best freeway data collection strategies. Third, this research examines the characteristics of good performance measures, constraints for data collection strategies, current and expected daily performance measures using a modified Delphi Method and stated preference surveys from TMCs in the United States. The same proposed framework is applied to develop the individual performance measures and integrate these performance measures to evaluate the overall impacts on daily freeway operations based on TMC goals. During the discussion and presentation of the proposed framework, this dissertation uses five minute aggregated traffic data from Lane 1 on SB Loop 12 at Irving Boulevard, Irving, Texas and four lanes on SB-I35W at Alta Mesa, Fort Worh, Texas to illustrate the application of the integrated performance measures.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Traffic congestion due to increasing automobile use is a crucial problem in the United States that creates longer travel times and congestion-related delays. Reducing traffic congestion on freeways not only enhances the mobility of trips, but also improves the safety and efficiency as well as reduces the pollution and economic losses due to traffic congestion. One of the effective strategies to reduce the traffic congestion on freeways is to manage and operate freeways effectively. According to Briglia [6], "Freeway operations, in its broadest context, entail a program to combat congestion and its damaging effects: user delay, inconvenience and frustration, reduced safety, and deteriorated air quality." The active operation of freeways was introduced in the late 1960s and early 1970s. Currently, freeway operational strategies have been developed using new technologies, such as Intelligent Transportation System (ITS), which provide faster and more accurate data than the past. For example, DataLink systems in San Antonio utilize inductive loop data, which allow planners to receive the data every five minutes [7]. Real time data provide an opportunity for decision makers at Traffic Management Centers (TMCs) to evaluate the operation and management of available daily operational strategies such as ramp metering, and dynamic message signs. Faced with limited roadway expansion alternatives, transportation agencies are considering investment in TMCs as a more viable way to operate and manage freeways effectively. In order to provide the reliable decision support for TMC freeway operation and management systems, this dissertation aims to examine the factors influencing the TMCs' investment, the effective methods for persuading the public to support TMC deployment, and the legal issues involved with deciding to deploy a TMC.

In addition, most TMCs evaluate the freeway performance using the performance measures at the states' level, which are suitable for planning in long term. Unfortunately, there are no current standards for performance measures used for daily operational strategies in the United States. This dissertation aims to examine the current uses of daily freeway performance measures in the United States. In addition, a model will be developed to evaluate the quality of those performance measures as well.

Because the quality of freeway assessment is based on the quality of data collection strategies and performance measures, the limitation of data collection strategies and performance measures should be considered at the same time when choosing the data collection strategies for TMCs. Unfortunately, there is no methodology to select the data collection strategies and performance measures at the same time. This research develops an innovative approach, using a multi-criteria decision framework for selecting data collection strategies by considering their limitations.

Since traffic congestion affects both road-users and non-road users, the assessment of freeway operational strategies' performance should consider all aspects related to their implementation such as increasing or decreasing on-road emissions. Most performance measures in the United States are constructed to evaluate only individual impacts such as safety, emission, etc. Unfortunately, there is no methodology to integrate the overall impacts of freeway operations. Thus, finally, this dissertation aims to develop a "Freeway Performance Index (FPI)" to evaluate overall impacts of freeway operations.

1.2 Problem statement

Traffic Management Centers (TMCs) have played an important role for freeway operations and management. At TMCs, freeway operational strategies such as ramp metering and information dissemination can be provided and adjusted to ensure that on-road travelers as well as traffic operators receive information and react to the existing conditions in real time. Most TMCs' goals show that they expect to reduce traffic congestion, enhance the mobility and safety on the roadway, improve the environment and reduce the economic losses due to traffic congestion. TMCs have played an important role in improving the roadways' situation and condition. The TMCs' investment decision includes many additional factors, which have to be determined. These include what are the most important factors that lead to TMCs' investment; what are the legal issues being considered in TMC deployment; and how to encourage the public to support TMCs in the long term. In addition, after deciding to construct a TMC, the decision makers must select the data collection strategies based on the preferred performance measures for evaluating the TMCs performance and responding to operational needs.

Since about the 1950s, the performance measurement concept has been used to assess a variety of roadway characteristics using performance indices, such as density, speed, and volume [26], and travel time index (TTI) [37]. Those performance measures have their own advantages and limitations. For example, Level of Service (LOS) [25] is used to evaluate the existing condition of intersections or roadways as well as new construction or design projects. LOS is constructed to reflect the perceptions of automobile drivers regarding the roadway condition. By using the letter grade (A, B, C, etc.), the LOS is easy to understand and apply at the state-wide level. However, LOS focuses on spot locations, which can not describe the overall quality of the roadway network [44]. In addition, the LOS cannot determine the customer satisfaction in terms of travel time or speed [13]. However, either speed or travel time alone can not be sufficient to determine the overall impacts of operational strategies on freeways.

Recently, as part of the research conducted for National Cooperative Highway Research Program (NCHRP) Synthesis 311, Shaw [56] examines the uses of performance measures for monitoring the operational management of highway segments and systems. The results show that many useful performance measures are identified; however, most of them are not available in real-time, which is not ideal for assessing the operational strategies on freeways. Thus, the performance measures, which can be useful to assess the daily operational strategies in each TMC, must be identified. Finally, a way to assess the overall impacts of multi-operational strategies can be developed by integrating performance measures to capture the agencies' goals.

For the reasons above, this research 's main efforts are into three parts involved with the TMCs' investment, data collection strategies, and integration of performance measures on freeways (in Figure 1.1).

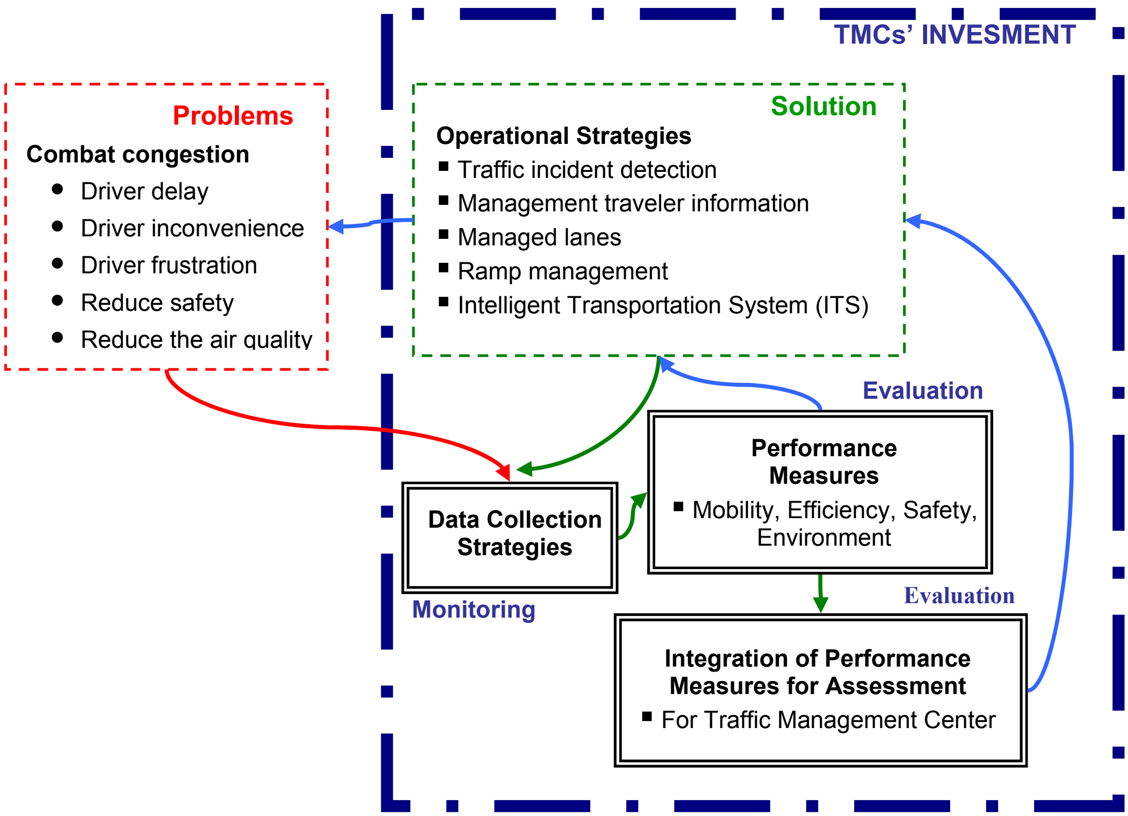


Figure 1.1 Scope of study

First, this research aims to examine the factors involved with the TMCs' investment, effective methods for persuading the public to support deployment of TMCs, and legal issues involved with making a decision to deploy TMCs. The factors involved with the TMCs' investment will be compared with the surveys results related to TMC goals in Section 3.

Second, the research examines the constraints of data collection strategies, and develops a framework for screening and ranking the data collection strategies based on data collection strategies and performance measures limitations. Finally, this research examines the current uses of daily performance measures at TMCs, and identifies the characteristics of performance measures and the TMCs' goals. Then, this research proposes daily freeway operations performance measures and a methodology to calculate their indices for freeway operations, and integrate these into models that evaluate the daily freeway operations. The proposed models and methodology here are expected to facilitate traffic operators' selection of the proper performance measures and data collection strategies, and allow them to examine the overall impacts of daily operational strategies on freeways. The final results are expected to improve the efficient use of operational strategies on freeways.

1.3 Purpose of the study

The objectives of this dissertation include:

1. Identify the existing performance measures and potential performance measures for daily freeway operations.
2. Identify the importance of factors influencing the TMCs' investment, effective methods for persuading the public to support deployment of TMCs, and legal issues involved with making a decision to deploy TMCs.
3. Recommend the weighting techniques for the proposed methodology.
4. Determine the importance of factors influencing performance measure selection.
5. Determine the objective criteria and performance measures for TMCs' goals.
6. Develop the framework and models to select data collection strategies based on the limitation of data collection strategies and performance measures.
7. Develop the methodology for integrating freeway operations' performance measures.
8. Develop the models for assessing the operational strategies on freeways.

1.4 Significance of the study

Freeways represent the backbone of the transportation network in the United States. Nowadays, traffic congestion on freeways not only degrades the mobility of trips, roadway safety, and environment, but it will inevitably lead to serious losses for the U.S. economy. Effective operational strategies have been introduced and developed in the United States through the TMCs, which represent the hub to monitor, evaluate, and adjust freeway operational strategies throughout the system. Effective freeway operations aim to reduce traffic congestion and improve responsiveness to non recurring incidents.

For long term support of TMCs, it is important to know when TMCs are needed, what are the factors impacting the TMCs' investment, what are effective methods for persuading the public to support deployment of TMCs, and legal issues involved with making a decision to deploy TMCs, what should be appropriate data collection strategies, and daily performance measures for freeway operations. The challenges are identifying daily performance measures other than congestion measures, which are suitable for most TMCs, and developing a framework to select an appropriate data collection strategy for freeways that considerers data collection strategies and performance measures limitations at the same time.

When making comparisons among different systems or strategies, standard indicators and methods need to be developed. Standard indicators and methods can allow management to create strategic improvement goals that can be assessed for a variety of locations. Performance measure programs must determine how to integrate traditional data collection system with ITS data collection systems.

To answer the previous questions, this research examines the factors influencing TMCs' investment, effective methods for persuading the public to support deployment of TMCs, legal issues involved with making a decision to deploy TMCs, and potential performance measures for daily freeway operations. Reliable models using the simple additive weight (SAW) method are developed to evaluate the quality of the existing performance measures and potential performance measures. In addition, the research suggests the performance measures that are useful and applicable for assessing the daily freeway operations. A framework to select data collection strategies using a screening approach was developed through a multi-criteria decision approach. Decision models such as SAW and ELECTRE III are utilized to select the best alternatives. Finally, the research will provide a suitable model for evaluating the overall impacts of freeway operational strategies.

1.5 Expected contribution of the research

This research develops the methodology that TMCs can use for assessing their operational strategies. The results from this research will help TMCs to learn the advantages and limitations of the approaches they currently use for evaluating their operational strategies. In addition, this research will provide a methodology that traffic operators at TMCs can use to select the proper performance measures and data collection strategies on freeways based on qualitative and quantitative constraints. In addition, this research will provide baseline performance measures that most TMCs can use for assessing their operational strategies. Finally, the integration of performance measures will be developed and used for evaluating the overall impacts of freeway operational strategies. The application of proposed framework for selecting the data collection strategies and integrated performance measures will be provided along with the explanation. It is expected that the framework, methodology, and models can be applied in most TMCs in the United States.

1.6 Organization of dissertation

This section briefly describes the organization and the contents of the remaining chapters of this dissertation. Chapter 2 provides a brief history of performance measurement, and transportation and emission performance measures currently in use. Chapter 3 describes the decision-making process in general and discusses the multi-criteria decision-making theories and weighting techniques used in this dissertation. Chapter 4 provides the research methodology including data collection effort, survey questionnaires, evaluation techniques, and data analysis. Chapter 5 describes a framework developed in this research for selecting the data collection strategies based on the performance measures. Then, an example of the proposed framework is provided at the end of chapter to illustrate the processes. Chapter 6 describes the model formulation and explanatory variables for selecting good performance measures and integrating them. A complete application of the models will be provided at the end of Chapter 5 and 6. Chapter 7 includes a discussion of the conclusions and a description of future research.

CHAPTER 2

PERFORMANCE MEASUREMENT

This chapter reviews performance measurement including a brief history of performance measurement, definition of performance measures, and performance measures currently in use for transportation, transportation operations, air quality measures, and integration of performance measures.

2.1. A brief history of performance measurement

According to NCHRP synthesis 311 [55] and Brydia *et al.* [7], “Deming Total Quality Management” or “Total Quality Management (TQM)” was first developed by William Edwards Deming. The concept of TQM derives from the principles of product quality, process control, quality assurance, and quality improvement. These principles aim to develop goals, which can be utilized to track, monitor, and evaluate using measurable results. Then, the strategies to improve the quality of products can be developed. Later, by embracing the TQM principles to evaluate the performance of programs or organizations to meet the customers’ satisfaction, those processes become known as “performance measurement”.

In the United States, performance measures for transportation have become popular since the Intermodal Surface Transportation Efficiency Act (ISTEA) promoted the use of performance measures and performance-based planning in 1991. Later, the Government Performance and Result Act of 1993 established specific performance measures. The major federal programs are required to use them for evaluating their programs. In 1997, the National Performance Review Report provides the recommendation of using performance measurement for assessing federal programs and local governments [56].

2.2 Definition of performance measures

Performance measures or indicators are scientific and systematic assessment tools generally used by governmental agencies for selecting appropriate projects or evaluating projects. Performance measures may be categorized by types, such as input measure, output measure, outcome measure, service measure, and cost effectiveness measure. Input measures are defined as the resources used in producing an output or outcome, while output measures are defined as the products or services from the activities or programs. Outcome measures are defined as the occurrence, condition, or consequence of activities or programs. Service measures are defined as a measurement of the user's satisfaction. Cost effectiveness measures are defined as a measurement of activity or program success [32].

Since performance measurement has been used in many fields, there is no single methodology or exact rule for selecting them. In addition, criteria for selecting appropriate performance measures should be decided by people who are involved in the program, such as those who collect and use the data or experts who understand the strengths and limitations of each performance measure. This research will develop tools for selecting good performance measures for freeway operations based on input from traffic engineers who manage and operate freeway systems described in Chapter 6.

Good performance measures in general should focus on the goals and objectives of the program. They should be simple, easy to understand for everyone, able to respond to changes in the system, inexpensive to obtain, organizationally acceptable, credible, timely, comparable, compatible, customer focused, consistent, measurable, available, balanced, valuable, and practical [7, 46, 30].

2.3 Performance measures in transportation

According to Brydia [7], performance measures have been used in transportation for a period of time, but initially, they have not been referred to as transportation performance measures. For example, the Highway Capacity Manual [26] refers to speed and density as measures of effectiveness (MOEs). Performance measures that are used in transportation include those for pavements, structures, right-of-way (ROW), utility work, and communications. The application of performance measures for transportation can vary by scales, spatial scope, transportation system users, and transportation facilities. For example, at the operational level, the performance measures should be able to evaluate the operational strategies in real time. On the other hand, performance measures used in transportation planning may differ from performance measures used in transportation operations because they usually look at the overall operational impacts over the long term. Shaw [56] recommends the performance measures for transportation investments at the planning level (in Table 2.1), which includes the areas of transportation performance, financial/economic performance, social impacts, land use/economic development impacts, and environmental impacts.

In addition, performance measures also can be categorized by area sizes. For example, a small area specifies only highway segments, while a larger area specifies a complete highway system or urban network. Shaw [56] defines a highway section as a part of a roadway extending from one signalized intersection; a corridor is defined as a combination of highway sections; and area wide is defined as a combination of all facilities or corridors in an area. This research defines a freeway segment as a section between one interchange and another interchange; while a corridor is defined as a combination of freeway segments and area wide is defined as a combination of corridors.

Performance measures for transportation also can be classified by users and non-users of the transportation system (in Table 2.2) as well as measurement of the transportation facility itself [8]. The multimodal performance measures developed from Cambridge Systematics [8] evaluates transportation performance in terms of users' service such as service frequency, travel time and travel comfort, and nonuser impacts such as congestion cost, noise, and emissions; and transportation facility performance such as volume to capacity (V/C), which is the ratio of flow to roadway capacity for persons or freights.

Table 2.1 Performance measures for evaluating the transportation projects

Area of Impact	Performance Measures
Transportation performance	• Average travel time • Average travel rate • Total delay • Person-miles of travel in congested ranges • Person-hours of travel in congested ranges • Person movement • Person movement speed • Accident reduction
Financial/economic performance	• Benefits/costs ratio (using full-cost analysis) • Financial feasibility • Cost per new person-trip
Social impacts	• Number of displaced persons • Number and value of displaced homes • Neighborhood cohesion • Accessibility to community services
Land use/economic development impacts	• Number and value of displaced business • Accessibility to employment • Accessibility to retail shopping • Accessibility to new/planned development sites
Environmental impacts	• Energy consumption • Mobile source emissions • Noise levels • Visual quality/aesthetics • Vibration • Water resources • Wildlife/vegetative habitat • Parkland/open/green space • Cultural resources • Agriculture/forest resources • Geologic resources • Hazardous wastes

Reference: Shaw [56]

Recently, Shaw [56] conducted a survey of current uses of transportation performance measures through agencies and metropolitan planning organizations (MPOs) in September of 2001. The results found that the top five performance measures used by DOTs and MPOs are level of service, traffic volume, vehicle-miles traveled, travel time, and speed (in Table 2.3). Shaw found that agencies in larger (population) areas are more likely to have a performance measure program. In addition, many agencies do not have performance measures. Most rely on their own experience and understanding to qualitatively assess the traffic situation.

Table 2.2 Performance measures for users and nonusers of transportation systems, and transportation facilities

Classified by:	**Performance Measures**
Users of transportation systems	• Service frequency • Travel time • Travel comfort • Travel time reliability • Probability of loss and/ or damage and costs
Nonusers of transportation systems	• Congestion costs • Noise • Fuel consumption • Emissions • Pavement maintenance costs • Bridge maintenance costs
Transportation facilities	• Volume/capacity (V/C) ratio for vehicles • V/C ratio for persons and goods moved expressed in any of the following units – persons, weight, cubic volume, or equivalent equipment movements • Speed on facilities and through nodes (time means speed, space mean speed, and variability • LOS • Cumulative person-hours of delay • Cumulative hours of delay for freight • Dollar value of cumulative delay for persons and freight • Cumulative delay by the most important delay sources such as recurring and non-recurring delay • Passenger and freight vehicle-mile traveled (VMT) on a facility • Additional trips on a facility • Accidents (persons and freight)

Reference: Cambridge Systematics [8]

The National Transportation Operations Coalition (NTOC) [43] conducted a survey of transportation agencies to identify performance measures that measure transportation activities using responses from city government, county government, MPO and regional council of governments (COG), state government, federal government, and consultant. NTOC [43] has conducted the survey to examine the current use of performance measures for transportation. The results indicate that performance measures for safety issue, intersection level of service, vehicle throughput, speed, and link travel time are the top five performance measures are currently in use (in Table 2.4).

Table 2.3 Frequency of performance measures in use by DOTs and MPOs

Performance Measures	In Use by DOTs and MPOs (%)
Level of Service	11.0
Traffic Volume	11.0
Vehicle-miles traveled	10.0
Travel time	8.0
Speed	7.0
Incidents	6.0
Duration of Congestion	5.0
Percent of system congested	5.0
Vehicle occupancy	5.0
Percent of travel congested	4.0
Delay caused by incidents	3.0
Density	3.0
Rail crossing incidents	3.0
Recurring delay	3.0
Travel costs	3.0
Weather-related traffic incidents	3.0
Response times to incidents	2.0
Commercial vehicle safety violations	1.0
Evacuation clearance time	1.0
Response time to weather-related incidents	1.0
Security for highway and transit	1.0
Toll revenue	1.0
Travel time reliability	1.0

Reference: Shaw [56]

Table 2.4 Frequency of performance measures in use

Performance Measure	% Use of Each Measure
Safety – A family of measures	78
Intersection Level of Service	76
Throughput per Vehicle	56
Travel Time – Link	46
Speed	45
Extent of Congestion	36
Customer Satisfaction – A family of measures	33
Recurring Delay	32
Travel Time – From Origin to Destination	28
Emissions	20
Incident Delay	16
Incident Characteristics	15
Throughput per Person	13
Reliability	5

Reference: NTOC [43]

As part of the research conducted for NCHRP Synthesis 238 by Poister [48], a survey is conducted to collect the uses of performance measures from State DOTs. The surveys aim to identify the frequency that performance measures are reported across all modes of transportation (in Table 2.5). The results show that most performance measures for highways such as multimodal transportation, highway construction, highway maintenance, and traffic safety are reported annually. Thus, they are expected to be used for planning rather than operation.

Table 2.5 Reporting frequency uses of performance measures

Program Area	**In Use by States (%)**	**Frequency of Reporting (%)**			
		Monthly	**Quarterly**	**Annually**	**Others**
Multimodal Transportation	28	17	-	92	8
Highway Construction	61	28	8	28	38
Highway Maintenance	89	47	13	60	35
Traffic Safety	83	10	7	83	22
Public Transportation	64	17	22	61	7
Ferry Service	36	62	23	46	15
Aviation	58	42	19	32	19
Railroads	44	22	-	72	6
Ports and Waterways	33	42	17	42	17
Licensing and Registration	28	67	22	33	33
Administrative Performance	36	46	18	46	9

Reference: Poister [49]

2.4 Performance measures in transportation operations

According to Shaw [56], most operational performance measures have been established during the mid-1990s. Operational performance measures include reliability of operations and transportation systems, and multimodal performance measures. The travel time reliability performance measure used by the Florida DOT is defined in terms of traveler's expectations; not in terms of a failure rate for mechanical equipment or devices. The concept of a travel time reliability performance measure comes from the variation between expected travel time and actual time [29]. Turner *et al.* [62] defines the trip time reliability as the range of travel times experienced during daily trips, which can be calculated by the mean and standard deviation of travel times within a sample. The range of travel time will be useful when it is compared with the same facility such as northbound versus southbound travel. Turner suggests the reasonable range of travel time should be between 7.5th to 92.5th percentiles. On the other hand, approximately 15% of the travel time is considered unreliable.

Lomax *et al.* [37] defined the reliability as the difference in delay experienced on incident days versus nonincident days. Then, the total delay is calculated by multiplying vehicle volume and the difference between actual and acceptable travel time. The acceptable travel time is the total travel time during expected conditions. This travel time is generally calculated at the posted speed limit.

According to Ikhrata and Michell [28], the reliability indicator is calculated from the following equation:

$$\textit{Reliability} = 1 - (\%Trips_{within} - \%Trips_{exceed}) \tag{2.1}$$

Where:

$\%Trips_{within}$ = the percent of trips in which travelers arrive at their destinations at the expected travel time or less.

$\% Trips_{exceed}$ = the percent of trips in which users do not arrive at destinations within the expected (average) travel time.

The 1998 California Transportation Plan [1] defines the reliability as the variability between the expected travel time (based on scheduled or average travel time) and the actual travel time. The Florida's Reliability Method report [29] defines the reliability as the percent of travel time plus a certain acceptable additional time. The acceptable time is obtained using the equation (6.14). Texas Transportation Institute (TTI) [37] suggests the "reliability buffer index" in 2002 as the difference between the average travel time and the 95th percentile travel time as the extra time compared with the average travel rate.

Brydia *et al.* [7] use a questionnaire survey to collect information regarding daily operations at traffic management centers (TMCs) in Texas, including TransVista (El Paso), TransGuide (San Antonio), TransStar (Houston), DalTrans (Dallas), TransVision (Ft. Worth), and TxDOT Traffic Operations Headquarters (Austin). The results indicate that no respondents report the use of performance measures in daily operations. Brydia *et al.* [7] suggests the application of NTOC performance measures (in Table 2.6), which identifies those daily operational strategies that are applicable in real time.

Table 2.6 NTOC performance measures

Measure	Basis	Capability in real time uses
Customer Satisfaction	Perception	No
Extent of Congestion-Spatial	Speed	Yes
Extent of Congestion-Temporal	Speed	Yes
Incident Duration Time	Time	Yes
Non-Recurring Travel Delay	Time	Maybe
Recurring Travel Delay	Time	Maybe
Speed	Speed	Yes
Throughput-Person	Volume	Yes
Throughput-Vehicle	Volume	Yes
Travel Time-Link	Speed	Yes
Travel Time-Reliability	Speed	Yes
Travel Time-Trip	Speed	Yes

Reference: Adapted from NTOC [43]

This dissertation applies some of the operational performance measures in Table 2.6 for developing an integrated assessment of system performance; this methodology is described in detail in Chapter 6.

In summary, from the recent surveys of current performance measure use by Shaw [56] and NTOC [43], most of them are constructed for use at the planning level; however, some can be applied for daily freeway operations. Due to the lack of performance measures for daily operations [56, 7, 49], this dissertation conducts a survey, which aims to establish the performance measures, which may be applicable for daily freeway operations based on input from TMCs throughout the United States. The details of the surveys are described in Chapter 4. From the viewpoint of the applicable spatial scale, the operational performance measures in this research should be applicable to both freeways segments and corridors. In addition, it is expected to be used by traffic operators at TMCs for evaluating the overall impacts of freeway operation improvements, policies, and strategies.

2.5 Performance measures in air quality

Emission performance measures are utilized to measure the quality of ambient air conditions. Many states have developed them to assess the status and trends of ambient air conditions. The emission performance measures may be a set of trend data or scored data within a period of exposure time that should indicate the system condition. For example, a roadway network should maximize flow, while minimizing on-road emissions. The emission performance measures should assist traffic operators in evaluating the impacts of transportation operational strategies that result in an impact on freeways emissions. In addition, emission performance measures should be beneficial for both transportation plans and operations in the short or long term.

A good emission performance measure should be practical and realistic. It should be easy to understand for all people and easy to develop with available data. Moreover, it should be provided in time, so the users, such as travelers or government, still have time to react to the air pollution condition. For example, an emission performance measure, such as Air Quality Index (AQI), which is an index to measure the ambient air quality, can provide air quality information along the roadway network so that travelers will know the air quality condition and try to avoid routes with high air pollutants.

2.5.1 Emission performance measures

Since the initial realization that air pollution is a significant problem in parts of the U.S., AQI has been used to assess the ambient air quality in many states and regions. Although the use of indicators has been increasing, the definition and selection of emission performance measures are still at an early stage. Thus, this dissertation provides a list of emission performance measures, which are utilized in different organizations. These emission performance measures are categorized by types: input measure, output measure, outcome measure, service measure, and cost effectiveness measure (in Figure 2.1). The descriptions of input, output, outcome, service, and cost effectiveness measures are provided in Section 2.1.2; however, the definition of input, output, outcome, service measure, and cost effectiveness measures will be different based on variations in programs, activities, or study purposes. Clarifying the definition of those measures for specific applications is important. In this research, transportation is considered as a part of human activities, and it is involved with the movement of people or goods. Thus, input measures will be defined as the vehicles, drivers, or roadways used for transporting people or goods from an origin to a destination, whereas output measures are people or goods being transported. Outcome measures are defined as the occurrence, condition, or consequence of activities, such as roadway conditions, or air quality. A service measure is defined as the measurement of traveler or resident satisfaction with the outputs. Finally, a cost effectiveness measure is defined as a measurement of the programs used to improve the outcome (air quality).

This research focuses on the outcome measures (emissions generated from vehicles). The outcome measures are first divided into two levels based on spatial and temporal applicability, tactical and strategic. The outcome measures at the tactical level (response planning) should enable traffic operators to assess the emission impacts in a short period of time and in a particular area, such as corridor. On the other hand, outcome measures at the strategic level (long term planning) should evaluate overall emission impacts in the long term over a wider area, such as a region. At the tactical level, the outcome measures should access the air quality in a particular area, such as intersections or freeway on-ramps. In addition, it should be able to assess the emission impacts due to incident events on freeways. At the strategic level, the outcome measures should assess the condition or well being of people in the region, or state, or the long-term results of different government programs, such as vehicle retirement, new alternative fuels, low emission vehicles, etc.

2.5.2 Criteria for selecting outcome measures for emission

There are no exact rules for performance measure selection. Criteria for choosing measures can be identified by the people who collect and use the data, or experts who understand the strengths and limitations of each performance measure. However, good performance measures should be a direct consequence of activities. For example, emissions generated from roadways are defined as an outcome measure. If the desired result is minimizing emissions, the emission rate should be a good performance measure (direct consequence). A proxy measure may sometimes be used in the absence of suitable performance measures due to time, budget constraints, or unavailability of data. For example, when considering the desired result of emission reductions, instead of using the direct outcome measure of emission rate, output measures such as the vehicle registration or congestion level may be used as indirect performance measures. Unfortunately, a proxy measure may not present a good result or measure because the correlation may be weak. Consistency and data availability will sometimes limit the effectiveness of the performance measures. In this dissertation, performance measures at the response planning level are used to capture the emission impacts during a short period of time. Thus, data used at the response level must be collected frequently in order to capture the changes in emissions, such as second by second at the tail pipe. Unlike performance measures at the response level, performance measures at the planning level should assess the emission impacts over a long period of time; data used at this level may be obtained from annual reports by state or local governments.

INPUTS

DIRECT INPUTS
- **Human**
- **Goods**

INDIRECT INPUTS RELATED TO SERVICE/QUALITY

Human
- Driving behavior
- Characteristics of traveler such as age, or education.

Vehicles
- # and type of vehicles
- # of stops
- # of accelerations or decelerations
- type of fuel

Roadway
- # of accidents
- # of incident events
- Purposes of trip
- Presence of construction
- Roadway improvement program such as ATMS. (Improving the mobility)

OUTPUTS
- **Human**
- **Goods**

OUTCOMES

California DOT [1]
- Airport-related air emissions

Massachusetts DOE [2]
- # of non-attainment areas
- # and % of residents exposed to air that meets NAAQS for SO_2, $PM_{2.5}$, PM_{10}, CO, O_3, NO_2, and Pb
- Trends in emissions of toxic air pollutants from air monitoring networks.

Puget Sound Regional Council [3]
- Sub-area Air Quality Index using on-road mobile sources during peak (concentration/ sq. kilometer grid cells; highest grid cell, median grid cell, etc.)

Mn DOT [4]
- Outdoor levels of ozone, nitrogen dioxide, carbon monoxide, and particulate matter
- Estimated carbon dioxide emissions from motor vehicles
- Percent of fuel consumption defined as cleaner fuels

U.S. DOT [5]
- On-road mobile source emission concentration (Emission rate)
- # of non-attainment and maintenance areas

Environmental Protection Energy (EPA) [6]
- Air Quality Index
- Tracking changes in ozone concentrations based on the 3-year average of the annual fourth highest daily maximum 8-hour concentration (8-hour ozone NAAQS)

Alberta Environment (Canada) [7]
- Calculating the percentage of days that exceed the air quality standard annually

Oregon DOT [8]
- Percent of time that the air is healthy to breathe for all people.

Wisconsin Department of Natural Sources [9]
- Reduce the # of deaths, hospitalizations, asthma attacks, and lost school and work days in the State.

Office of Management and Budget [10]
- Pounds of pollutants reduced

Tennessee DOT [11]
- Increase/ decrease in air quality pollutants in major transit corridors

SERVICE/ QUALITY OUTCOMES

Wisconsin Department of Natural Sources [9]
- The percentage of respondents that rate air management's permitting programs as good or excellent in five categories; responsiveness, efficiency, timeliness, effectiveness and

COST-EFFECTIVENESS OUTCOMES

Wisconsin Department of Natural Sources [9]
- Reduce the cost of illness in the state (based on an EPA model) associated with exposure to ground-level ozone and fine particles.

Reference: [1] http://www.dot.ca.gov/hq/tsip/tspm/tspmdocs/pm11_01avitech.doc
[2] http://www.mass.gov/dep/about/priorities/ppagoals.htm
[3] http://www.psrc.org/projects/cms/measures.htm
[4] http://www.cts.umn.edu/research/rfp/documents/MnDOT-Performance-Measures.pdf
[5] http://www.fhwa.dot.gov/Environment/perform/aqrpt03.htm
[6] http://airnow.gov/
http://www.epa.gov/oar/aqtrnd97/chapter2.pdf
[7] http://www.ec.gc.ca/dpr/2002/en/c3a.htm#anchor311
[8] http://www.oregon.gov/DAS/OPB/docs/apr/EnvironQ_LDSR.doc
[9] http://www.dnr.state.wi.us/environmentprotect/pm/cancerrisk.html
[10] http://www.whitehouse.gov/omb/part/performance_measure_examples.html
[11] http://www.tdot.state.tn.us/plango/pdfs/Performance%20Measures.pdf

Figure 2.1 Emission performance measures

This dissertation lists the emission performance measures (direct outcome measures and proxy outcome measures) from different organizations based on data availability and application of emission performance measures (in Table 2.7). Those appropriate outcome measures applicable to transportation will be discussed and grouped based on temporal-spatial variation for each level of planning (in Table 2.8). Table 2.8 lists only the appropriate outcome measures applicable to transportation based on temporal-spatial variation for each level of planning. Considering the criteria for choosing measures, direct outcome measures (occurrence, condition, or consequence of activities comes from transportation process related to air quality) should assess the quality of ambient air better than the proxy or contributing outcome measures. However, direct emission performance measures seem difficult to apply on freeways due to the lack of nearby monitoring stations. In addition, the accuracy of proxy measures may also be affected by additional factors such as industrial sources, temperature, and wind speed.

Table 2.7 Outcome emission measures

OUTCOME EMISSION MEASURES	TARGET	Qualitative/ Quantitative	Data Needs	Note
• On road emissions - Ambient concentration (ppm) - Emission rate (ppm/mile) (Tactical level)	• Maintain the ambient concentration less than the NAAQS	*Quantitative*	• 1 minute, 5 minute, 1 hour, 24 hour data for tactical level (depending on each pollutant)	• Applicable for transportation
• # of non-attainment areas (Strategic level)	• Lowering each year the percentage of non-attainment and maintenance areas in a state	*Quantitative*	• Annual data	• Applicable for transportation
• # and % of residents exposed to air that meets NAAQS for SO_2, $PM_{2.5}$, CO, O_3, NO_2, and Pb (Strategic level)	• Reducing of # of deaths, hospitalizations, asthma attacks, and lost school and work days in the state	*Quantitative*	• Annual data	• Not applicable for transportation • Due to the metrological conditions, emission disperse everywhere; it is difficult to capture the exact # of residents exposed to air that meets NAAQS.
• Subarea Air Quality Index using on-road mobile sources during peak (concentration/ sq. kilometer grid cells; highest grid cell, median grid cell, etc.) (Tactical level)	• Maintain the air quality index less than 100	*Quantitative*	• 1 minute, 5 minute, 1 hour, 24 hour data	• Applicable for transportation
• Air Quality Index (AQI) (Strategic level)	• Maintain the air quality index less than 100	*Quantitative*	• 1 hour data for AQI reporting	• Applicable for transportation

Table 2.7 - *Continued*

OUTCOME EMISSION MEASURES	TARGET	Qualitative/ Quantitative	Data Needs	Note
• Number of days exceeding air quality standard annually (Strategic level)	• Reducing the percentage of days exceeding the air quality standard in each year	*Quantitative*	• Annual data	• Applicable for transportation
• Tracking changes in ozone concentrations based on the 3-year average of the annual fourth highest daily maximum 8-hour concentration. (8-hour NAAQS for ozone) (Strategic level)	• Decrease the 3-year average ozone concentration	*Quantitative*	• Annual data	• Applicable for transportation
• # of deaths, hospitalizations, asthma attacks, and lost school and work days in the State (Strategic level)	• Reduce the # of deaths, hospitalizations, asthma attacks, and lost school and work days in the State	*Quantitative*	• Annual data	• Not applicable for transportation Factors unrelated to air pollution (epidemics, incidences of smoking, etc.) can impact number of deaths, hospitalizations, and the other measures. Separating out the impacts of air quality requires extensive statistical analysis.
• Percent of fuel consumption of cleaner fuels (Strategic level)	• Improving each year the percentage of cleaner fuels	*Quantitative*	• Annual data	• Applicable for transportation
• Pounds of pollutants emitted from roadways (Strategic level)	• Reducing the pounds of pollutants emitted each year	*Quantitative*	• Annual data	• Applicable for transportation

Table 2.7 - *Continued*

OUTCOME EMISSION MEASURES	TARGET	Qualitative/ Quantitative	Data Needs	Note
• Avg. fuel economy for TXDOT fleet - Maintenance veh. - Non-maintenance veh. (Strategic level)	• Improving each year the percentage of avg. fuel economy for TXDOT fleet	*Quantitative*	Annual data	Applicable for transportation
• Percentage of passenger car fleet classified as high fuel economy (Strategic level)	• Improving each year percentage of passenger car fleet classified as high fuel economy •	*Quantitative*	Annual data	Applicable for transportation
• VMT of all vehicles (Strategic level)	• Reducing each year the VMT of all vehicle •	*Quantitative*	Annual data	Applicable for transportation
• VMT of commercial vehicles in non-attainment areas (Strategic level)	• Reducing each year the VMT of commercial vehicles in non-attainment areas	*Quantitative*	Annual data	Applicable for transportation
• # of incidents on roadways (Strategic level)	• Reducing each year the # of incidents and accidents on roadways	*Quantitative*	Annual data	Applicable for transportation
• Vehicle occupancy rate (Strategic level)	• Improving each year the rate of vehicle occupancy	*Quantitative*	Annual data	Applicable for transportation

Table 2.7 - *Continued*

OUTCOME EMISSION MEASURES	TARGET	Qualitative/ Quantitative	Data Needs	Note
• Lbs. of transportation emissions per number of vehicles (modeled) (Strategic level)	Reducing each year lbs. of transportation emissions per number of vehicles (modeled)	*Quantitative*	Annual data	Applicable for transportation
• Lbs. of transportation emissions per VMT (modeled) (Strategic level)	Reducing each year lbs. of transportation emissions per VMT (modeled)	*Quantitative*	Annual data	Applicable for transportation

Table 2.8 Emission measures applicable to transportation

OUTCOME EMISSION MEASURES	Spatial variation	Temporal variation	Type of outcome measure	Transportation Impacts	Data applicable in real time	DISCUSSION
• On road emission - Ambient concentration (ppm) - Emission rate (ppm/mile) (Tactical level)	Corridor/ Local/ Sub-Regional	Less than one year	Direct outcome measure	Direct	Applicable	• Ambient Concentration (ppm) data is obtained from the monitoring sites. The data is collected in real time. • Emission rate (ppm/mile) can be obtained directly from on-road emission measurement. It also can be estimated by using microscopic emission models such as CORSIM and VISSIM, and macroscopic emission model such as MOBILE6. • Modeling using CALINE with the emission rate obtained by on-road emission measurement or microscopic emission model can allow us to predict ambient concentration on road; in addition, contour of ambient concentrations along the road using CALINE can be used to compute the subarea air quality index.
• # of non-attainment areas (Strategic level)	Statewide	One to twenty five years	Direct outcome measure	Contributing	Not applicable	• # of non-attainment areas can be obtained from TCEQ website.
• Subarea Air Quality Index (concentration/ sq. kilometer grid cells; highest grid cell, median grid cell, etc.) (Tactical level)	Corridor/ Local	Less than one year	Direct outcome measure	Direct	Applicable	• Subarea Air Quality Index can be calculated by using on-road emission measurement or modeled value as an input to the dispersion model CALINE, used to compute pollutant concentrations.

Table 2.8 - *Continued*

OUTCOME EMISSION MEASURES	Spatial variation	Temporal variation	Type of outcome measure	Transportation Impacts	Data applicable in real time	DISCUSSION
• Air Quality Index (AQI) (Strategic level)	Regional	Less than one year	Direct Outcome measure	Contributing	Applicable	• Air Quality Index (AQI) is calculated by the states and posted on the TCEQ website at http://www.tceq.state.tx.us/cgi-bin/compliance/monops/psi_rpt
• Number of days exceeding air quality standard annually (Strategic level)	Regional	One to twenty five years	Direct outcome measure	Contributing	Not applicable	• Percentage of days exceeds air quality standard can be calculated using data from annual air pollution report from state and local information. Data Source: http://www.epa.gov/aqspubl1/select.html • For DFW, tracked directly by NCTCOG.
• Tracking changes in ozone concentrations based on the 3-year average of the annual fourth highest daily maximum 8-hour concentration. (Strategic level)	Regional	One to twenty five years	Direct outcome measure	Contributing	Not applicable	• Changes in ozone concentration can be determined using data from states and local data. • For DFW, tracked directly by NCTCOG.
• Percent of fuel consumption defined as cleaner fuels (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Direct	Not applicable	• Could be subdivided into gasoline, diesel, and other cleaner fuels such as electricity, natural gas, fuel cells, ethanol, methanol and propane.

Table 2.8 - *Continued*

OUTCOME EMISSION MEASURES	Spatial variation	Temporal variation	Type of outcome measure	Transportation Impacts	Data applicable in real time	DISCUSSION
• Avg. fuel economy for TXDOT fleet - Maintenance veh. - Non-maintenance veh. (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Direct	Not applicable	
• Percentage of passenger car fleet classified as high fuel economy • (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Direct	Not applicable	
• VMT of all vehicles (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Direct	Not applicable	
• VMT of commercial vehicles in non-attainment areas (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Direct	Not applicable	• Data source: MPOs provide data.
• # of incidents on roadways (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Direct	Not applicable	

Table 2.8 - *Continued*

OUTCOME EMISSION MEASURES	Spatial variation	Temporal variation	Type of outcome measure	Transportation Impacts	Data applicable in real time	DISCUSSION
• Vehicle occupancy rate (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Direct	Not applicable	
• Lbs. of transportation emissions per number of vehicles (modeled) (Strategic level)	Regional	One to twenty five years	Proxy outcome measure	Contributing	Not applicable	
• Lbs. of transportation emissions per VMT (modeled) (Strategic level)	Statewide	One to twenty five years	Proxy outcome measure	Contributing	Not applicable	

Note: some outcome measures such as ambient concentration and emission rate may be utilized for both tactical level and strategic level in longer periods of time. The application of outcome measures is not specific. It varies depending on the specific purposes of studies according to the users, departments, or organizations.

2.6 Integration of performance measures

This research reviews the integration of performance measures, which relate to transportation, based on the purposes of their uses; this study specifically considers:

- Integration of performance measures for transit quality of service
- Integration of performance measures for traffic congestion
- Integration of performance measures for ITS systems

2.6.1 Integration of performance measures for transit quality of service

The Transit Capacity and Quality of Service Manual (TCQSM) was first developed in 1999 and aims to provide a tool to evaluate the quality of transit service in the United States. The Florida Department of Transportation (FDOT) has been one of the pioneers in implementing the TCQSM at a statewide level. FDOT requires all metropolitan planning organizations (MPOs) to assess their quality of transit service based on the performance measures in the TCQSM. The TCQSM is applied not only in the United States such as Chicago [58] and Seattle [43], but it is useful to assess the transit quality in other countries such as Ireland [11], Italy [10], and Great Britain [65]. The transit performance measures in TCQSM include:

Fixed-route transit

- Frequency (vehicles per hour)
- Hours of Service (hours)
- Service Coverage (% Transit Service Areas covered)
- Passenger Load (p/seat)
- On-Time percentage in a period of time (%)
- Headway adherence (Coefficient of variation of headways)
- Travel time difference between transit vs. automobile (minutes)

Demand responsive transit (DRT)

- Response time (hours)
- Span of service (hours per day and days per week)
- On-time percentage
- Trips Not Serviced (Percent Trips not served)
- Travel time difference between transit vs. automobile (minutes)

In order to find the overall transit quality of service, Nelson and Nygaard [44] constructed an index composed of five transit performance measures in the TCQSM. This index is used to evaluate the quality of service for Seattle's Urban Village Transit Network. Those measures include frequency, span of service, reliability, loading, and travel speed. They suggest another threshold (pass/ fail) based on the LOS of the TCQSM where "pass" means the LOS is better or equal to LOS C and "fail" means the LOS is lower than LOS C. They score LOS A,B, C, D, E and F as +3, +2, +1, -3, -6, and -9, respectively. The total quality of service scores are computed by multiplying the weight and individual scores of each performance measure.

Unlike Nelson and Nygarrd [44], this dissertation develops a threshold using the quantitative data provided from ITS systems. The index must be capable of being calculated in real time.

Sandlin and Anderson [54] provided another application of the transit quality service index by multiplying the LOS measures to evaluate the service levels and operating condition. This index is called a serviceability index for demand-responsive transit operators based on regional socio-economic conditions and internal operation data. The serviceability index (SI) is constructed from the agency performance measures [54]. The proposed performance measures include the percent of transit supportive areas that can be served based on agency operating costs, the number of passengers per vehicle mile, the percent of unmet passenger demand based on census data and existing coverage area, the percent of passengers sixty years of age or older, the percent of costs consumed by administrative costs, the average age of the fleet (in years). The formulation of the serviceability index (SI) is shown in equation 2.2.

$$SI = \frac{\sum w_i Q_i}{n} \times 100 \qquad (2.2)$$

Where:

w_i = the weight of performance measure *i*

Q_i = Performance measure *i*

n = number of performance measure used

The final equation for the serviceability index (SI) in equation (2.2) after the weights developed by Sandlin and Anderson are provided is shown in equation (2.3).

$$SI = \frac{\left[(4.8Q_1) + (6.2Q_6) + \left[4.2(100 - Q_4)\right] + \left[4.3(100 - Q_{12})\right] + \frac{5.1(15 - Q_{15})}{15} + 5.1Q_3\right]}{4.9667} \qquad (2.3)$$

Where:

Q_1 = the percent of transit supportive areas that can be served based on operating costs of the agency

Q_3 = the number of passengers per vehicle mile

Q_4 = the percent of unmet passenger demand based on census data and existing coverage area

Q_6 = the percent of passengers 60 years of age or older

Q_{12} = the percent of costs consumed by administrative costs

Q_{15} = the average age of the fleet (in years)

Like Sandlin and Anderson [54], this dissertation develops the threshold using the quantitative data and similar model formulation using SAW.

2.6.2 Integration of performance measures for traffic congestion

Pasarski [47] divides that traffic congestion can be divided into four dimensions (i.e. breadth, duration, extent, and intensity). The breadth dimension concerns the geographic expansion of congestion over the roadway network in the selected areas, while duration considers that the amount of time that congestion lasts. Sometimes, it may recur at a consistent time. Extent concerns the number of persons or vehicles affected by travel delays, and intensity considers the congestion's "seriousness" such as the travel speed or environmental impacts during the congestion [13]. The congestion measures are grouped by breadth, duration, extent, and intensity as shown in Table 2.9. Some researchers developed a congestion index by multiplying the congestion measures among the different dimensions. For example, the lane-mile duration index (LMDI) is developed by Epps *et al.* [18] was constructed by multiplying between the breath and duration of congestion as below:

$$LMDI = \sum_{i=1}^{n} (lane - miles_F \times DUR)_i \tag{2.4}$$

Where:

i = a freeway segment

n = the total number of freeway segments in an urbanized area

$lane\text{-}miles_F$ = the freeway lane-mileage experiencing LOS "F"

DUR = the number of hours per day of LOS "F" operation (V/C ≥ 1.0)

The disadvantage of developing congestion indices by multiplying various dimensions using Pasarski's concept is the magnitudes of those indices are very high and difficult to explain in terms of program success. In addition, this research aims to develop an index, which is readily normalized and program success can be determined based on this index. Furthermore, the significance of changes in performance related to index values should be examined.

Table 2.9 Congestion measures by four dimensions

Measures of Congestion	Units	Reference
Breadth		
Congested roadway	Miles	Shaw [55]
Lane-miles at a certain LOS	Lane-miles	Federal Register [19]
Duration		
Queuing duration	Hours or minutes	Levinson *et al.* [34]
Duration of peak period	Hours or minutes	Levinson *et al.* [34]
Extent		
Vehicle Mile Travel	VMT	Shaw [55]
Extent, Intensity		
Person-hours of delay	Person-hours	Federal Register [19]
Total delay	Person-hours; vehicle hours	Shaw [55]
Intensity		
Average travel time per trip	Minutes/ trip	Levinson *et al.* [34]; Federal Register [19]; Shaw [55]
Delay per trip	Minutes/ trip	Federal Register [19]
Delay per vehicle	Minutes/ per vehicle	Federal Register [19]
Delay per VMT	Minutes/ VMT	Federal Register [19]
Delay rate	Minutes/ mile	Federal Register [19]
Density	Vehicles/ lane/mile	Levinson *et al.* [34]
Lane occupancy	Percent of time	Levinson *et al.* [34]
Level of service	none	Levinson *et al.* [34]; Federal Register [19]
Travel rate	Minutes/ mile	Shaw [55]
Travel speed	Miles per hour	Levinson *et al.* [34]
V/C ratio	none	Levinson *et al.* [34]

Reference: Adapted from Cottrell [16]

2.6.3. Integration of performance measure for ITS systems

Wang [64] constructed a multi-attribute utility model (MAUT) using the values of aggregated utilities as the performance measures in the areas of reduce fuel and environmental cost, improve mobility, improve safety, improve transportation system efficiency, and improve economic productivity. Wang collected data at a TMC in Austin, Texas to obtain the weights (W_{ik}) for this model. The utility value can be obtained from the ITS Market Packages. A formulation model developed by Wang [63] is shown in equation (2.5).

$$V_{tot} = \sum_{i=1}^{n} w_{ik} U_{ijk} \tag{2.5}$$

Where:

w_i = the weight of utility of agency goal *i*

U_i = Utility of agency goal *i*

n = number of Utility of agency goal *i*

Unlike Wang [64], this dissertation considers explanatory variables, which should be collected in real time, so that traffic operators can monitor, evaluate, and adjust operational strategies in a timely manner. Some of the congestion measures for breath, duration, intensity, and extent may be included; however, the proposed measures should be very flexible and may be utilized not only at the operational level, but also at the planning level. Furthermore, the model developed in this research can track the change of additional operational strategies that may be provided in the future, which the ITS Market Package does not currently include.

CHAPTER 3

MULTI-CRITERIA DECISION MAKING APPROACH

This chapter describes the decision-making process and multi-criteria decision-making models in general. The models will be described in detail when the applications are made in Chapters 4, 5, and 6. Group decision-making and weighting techniques are explained in this chapter. The end of this chapter provides a discussion of multi-criteria decision-making techniques and various weighting techniques such as the ranking system and one hundred point systems utilized in this research.

3.1 Decision making process

Decision making is a reasonable process, which can be simple or complex, rational or irrational, recognized or unrecognized. It should be supported by established assumptions or models that provide the guidelines for appropriate decisions. A basic decision making process, which is shown in Figure 1, involves the following five steps [57]:

Step 1: Identifying a problem and establishing a decision statement. A decision statement is established in order to scope the problem's boundary and possible solutions such as whether the solutions should be "simple or complex", or "broad or narrow". For example, a decision statement "select a strategy for reducing traffic congestion on freeway", the only current concern is finding the one best strategy to reduce traffic congestion on freeway. However, if a decision statement is changed to "select the best way for reducing traffic congestion on freeway", not only one best strategy will be selected, but additional strategies that may help minimize the traffic congestion on freeway. In addition, if the proposed of decision statement is "select a best strategy for freeway", the analysis should not only consider freeway traffic congestion, but also environmental issues such as reducing air pollution on freeway can be included.

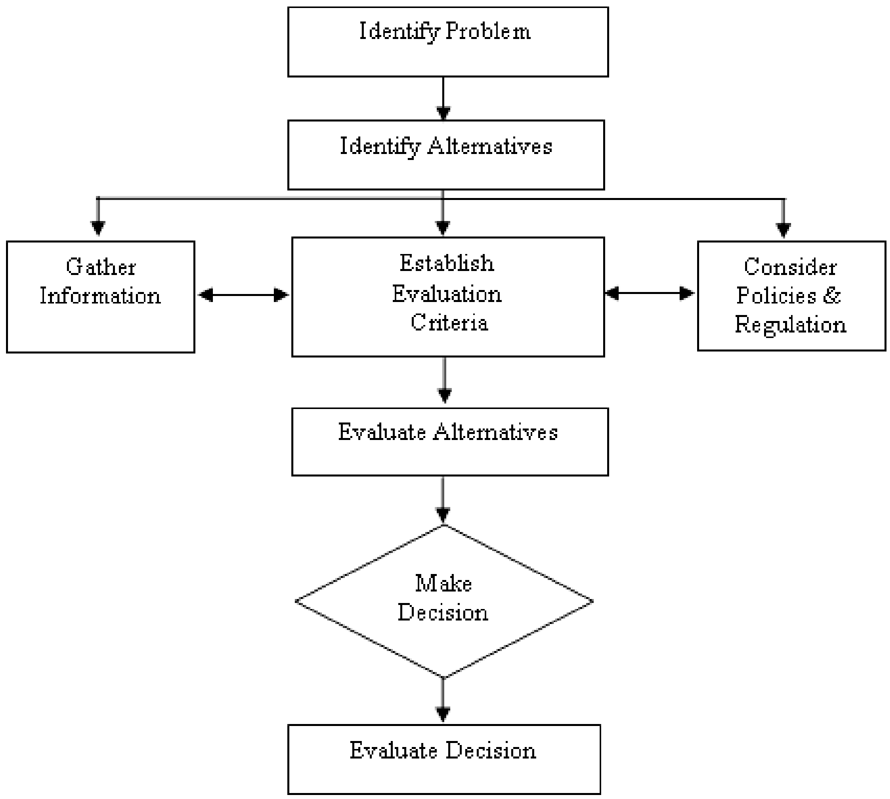


Figure 3.1 Decision-making process

Step 2: Selecting the set of alternatives. Once a decision statement is clarified; candidate alternatives will be generated based on the decision statement. Decision makers must identify the set of alternatives that may provide the most benefits for the improvement and achieve the purpose of the decision statement.

Step 3: Setting the criteria or sub-criteria for evaluating the alternatives. After the alternatives are defined, the criteria as well as sub-criteria related to the selected alternatives will be established. Those criteria or sub-criteria are used as “standards of judging the selected alternatives”, which influence overall decision process. The criteria and sub-criteria will be ranked or weighted according to their importance by decision makers.

Step 4: Once the criteria and sub-criteria are established, the alternatives will be evaluated under the set of established criteria and sub-criteria by using a mathematical model, which is selected based on the problems’ context. For example, when the problems involve attributes that can be defined and measured in money terms, cost benefit analysis can be used to assess the ratio of benefits to costs of a project improvement. On the other hand, when decision makers have to deal with attributes that are difficult to measure in monetary terms such as safety and reliability; a multi-criteria decision-making (MCDM) model is an effective method to transform those attributes into a comparable scale in order to evaluate the overall value of each alternative.

Step 5: The final decision will be based on the selection of the best alternatives using the MCDM model in step 4.

3.2 Multiple-criteria decision-making (MCDM) models

Without an appropriate method, it is impossible to balance, weight, and compare performance measures. MCDM models will provide the overall ranking of alternatives, which is useful for the final decision. According to Rogers [51], MCDM models allow decision makers to analyze complex decision problems. This type of analysis can be used to evaluate strategies when their attributes may be not valued in monetary terms. The process of multi-criteria decision making involves two processes: decomposition and aggregation. Decomposition is a process where the decision problems are divided into smaller parts, which are easy to understand and analyze individually, while aggregation is a process of integrating smaller parts in order to judge all attributes in the final decision.

Rogers [51] identifies four types of MCDM models.

1. Simple ‘non-compensatory’ method
2. Simple Additive Weighting Method

3. Analytic Hierarchy Process

4. Concordance Analysis Techniques

3.2.1 Simple non-compensatory method

According to Rogers [51], the simple 'non-compensatory' method includes dominance, satisficing, sequential elimination, and attitude oriented techniques. Each simple 'non-compensatory' method is a simple process without the process of aggregation. In addition, each criterion is set to a equal weight, while the criteria value for each option is set differently and they are not compared with each other. Therefore, the final decision does not consider the overall criteria value for each option like some other methods such as simple additive weighting (SAW). A simple 'non-compensatory' method may result in more than one best solution; however, the dominance technique can provide one best option when no other options perform better than it for all criteria.

3.2.2 Simple additive weight method

According to Rogers [51], the SAW method is a "compensatory" model used for analyzing criteria by transferring them into a common scale of measurement so that they can be compared with each other. The final decision can be considered from the sum of the products of the criteria rating (score) and weights in order to find the overall performance of each option. The overall performance of each option *i*, V_i can be calculated in equation (3.1):

$$V_i = \sum_{j=1}^{j=n} W_j r_{ij} \tag{3.1}$$

Where:

W_j = Weighting for criterion j

r_{ij} = Rating for option i on criterion j

Group decision-makers such as planners or experts will establish the weights (W_j) for each criterion. The method for assigning the weight will be explained in the section 3.3. After defining the weights and threshold accomplishes, the change in overall valuation for a strategy depends on rating for option (r_{ij}). The best option with the maximum value of overall performance will be selected.

The SAW method is a simple and useful method. This research provides an application of this method for ranking the data collection strategies and evaluating the freeway operations in Chapters 5 and 6. The final results yield a complete order, which allows decision makers to select the best alternative.

3.2.3 Analytic hierarchy process (AHP)

According to Saaty [53], the decision process can be divided to different levels of hierarchy. Then, a pairwise comparison method can be used to give the priorities within each level of the hierarchy and between the levels. The final decision will be recommended based on a mathematical manipulation of scores for all combinations of options. The AHP is very useful for selecting alternatives at the planning level by using qualitative data from the decision makers' perspectives. This research does not consider using the AHP method for daily freeway operations because it is difficult to obtain the qualitative data from the decision makers. In addition, this research aims to use the benefits of quantitative real time data from an ITS system to monitor freeway performance in real time, which is an unsuitable application for AHP.

3.2.4 Concordance analysis techniques

According to Rogers and Bruen [51], unlike the SAW method and AHP that recommend the best option for the final decision, concordance analysis techniques, which utilize a partially compensatory approach, provide a set of preferred options for the final decision. The preferred options will be selected based on the overall concordance score indices calculated from the sum of each criterion concordance score for each option. The overall concordance score indices for each option can be used to indicate how much one option dominates the others.

With concordance analysis, the comparison of each criterion or factor is based on a pairwise comparison with respect to each criterion, and establishes the degree of dominance that one option has over another called “concordance score”. Each criterion is compared with others. Two scores will be assigned by using the following pairwise comparison as below:

- If option A is at least as good as option B for criterion j, then it is given the score 1.0 or $c_j(a,b) = 1.0$.
- If A is not good as B on criterion j, it will be given the score 0.0 or $c_j(a,b) = 0.0$.

3.2.4.1 PROMETHEE I and II

According to Rogers [51], when the concordance matrix is established, the PROMETHEE I method developed by Brans and Vincke [5] is one of the straightforward approaches to rank the alternatives based on the dominance scores. When the concordance matrix is developed, the sum of scores along the concordance matrix’s row and column indicates whether the selected alternative performs better or worse than the other alternatives. A stronger alternative will receive higher scores for the row sum and lower scores for the column sum. The PROMETHEE I method will rank the alternatives based on the results of row and column sums. The results of final ranking may yield a complete or partial order depending on the conflict of the ranking results of row and column sums. If the ranking results of row and column sum are the same, it will yield a complete order; otherwise, it is will be a partial order.

A partial order does not guarantee a single recommended alternative because a single alternative may not dominate all others. Unlike the PROMETHEE I method, the PROMETHEE II method ignores the inconsistencies of the partial order situation and allows the decision makers to generate a set of dominated alternatives by subtracting the scores of column sum from the row sum for each alternative. The stronger alternatives will receive higher scores.

In this research, the PROMETHEE method is applied for ranking the objective criteria based on survey responses. The results from the PROMETHEE method will be used to help determine setting up the proposed weights in a subsequent survey described in Chapter 4.

3.2.4.2 The ELECTRE III method

The ELECTRE III method uses the concept of a concordance and discordance index to obtain alternative rankings. A concordance index *C(a,b)* for any pair of alternatives implies that alternative *a* is at least as good as alternative *b*. Then, the concordance index, *C(a,b)*, is calculated as follows:

$$C(a,b) = \sum_{j=1}^{n} w_j c_j(a,b) \tag{3.2}$$

Where w_j is the relative importance of the different criteria; $c_j(a,b)$ is the local concordance index and can take values from 0 to 1.

$$c_j(a,b) = \begin{cases} 1, \text{ if } g_j(a) + q_j \geq g_j(b) \text{ ; means that alternative } b \text{ is not preferred} \\ 0, \text{ if } g_j(a) + p_j \leq q_j(b) \text{ ; means that alternative } b \text{ is preferred} \\ \text{Otherwise: } c_j(a,b) = \dfrac{g_j(a) - g_j(b) + p_j}{p_j - q_j} \end{cases} \tag{3.3}$$

Where $g_j(a)$ and $g_j(b)$ are the performance scores of criterion *j* for alternative *a* and *b;* p_j and q_j are the preference and indifference thresholds for criterion *j*. Roy *et al.* [46] describes the value of the preference threshold (*p*) and indifference threshold (*q*), which is set as the margins of uncertainty, error or imprecision. The *p* and *q* threshold can be defined by the decision makers' opinions. The *p* threshold is related to the positive attitude that a decision-maker may have for a particular criterion's score. In addition, the *q* threshold is the point where decision makers perceive a difference between alternatives [23].

The discordance index is used to model the magnitude of the lack of compensation between the criteria by using a veto threshold v_j (constant threshold), which is set to check if one alternative is very much preferred to another. The veto threshold (*v*) can be set against the hypothesis that alternative *a* will usually be better than *b*. However, sometimes alternative *a* may be worse, or alternative *b* outperforms alternative *a* by at least the veto threshold. Thus, the veto threshold (*v*) must be greater than the *p* threshold.

If such a case occurs, the credibility index will be adjusted in order to decrease the global concordance index. A discordance index $D_j(a,b)$ for each pair of alternatives implies no alternative *a* is better than alternative *b*. Then, the discordance index is calculated as follows:

$$D_j(a,b) = \begin{cases} 0, \text{ if } g_j(a) + p \geq g_j(b) \text{; means that alternative b is not preferred} \\ 1, \text{ if } g_j(a) + v_j \leq g_j(b) \text{; means that alternative b is much preferred} \\ \text{Otherwise: } D_j(a,b) = \dfrac{g_j(b) - g_j(b) - p_j}{v_j - p_j} \end{cases} \quad (3.4)$$

The discordance indices of different criteria are not aggregated using the criteria weights because each criterion is evaluated for discordance individually. The degree of outranking or credibility index is defined as follows:

$$S(a,b) = \begin{cases} C(a,b) \text{, if } Dj(a,b) \leq C(a,b), \forall_j \text{; otherwise} \\ C(a,b) \prod_{j \in J(a,b)} \dfrac{1 - D_j(a,b)}{1 - C_j(a,b)} \end{cases} \quad (3.5)$$

Where: $J(a,b)$ is a set of criteria for which $D_j(a,b) > C(a,b)$

The credibility index is used to assess the trade off between alternatives *a* and *b*. Alternative *a* will outrank alternative *b* when $S(a,b)$ is greater than a minimum 'threshold' value, λ, which is usually set at approximately 0.85 and $S(a,b)$ minus $S(b,a)$ is greater than a minimum 'threshold' value, *s*, usually set at approximately 0.15. Then, a positive score *+1* will be given to alternative *a*. In contrast, a negative score *-1* will be given to alternative *b* being outranked. The final ranking will be established based on the total score through the process of descending and ascending distillation.

The descending distillation will rank the best alternative as the one with the highest score; after removing the highest scored alternative from the set of unranked alternatives, those remaining alternatives will be ranked using the same process. Unlike the descending distillation, the ascending distillation will rank the worst alternative first then exclude it from the next iteration; the remaining alternatives will continue to be ranked using this process until the top alternative is selected.

When decision makers have to deal with the uncertainty of data quality as well as budget constraints for choosing the data collection strategies, this research suggests the ELECTRE III method to finalize the decision in Chapter 5.

Comparing these multiple-criteria decision-making models above, each method can provide the rank of each option; however, no one can be used to fit every decision problem completely because each method has its advantages and limitations. For example, SAW, the simplest multi-criteria decision model, requires high quality data (using actual score). Second, AHP with the use of hierarchies can describe the impacts of an upper level on a lower level, and its use of pairwise comparisons can allow decision makers to assess alternatives and criteria when quantifiable information is not available. However, with the AHP method, decision makers may have a difficult time assessing the trade-offs between diverse criteria and options at a given level of analysis. Unlike the AHP method, in the concordance method, decision makers do not have to answer how important one criterion is against all others. However, this method may provide only a partial ranking and preferred options rather than one best option. A summary of the most often used MCDM models is shown in Table 3.1.

Table 3.1 A summary of the MCDM method

MCDM Method	Input	Output	Decision Types
Scoring (SAW)	Attribute scores, weights	Ordinal ranking	Individual DM, deterministic
Analytic hierarchy process (AHP)	Attribute scores, pairwise comparisons	Cardinal ranking (ratio scale)	Individual and group DMs, deterministic, probabilistic, fuzzy
Concordance	Attribute scores, weights	Partial or ordinal ranking	Individual and group DMs, deterministic, probabilistic, fuzzy

Reference: adapted from Middle East Technical University [41]

3.3 Techniques for obtaining criteria weights

According to Rogers [51], obtaining the criteria weights is an important step in most MCDM methods. The techniques for assigning the weight include a presumption of equal weights, ranking system, ratio system, basic pairwise analysis, and one-hundred point system.

3.3.1 Presumption of equal weights

This is an initial step when decision makers are not ready to assign the weight for the criteria. They may assume that the weight of each criterion is equal. However, equal weights may be used when a group of decision-makers determine that the importance of each criterion is equal.

3.3.2 Ranking system for obtaining weights

This technique requires data ranked with their importance for calculating weights. The normalised importance weight for each criterion can be calculated using equation (3.7).

$$W_i = \frac{n - r_i + 1}{\sum_{i=1}^{n} (n - r_i + 1)} \qquad (3.6)$$

Where:

W_i = Normalised weighting for the i th criterion.

R_i = Ranking score for the i th criterion.

n = Number of decision criteria.

3.3.3 Ratio system for obtaining weights

With in this technique, decision makers are asked to give the score of “1” to the least important criterion, while other criteria are given the greater scores reflecting the importance of those criteria relative to the least important criterion. Normalised importance weight for each criterion can be calculated using the equation (3.8).

$$W_i = \frac{Z_i}{\sum_{i=1}^{n} Z_i} \qquad (3.7)$$

Where:

W_i = Normalised weighting for the i th criterion.

Z_i = weight score assigned to i th criterion.

n = number of decision criteria

3.3.4 Pairwise comparison weighting system

Each criterion is compared with all others. Three scores will be assigned by using pairwise scores, which are determined according to the following rules:

- If A is less important than B, then A equals 0
- If A is equally important as B, then A equals 1
- If A is more important than B, then A equals 2

3.3.5 One-hundred point system

According to Mattingly [40], one-hundred point system is a widely used method due to its simplicity. This method is based on allocating a total of one hundred points amongst all of the attributes [42]. An attribute given no points can be ignored, while a score of “100” indicates that only one attribute needs to be considered.

For finding the weights, this research applies two ranking techniques, the ranking system and one-hundred point systems. The ranking system for obtaining the weight is applied for the ranked data, while one-hundred point system is applied for the survey data.

CHAPTER 4

RESEARCH METHODOLOGY

This chapter describes the research approach including the data collection, survey questionnaires, evaluation techniques, and data analysis. The evaluation techniques described in previous sections will be applied for the survey data. The analysis results in this section will be used for developing the models for the performance measures' selection in Chapter 5 and integration of performance measures in Chapter 6.

4.1 Data Collection

The study uses survey data to assess decision maker goals and priorities as well as other factors influencing TMC deployment and daily operations. The first part uses ITS deployment statistics to determine the factors involved with TMCs' investment, effective methods in persuading the public to support deployment of TMCs, and legal issues involved with making a decision to deploy TMCs [50]. The relationship between the factors encouraging the TMCs' investment will be compared with the TMCs' goals determined from the survey data. However, the rest of the ITS deployment statistics are included to provide information on the other issues facing TMC deployment. While these issues many not directly impact operations, they may influence decision-maker goals and priorities. Finally, these later issues serve no role in the development of the proposed framework in Chapter 5 and 6 in this research.

The second survey data are collected from various TMCs using the surveys prepared by Texas Transportation Institute (TTI) and University of Texas at Arlington (UTA) for the FHWA/TX-07/0-5292 Project. TTI and UTA administered a series of questionnaires where the first one sought to determine if, how, and where performance measurement was being used in

Texas. The surveys were conducted via face-to-face or telephone with traffic operators for six locations within Texas (i.e. TransVista (El Paso), TrasGuide (San Antonio), TransStar (Houston), DalTrans (Dallas), TransVision (Ft. Worth), and TxDOT Traffic Operations Headquarters (Austin)). The surveys results are used to identify the characteristics of data collection strategies in Chapter 5. More details of these surveys are described by Brydia *et al.* [7].

In addition, this chapter will describe the details of the ***third and forth surveys*** that UTA undertook. The surveys are developed to examine daily performance measures in the United States. In addition, the questionnaire surveys are designed to examine the importance of factors influencing performance measures' selection and agency goals.

4.2 Decision making at TMCs

4.2.1 The roles of TMCs in United States

A TMC plays an important role in monitoring, operating, and examining any implemented operational strategies such as incident management, ramp metering, and information dissemination on freeways. At the TMC, the roadway information will be gathered and examined by traffic operators before the appropriate operational strategies will be provided to manage freeways effectively. Most TMCs embrace Intelligent Transportation System (ITS) technologies such as closed circuit video equipment, roadside count stations, and dynamic message signs, which allow traffic operators to monitor and operate freeways in real time [60].

A TMC provides many benefits to both decision makers and on-road travelers. For example, with real time data and operation, incident events can be detected and decision makers can react to the situation in a timely manner. In addition, roadway information broadcasted to on-road travelers allow them to realize the situation before they make the decision whether to continue on the same route or divert to another uncongested route, or discontinue the trip. Roadway information distributed to other agencies can also provide useful information for decision makers to operate nearby roadways more effectively. The TMCs' final goals are expected to enhance the effectiveness of transportation management, which should lead to the reduction of crashes, traffic congestion, environmental problems, and agency cost. A MnDOT TMC reported that accident rates reduced by 25%, while average speed and freeways capacity increased by 35% (34 mph to 46 mph) and 22% respectively during peak hour after the TMC began operation [61].

Although a TMC provides many benefits for both traffic operators and on-road travelers, the investment in an individual TMC and the success of TMC operation and management are impacted by various factors that decision makers can influence. In this section, this research examines those factors including factors influencing TMCs' investment, effective methods in persuading the public to support TMC deployment, and legal issues with making a decision to deploy a TMC by using the recent 2006 survey data from the ITS deployment statistics website [50].

4.2.2 Factors influencing the TMCs' investment

The scope of this section is to examine the factors influencing TMCs' investment from the viewpoint of decision makers. The individual TMC data from the city level is grouped for the state level and the entire United States in order to compare the viewpoints of traffic operators among different states and the entire United States. The information may be useful for the cities or states considering TMC investments in the future, and help decision-makers prioritize operational goals. Table 4.1 lists the survey questions and available responses in this section.

Table 4.1 TMCs' investment

Question	Type of Response
Select the 3 most important factors in making a decision to invest in a TMC and rank your choices using a scale of 1-3 where 1=most important.	Multiple Choice: (Select and scoring the importance) • Agency cost saving • Incident management • Voter or customer satisfaction • Improved travel reliability • Improved safety • Evacuation management • Other (Please specify)

4.2.3 Effective methods in persuading the public to support TMC deployment

This section of the questionnaire examines the most effective methods in persuading the public to support TMC deployment. Traffic operators are asked to state the three most effective methods and their significance. These strategies can be explored to develop long term TMC support. The analysis will be made by evaluating the significance of the methods that effectively persuade the pubic to support TMC deployment based on their rating. Table 4.2 provides the question from the survey that is used to acquire this information.

Table 4.2 Methods for persuading the public to support TMCs

Question	**Type of Response**
Select the 3 most effective methods in persuading the public to support deployment of your TMC and rank your choices using a scale of 1-3 where 1=most effective.	Multiple Choice: (select and scoring the importance) • Open meetings with the public • Contractor provided briefings • Emergency situation • Public involvement • Newspaper articles and other local media • Scanning tours for elected officials • On-line message boards • Other (Please specify)

4.2.4 Legal issues involved with deciding to deploy a TMC

The scope of this section is to examine the legal issues involved with making the decision to deploy a TMC. Decision makers have to state the three most important legal issues and rank their significance. These issues appear unlikely to impact operations directly, but the selection of performance measures, data collection strategies and operating policies may be indirectly influence. The analysis will be made by assessing the importance of those legal issues by generating the weights based on the respondents' rating. Table 4.3 provides the question and responses available in the survey.

The U.S. Federal Highway Administration's Research and Innovative Technology Administration (RITA) [49] provided an explanation of the concerns related to the aforementioned legal issues.

Table 4.3 Legal issues involved with deciding to deploy a TMC

Question	Type of Response
Select the 3 most important legal issues involved with making a decision to deploy a TMC and rank your choices using a scale of 1-3 where 1=most important.	Multiple Choice: (Select and scoring the importance) • Rules and regulations • Contract disputes and claims • Intellectual property • Liability • Privacy • Other (Please specify)

Rules and Regulations are related to the standards or protocols for TMCs such as operational standards of electronic toll collection and enforcement with value pricing projects for TMCs, a formal ITS data sharing policy for the agency, or written policies that delimit the use and distribution of data. In order to avoid contract disputes and claims, the contracts must be valid under existing written policies and address liability issues among project participants. Intellectual Property is related to the exclusive rights to the ITS technologies, ITS standards, or private sector technologies provided by vendors in the deployment of ITS. Liability is related to the obligation of the issues regarding the collection, distribution, and retention of transportation data. Privacy is related to the protection of data privacy such as limiting the use and distribution of data, and sharing ITS data among the TMCs.

4.2.5 Evaluation techniques

The evaluation of the aforementioned factors will be made based on two approaches. Although the questionnaire only asks decision makers to rank the three most important factors, additional unselected factors may also be important to the decision-makers. In the first approach, this research calculates the weight of the selected factors using the ranks provided by traffic operators, while the other un-selected factors will be ignored and they will not be used for calculating the weights. In the second approach, the factors that traffic operators do not rank are still considered significant and used for calculating the weights.

4.2.5.1 Calculating the criteria weights using the first approach

Three selected criteria are ranked using equation (4.1), while other criteria are ignored. The number of decision criteria (*n*) is set at three. Table 4.4 presents an example of calculating the criteria weight using the first approach.

$$W_i = \frac{n - r_i + 1}{\sum_{i=1}^{n}(n - r_i + 1)} \tag{4.1}$$

Where:

W_i = Normalised weighting for the i^{th} criterion.

r_i = Ranking priority for the i^{th} criterion, where a ranking of “1” is the highest significance and ranking of “3” is the lowest significance.

n = Number of decision criteria.

Table 4.4 Weighting using Approach 1 for TMC at Phoenix, Arizona

FACTORS	**TMC at Phoenix, Arizona**		
	Rank (r_i)	**n-r_i+1**	**Weights (W_i)**
Agency cost saving	0	0	0.000
Incident management	1	3	0.500
Voter or customer satisfaction	0	0	0.000
Improved environment	0	0	0.000
Improved travel reliability	2	2	0.333
Improved safety	3	1	0.167
Evacuation management	0	0	0.000
	Sum	**6**	**1.000**

The average weights of all TMCs (in Table 4.5) in Arizona State can be calculated using equation (4.2).

$$AvgW_{ij} = \frac{\sum_{k=1}^{n} W_{ijk}}{n} \tag{4.2}$$

Where:

$AvgW_{ij}$ = Average weighting for criterion *i* for state *j*

W_{ijk} = weight scores assigned to individual TMC k for criterion i and state j

n = number of TMC within state j

Table 4.5 Average Weights using approach 1 for the TMCs, Arizona

FACTORS	Phoenix			Tucson			Average Weights
	Rank (r_i)	n-r_i+1	Weights (W_i)	Rank (r_i)	n-r_i+1	Weights (W_i)	
Agency cost saving	0	0	0.000	0	0	0.000	0.000
Incident management	1	3	0.500	1	3	0.500	0.500
Voter or customer satisfaction	0	0	0.000	0	0	0.000	0.000
Improved environment	0	0	0.000	0	0	0.000	0.000
Improved travel reliability	2	2	0.333	2	2	0.333	0.333
Improved safety	3	1	0.167	3	1	0.167	0.167
Evacuation management	0	0	0.000	0	0	0.000	0.000

4.2.5.2 Calculating the criteria weights using the second approach

Once again, the weights for individual TMC are determined using equation (4.1) based on the ranking provided by all TMCs; however all seven criteria are allocated a portion of the total weight. Table 4.6 presents an example of the criteria weights that are calculated using the second approach. The average weights of all TMCs (in Table 4.7) can be calculated using equation (4.2).

Table 4.6 Weighting using approach 2 for TMC at Phoenix, Arizona

FACTORS	TMC at Phoenix, Arizona		
	Rank (r_i)	n-r_i+1	Weights (W_i)
Agency cost saving	5.5	2.5	0.089
Incident management	1	7	0.250
Voter or customer satisfaction	5.5	2.5	0.089
Improved environment	5.5	2.5	0.089
Improved travel reliability	2	6	0.214
Improved safety	3	5	0.179
Evacuation management	5.5	2.5	0.089
	Sum	**6**	**1.000**

Table 4.7 Average Weights using approach 2 for the TMCs in Arizona

FACTORS	Phoenix			Tucson			Average Weights
	Rank (r_i)	n-r_i+1	Weights (W_i)	Rank (r_i)	n-r_i+1	Weights (W_i)	
Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	0.089
Incident management	1	7	0.250	1	7	0.250	0.250
Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	0.089
Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	0.089
Improved travel reliability	2	6	0.214	2	6	0.214	0.214
Improved safety	3	5	0.179	3	5	0.179	0.179
Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	0.089

4.2.6 Data analysis of decision making of TMCs

4.2.6.1 Factors influencing TMCs' investment

Approach 1

Table 4.8 presents the average weights for the factors influencing TMCs' investments using the first approach. The analysis at the city level is shown in Appendix A. In Table 4.8, the range of factors' weights can be divided into three levels: high, mid, and low levels. At the high level, incident management has an overall weight of 0.363. At the mid level, improved safety and travel reliability have weights of 0.287 and 0.218, respectively. At the low level, agency cost saving, voter or customer satisfaction, improved environment, and evacuation management and other factors including personal face-to-face interaction, to maintain an effective and efficient transportation system, traffic information dissemination, and motorist aid are of minimal importance because their weights are 0.05 or less.

Approach 2

Table 4.9 shows the average weights for the same factors using the second approach. The analysis at the city level is also shown in Appendix A. The results in Table 4.9 are similar to those of the first approach where incident management has the highest weight of 0.217. The second and third most important are improved safety and travel reliability with weights of 0.202

and 0.177, respectively. The results using the second approach can be divided into two levels: a top level (the weight is above 0.177) and lower level (the weight is lower than 0.104). The top level includes the aforementioned factors, while the remaining factors fall into the lower level.

The result from approaches 1 and 2 provides the potential range of weights for factors influencing the TMCs' investment shown in Figure 4.1. Considering the potential range of weights, one may not be able to distinguish the superior or inferior between the factors when the lower bound of one factor is lower than the upper bound of the another factor, while the upper bound of the first is higher than the upper bound of the second factor. On the other hand, one factor will dominate another factor if its lower bound is higher than the upper bound of the other factors. In order to rank the factors influencing TMCs' investment from the potential range of weights, the concordance approach described in Chapter 3 can be utilized. The factors can be divided into lower and upper levels. The factors at the upper level are composed of incident management, improved travel reliability, and improved safety, while the factors at the lower level are agency cost, voter or customer satisfaction, improved environment, and evacuation management.

Table 4.8 Average weights for factors influencing TMCs' investment using approach 1

Approach 1								
States	**Agency cost saving**	**Incident management**	**Voter or customer satisfaction**	**Improved environment**	**Improved travel reliability**	**Improved safety**	**Evacuation management**	**Others**
Texas	0.067	0.300	0.033	0.067	0.067	0.367	0.000	0.100
California	0.014	0.376	0.006	0.006	0.209	0.302	0.032	0.056
Arizona	0.000	0.500	0.000	0.000	0.333	0.167	0.000	0.000
New Mexico	0.000	0.500	0.000	0.000	0.167	0.333	0.000	0.000
Nevada	0.000	0.333	0.000	0.000	0.500	0.167	0.000	0.000
Utah	0.107	0.214	0.107	0.107	0.214	0.214	0.036	0.000
Colorado	0.167	0.000	0.000	0.000	0.333	0.500	0.000	0.000
Oregon	0.083	0.417	0.000	0.000	0.083	0.417	0.000	0.000
Washington	0.083	0.250	0.000	0.000	0.458	0.208	0.000	0.000
Nebraska	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
Minnesota	0.167	0.500	0.000	0.000	0.333	0.000	0.000	0.000
Iowa	0.000	0.500	0.000	0.000	0.333	0.167	0.000	0.000
Missouri	0.000	0.375	0.042	0.000	0.250	0.333	0.000	0.000
Louisiana	0.250	0.333	0.083	0.000	0.083	0.250	0.000	0.000
Michigan	0.167	0.250	0.000	0.000	0.083	0.500	0.000	0.000
Wisconsin	0.000	0.333	0.083	0.000	0.250	0.333	0.000	0.000
Illinois	0.000	0.333	0.000	0.000	0.500	0.167	0.000	0.000
Indiana	0.000	0.500	0.000	0.000	0.333	0.167	0.000	0.000
Kentucky	0.000	0.333	0.000	0.000	0.167	0.500	0.000	0.000
Tennessee	0.000	0.500	0.000	0.167	0.000	0.333	0.000	0.000
Alabama	0.000	0.333	0.000	0.000	0.167	0.500	0.000	0.000
Ohio	0.000	0.333	0.000	0.167	0.000	0.500	0.000	0.000
Pennsylvania	0.000	0.667	0.000	0.000	0.000	0.333	0.000	0.000
Georgia	0.000	0.333	0.000	0.000	0.500	0.167	0.000	0.000
Florida	0.009	0.335	0.058	0.009	0.169	0.224	0.196	0.000
Massachusetts	0.000	0.667	0.000	0.000	0.000	0.333	0.000	0.000
Connecticut	0.000	0.444	0.000	0.000	0.389	0.167	0.000	0.000
New York	0.000	0.271	0.000	0.000	0.354	0.313	0.063	0.000
Maryland	0.000	0.333	0.000	0.000	0.167	0.500	0.000	0.000
Washington DC	0.018	0.337	0.060	0.018	0.171	0.337	0.060	0.000
Virginia	0.000	0.417	0.000	0.000	0.250	0.250	0.083	0.000
North Carolina	0.018	0.348	0.098	0.045	0.211	0.182	0.098	0.000
South Carolina	0.024	0.298	0.131	0.060	0.115	0.242	0.131	0.000
Normalised Weight	0.036	0.363	0.052	0.020	0.218	0.287	0.021	0.005
Standard Deviation	0.065	0.142	0.174	0.045	0.154	0.138	0.046	0.020
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.250	0.667	1.000	0.167	0.500	0.500	0.196	0.100

Table 4.9 Average weights for factors influencing TMCs' investment using approach 2

Approach 2								
States	**Agency cost saving**	**Incident management**	**Voter or customer satisfaction**	**Improved environment**	**Improved travel reliability**	**Improved safety**	**Evacuation management**	**Others**
Texas	0.110	0.195	0.106	0.113	0.124	0.219	0.088	0.044
California	0.093	0.225	0.085	0.085	0.178	0.208	0.103	0.025
Arizona	0.089	0.250	0.089	0.089	0.214	0.179	0.089	0.000
New Mexico	0.089	0.250	0.089	0.089	0.179	0.214	0.089	0.000
Nevada	0.089	0.214	0.089	0.089	0.250	0.179	0.089	0.000
Utah	0.107	0.214	0.107	0.107	0.214	0.214	0.036	0.000
Colorado	0.179	0.089	0.089	0.089	0.214	0.250	0.089	0.000
Oregon	0.134	0.232	0.089	0.089	0.134	0.232	0.089	0.000
Washington	0.121	0.196	0.089	0.089	0.241	0.174	0.089	0.000
Nebraska	0.129	0.129	0.226	0.129	0.129	0.129	0.129	0.000
Minnesota	0.179	0.250	0.089	0.089	0.214	0.089	0.089	0.000
Iowa	0.089	0.250	0.089	0.089	0.214	0.179	0.089	0.000
Missouri	0.089	0.223	0.112	0.089	0.183	0.214	0.089	0.000
Louisiana	0.170	0.214	0.134	0.089	0.134	0.170	0.089	0.000
Michigan	0.152	0.196	0.089	0.089	0.134	0.250	0.089	0.000
Wisconsin	0.089	0.214	0.134	0.089	0.170	0.214	0.089	0.000
Illinois	0.089	0.214	0.089	0.089	0.250	0.179	0.089	0.000
Indiana	0.089	0.250	0.089	0.089	0.214	0.179	0.089	0.000
Kentucky	0.089	0.214	0.089	0.089	0.179	0.250	0.089	0.000
Tennessee	0.089	0.250	0.089	0.179	0.089	0.214	0.089	0.000
Alabama	0.089	0.214	0.089	0.089	0.179	0.250	0.089	0.000
Ohio	0.089	0.214	0.089	0.179	0.089	0.250	0.089	0.000
Pennsylvania	0.107	0.250	0.107	0.107	0.107	0.214	0.107	0.000
Georgia	0.089	0.214	0.089	0.089	0.250	0.179	0.089	0.000
Florida	0.080	0.224	0.115	0.080	0.193	0.181	0.126	0.000
Massachusetts	0.107	0.250	0.107	0.107	0.107	0.214	0.107	0.000
Connecticut	0.089	0.238	0.089	0.089	0.226	0.179	0.089	0.000
New York	0.085	0.201	0.085	0.085	0.219	0.210	0.116	0.000
Maryland	0.089	0.214	0.089	0.089	0.179	0.250	0.089	0.000
Washington DC	0.077	0.214	0.119	0.077	0.179	0.214	0.119	0.000
Virginia	0.089	0.232	0.089	0.089	0.170	0.196	0.134	0.000
North Carolina	0.063	0.223	0.143	0.089	0.152	0.188	0.143	0.000
South Carolina	0.054	0.214	0.161	0.089	0.119	0.202	0.161	0.000
Normalised Weight	0.102	0.217	0.104	0.097	0.177	0.202	0.098	0.002
Standard Deviation	0.030	0.033	0.029	0.023	0.048	0.036	0.022	0.009
Minimum	0.054	0.089	0.085	0.077	0.089	0.089	0.036	0.000
Maximum	0.179	0.250	0.226	0.179	0.250	0.250	0.161	0.044

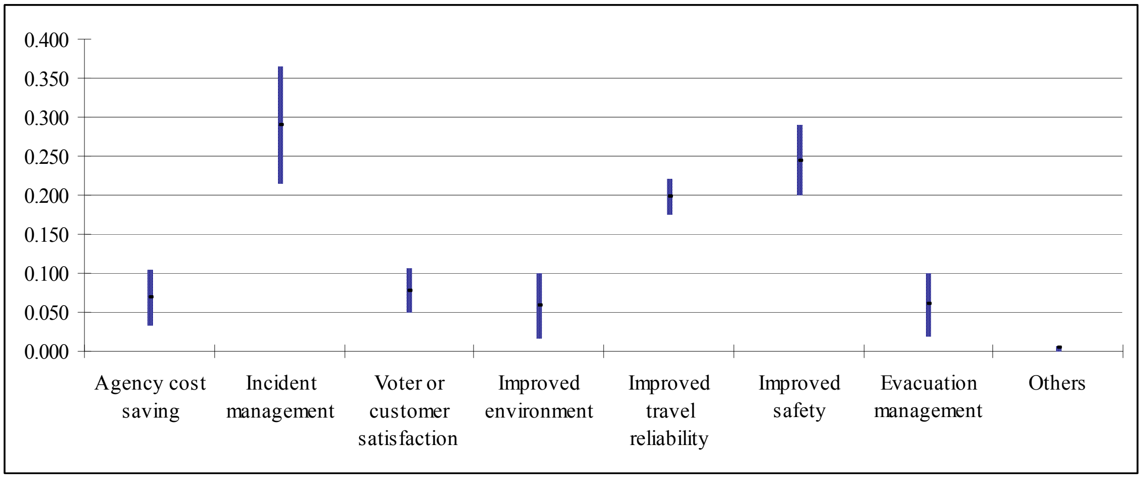


Figure 4.1 The range of scores for the factors influencing TMCs' investment from approaches 1 and 2

4.2.6.2 Effective methods in persuading the public to support deployment of TMCs

Approach 1

Table 4.10 presents the weights for the effective methods in persuading the public to support deployment of TMCs using the first approach. The analysis at the city level is shown in high, mid, and low levels. At the high level, newspaper articles and other media has an overall weight of 0.327. At the mid level, emergency situation, public involvement, and scanning tours for elected officials have weights of 0.178, 0.134, and 0.150, respectively. At the low level, open meeting with the public, contractor, on-line message boards have weights of 0.038, 0.020, and 0.060 which are of minimal importance. Other effective methods including help trucks, presentation to elected officials, improved incident management and traveler information, and budget enhancement submitted to legislature also are considered minimal importance with weights lower than 0.10.

Approach 2

Table 4.11 shows the weights for the same factors using the second approach. The analysis at the city level is also shown in Appendix A. The results in Table 4.11 are similar to those of the first approach; the newspaper articles and other local media have the highest weight of 0.205. The results using the second approach can be divided into two levels (a top and lower level), which show a slight difference of approximately 0.035 between the two levels. The effective methods for persuading the public to support deployment of TMCs at the top level include emergency situation, public involvement, newspaper articles and other local media, and scanning tours for elected officials with weights of 0.162, 0.139, 0.205, and 0.143, while those at the lower level (the weight is lower than 0.105) include open meetings with the public, contractor-provided briefings, on-line message boards, and other effective methods including help trucks, presentations to elected officials, improved incident management and traveler information, and budget enhancement submitted to legislature.

The results from approaches 1 and 2 provide the potential range of weights for the effective methods in persuading the public to support deployment of TMCs as shown in Figure 4.2. Using the concordance approach, the range of weights in Figure 4.2 can be divided into four levels. At the highest level, the results are similar to the results from the average weights from approaches 1 and 2 where newspaper articles and other media are the most effective method (1^{st} rank) in persuading the public to support deployment of TMCs. Emergency situations are ranked at the next lower level (2^{nd} rank), and at the next lower level (3^{rd} rank), scanning tours for elected officials and public involvement are ranked at the same level. The open meetings with the public, contractor provided briefings, and on-line message boards are ranked at the lowest level (4^{th} rank).

Table 4.10 Average weights for effective methods in persuading the public to support deployment of TMCs by approach 1

Approach 1								
States	**Open meetings with the public**	**Contractor provided briefings**	**Emergency situation**	**Public involvement**	**Newspaper articles and other local media**	**Scanning tours for elected officials**	**On-line message boards**	**Others**
Texas	0.133	0.000	0.400	0.167	0.167	0.133	0.000	0.000
California	0.187	0.020	0.282	0.211	0.187	0.068	0.044	0.000
Arizona	0.000	0.000	0.667	0.000	0.333	0.000	0.000	0.000
New Mexico	0.000	0.000	0.333	0.000	0.500	0.000	0.000	0.167
Nevada	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000
Utah	0.000	0.000	0.333	0.000	0.167	0.000	0.500	0.000
Oregon	0.000	0.000	0.500	0.250	0.250	0.000	0.000	0.000
Washington	0.167	0.000	0.111	0.111	0.167	0.444	0.000	0.000
Nebraska	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
Minnesota	0.000	0.000	0.167	0.000	0.500	0.333	0.000	0.000
Iowa	0.000	0.000	0.167	0.000	0.500	0.000	0.000	0.333
Missouri	0.125	0.000	0.250	0.083	0.417	0.083	0.042	0.000
Louisiana	0.000	0.000	0.417	0.083	0.250	0.250	0.000	0.000
Michigan	0.000	0.000	0.167	0.000	0.333	0.500	0.000	0.000
Wisconsin	0.027	0.027	0.432	0.098	0.098	0.054	0.098	0.167
Illinois	0.000	0.000	0.000	0.000	0.500	0.167	0.333	0.000
Idiana	0.000	0.000	0.167	0.000	0.333	0.000	0.000	0.500
Kentucky	0.167	0.000	0.000	0.333	0.500	0.000	0.000	0.000
Tennessee	0.000	0.000	0.000	0.083	0.750	0.167	0.000	0.000
Alabama	0.167	0.000	0.000	0.333	0.500	0.000	0.000	0.000
Ohio	0.000	0.000	0.000	0.500	0.333	0.167	0.000	0.000
Pennsylvania	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000
Georgia	0.000	0.000	0.000	0.333	0.500	0.000	0.167	0.000
Florida	0.021	0.074	0.210	0.121	0.210	0.243	0.121	0.000
Connecticut	0.000	0.000	0.167	0.333	0.500	0.000	0.000	0.000
New York	0.054	0.054	0.208	0.220	0.304	0.107	0.054	0.000
Maryland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
Washington DC	0.000	0.000	0.083	0.167	0.000	0.250	0.000	0.500
Virginia	0.000	0.250	0.083	0.000	0.417	0.250	0.000	0.000
North Carolina	0.119	0.064	0.093	0.036	0.314	0.260	0.114	0.000
South Carolina	0.052	0.136	0.303	0.163	0.099	0.148	0.099	0.000
Idaho	0.000	0.000	0.167	0.000	0.000	0.500	0.000	0.333
Normalised Weight	0.038	0.020	0.178	0.134	0.327	0.150	0.060	0.094
Standard Deviation	0.064	0.052	0.174	0.166	0.223	0.179	0.119	0.220
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.187	0.250	0.667	0.667	1.000	0.667	0.500	1.000

Table 4.11 Average weights for effective methods in persuading the public to support deployment of TMCs by approach 2

Approach 2								
States	**Open meetings with the public**	**Contractor provided briefings**	**Emergency situation**	**Public involvement**	**Newspaper articles and other local media**	**Scanning tours for elected officials**	**On-line message boards**	**Others**
Texas	0.139	0.089	0.218	0.146	0.168	0.150	0.089	0.000
California	0.156	0.097	0.184	0.168	0.163	0.122	0.110	0.000
Arizona	0.107	0.107	0.250	0.107	0.214	0.107	0.107	0.000
New Mexico	0.083	0.083	0.194	0.083	0.222	0.083	0.083	0.167
Nevada	0.107	0.107	0.107	0.107	0.107	0.250	0.214	0.000
Utah	0.089	0.089	0.214	0.089	0.179	0.089	0.250	0.000
Oregon	0.089	0.089	0.250	0.196	0.196	0.089	0.089	0.000
Washington	0.155	0.101	0.143	0.161	0.155	0.185	0.101	0.000
Nebraska	0.125	0.125	0.125	0.125	0.250	0.125	0.125	0.000
Minnesota	0.089	0.089	0.179	0.089	0.250	0.214	0.089	0.000
Iowa	0.000	0.000	0.167	0.000	0.500	0.000	0.000	0.333
Missouri	0.129	0.089	0.183	0.121	0.232	0.134	0.112	0.000
Louisiana	0.089	0.089	0.232	0.134	0.196	0.170	0.089	0.000
Michigan	0.089	0.089	0.179	0.089	0.214	0.250	0.089	0.000
Wisconsin	0.075	0.075	0.209	0.147	0.147	0.102	0.147	0.097
Illinois	0.089	0.089	0.089	0.089	0.250	0.179	0.214	0.000
Idiana	0.083	0.083	0.167	0.083	0.194	0.083	0.083	0.222
Kentucky	0.179	0.089	0.089	0.214	0.250	0.089	0.089	0.000
Tennessee	0.107	0.107	0.107	0.152	0.250	0.170	0.107	0.000
Alabama	0.179	0.089	0.089	0.214	0.250	0.089	0.089	0.000
Ohio	0.089	0.089	0.089	0.250	0.214	0.179	0.089	0.000
Pennsylvania	0.107	0.107	0.107	0.250	0.214	0.107	0.107	0.000
Georgia	0.089	0.089	0.089	0.214	0.250	0.089	0.179	0.000
Florida	0.114	0.082	0.168	0.161	0.193	0.168	0.114	0.000
Connecticut	0.089	0.089	0.179	0.214	0.250	0.089	0.089	0.000
New York	0.098	0.098	0.214	0.161	0.179	0.152	0.098	0.000
Maryland	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.222
Washington DC	0.100	0.100	0.145	0.163	0.100	0.181	0.100	0.111
Virginia	0.089	0.170	0.134	0.089	0.232	0.196	0.089	0.000
North Carolina	0.134	0.125	0.161	0.089	0.205	0.223	0.063	0.000
South Carolina	0.088	0.147	0.235	0.130	0.141	0.193	0.065	0.000
Idaho	0.083	0.083	0.167	0.083	0.083	0.222	0.083	0.194
Normalised Weight	0.105	0.096	0.162	0.139	0.205	0.143	0.108	0.042
Standard Deviation	0.034	0.026	0.051	0.057	0.073	0.058	0.048	0.088
Minimum	0.000	0.000	0.089	0.000	0.083	0.000	0.000	0.000
Maximum	0.179	0.170	0.250	0.250	0.500	0.250	0.250	0.333

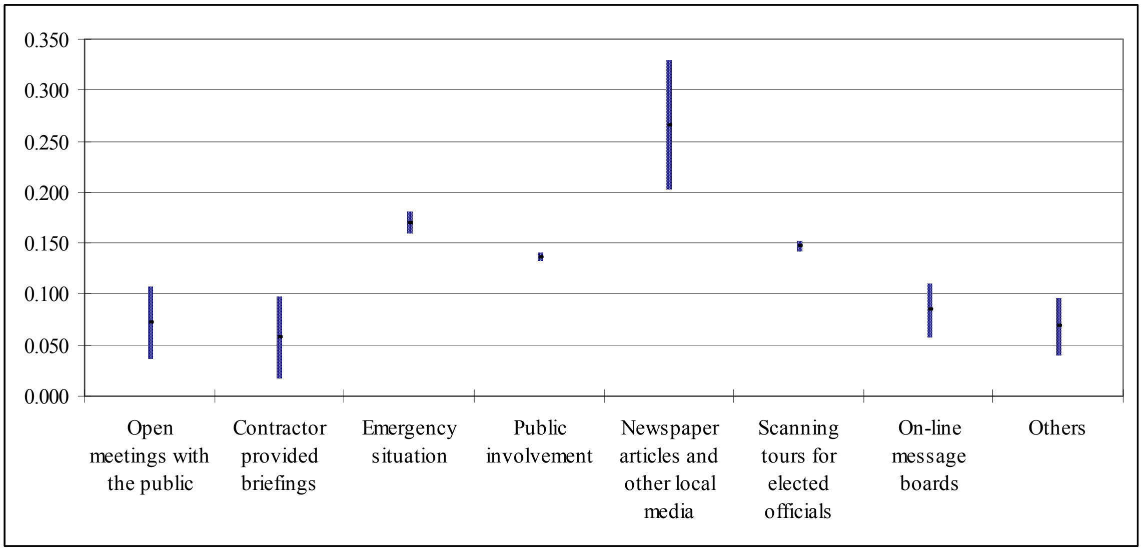


Figure 4.2 The range of scores from approaches 1 and 2 for the effective methods of persuading the public to support TMC deployment

4.2.6.3 Legal issues involved with making a decision to deploy a TMC

Approach 1

Table 4.12 presents the weights for the legal issues involved with making a decision to deploy a TMC. The analysis at city level is shown in Appendix A. In Table 4.12, the range of factors' weights can be divided into high, mid, and low levels. At the high level, rules and regulations has an overall weight of 0.377. At the mid level, privacy, liability, and intellect have weights of 0.206, 0.170, and 0.140, respectively. At the low level, a contract dispute and other legal issues including inter-agency agreements, public safety, and funding are of minimal importance with weights lower than 0.072.

Approach 2

Table 4.13 presents the weights for same legal issues using the second approach. The analysis at the city level is also shown in Appendix A. The results in Table 4.13 are similar to those of the first approach where rules and regulations are the most important issues. Unlike the first approach, the results using the second approach can be divided into two levels: a top and lower level. Rules and regulations are the most important issues at the top level with weights of 0.246, while contract disputes and claims, intellect, liability, and privacy are at the lower level with the weight between 0.143 and 0.201. Other legal issues including inter-agency agreements, public safety, and funding are of minimal importance with weights of 0.036.

At the highest level, the results are similar to the results of average weights in approach 1 and 2 that rules and regulations are the most important legal issues (1^{st} rank) involved with making a decision to deploy a TMC. Second, liability is ranked at the next lower level. At the next lower level (3^{rd} rank), intellect and privacy are ranked at the same level. At the lowest level (4^{th} rank), contract disputes and claims are of minimal importance. Other legal issues including inter-agency agreements, public safety, and funding are considered of minimal importance with weights lower than 0.050. According to Kraft [34], rules and regulations, contract disputes and claims, intellect, liability, and privacy are critical issues affecting TMC design and deployment. The liability issues become less significant once the rules and regulations are developed and more comprehensive legal and institutional policies are established among TMCs that minimize the impacts of liability issues.

Table 4.12 Average weights for legal issues involved with making a decision to deploy a TMC by approach 1

Approach 1						
States	**Rules and regulations**	**Contract disputes and claims**	**Intellect**	**Liability**	**Privacy**	**Others**
Texas	0.250	0.000	0.333	0.208	0.208	0.000
California	0.257	0.062	0.086	0.376	0.171	0.048
New Mexico	0.333	0.000	0.000	0.000	0.000	0.667
Nevada	0.500	0.333	0.167	0.000	0.000	0.000
Colorado	1.000	0.000	0.000	0.000	0.000	0.000
Oregon	0.333	0.000	0.167	0.500	0.000	0.000
Washington	0.333	0.056	0.056	0.389	0.167	0.000
Iowa	0.500	0.000	0.000	0.167	0.333	0.000
Missouri	0.333	0.125	0.333	0.125	0.083	0.000
Louisiana	0.417	0.250	0.000	0.333	0.000	0.000
Michigan	0.417	0.083	0.167	0.083	0.250	0.000
Wisconsin	0.300	0.117	0.050	0.283	0.250	0.000
Illinois	0.333	0.000	0.000	0.667	0.000	0.000
Idiana	0.500	0.000	0.333	0.000	0.167	0.000
Kentucky	0.500	0.000	0.000	0.167	0.333	0.000
Tennessee	1.000	0.000	0.000	0.000	0.000	0.000
Alabama	0.000	0.000	0.167	0.500	0.333	0.000
Ohio	0.333	0.000	0.500	0.167	0.000	0.000
Georgia	0.000	0.167	0.500	0.000	0.333	0.000
Florida	0.500	0.000	0.000	0.167	0.111	0.222
Connecticut	0.000	0.167	0.000	0.333	0.500	0.000
NewYork	0.000	0.167	0.000	0.333	0.500	0.000
Marryland	0.667	0.000	0.000	0.333	0.000	0.000
Washington DC	0.500	0.000	0.111	0.222	0.167	0.000
Virginia	0.333	0.000	0.167	0.000	0.500	0.000
North Carolina	0.167	0.333	0.500	0.000	0.000	0.000
Normalised Weight	0.377	0.072	0.140	0.206	0.170	0.036
Standard Deviation	0.254	0.105	0.172	0.188	0.173	0.136
Minimum	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	1.000	0.333	0.500	0.667	0.500	0.667

Table 4.13 Average weights for legal issues involved with making a decision to deploy a TMC by approach 2

Approach 2						
States	**Rules and regulations**	**Contract disputes and claims**	**Intellect**	**Liability**	**Privacy**	**Others**
Texas	0.225	0.100	0.267	0.208	0.200	0.000
California	0.303	0.113	0.114	0.266	0.171	0.034
New Mexico	0.238	0.119	0.119	0.119	0.119	0.286
Nevada	0.333	0.267	0.200	0.100	0.100	0.000
Colorado	0.333	0.167	0.167	0.167	0.167	0.000
Oregon	0.267	0.100	0.200	0.333	0.100	0.000
Washington	0.267	0.133	0.133	0.289	0.178	0.000
Iowa	0.333	0.100	0.100	0.200	0.267	0.000
Missouri	0.267	0.167	0.267	0.158	0.142	0.000
Louisiana	0.300	0.233	0.100	0.267	0.100	0.000
Michigan	0.009	0.003	0.003	0.007	0.011	0.000
Wisconsin	0.217	0.167	0.100	0.250	0.267	0.000
Illinois	0.267	0.133	0.133	0.333	0.133	0.000
Idiana	0.333	0.100	0.267	0.100	0.200	0.000
Kentucky	0.333	0.100	0.100	0.200	0.267	0.000
Tennessee	0.333	0.167	0.167	0.167	0.167	0.000
Alabama	0.100	0.100	0.200	0.333	0.267	0.000
Ohio	0.267	0.100	0.333	0.200	0.100	0.000
Georgia	0.100	0.200	0.333	0.100	0.267	0.000
Florida	0.257	0.129	0.129	0.206	0.184	0.095
Connecticut	0.100	0.200	0.100	0.267	0.333	0.000
NewYork	0.100	0.200	0.100	0.267	0.333	0.000
Marryland	0.333	0.133	0.133	0.267	0.133	0.000
Washington DC	0.311	0.111	0.167	0.211	0.200	0.000
Virginia	0.267	0.100	0.200	0.100	0.333	0.000
North Carolina	0.200	0.267	0.333	0.100	0.100	0.000
Normalised Weight	0.246	0.143	0.172	0.201	0.186	0.016
Standard Deviation	0.092	0.059	0.085	0.086	0.085	0.058
Minimum	0.009	0.003	0.003	0.007	0.011	0.000
Maximum	0.333	0.267	0.333	0.333	0.333	0.286

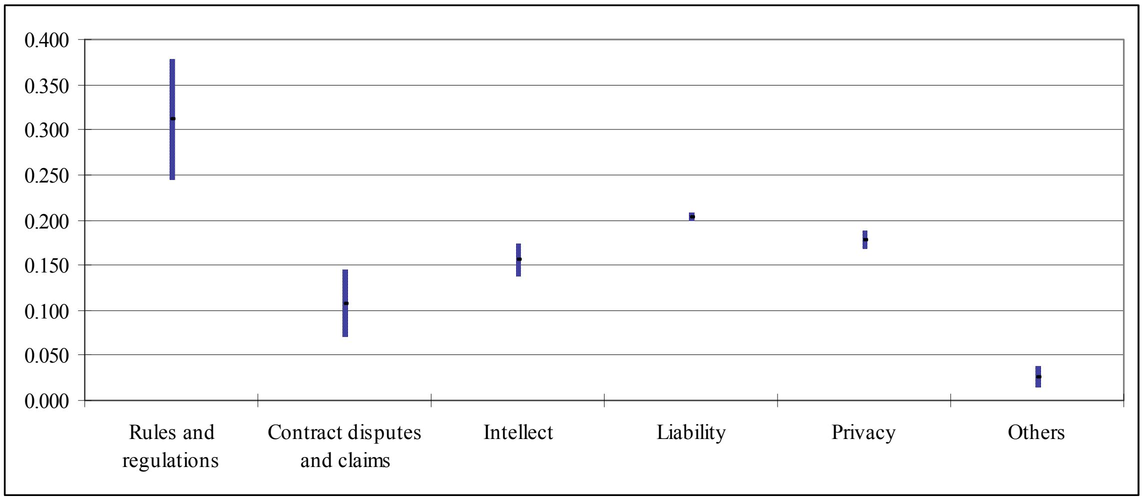


Figure 4.3 The range of scores from approaches 1 and 2 for the legal issues involved with making a decision to deploy a TMC

4.3 Evaluation of TMCs

The surveys target the traffic engineers who manage and operate freeways at TMCs in metropolitan areas in the United States. The author made Email and telephone contacts to ask the respondents to participate. These surveys benefit from their flexibility because they can avoid conforming influences so that the respondents feel free to answer them. However, to avoid any misunderstanding with the survey questions, contact information is provided. This process seeks consensus amongst the respondents; the first round must be checked and analyzed to verify its validity. For an invalid survey, the respondents will be contacted again to correct the problem. After that, a second survey is conducted where the decision makers are provided a summary of the first round. Then, they are asked to either keep or edit their results from the first survey. The reason for using multiple rounds is to enhance the perspective of decision makers and provide more information for their decisions.

The surveys address issues in four areas:

1. Daily performance measures for freeway operations
2. The factors influencing the performance measures' selection
3. The constraints for data collection strategies

4. The potential daily performance measures and the significance of agency goals

This study distributed the questionnaires to approximately fifty-five agencies (TMCs) in the United States. Responses came from sixteen agencies; however, only eleven entities: Texas (5), California (1), Georgia (1), Wisconsin (1), Colorado (1), Oregon (1), and Iowa (1) could actually provide the survey information. When agencies can not provide a response, they often give a reason, which includes having a contract with a consultant to determine the available data and daily performance measures, lacking the information, and focusing only on statewide congestion performance measures. Although less than half of the agencies responded, the responses come from a variety of operators' viewpoints. An example of the questionnaire is shown in Appendix B.

4.3.1 Daily performance measures for freeway operations

The scope of this section is to examine the agency background, decision makers, and daily performance measures currently in use. This dissertation targets the State Department of Transportation, which is responsible mainly for freeways (toll roads, traffic data collection systems, and intelligent transportation systems may be included). Traffic operators should have an experience using performance measures. Traffic operators will be asked whether they currently use performance measures for daily freeway operations. They have to indicate the performance measures currently used for assessing daily freeway operations at their agency and the main motivation for using those performance measures. Table 4.14 lists the specific questions and types of responses.

4.3.2 Factors influencing the performance measure's selection

The scope of this section is to define the importance of the factors influencing the performance measures' selection. Shaw [56] has developed a scoring approach to assess the strengths and weakness of various measures based on the qualitative criteria and sub-criteria in Table 4.15.

Table 4.14 Agency and personal background information

Number	Questions	Types of Response
1	Name and contact information	Personal information
2	What type of organization, agency and firm do you work at?	Multiple Choice: • State Department of Transportation • Metropolitan Planning Organization • City or County • Other (Specify)
3	Is your agency responsible for?	Multiple Choice: • Freeways • Toll roads • Traffic data collection systems • Intelligent Transportation Systems • Other (Specify)
4	How many employees are working in your agency?	# of Persons
5	How many centerline-miles of roadways are present in your agency's jurisdiction?	# of centerline-miles
6	Do you currently use performance measures for assessing freeways operational strategies?	Yes / No
6.1	How long have you used the performance measures for assessing the freeway operations?	Multiple Choice: • Less than one year • 1-2 years • 2-5 years • 5-10 years • More than 10 years
6.2	Are the performance measures used to assess daily freeway operations?	Yes / No
6.3	What are the performance measures currently used for assessing daily freeway operations at your agency?	Lists of performance measures based on multi-operational strategies on freeways
6.4	What is the main motivation for your agency using performance measures for assessing daily freeway operations?	Respondents can answer freely.

Table 4.15 Performance measure criteria

Criteria	Sub-Criteria
Clarity and simplicity	• The measure is simple to present, analyze, and interpret • The measure is unambiguous • The measure's units are well defined and quantifiable • The measure has professional credibility • Technical and nontechnical audiences understand the measure
Descriptive and predictive ability	• The measure describes existing conditions • The measure can be used to identify problems • The measure can be used to predict change and forecast condition • The measure reflects changes in traffic flow conditions only
Analysis capability	• The measure can be calculated easily • The measure can be calculated with existing field data • There are techniques available to estimate the measure • The results are easy to analyze • The measure achieves consistent results
Accuracy and precision	• The accuracy level of the estimation techniques is acceptable • The measure is sensitive to significant changes in assumptions • The precision of the measure is consistent with planning applications • The precision of the measure is consistent with an operation analysis
Flexibility	• The measure applies to multiple modes • The measure is meaningful at varying scales and settings

Reference: Shaw [56]

The performance measures, which meet a sub-criteria requirement, will be given a score +1; otherwise, they will be given a score of 0. Using this scoring approach, the significance of the clarity and simplicity issues can be explained by its score (5/20); scores for the descriptive and predictive ability, analysis capability, accuracy and precision, and flexibility issues are (4/20), (5/20), (4/20), and (2/20), respectively. Any performance measures that receive a minimum score of 15 out 20 are considered acceptable. The performance measures in the report that pass the minimum score of 15 out 20 are listed in Table 4.16.

Table 4.16 Performance measure scores

Performance measures	Total Score	Clarity and Simplicity (out of 5)	Descriptive and Predictive Capability (Out of 5)	Analysis Capability (out of 4)	Accuracy and Precision (out of 4)	Flexibility (out of 2)
Air quality impacts	16	5	3	3	3	2
Bridge condition	16	5	4	4	3	0
Delay caused by incidents	17	5	2	4	4	2
Delay recurring	20	5	5	4	4	2
Delay total	20	5	5	4	4	2
Density (vehicles per hour per lane)	19	5	5	4	4	1
Density (vehicles per lane-mile)	18	5	4	4	4	1
Duration of congestion	19	4	5	4	4	2
Evacuation clearance time	15	5	3	3	3	1
Incident response time	17	5	3	4	4	1
Incidents (fatal) per million vehicle-miles	17	5	3	4	4	1
Incidents (injury) per million vehicle-miles	16	5	3	3	4	1
Incidents (number of crashes or stopped vehicles)	17	5	3	4	4	1
Incidents (property damage only) per million vehicle-miles	16	5	3	3	4	1
Level of service	17	5	4	3	4	1
Number of miles operating in desired speed range	19	5	5	4	4	1
Pavement condition	18	5	4	4	4	1
Percent of ITS equipment	17	5	3	4	4	1
Percent of travel congested	15	3	3	3	4	2
Person-miles traveled	20	5	5	4	4	2

Table 4.16 – *Continued*

Performance measures	**Total Score**	**Clarity and Simplicity (out of 5)**	**Descriptive and Predictive Capability (Out of 5)**	**Analysis Capability (out of 4)**	**Accuracy and Precision (out of 4)**	**Flexibility (out of 2)**
Queuing of traffic (frequency)	18	5	5	4	4	0
Queuing of traffic (length)	18	5	5	4	4	0
Rail crossing incidents	17	5	3	4	4	1
Response time to weather-related incidents	15	4	2	4	4	1
Response times to incidents	15	4	2	4	4	1
Speed	20	5	5	4	4	2
Toll revenue	16	5	3	3	3	2
Traffic volume	19	5	5	4	4	1
Travel time	19	5	5	4	4	1
Travel time predictability	18	5	5	3	4	1
Travel time reliability	15	3	3	4	4	1
Vehicle-miles traveled	19	5	5	4	4	1
Vehicle occupancy (persons per vehicle)	18	5	3	4	4	2
Volume/capacity ratio	19	5	5	3	4	2

Reference: Shaw [56]

These criteria and sub-criteria can be used for assessing performance measure quality and identify an initial set for consideration. However, in practice, decision makers may consider the significance of each issue differently. For example, the score for flexibility may be higher than (2/20). Thus, this research asks traffic operators to weight the significance of the five criteria categories. Using the one hundred point approach explained in Chapter 3, decision makers have to distribute one hundred points amongst the categories based on their significance when selecting performance measures. The example of weighting is shown in Table 4.17. The description of each criterion is explained in Table 4.15.

Table 4.17 One decision makers' weights for the criteria categories influencing performance measure's selection

Criteria	Score	Description
Clarity and simplicity	15	It is important for assessing performance measures (PM) for performance measure selection.
Descriptive and predictive ability	25	It is critically important for assessing PM for performance measure selection.
Analysis capability	20	It is very important for assessing PM for performance measure selection.
Accuracy and precision	20	It is very important for assessing PM for performance measure selection.
Flexibility	20	It is very important for assessing PM for performance measure selection.
Total Score	**100**	

Note: For the decision makers, the descriptive and predictive ability is given the highest importance because it can be used to identify problems.

4.3.3 The constraints for data collection strategies

This section establishes the constraints of data collection strategies. Since various data collection techniques such as loop detectors, video image processing, and acoustic sensors are used to collect real time data on freeways and each data collection technique provides different measurement quality based on their timeframe, cost, accuracy and reliability, an agency must be sure that any prospective data collection approach meets the agency's needs for operations, management and performance measures. The traffic operators have to determine either minimum or maximum acceptable performance level on the proposed criteria. Table 4.18 lists the specific questions and types of responses.

Table 4.18 Data collection strategy constraints

#	Question	Type of Response
8	What is the time duration required for gathering an appropriate amount of data from field before it is transferred to traffic management centers?	Multiple Choice: • Less than 15 sec. • Less than 30 sec. • Less than 60 sec. • Less than 2 min. • Other (Specify)
9	What is the time duration required for roadside controllers to transmit the data from question 8 to the traffic management centers?	Multiple Choice: • Less than 15 sec. • Less than 30 sec. • Less than 60 sec. • Less than 2 min. • Other (Specify)
10	What is the time duration required at TMC to calculate the performance measure? What is the acceptable value you expect?	Multiple Choice: • Less than 15 sec. • Less than 30 sec. • Less than 60 sec. • Less than 2 min. • Other (Specify)
11	What is the operational and maintenance cost of new data collection technique?	$ of operational and maintenance cost
12.1	What do you expect for the accuracy: Data processing accuracy (%) is the quality of value being estimated or calculated by computable systems compared with the actual value being estimated by reliable computer systems. It should be higher than?	% of accuracy
12.2	What do you expect for the accuracy: Instrumental accuracy (%) is the quality of value being measured by field equipment compared with the actual value measured by reliable instrument. It should be higher than?	% of accuracy
12.3	What do you expect for the accuracy: Data aggregation accuracy (%) is the quality of value being gathered by computers or humans compared with the actual value gathered by reliable approach. It should be higher than?	% of accuracy
13.1	What do you expect for the reliability: The percentage of field equipment failure should be less than?	% of reliability
13.2	What do you expect for the reliability: The percentage of communication failure should be less than?	% of reliability
13.3	What do you expect for the reliability: The percentage of database failure should be less than?	% of reliability

4.3.4 Relating daily performance measures and agency goals

The scope of this section is to establish the potential daily performance measures and to determine their importance based on agency goals. Traffic operators have to identify the current daily performance measures and expected daily performance measure for assessing freeway operations according to their current and expected agency goals. The importance of the performance measures will be evaluated using the one hundred point approach. The results in this section will be used to examine the daily performance measures and agency goals, and then, develop the models for evaluating the overall impacts of multiple operational strategies on freeways in Chapter 6.

Most proposed performance measures provided in this section come from the National Transportation Operations Coalition (NTOC) and other studies, which may be applied for daily freeway operations. NTOC serves as an important foundation for institutionalizing management and operations into the transportation industry. The proposed agency goals come from the Joint Program Office of the U.S. DOT. The examples of agency goals and performance measures are shown in Table 4.19. The example of weighting is shown in Table 4.20.

Table 4.19 Lists of proposed agency goals and performance measures

Goals	Performance Measures
Safety	Total number of crashes or stopped vehicles
Energy and environment	Emissions: The noxious byproducts resulting from the combustion of fuels by vehicles traveling on the freeways
Mobility	Extent of congestion: Actual time or percentage of time that traffic on freeways is flowing at less than free-flow speeds
	Recurring Delay: The difference between actual travel time and travel time at free flow speeds experienced by individuals due to repetitive factors
	Incident Delay: The increase in travel time experienced by individuals due to incidents
	Reliability: The amount of additional time that travelers must add to their average trip time in order to be 95% on time to the destination
	Speed: average speed on roadway segment or network
	Travel Time: average travel time on roadway segment or network
Efficiency	Throughput per person: The number of people accommodated by a roadway segment or network
	Throughput per vehicle: The number of vehicles that are being accommodated by a roadway segment or network
	Customer Satisfaction: A measure of the degree to which roadway users (travelers) are satisfied with their use of the roadway system

Table 4.20 Example of scoring agency goals

Goals	Score
Goal 1: Improve the safety of the transportation system	40
Goal 2: Reduce the energy and environmental impacts	10
Goal 3: Enhance the mobility of the transportation system	30
Goal 4: Increase the efficiency of transportation system	20
Others please specify:	
Goal 5:	
Goal 6:	
Total	**100**

4.3.5 Evaluation techniques for setting the proposed weights

The consensus of the traffic operators may be related to the average value of each criterion. However, when some traffic operators rank the importance of one criterion much higher than others, this behavior tends to skew the average weight. Thus, this research uses a "concordance analysis" technique described in Chapter 3 to evaluate the decision makers' ranks. The results of both methods must be compared and judged again by decision makers before initiating the subsequent surveys. The subsequent surveys are conducted to verify the proposed criteria weights.

This research assumes that the significance of all traffic operators is equal; therefore, each respondent is assigned an identical weight. For example, Table 4.21 presents the factor scores influencing the performance measures' selection, which are weighted by six decision makers. The normalized weight in this example based on six decision makers equals 1/6 or 0.167 for each person. The overall concordance index for (*a,b*) can be calculated using equation (3.2).

$C(a,b) = 0.167(1)+0.167(1)+0.167(0)+0.167(1)+0.167(1)+0.167(0) = 0.668$

Table 4.21 Criteria scores

Factors for selecting the PMs	Decision Makers (i)					
	DM1	DM2	DM3	DM4	DM5	DM6
a	15	25	15	25	30	20
b	15	25	30	25	15	20
c	30	20	20	15	30	25
d	35	20	20	25	15	25

The concordance matrix is provided in Table 4.22.

Table 4.22 The concordance matrix

	a	b	c	d
a	-	0.835	0.501	0.501
b	0.835	-	0.501	0.668
c	0.668	0.501	-	0.668
d	0.668	0.668	0.835	-

After the concordance matrix is established, this research considers ranking the alternatives using the method called “PROMETHEE I” developed by Brans and Vincke [5] to generate the rank order. The concordance matrix in Table 4.22 will be used to generate the sum of row and column scores. The sum of row scores indicates how well option (a) performs better than other options. On the other hand, the sum of each column will indicate how well the other options perform than it. A higher row sum and lower column sum will result in a higher overall ranking. Table 4.23 presents the row sum and column sum for each option.

Table 4.23 Row and column sums for the options

	Row sum	Column sum
a	1.837	2.171
b	2.004	2.004
c	1.837	1.837
d	2.171	1.837

Figure 4.4 presents the ranking of the options from the best to the lowest performance using the row sum scores.

d (2.171)

↓

b (2.004)

↓

a, c (1.837)

Figure 4.4 Ranking based on row sum

These scores reflect the degree to which each of the given options dominates the others. Second, the options will be ranked using the column sum score from the first to last in order of their increasing column sum score shown in Figure 4.5.

c, d (1.837)

↓

b (2.004)

↓

a (2.171)

Figure 4.5 Ranking based on column sum

The overall ranking of the options is obtained by combining the results of row sum and column sum is shown in Figure 4.6. Figure 4.6 shows that option (d) perform better than option (b), (c), and (a), while option (b) and (c) are better than option (a). However, option (b) and (c) are incomparable with each other.

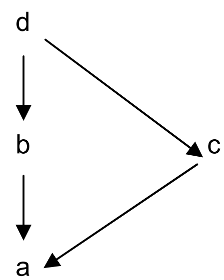


Figure 4.6 Overall ranking

When a conflict occurs where a clear case of dominance cannot be determined, such as the relation between option (b) and option (c) in Figure 4.4, the PROMETHEE II model can be utilized. For each option, the column sum will be subtracted from the row sum. Then, every option will be compared over this single overall score given in Table 4.24.

Table 4.24 The subtraction of row and column sum

Option (*i*)	**Row sum – Column sum**
a	-0.334
b	0
c	0
d	0.334

The ranking of the options is based on the average of the two rankings and the results of this PROMETHEE II model are shown in Figure 4.7, where option (d) is ranked first; option (b) and (c) are both ranked second and option d is ranked lowest.

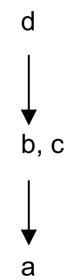


Figure 4.7 Overall ranking by PROMETHEE II

By using the ranking method (see section 3.3.2), a weight for each option from the PROMETHEE II results can be calculated. These weights can be compared with the average weight for setting the proposed criteria weights before the subsequent surveys are conducted to verify the final judgment.

4.3.6 Survey results

Survey results indicate that 90% of the respondents are responsible for the freeways, data collection, and ITS systems. Approximately 50% of respondents have experience using performance measures; however, only 30% of respondents have experience using performance measures for daily freeway operations. The responding TMCs currently use the following daily performance measures in Table 4.25.

Table 4.25 Surveys of daily performance measures in use

Performance Measures	Respondents (%)
Response and clearance time	18%
Number of calls to 511	18%
Number of incidents	9%
HOV ramp usage	9%
Number of special events	9%
Data accuracy	9%
90 minute clearance goal	9%
Number of devices requiring maintenance	9%
Detection time	9%
Queue clearance time	9%
Notification time	9%
Multichannel notification	9%
Percent of devices operated	9%
Real-time en-route notification	9%
Customer satisfaction	9%
Number of lane closure system delay <30min	9%

Daily performance measures are developed for improving daily operations' service and reliability. Traffic operators must be able to evaluate a variety of data collection strategies; the survey asks the respondents to determine minimum performance criteria for data collection strategies based on time, cost, reliability and accuracy. Most of the respondents indicate that the time required for gathering an appropriate amount of field data before it is transferred to TMCs should be less than sixty seconds (50% of respondents indicated less than thirty seconds). Additionally, the time required for roadside controllers to transmit the field data to the TMCs should be less than two minutes (50% of respondents indicated less than thirty seconds). Finally, the time required at TMCs for calculating performance measures should be less than two minutes (45% of respondents indicated less than sixty seconds). The stated maintenance and operating cost varies from $5,000 to $20,000. The percentage of accuracy for data processing should be at least 75% (mean-92%), for instrumentation should be at least 75% (mean-90%) and for data aggregation should be at least 80% (mean-93%). The percentage of reliability for field equipment should be at least 80% (mean-91%), for communication systems at least 80% (mean-92%), and for database systems at least 80% (mean-96%).

4.3.6.1 The selection of performance measures

This research utilizes performance measures such as delay, speed, throughput-person and vehicle, travel time link and trip, and travel time reliability suggested in NTOC [43], by the Joint Program Office (JPO) of the USDOT and Shaw [56] as the proposed performance measures for daily freeway operations. Those performance measures are categorized into four areas (safety, mobility, efficiency, energy and environment) suggested by the JPO for evaluating ITS system benefits. Table 4.26 shows the respondents' votes for the performance measures sorted by agency goals. The survey responses (80%) indicate that number of incidents should be the candidate performance measure for safety while emissions are the candidates for energy and environment with 40% of votes. Mobility has six candidate performance measures (incident delay, speed, extent of congestion, travel time, recurring delay and reliability) that capture either 80% or 70% of votes. Three candidate measures exist for transportation system efficiency where customer satisfaction captures 70% of the responses, throughput per vehicle captures a 50% share, and throughput per person captures 40% of the responses.

Table 4.26 Percentage of selected performance measures

Performance Measures (PMs)	**% of selected PMs**
Safety on Freeways	
- Incidents including crashes or stopped vehicles	80%
- Secondary collisions	20%
- Fatal crash	10%
- Injury	10%
- Property damage	10%
- Safe drivers (% people with clean driving records)	10%
- Safety belts (% people wearing safety belts)	10%
- Travelers feel safe (survey)	10%
Energy and environment	
- Emissions	40%
- Intercity passenger service	10%
- Alternative to one-person commuting	10%
- Passenger rail ridership	10%
- Number of Environmental Compliance Violations	10%
Enhance of the mobility of persons, freights, etc.	
- Incident delay	80%
- Speed	80%
- Extent of congestion	80%
- Travel time	80%
- Recurring Delay	70%
- Reliability	70%
- Vehicle Miles of Travel in Congested Conditions	10%
- Travel Time Delay in Designated Corridors	10%
- Vehicle hours of Delay in Designated Corridors	10%
- Demand Diversion – the number of travel re-distributed among alternative routes and travel modes to maintain reliability	10%
Efficiency of transportation system	
- Customer Satisfaction	70%
- Throughput per vehicle	50%
- Throughput per person	40%
- Traffic Volume	10%
System Quality	
- Percent statewide highway pavement in good/ fair condition	10%
- Percent of bridge deck are in good/ fair condition	10%
- Annual maintenance level of service	10%

Note: Percentage of votes by 10 decision makers

System quality does not fit into this research's scope because its candidate performance measures do not focus on operations and cannot be evaluated effectively in a real-time environment. Incidents and emissions may also be difficult to evaluate with respect to daily operations; however, they represent strategic operating performance measures that may be assessed using surrogate measures.

4.3.6.2 Expected weight of characteristics of performance measures

Table 4.27 shows the decision maker scores for the performance measures' categories from the first survey. The results show that most traffic operators have a wide range of viewpoints regarding performance measure selection. The minimum and maximum scores of each criterion are between 10 and 35. The range of minimum and maximum score for each criterion is between 10 and 20. The mean scores of clarity and simplicity, descriptive and predictive ability, analysis capability, accuracy and precision, and flexibility are 21, 21, 23, 23, and 12, respectively.

In order to verify the result of the first survey, a subsequent survey was conducted and six respondents gave the feedback of the scores in Table 4.28. The proposed weights are given to six respondents (DM1, DM3, DM6, DM7, DM10, and DM11) and they have to agree or reject the proposed scores. The proposed consensus scores are generated from the ranking results using PROMETHEE II that is described in section (4.3.5). The calculation of scores is provided in Appendix C. The proposed scores for clarity and simplicity, descriptive and predictive ability, analysis capability, accuracy and precision, and flexibility are 20, 21, 24, 25, and 10, respectively.

Most of respondents agreed to accept the proposed consensus weights, and only DM3 rejected the proposed weight and close to keep the previous answer. DM3 gave a reason that the weights provided already reflected a consensus position from a group discussion within an individual state, while other states, the weights were given by individual traffic operator. The average weight of clarity and simplicity, descriptive and predictive ability, analysis capability, accuracy and precision, and flexibility are 21, 21, 24, and 11, respectively that are very close to the proposed weights. Thus, the proposed weights will be utilized for constructing the models for selecting performance measures in Chapter 6.

Table 4.27 The scores of characteristics of performance measures (1st survey)

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Avg. Score
Clarity and simplicity	10	15	25	15	30	25	20	25	20	25	25	21
Descriptive and predictive ability	10	15	25	30	15	25	20	25	25	25	15	21
Analysis capability	30	30	20	20	30	15	25	20	25	15	25	23
Accuracy and precision	30	35	20	20	15	25	25	20	20	20	25	23
Flexibility	20	15	10	15	10	10	10	10	10	15	10	12

Table 4.28 The scores of characteristics of performance measures (2nd survey)

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Avg. Score
Clarity and simplicity	20	15	25	15	30	20	20	25	20	20	20	21
Descriptive and predictive ability	21	15	25	30	15	21	21	25	25	21	21	22
Analysis capability	24	30	20	20	30	24	24	20	25	24	24	24
Accuracy and precision	25	35	20	20	15	25	25	20	20	25	25	23
Flexibility	10	15	10	15	10	10	10	10	10	10	10	11

4.3.6.3 Expected weight of TMCs' goals

Table 4.29 presents the scores of the TMC goals given by the traffic operators in the first survey. The results from the first survey show that most traffic operators believe that safety should be ranked as the first priority with a mean score of forty; the mobility and efficiency trail behind with similar scores of 24 and 23, respectively, while energy and environment has the lowest score of thirteen. The energy and environment may pose a smaller concern than other goals because air pollution results from many sources such as industrial. The lack of air monitoring stations nearby freeways makes it difficult to pinpoint the system links and conditions that are the main causes of air pollution. A high score from a single respondent can skew the mean weight for this criterion. For example, in Table 4.29, DM1 is only concerned with freeway safety and disregards the other criteria. As a result, it induces the high mean score for safety.

Table 4.29 The scores of agencies' goals (1st survey)

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Avg. Score
Safety	100	50	30	30	30	25	25	N/A	N/A	40	30	40.0
Energy and environment	0	0	15	15	15	25	25	N/A	N/A	0	20	12.8
Mobility	0	25	30	25	30	25	25	N/A	N/A	30	30	24.4
Efficiency	0	25	25	30	25	25	25	N/A	N/A	30	20	22.8

Using PROMETHEE II, one can provide the compromised weights (in Appendix C), the proposed weights are given to six respondents (DM1, DM3, DM6, DM6, DM10, and DM10). The proposed score of safety, energy and environment, mobility, and efficiency are 35, 15, 25, and 25, consecutively. The five respondents to the second survey agreed to accept the proposed consensus weights (in Table 4.30). Only DM3 rejects the proposed weight and kept the previous answer from the same reason as before. The average weight of safety, energy and environment, mobility, and efficiency come up with 35, 13, 26, and 26, respectively. The results appear to be close to the proposed weight. In addition, the proposed weights will be utilized for developing the models in Chapter 6.

When compared the proposed weights of TMC goals in Table 4.30 with the range of weights from the analysis results of factors involved with TMCs' investment described in section 4.2.6.1 (in Table 4.31), similar results appears that safety, mobility, and efficiency are the most important factors for TMCs' goals and investment with the weights higher than 0.20, while the environmental factor is less important with weights lower than 0.15.

Table 4.30 The scores of agencies' goals (2nd survey)

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Avg. Score
Safety	35	50	30	30	30	35	35	N/A	N/A	35	35	35.0
Energy and environment	15	0	15	15	15	15	15	N/A	N/A	15	15	13.3
Mobility	25	25	30	25	30	25	25	N/A	N/A	25	25	26.1
Efficiency	25	25	25	30	25	25	25	N/A	N/A	25	25	25.6

Table 4.31 The weight of factors involved with TMCs' investment

Criteria	Weights Range	Avg. Weights
Agency cost saving	0.04 - 0.10	0.07
Incident management	0.22 - 0.36	0.29
Voter or customer satisfaction	0.05 - 0.10	0.08
Improved environment	0.02 - 0.10	0.06
Improved travel reliability	0.18 - 0.22	0.20
Improved safety	0.20 - 0.29	0.24
Evacuation management	0.02 - 0.10	0.06
Others	0.00 - 0.01	0.00

In summary, the first part of this chapter evaluates the significant of the factors influencing TMCs' investment, effective methods in persuading the public to support the deployment of TMCs and legal issues involved with making a decision to deploy a TMC. The results found that safety, travel time reliability, and incident management are most important factors for TMCs' investment and those three factors are also important as the main TMCs' goals in most TMCs (results from the surveys). Rules and regulations are the most important legal factors when deploying a TMC, while newspaper and local media are the main factors for persuading the public to deploy a TMC. The second part of this chapter indicates the current and potential daily performance measures in the areas of safety, mobility, environment, and efficiency including crashes, emissions, speed, travel time, extent of congestion, recurring and incident delay, and through put per vehicle. The proposed weights are suggested by comparing the results from the average weights and PROMETHEE I and II methods. Then, a final adjustment of the proposed weights is based on the author's assessment who acts as the coordinator described in Chapter 5. In order to yield a consensus agreement, the subsequent surveys with the proposed weights were conducted. The results indicate that most respondents or traffic operators agree with the proposed weights, so the author stops conducting the surveys; otherwise, subsequent surveys would need to be made until all respondents agreed with the proposed weights. Even though the PROMETHEE I and II method are suggested in this research, the ELECTRE III method using a preference and indifference threshold may help the coordinator in setting the proposed weights better than the proposed PROMETHEE I and II method. However, the ELECTRE III method requires the value of the preference and indifference thresholds from decision makers, which are sometimes difficult to identify. The proposed weights in this chapter including the weights for characteristics of performance measures and TMCs goals will be utilized to develop the models in Chapter 5 and 6.

CHAPTER 5

A FRAME WORK FOR SELECTING THE DATA COLLECTION STRATEGIES BASED ON PERFORMANCE MEASURES

This chapter describes concepts of performance measure development. Performance measures can be utilized to evaluate program success at multiple levels such as goals, objectives, implementations, and resources. In addition, the developed performance measures can also be used at multiple managerial levels such as at the state, inter-agency, or individual agency. This chapter provides a framework, which can be used to develop a performance measure or integration of performance measures, based on the limitations of the performance measures themselves or data collection strategies. The proposed qualitative constraints are based on the characteristics of performance measures such as comprehension, measurability, availability, comparability, and importance, while the proposed quantitative constraints are based on the limitations of data collection strategies such as time, cost, accuracy, and reliability. Other quantitative constraints can be tailored to particular performance measures and data requirements. The five steps of this proposed framework will be used to screen, rank, and generate the scores for freeway performance measures and data collection strategies. The application of the framework in this chapter can be used at the operational level select the data collection strategies and performance measures at the same time. Another application of this framework is utilized to develop the Freeway Performance Index (FPI) in Chapter 6.

5.1 Developing performance measures

Before the discussion of how to assess performance measures, one must first understand how performance measures are developed. One possible use of performance measures is in the assessment of freeway operational strategies. Planners can use a top-down methodology where the type of performance measures may be established at the highest level to assess the program goals, which may not be easily measurable; then at the next lower level, either output or outcome measures may be used to evaluate the program objectives; at the next lower level, output measures are commonly used to assess the immediate impacts of policies or projects. At the lowest level, input measures are generally used to assess the program resources. The use of program targets may be integrated into this process to provide ongoing monitoring and assistance with future improvement decisions. Figure 5.1 is an example of a transit system improvement that shows the impacts at each level.

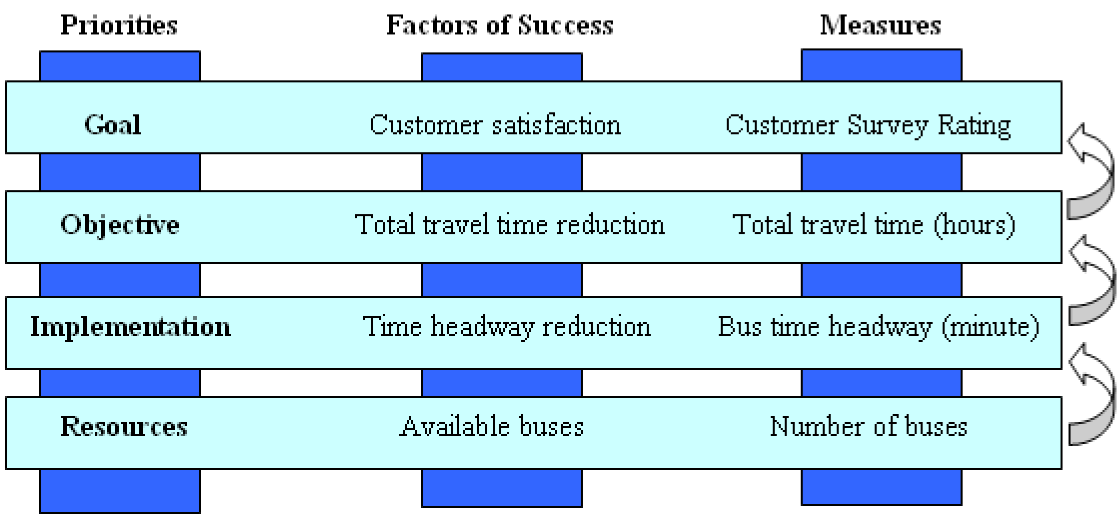


Figure 5.1 Multilevel structures for performance measures

The top-down methodology can be utilized in multi-level operations to assess freeway performance from system-wide to a particular area as shown in Figure 5.2. According to Brydia *et al*. [7], the application of performance measurement in freeway operations can incorporate multiple scales or levels based on the number of agencies using the performance measures. At the top level, system wide, the measures are used to assess a global view of operations. In the next lower level, called the interagency level, many agencies will share resources in order to improve their operational programs, such as incident management and air quality. The third level (daily operations) focuses on Transportation Management Center (TMC) operations, such as lane shifts, dynamic messages, signal timing, and ramp metering. TMCs operators may use these measures to assess their programs and strategies. At the bottom level, the measures are used to assess equipment or discrete elements of the transportation system, such as equipment reliability. Since the performance measures can be used in multiple scales, good performance measures should be able to assess the freeway performance in multiple scales also. For example, performance measures used to assess the system-wide level should also apply at the interagency level.

Since performance measurement has been used in many fields, there is no single methodology or exact rule for selecting specific measures. In addition, criteria for selecting appropriate performance measures should be decided by the people who are involved in the performance measurement program, such as those who collect and use the data or experts who understand the strengths and limitations of each performance measure.

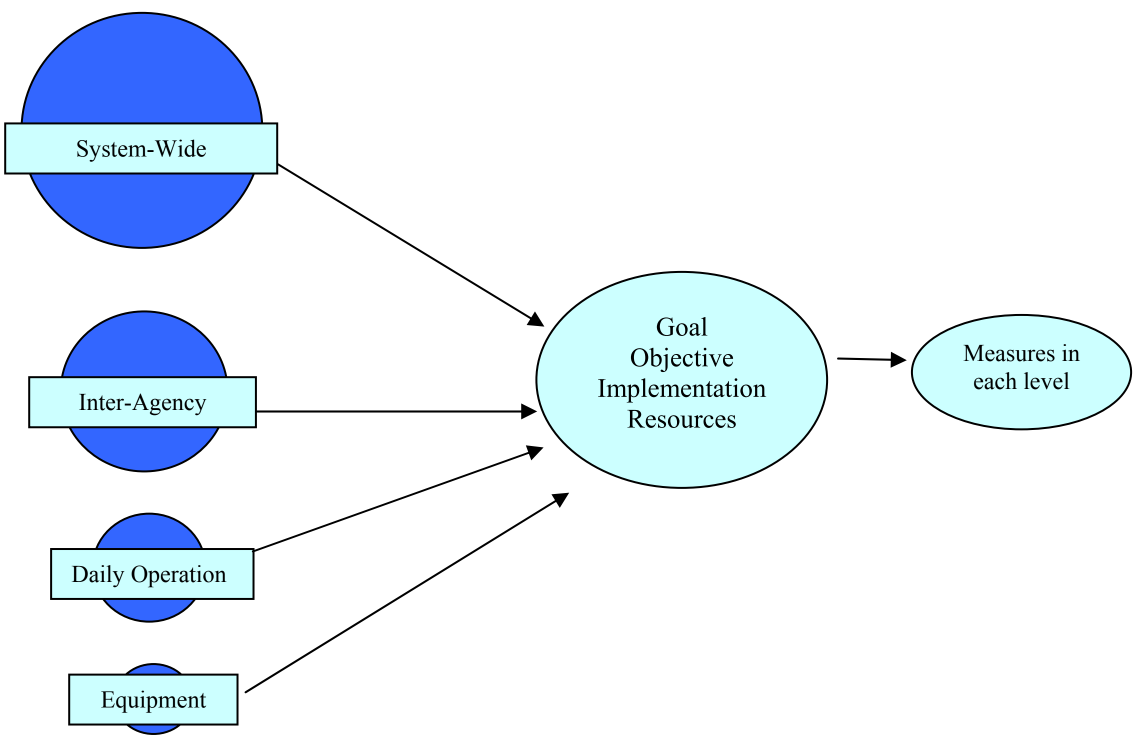


Figure 5.2 Multilevel operation approach

Good performance measures, in general, should focus on the goals and objectives of the program whose performance is to be assessed. They should be simple, easy to understand for everyone, able to respond to the changes in the system, inexpensive to obtain, organizationally acceptable, credible, timely, comparable, compatible, customer focused, consistent, measurable, available, balanced, valuable, and practical [7, 46, 30]. The following section provides a framework for developing good performance measures.

5.2 Performance measure creation and selection methodology

This dissertation provides a framework of five steps, which identify the roles of decision makers and coordinators in creating and screening performance measures; the framework can also be used for selecting data collection strategies for freeways. The decision makers are defined as the individuals responsible for using the performance measures for evaluating freeway operational strategies, while the coordinators are defined as individuals who assist the decision makers by guiding the process and conducting any necessary analysis during the performance measure selection process. The survey results related to the limitations of data collection strategies described in Chapter 4 will be used for the framework's application.

5.2.1 Step 1: Establish the "decision statement"

Specifying the proper "decision statement" is a crucial step for the decision makers because it can determine if the solution meets the desired goal. In addition, the established decision statement will lead the solutions to be "simple versus complex" or "broad versus narrow" as described in Section 3.1. The roles of decision makers and coordinators involved in this step are:

- Decision makers have to clarify the objective by identifying a problem and establishing a decision statement in order to scope the problem's boundary and candidate solutions. A problem can cause various challenges, for example, traffic congestion may lead to environmental externalities, such as air pollution. Thus, decision makers should focus on the main cause of the problem rather than the outcomes of the problem.

- Coordinators should ensure that the results of the discussion lead to the problem's main cause. They should provide useful information, which includes traffic condition data, travel behavior, on-road activities, etc.

The example of this step 3 in this dissertation is provided in section 4 inside the Appendix B where the author acts as a coordinator, while the decision makers (traffic operators) are asked to indicate their TMCs goals.

5.2.2 Step 2: Identify the "set of alternatives or solutions"

Once a decision statement is identified, the decision makers must clearly understand the program goals and performance measures. They must establish the possible alternatives or solutions based on the decision statement described in Step 1. The roles of the decision makers and coordinators involved in this step are:

- Decision makers must establish the candidate alternatives or solutions.
- Coordinators should provide any additional information as needed. The useful information will enhance decision makers' viewpoints in the selection of candidate alternatives or solutions. To accomplish this, coordinators may conduct a survey for the decision makers that may include the following questions:
    - What are the objectives of the program?
    - What are the current operational performance measures used in the program?
    - What operational performance measures do you expect to be applied in the future?

The purpose of providing the program objectives is to make sure that the decision makers consider these objectives when generating candidate alternatives. An example of this step is provided in section 1 and 4 inside the Appendix B. The author acts as a coordinator and asks decision makers to establish the daily performance measures for freeway operations.

5.2.3 Step 3: Establish the "set of criteria used for assessing performance measures based on equipment and data collection techniques used on freeway systems"

Once the set of candidate alternatives is generated in Step 2, the set of constraints for identifying the feasible alternatives should be established. The set of constraints may include qualitative and quantitative criteria. The qualitative criteria will be used to determine the possibility of assessing the performance measures, and they may include measurability, comprehension, and availability. The quantitative criteria may include budget constraints or limitations of equipment and data collection techniques. The roles of the decision makers and coordinators involved in this step are:

- Decision makers have to identify the "set of constraints" for assessing the quality of the freeway performance measures in the next step. They should indicate the critical criteria.
- Coordinators should provide any additional information, especially information that enhances the decision makers' criteria selection, as needed. The information should include the limitations of the candidate alternatives provided in the previous step. The possible decision maker questions include:
    - What are the current performance measures used in the program at the system wide, interagency, daily operation, or equipment level?
    - What factors affect the use of those performance measures?

The example of this step in this dissertation is provided in section 3 inside the Appendix B where the author acts as a coordinator and asks decision makers to indicate the objective criteria.

Within Steps 2 and 3, various techniques, such as brainstorming, nominal group technique (NGT), surveys, or the Delphi method may be used to generate candidate alternatives and their criteria. Coordinators need to select the proper technique for the particular situation because each technique has its own advantages and limitations. For example, according to Ababutain [2], the objective of brainstorming is to generate all possible ideas in order to enhance the possibility of reaching ideal solutions. Thus, the final results may generate an unlimited number of solutions; however, the limitation of brainstorming occurs when some members of the group have strong opinions, which lead the other members to quickly reach an agreement without a complete discussion. Thus, the results may not include other potentially better solutions. Unlike the brainstorming technique, the nominal group technique (NGT) uses a questionnaire survey to allow decision makers to communicate in writing, which can avoid preliminary arguments. However, surveys that allow face-to-face and phone interviews may create conforming influences and decrease the possibility of generating ideas freely. Because the selection of freeway operational strategies uses experts who are directly involved with the freeway management system, the researchers recommend the Delphi method. According Dalkey and Helmer [17], coordinators will select the respondents from a group of experts that will be asked intensive questions with controlled opinion feedback. Disagreements among the experts will develop successive iterations until the various opinions yield to a widely acceptable view. The process ends at this point. The success of this method depends on experts' knowledge, experience, and viewpoint that can reflect the true value of whatever they judge. For example, constructing a new freeway can provide both advantages and disadvantages depending on the expert's viewpoints. A new freeway can reduce traffic congestion; however, it can induce new vehicles to use it and increase on-road emissions.

Due to time and distance constraints amongst the selected experts, the Delphi method is suggested. In an attempt to reach consensus, subsequent surveys are made where the respondents must either accept or reject the proposed weights. Due to differences in decision-makers, a complete consensus appears unlikely, and the process should end when most of them agree with the proposed condition.

5.2.4 Step 4: Screening the "set of alternatives or solutions in step 2"

Quality is better than quantity. More performance measures do not mean that they will provide a better assessment of the program. Thus, Step 4 provides an approach for screening the candidate alternatives and identifying the feasible alternatives, which can be used to assess freeway operations; then, Step 5 utilizes MCDM models to rank the feasible alternatives. Within Step 4, the processes includes grouping the performance measures, defining the direct or proxy performance measures, setting the constraints, and eliminating the performance measures based on minimal assessment levels established by the decision makers.

An example of step 4 is provided in Chapter 2 in where the author defines the air quality measures in Table 2.8.

5.2.4.1 Step 4.1: Grouping the alternatives which conveys the same meaning

In order to avoid using redundant performance measures, the performance measures that convey the same meaning must be grouped. For example, when planners consider the human health impacts due to traffic congestion, the Air Quality Index (AQI) used in the United States and the Air Quality Health Index (AQHI) used in European countries are possible indicators for assessing ambient air quality. However, both indices convey the same meaning; to be practical, decision makers should select either AQI or AQHI, not both. The coordinators must clearly understand the definition of the alternatives obtained through Step 2 before they group them.

An example of this step 4.1 in this dissertation is provided in section 4 inside the Appendix B where the performance measures are grouped by objective or goal criteria.

5.2.4.2 Step 4.2: Defining direct or proxy performance measures

Ideally, decision makers should consider direct performance measures before resorting to proxy performance measures. Good performance measures should be a direct consequence of activities. For example, if the desired result is minimizing traffic congestion, traffic volume should be a good performance measure (direct consequence). A proxy measure, such as vehicle registration, may sometimes be used in the absence of suitable performance measures due to time, budget constraints, or unavailability of data. Unfortunately, a proxy measure may not provide a good result because it relies on strong correlation between the factors. The coordinators have to define the performance measures in Step 4.1 as either direct or proxy measures.

An example of this step is provided in section 4 inside the Appendix B that the performance measures are grouped by objective or goal criteria.

5.2.4.3 Step 4.3: Setting the constraints for screening "set of alternatives or solutions in step 2"

Qualitative criteria and quantitative criteria will be used to screen the candidate performance measures for feasibility in the next step. Both qualitative and quantitative criteria established in Step 3 may have either a minimum or maximum acceptable value for each criterion, which represents the threshold that the performance measures must reach. The decision makers have to establish the set of constraints and their thresholds.

An example of this step 4.3 is provided in section 3 inside the Appendix B. The traffic operators have to indicate either the minimum or maximum acceptable value for the criteria describing the data collection strategies' quality (see in Table 5.1).

5.2.4.4 Step 4.4: Eliminating the alternatives by aspects

Once the set of constraints is established in Step 4.3, the alternatives that do not meet the standard thresholds of the criteria are eliminated. Coordinators have to screen the alternatives using qualitative and quantitative criteria using the thresholds provided in Step 4.3. The qualitative criteria used in this dissertation include:

- *Comprehension* – performance measures should be understandable at any managerial level without defining the terminology.
- *Measurability* – performance measures should be measurable.
- *Availability* – performance measures should be readily available.
- *Comparability* – performance measures should be comparable with other agencies.
- *Importance* – performance measures should be useful for public.

The quantitative criteria suggested in this dissertation include:

- *Time* – includes data aggregation time, data processing time, and updating data frequency time.
- *Cost* – includes capital costs, operational costs, and maintenance costs.
- *Accuracy* – includes data processing accuracy, instrumental accuracy, data aggregation accuracy, and human accuracy.
- *Reliability* – includes the failure of field equipment, communication, and database.

Table 5.1 The constraints for data collection strategies

Constraints for data collection strategies	**Criteria**	**Threshold**
Time	The time required for gathering an appropriate amount of field data before it is transferred to TMCs	< 60 seconds
	the time required for roadside controllers to transmit the field data to the TMCs	< 2 minutes
	calculating performance measures	< 2 minutes
Cost	maintenance and operating cost	< $20,000/ months
Accuracy	percentage of accuracy for data processing	> 75% (mean-92%)
	percentage of accuracy for instruments	> 75% (mean-90%)
	percentage of accuracy for data aggregation	> 80% (mean-93%)
Reliability	The percentage of reliability for field equipment	> 80% (mean-91%)
	The percentage of reliability for field equipment	> 80% (mean-92%)
	The percentage of reliability for field equipment	> 80% (mean-96%)

Shaw [56] provides a scoring approach to assess the strengths and weaknesses of various measures based on the qualitative criteria and sub-criteria as described in Section 4.3.2. This method can be utilized to select better performance measures once they are screened by Step 4.4. The limitation of this approach is that Shaw [56] assumes a rigid weight that may be not accurate because the decision makers may have different viewpoints. Unlike Shaw [56], this research asked traffic operators to provide the weight of each criterion based on their priorities. A simple additive weight (SAW) model is developed to evaluate the significance of each performance measure using equations (5.1) and (5.2).

$$V_i = \sum_{j=1}^{j=n} W_j r_{ij} \tag{5.1}$$

$$r_{ij} = \frac{S_{jk}}{\sum_{k=1}^{n} S_{jk}} \tag{5.2}$$

Where:

V_j = utility value of performance measure *i*

W_j = average weight for criterion *j*

r_{ij} = ranking importance for performance measure *i* on criterion *j*

S_{jk} = score of sub-criterion *k* on criterion *j*

The results of the proposed weights (W_j) from section 4.4.2 in Chapter 4 is used in equation (5.1) for clarity and simplicity, 0.20; descriptive and predictive capability, 0.21; analysis and capability, 0.24; accuracy and precision, 0.25, and flexibility, 0.10. The weight of each sub-criterion assumes an equal weight for all sub-criteria; therefore the individual sub-criterion weights may be found by dividing the broad criterion weight by the number of its sub-criteria (i.e. 0.20/5, 0.21/5, 0.24/4, 0.25/4, and 0.10/2 or 0.040, 0.042, 0.060, 0.0625, 0.050). This implies that the three most important issues for selecting performance measures are analysis and capability, accuracy and precision, and flexibility. The performance measures selection model based on the general equation (5.1) is given in equation (5.3).

$$V_i = 0.20\ R_{cs} + 0.21\ R_{dp} + 0.24\ R_{ac} + 0.25\ R_{ap} + 0.10\ R_f \tag{5.3}$$

where:

R_{cs} = ranking score for clarity and simplicity (max score = 5)

R_{dp} = ranking score for descriptive and predictive capability (max score = 5)

R_{ac} = ranking score for analysis and capability (max score = 4)

R_{ap} = ranking score for accuracy and precision (max score = 4)

R_f = ranking score for flexibility (max score = 2)

V_i = utility value of performance measure *i*

This approach may be very useful for screening the feasible performance measures in Step 4.4 in detail. However, additional criteria may be supplemented for making the final recommendation of performance measures in this process.

5.3 Multi-criteria decision making models

Selecting performance measures is usually based on more than one criterion, a MCDM approach allows decision makers to analyze complex decision problems with conflicting points of view. According to Polatidis *et al*. [49], there are two main families of MCDM models: utility function-based models and outranking methods. The utility function-based models include Multi-Attribute Utility Theory (MAUT) [54], and Simple Additive Weighting (SAW) [50]. Outranking methods include the ELECTRE families [53].

All MCDM models can provide a ranking of alternatives, but none of them can be described to fit decision problems completely. For example, SAW uses a simple utility function model, which requires high quality data (using real data or actual scores); however, decision makers may only require a ranking of the alternatives rather than their actual scores. Concordance methods do not require exact scores; therefore, they can effectively address criteria uncertainty. This method may provide only a partial ranking and preferred options rather than one best option. The selected MCDM methods should fit the complexity of problems, availability of data, and weighting technique. The author provides an application of the SAW and ELECTRE III methods, which are assumed to fit with the available data and decision problems.

5.3.1 Example using "MCDM models" in Step 5

Following Steps 1 through 4, the author assumes that the decision makers decide to use speed as a performance measure to assess the freeway performance at the implementation level. Decision makers are asked to define the criteria and weights to assess the data collection strategies. Assuming a weighting technique is used to obtain the weight for each criterion and sub-criterion shown in Figure 5.3, the three main criteria are composed of cost, accuracy, and reliability weighted by 65%, 20%, and 15%, respectively. The data processing time criterion is not considered because all equipment meets the criterion thresholds.

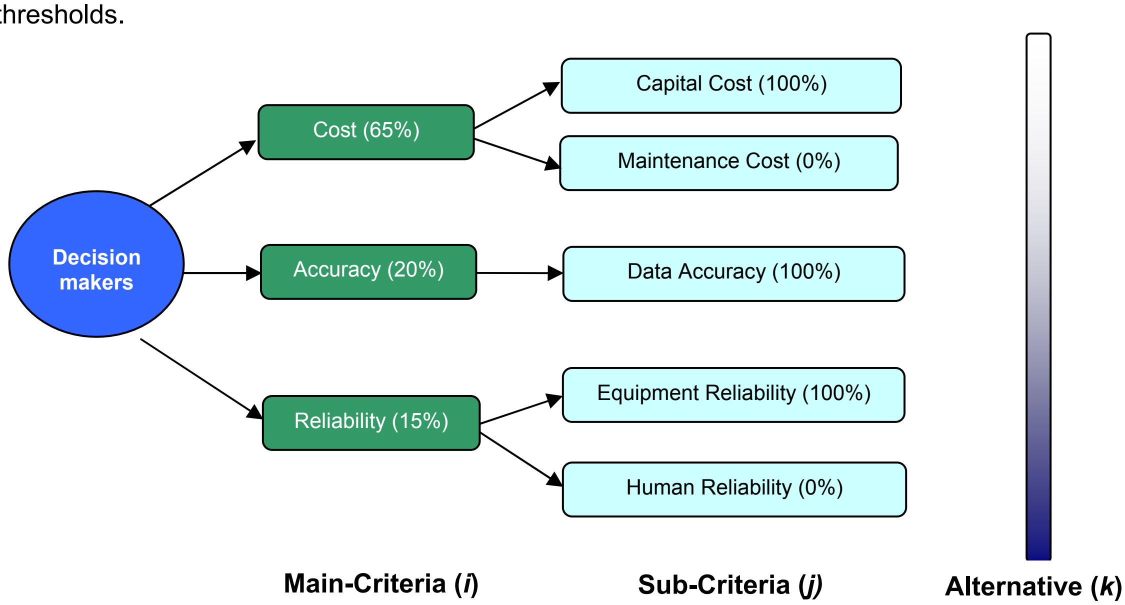


Figure 5.3 Weighting criteria and sub-criteria

Five sub-criteria are considered; however, the author assumes that decision makers are not concerned about the maintenance cost and human reliability criteria and assign them a zero for their weight.

Based on the screening of alternatives in Step 4, the six remaining alternatives are loop detector, microwave sensor, video sensor, infrared sensor, acoustic sensor, and ITS probe vehicle. For the quantitative criteria, the "ideal point concept" proposed by Hwang and Yoon [27] is typically employed for criteria normalization:

$$C_{ijk} = \frac{x_{ijk} - \min x_{ijk}}{\max x_{ijk} - \min x_{ijk}} \tag{5.4}$$

$$C_{ijk} = \frac{\max x_{ijk} - x_{ijk}}{\max x_{ijk} - \min x_{ijk}} \tag{5.5}$$

Where:

x_{ijk} is the score of alternative *k* with respect to criteria *i* on sub-criteria *j,*

C_{ijk} indicates the benefit of performance measure.

Within the ideal point concept, the quantitative data is converted into a comparable unit between "0 and 1" where "0" is the lowest utility value. The use of equations (5.4) and (5.5) depend on the variable x_{ijk}. If an increase of x_{ijk} leads to improvement, then equation (5.4) is used; otherwise equation (5.5) is applied. For example, if x_{ijk} means an increase of travel time, then a travel time increase will be unfavorable and equation (5.5) is used. Equations (5.4) and (5.5) are applied in this example and the scaling values are shown in Table 5.2. Even though the "ideal point concept" is simple and easy to apply, decision makers should be aware that small relative differences in the range of a criterion's values may lead to unrealistic criterion scaling. To counter this problem, the ELECTRE III method, which uses an indifference threshold, may be used. If the difference between criterion scores is less than the indifference threshold, the alternatives have the same performance level.

5.3.2 SAW method

In Figure 5.3, the decision hierarchies are composed of two levels: main criteria (level *i*) and sub-criteria (level *j*). The form of an additive utility function in the upper level (*i*) is:

$$V_{tot} = \sum_{i=1}^{n} w_{ik} U_{ijk} \tag{5.6}$$

Where, V_{tot} is the overall valuation for alternative k; w_{ik} is the weight assigned to criterion i for alternative k; U_{ijk} is the utility in the lower level j for alternative k to criterion i; and n is the number of criteria. The utility function in the lower level is calculated as follows:

$$U_{ijk} = \sum_{j=1}^{m} w'_{ijk} C_{ijk} \tag{5.7}$$

Where, U_{ijk} is the utility in the lower level j for alternative k to criterion i; m is the number of sub-criteria of criterion j; w'_{ijk} is the weight assigned to sub-criterion j to criterion i; C_{ijk} is the scaling value calculated from either equation (5.4) or (5.5). The final decision is based on the result from the overall valuation in equation (5.6).

Table 5.2 Scaling alternative criteria scores

Sub-Criteria	**Loop Detector**	**Microwave Sensor**[b]	**Video Sensor**[c]	**Infrared Sensor**	**Acoustic Sensor**[d]	**ITS probe vehicle**
Capital Cost ($)	14,400[a]	13,000	13,000	20,000	5,600	100,000
Data Accuracy (%)	95	95	95	90	90	90
Equipment Reliability (%)	95	95	95	95	92.5	96
Scaling the sub-criteria using equation (1) and (2)						
Capital Cost ($)	0.91	0.92	0.92	0.85	1.00	0.00
Data Accuracy (%)	1.00	1.00	1.00	0.00	0.00	0.00
Equipment Reliability (%)	0.71	0.71	0.71	0.71	0.00	1.00

Note: All data is assumed at a freeway segment, approximately two miles. The percent of data accuracy and reliability come from surveys by the FHWA/TX-07/0-5292 Project.
[a] approximately cost for four lanes
[b] covers up to eight lanes wide for one detector
[c] one camera can cover approximately four lanes
[d] one detector can cover approximately five lanes

5.3.3 ELECTRE III method

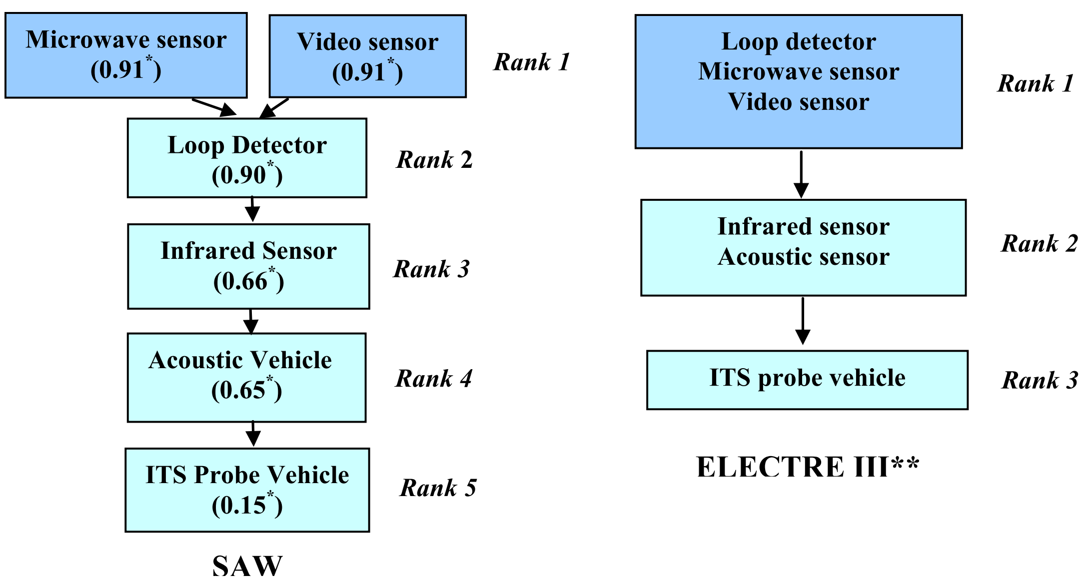
Performance scores, g_j (*a*) and g_j (*b*) use the scaled criterion scores in Table 5.2. The veto threshold is assumed to be equal to zero, while decision makers perceive the value of the *p* and *q* thresholds as follows:

- *Capital Cost* – This is an important criterion with the maximum weight because it relates directly to the availability of types of equipment, techniques, etc. Thus, the *q* threshold is set to a "small" value (q = 0.15), while the preference threshold is set twice as large (p = 0.30). On the other hand, using equation (5.2) and maximum and minimum value of capital equipment's cost in Table 1, decision makers can not distinguish the difference of equipments' cost if it is less than [0.15x(100,000-5,600)]=$14,160. In addition, decision makers can pay extra money approximately [0.3x(100,000-5,600)]=$28,320 in any equipment they prefer.
- *Data Accuracy* and *Equipment Reliability* – This relates to the quality of information obtained. However, current technologies lead to only slight differences in equipment accuracy and reliability. Thus, the *q* threshold is set to a "large" value (q = 0.25), while the preference threshold is set twice as large (p = 0.50). On the other hand, decision makers cannot distinguish the difference of equipments' performance if its percent accuracy and reliability are less than 1.25% and 0.875%, respectively.

5.3.4 Analysis results

The full ranking of alternatives using the SAW model based on the scaling data (Table 5.2) and weighting criteria (Figure 5.3) are analyzed. From this analysis, the microwave and video sensors appear to be the best alternative with the same highest score (0.91) for the SAW method. Loop detector, infrared sensor, acoustic sensor, and ITS probe vehicle trail behind in that order. The ELECTRE III model is utilized to assess the same alternatives and the microwave and video sensors are again the best alternatives at the highest level; however, the loop detector is also one of the top alternatives (Figure 5.4). The analysis details for ELECTRE III and SAW are shown in Appendix D.

The rank order for the two techniques is very similar; however, ELECTRE III does not provide a score for the alternatives as SAW does. This difference between the two techniques is critical for the decision makers and coordinators to consider. Recall specifically, the earlier discussion regarding the decision statement in Step 1; the choices made at this stage will likely determine the appropriate technique to apply in Step 5. The core concept behind the difference in the two techniques is ELECTRE III's assumption that small differences between alternatives are indistinguishable from one another due to inherent uncertainties in the decision-making process. As seen in Figure 5.4, the alternatives that share the same rank in ELECTRE III all have very similar scores in the SAW technique.



Note: * the total score for each alternative using equations (3) and (4).

** ranking results of descending distillation is the same as ascending distillation and final ranking

Figure 5.4 Ranking of alternatives by using SAW and ELECTRE III methods

The framework provided in this chapter improves on earlier research by facilitating the constrained selection of freeway operational performance measures. The process allows decision makers to generate candidate solutions and criteria before using qualitative and quantitative performance thresholds to reduce them to a set of feasible alternatives. The use of MCDM strategies provides an opportunity for the decision makers to evaluate the trade-offs across the different criteria. The decision makers must select the appropriate weighting techniques or MCDM strategies based on the complexity of their problem or the required results because each technique and MCDM strategy has strengths and limitations. The proposed criteria and application framework provides the guidelines for future applications by any agency. The successful implementation of the proposed methodology requires complete and engaged participation from the decision makers.

CHAPTER 6

ASSESSMENT OF PERFORMANCE MEASURES AND OPERATIONAL STRATEGIES ON FREEWAYS

This Chapter provides another application of the framework proposed in Chapter 5 to develop an integration of performance measures which aim to evaluate the success of TMC goals or objectives. In addition, the author develops an integration of performance measures named a “Freeway Performance Index” or “FPI” that may be utilized to assess the quality of freeway performance and capture changes in daily freeway operations. A complete application of the framework is applied on Lane 1 at SB Loop 12, Irving Boulevard in Irving, Texas and on SB-I35W at Alta Mesa, Fort Worth, TX. The sensitivity of the model is analyzed and discussed at the end of this chapter.

6.1 Integration of performance measures for freeway operations

This research seeks to develop flexible models that can be applied at both the strategic and operational levels. In addition, the proposed models presented in this chapter should be able to facilitate the comparison of multiple operational strategies, which will also be useful for planning. Performance measures can be used to evaluate the program success and they can be used at different levels as described in Section 5.1.

The integration of performance measures in this chapter is expected to be used at the highest level for evaluating how well TMCs operate and manage freeways to meet their goals or objectives. The framework described in Chapter 5 provides the steps to develop an integration of performance measures model for freeway operations. The procedure is as follows:

6.1.1 Step 1: Establish the "decision statement"

Most TMCs' goals are to provide travelers with a faster and safer trip. In order to meet most TMCs' goals, traffic operators apply various operational strategies such as ramp metering, dynamic message signs, etc. on freeways. The impacts of freeway operational strategies affect both on-road users and non road users as described in Chapter 2. In addition, there is currently no integration of performance measures to evaluate overall impacts of the freeway operational strategies. In this step, traffic operators are expected to develop the "Freeway Performance Index" to assess those impacts. The "Decision Statement" is established to "develop an integration of performance measures for assessing the impacts of daily freeway operations".

6.1.2 Step 2: Identify the "set of alternatives or solutions"

In this step, once a decision statement is established in step 1, decision makers or traffic operators must establish the objective criteria and their performance measures which are useful to meet their TMCs' goals. The research surveys in Chapter 4 show that the important objective criteria (safety, energy and environmental, mobility, and efficiency) are the main objective criteria for most TMCs (See Figure 6.1) and should be included in the integrated performance measures model.

6.1.3 Step 3: Establish the "set of criteria used for assessing performance measures"

The proposed criteria for screening the individual performance measures here are measurability, comprehension, comparability, availability, and importance. The performance measures should be able to be measured in real time; they should be understandable by most agencies; they should be comparable among TMCs; they should readily be available; and they should be useful for the public. However, the most of performance measures in this chapter are expected to be used by traffic operators, which may not be useful for the public.

6.1.4 Step 4: Screening the "set of alternatives or solutions in step 2"

6.1.4.1 Step 4.1: Grouping the alternatives which conveys the same meaning

In order to avoid redundant performance measures, the grouped measures from step 2 should be compared. If the performance measures grouped for a TMCs goal or objective convey the same meaning, they should be omitted as described in Chapter 5. This research suggests the daily performance measures based on the survey results in Table 6.1; these measures are grouped in areas of safety, energy and environment, mobility, and efficiency.

Table 6.1 Percentage of selected performance measures

Performance Measures (PMs)	**% of selected PMs**	**Operational Level**	**Planning Level**
Safety on Freeways			
- Incidents including crashes or stopped vehicles	80%	*	√
Energy and environment			
- Emissions	40%	*	√
Enhance of the mobility of persons, freights, etc.			
- Incident delay	80%	*	√
- Speed	80%	√	√
- Extent of congestion	80%	√	√
- Travel time	80%	√	√
- Recurring Delay	70%	√	√
- Reliability	70%	√	√
Efficiency of transportation system			
- Throughput per vehicle	50%	√	√

Note: * possible at operational level by using proxy measure

6.1.4.2 Step 4.2: Defining direct or proxy performance measures

Direct performance measures are preferred as described in Section 2.5.2. However, in the absence of direct performance measures, proxy measures can be applied. Most performance measures that result from the surveys (in Table 6.1) are direct performance measures. Only safety and environment may not be available in real time; however, the proxy measures for safety and environment are available.

Definition of individual performance measure and how to calculate

Safety

Many studies found that speed was one of the most important indicators for determining crash rates on roadways [58, 12, 22, 24]. Finch *et al*. [20] studied the relationship between crash rate and speed using data from Finland, Denmark, Switzerland, and United States. They found that a change in accident rate was proportional to an increase or decrease in speed as follows:

$$\Delta A = 4.92 \ \Delta\overline{V_{mph}} \tag{6.1}$$

Where:

ΔA = percent changes of accident rate (%)

$\Delta\overline{V_{mph}}$ = the change of average vehicular speed (mph)

Solomon [57] found that the relationship between speed and crashes could be explained by a U-Shaped curve with a speed higher or lower than 6 mph above the operating speed. Based on Solomon's study, the researchers establish that a standard deviation of a facility's speed greater than 6 mph is unsafe.

How to calculate performance measures

1. Definition of safety performance measures

A proxy measure is proposed as the safety performance measure in this dissertation. It is defined as the potential of crash on a particular freeway section. Crash potential is higher when the standard deviation of a facility's speed greater than six mph. (Solomon [58]).

2. Obtain the performance measures and index

The standard deviation of a facility's speed can be obtained directly from ITS data. The safety index (C_s) is set based on the crash potential. The safety index (C_s) will be "1" if the facility's speed is very close to the mean, whereas "0" indicates very few vehicles' speeds are 6 mph away from the mean.

Energy and Environment

Speed is one of the most important indicators for increases or decreases of on-road emissions ([14], [4]). Due to the unavailability of monitoring stations, on-road emissions data are difficult to obtain. A surrogate model is commonly utilized to estimate emissions on freeways [3, 4, 67]. In this dissertation, a surrogate model for nitrogen oxide (NO_x) emissions developed by Yerramalla [67] is suggested for any "nonattainment areas for where NO_x concentration levels persistently exceed National Ambient Air Quality Standards or where NO_x emission control the creation of ozone in a "non attainment area".

How to calculate those performance measures

1. Definition of performance measure

A proxy measure is proposed for quantifying emissions in this dissertation. The emission measure is defined as the pollutant (nitrogen oxide) emission rate during five minute intervals for a particular freeway section (grams/mile during 5 minute intervals).

2. Calculate a proxy measure and index

The most common method to determine emissions on a roadway (a line source per unit length) can be obtained from Equation (6.2).

$$q = \sum_i e_i N_i \qquad (6.2)$$

where:

e_i is the emission factor (g. $mile^{-1}$. $vehicle^{-1}$) for NO_x or another pollutant (the emission factor may need to be determined) using a surrogate model for emission factor developed by Yerramalla [67]. The emission rate varies by vehicular speed and composition of traffic volume. As an alternative, MOBILE 6.2 or MOVES can be used to obtain the emission factors; however, these emission factors vary based on current weather conditions as well as the average speed on the freeways.

N_i is the traffic volume during a five minute interval (See Appendix E).

q is the pollutant emission rate during a five minute interval for a particular freeway section (g. mile^{-1} during 5 minute intervals). [The length of the section is required for determining the total mass emissions.]

The “ideal point concept” described in Section 5.3.1 is utilized to generate the emission index (C_{ee}) based on the observed on-road emissions. The maximum observed mass emission is given an index value of “0”, while the emission index (C_{ee}) becomes “1” with a minimum on-road emission.

Mobility

This dissertation proposes mobility performance measures based on the survey results that include speed, travel time, delay, extent of congestion, and reliability. Since all mobility measures can be calculated based on distance and speed, the mobility index developed here is also based on distance and speed.

Calculation of performance measures

1. Decision makers must define the acceptable travel time

This dissertation defines acceptable travel time using a concept from the Florida’s Reliability Method [29]. The acceptable time is obtained using the following equation:

$$AcceptableTravelTime = x_{50} + \Delta \tag{6.3}$$

Where:

x_{50} = the median travel time across the corridor for a particular period.

Δ = an additional travel time increment, which is estimated as a percentage of the median travel time.

The median travel time is used instead of the mean in order to reduce the outlier effects of the major incidents during the study period. The additional travel time may be set at 5%, 10%, 15%, and 20%. The percentage of additional travel time may be higher or lower based on the time period and traffic conditions at different locations. The additional travel time should be based on travelers’ experiences, which can be assessed thru travelers’ surveys [29].

Similar to acceptable travel time, the acceptable travel speed is defined as the minimum acceptable travel speed for transversing a freeway segment within the acceptable travel time described above. The acceptable speed can be calculated using equation (6.4).

$$AcceptableTravelSpeed = \frac{freeway\ segment\,(mile)}{AcceptableTravelTime\,(hour)} \tag{6.4}$$

2. Definition of individual performance measure and how to calculate

Speed: this dissertation defines speed as the average vehicles' speed over a distance measured in a single lane, for a single direction of flow, at a specific roadway section and time period. Speed is a direct performance measure that can be obtained from various data collection strategies such as gun radar, loop detector, microwave sensor, video sensor, infrared sensor, and acoustic sensor.

Travel time: this dissertation defines travel time as the average vehicles' travel time required for traversing a freeway section in a single direction. Travel time is a direct performance measure that can be obtained from various data collection strategies such as test vehicle (floating car) technique, license plate matching technique, video matching technique, ITS probe vehicle technique, time lapse photography, and toll tag matching technique.

Recurring delay: this dissertation defines recurring delay as the difference between the average actual travel time and unconstrained travel time for a specific roadway section and time period. The total recurring delay can be calculated by multiplying the recurring delay with traffic volume during a time period. For calculating the unconstrained travel time, this dissertation assumes that travelers should drive at the posted speed limit; unconstrained travel time can be calculated from travel distance divided by posted speed limit. However, some drivers may drive above the speed limit during unconstrained traffic condition. As an alternative, the value for the unconstrained travel time can be set at the free flow speed based on the traffic operators' perspectives or traffic characteristics of a particular freeway.

Extent of congestion: this dissertation defines the extent of congestion as the miles of roadway within a predefined area during a specific time period where the additional travel time may be considered at 5%, 10%, 15%, and 20% longer than the median travel time. On the other hand, if the actual travel time is longer than the acceptable travel time, it likely indicates congestion. The percentage of additional travel may be set differently based on traffic conditions in different locations or based on travelers' perceptions of traffic congestion [29]. This dissertation calculates the extent of congestion by multiplying the additional travel time with the average actual travel speed.

NTOC [42] defined the extent of congestion as the miles of roadway within a predefined area during a specific time period where the average travel times are 30% longer than unconstrained travel times.

Travel Time Reliability: this dissertation defines reliability as the period of time where exceeds the acceptable travel time. As a result, this measure is not applicable in real time and should be applied at the planning level.

Efficiency

Throughput measured in vehicles can be used as a direct performance measure for freeway efficiency. When freeways service a high number of vehicles at high speed, the overall system is functioning more efficiently. However, as higher traffic volumes approach capacity lower travel speed and longer travel time result. When freeways operate well, travelers should be able to transverse a freeway segment with a speed above the acceptable travel speed. Using an acceptable travel speed as the efficiency boundary for counting the vehicles seems like a good concept; however, this approach may cause the freeway efficiency index to decrease dramatically from "1" to "0" during peak hour. This dissertation develops a new efficiency measure (EFM) that can be calculated by multiplying the vehicular volume during a five minute interval and the mean speed. The EFM can be calculated as follows:

$$\text{EFM (vehicles in 5 mins-mile/hour)} = \#Vehicles \times AverageSpeed \qquad (6.5)$$

6.1.4.3 Step 4.3: Setting the constraints for screening "set of performance measures in step 2"

The daily performance measures should be selected based on their availability in real time. The common performance measures, which are measureable, and present at most TMCs, should be considered so that operations among most TMCs can be compared and they can be combined into an integrated performance measures model.

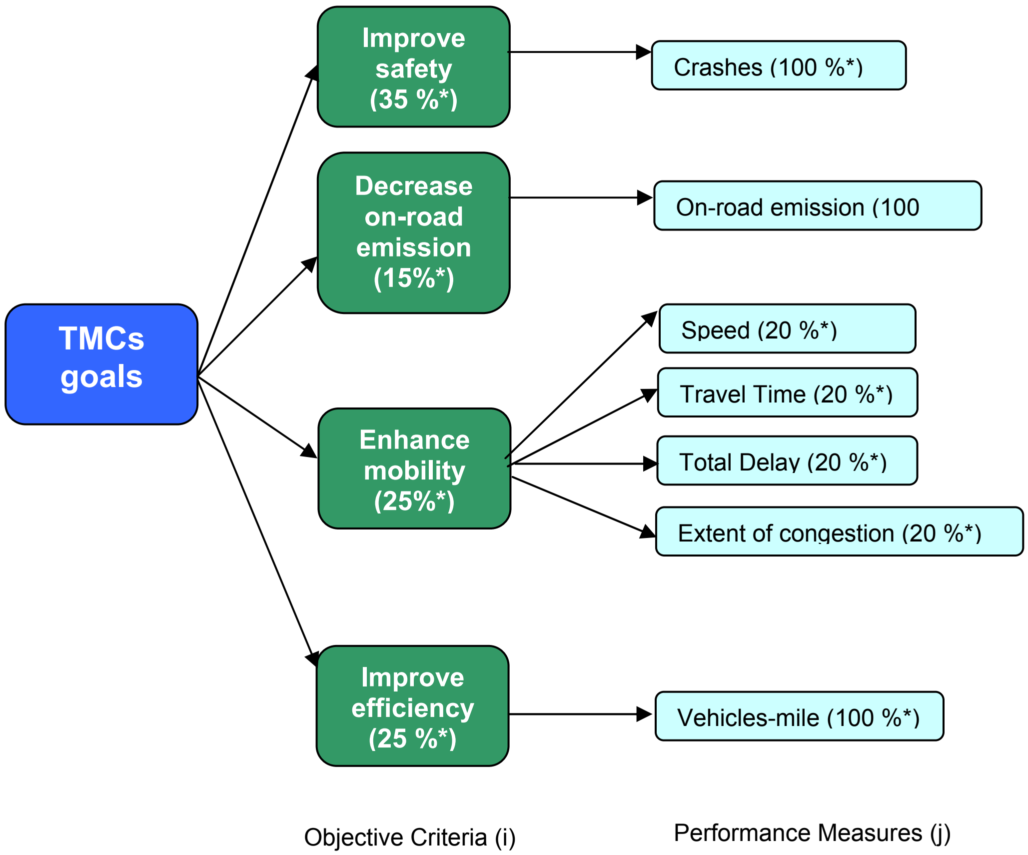
6.1.4.4 Step 4.4: Eliminating the alternatives by aspects

Most performance measures in Table 6.1 pass the requirements of the qualitative constraints based on comprehension, availability, measurability, comparability, and usefulness for traffic operators at the planning level. At the operational level, the proxy measures are suggested in the absence of direct measures, which are not available in real time.

6.1.5 Step 5: Multi-criteria decision making models.

Once the objective criteria and their performance measures are identified and selected, the formulation of the model must be established. All multi-decision making models described in Chapter 3 can be utilized to rank alternatives in different perspectives. However, selecting an appropriate model should be based on the analysis issues and data availability. For example, if only the ranking priority of alternatives is needed without knowing how much the quality of one alternative is different from the other alternatives, concordance models such as PROMETHEE and ELECTRE III are adequate. For developing this integration of performance measures, SAW is proposed due to the availability of high quality data and an ability to compare the difference in freeway performance in real time.

The criteria weights are important for making a decision as well as developing all MCDM models. In order to obtain the objectives and performance measure weights, this dissertation conducts the surveys as described in Chapter 4. Traffic operators must define their objective criteria and performance weights. The proposed weights in Section (4.4.3) are utilized for integrating the performance measures. However, because most TMCs do not have daily performance measures, most traffic operators could not establish the performance measures' weights. As a result, this dissertation proposed the presumption of equal weights.



Note: ** is the proposed weights

Figure 6.1 Composed criteria hierarchy for the TMCs

In Figure 6.1, the decision hierarchies are composed of two levels: main criteria (level *i*) and sub-criteria (level *j*). The form of the additive utility function in the upper level (*i*), which is similar to equation (5.3) in Chapter 5, is presented in equation (6.6):

$$V_{tot} = \sum_{i=1}^{n} w_i U_{ij} \qquad (6.6)$$

Where, V_{tot} is the overall valuation for freeway operations at the TMC; w_i is the weight assigned to objective criterion *i*; U_{ij} is the utility in the lower level *j* for to objective criterion *i*; and

n is the number of objective criteria. The utility function in the lower level is calculated as follows:

$$U_{ijk} = \sum_{j=1}^{m} w'_{ijk} \, C_{ijk} \tag{6.7}$$

Where, U_{ij} is the utility in the lower level j associated with objective criterion i; m is the number of sub-criteria of criterion j; w'_{ij} is the weight assigned to sub-criterion j for objective criterion i; C_{ij} is the scaling value calculated from either Equation (5.1) or (5.2). The final decision is based on the result from the overall valuation in equation (6.7).

Similar to Chapter 5, the "ideal point concept" described in section 5.3.1 is used for converting the objective criteria and performance measures to a common scale. Once the performance measures and the methodology to calculate them in Step 2 are established, decision makers should define the "max and min value" in equations 5.1 and 5.2.

The maximum value for most performance measure may be set at the 95th percentile, while the 5th percentile can be used for the minimum value; however, under ideal conditions, the decision-makers will establish these. If a performance measure value performs better than the maximum boundary (95th percentile), its index will become "1", while it becomes "0" when performs worse than minimum boundary (5th percentile). The maximum and minimum value can be calculated and obtained from historical data for any time period (e.g. daily, peak, and off-peak). The values for the minimums and maximums of individual performance measures are shown in Table 6.3.

6.2 Application of the integrated performance measure models

Two applications of the integrated performance measures model are applied in different locations. The first location is Lane 1 on SB Loop 12 at Irving Boulevard in Irving, Texas. Another location is on SB-I35W at Alta Mesa, Fort Worth, TX. The results of both applications will be compared with each other.

Table 6.2 Performance measures threshold and boundary values

Performance measures	Xmin (minimum)	Xmax (maximum)	Individual Index
Standard deviation of avg. speed	N/A	N/A	C_s = 0 if std. of avg. speed > 6 mph.; otherwise C_s = 1; Where: C_s is safety index
NOx emissions	0	95th percentile	$C_{ee} = (X_{max}-X_i) / (X_{max})$; where Cee is emission and energy index; X_i = NO_x emissions during five minutes.
Avg. speed	Acceptable travel speed	Posted speed limit	$C_v = (X_i-X_{min})/(X_{max}-X_{min})$; where C_v = speed index; X_i = avg. speed during five minutes.
Avg. travel time	Unconstrained travel time	Acceptable travel time	$C_{tt} = (X_{max}-X_i)/(X_{max}-X_{min})$; where C_{tt} = travel time index; X_i = avg. travel time during five minutes.
Total delay (recurring)	0	95th percentile	$C_d = (X_{max}-X_i) / (X_{max})$; where C_d = total delay index; X_i = total delay during five minutes.
Extent of congestion	0	Roadway distance*	$C_{ec} = (X_{max}-X_i) / (X_{max})$; where C_{ec} = extent of congestion index; X_i = extent of congestion during five minutes.
EFM	0	95th percentile	$C_{ef} = (X_i) / (X_{max})$; where C_{ef} = efficiency index; X_i = vehicles-mile during five minutes.

Note:

- Minimum NO_x emissions value is set to "0" when no traffic occurs.
- Minimum total delay is set to "0", when there is no difference between actual time and unconstrained travel time.
- Maximum extent of congestion occurs when all vehicles exceed the acceptable travel time on a freeway segment. The maximum extent of congestion is set to the length of the selected freeway segment.
- Minimum travel time reliability is set to "0" when the actual travel time is less than mean travel time. Traveler expectation is meted.
- Minimum vehicle-mile during five minutes is set to "0", when no vehicles use the facility.

For the first location, the model in equation (6.7) is applied to five minute interval detector data from Lane 1 on SB Loop 12 at Irving Boulevard in Irving, Texas. The peak period occurs from 4:00PM – 6:00PM, and the maximum five minute traffic volume is 140 vehicles per lane. The maximum and minimum on-road emissions can be calculated using equation (5.4) with the NO_x emission functions developed by Yerramalla [67] (see in Appendix G), traffic composition from Harris County in 2007 (see in Appendix F), and number of vehicles. Using equation (6.7) and the proposed objective criteria weights shown in Figure 6.1, the overall freeway performance index can be constructed as shown in using equation (6.8).

$$FPI = 100\ [0.35\ (U_s) + 0.15\ (U_{ee}) + 0.25\ (U_m) + 0.25\ (U_{ef})]\ /\ m \qquad (6.8)$$

Where:

FPI = percent of freeway performance;

m = number of criteria;

U_s = utility in the lower level *j* of the safety criterion

= $W_s \cdot C_s$; where W_s is 100% for one criterion; $U_s = C_s$

U_{ee} = utility in the lower level *j* of the energy and environment criterion;

= $W_{ee} \cdot C_{ee}$; where W_{ee} is 100% for one criterion; $U_{ee} = C_{ee}$

U_m = utility in the lower level *j* of the mobility criterion;

= $\sum_{j=1}^{m} w'_{ijk}\ C_{ijk}$; where the weights are equal;

= $0.25 \cdot C_v + 0.25 \cdot C_{tt} + 0.25 \cdot C_d + 0.25 \cdot C_{ec}$

U_{ef} = utility in the lower level *j* of the efficiency criterion

= $W_{ef} \cdot C_{ef}$; where W_s is 100% for one criterion; $U_{ef} = C_{ef}$

Other candidate scenarios (equations 6.9 - 6.13) are considered for evaluating freeway performance by removing some criteria due to the unavailable of data; these scenarios are based on sensitivity analysis, which evaluates the changes in *FPI(%),* after altering the weights in equation (6.9). The calculation of weights for each scenario is shown in Appendix H. The five scenarios are as follows:

Scenario 1: without emissions

$$FPI\ (\%) = 100.\ [0.3750\ (C_s) + 0.3125\ (C_m) + 0.3125\ (C_{ef})] \qquad (6.9)$$

Scenario 2: without safety

$$FPI\ (\%) = 100.\ [0.2308\ (C_{ee}) + 0.3846\ (C_m) + 0.3846\ (C_{ef})] \quad (6.10)$$

Scenario 3: without safety assuming the equal weight

$$FPI\ (\%) = 100.\ [0.3333\ (C_{ee}) + 0.3333\ (C_m) + 0.3333\ (C_{ef})] \quad (6.11)$$

Scenario 4: without emissions and safety

$$FPI\ (\%) = 100.\ [0.5000\ (C_m) + 0.5000\ (C_{ef})] \quad (6.12)$$

Scenario 5: assuming equal weights

$$FPI\ (\%) = 100.\ [0.2500(C_s) + 0.2500(C_{ee}) + 0.2500(C_m) + 0.2500(C_{ef})] \quad (6.13)$$

This dissertation sets the additional travel time increment at 20% of the median travel, which is suggested by the Florida DOT [29]. The acceptable travel time is calculated using equation (6.3). The median travel time can be derived from the distance of the freeway segments and their median speed. This dissertation considers that the vehicles transverse five miles of a freeway segment. The median speed is 61 mph., while the median travel time will be 5/61 = 0.082 hour or 4.92 minutes. The acceptable travel time will be 4.92 + 0.2 (4.92) = 5.9 minutes, while the acceptable speed will be (5 / (5.9/60)) = 50.8 miles per hour. The maximum designed speed here is set at the posted speed limit of 65 mph, so the unconstrained travel time is (5 miles/ 65 mph.) = 0.077 hour or 4.6 minutes. It is assumed that the speed limit is a reasonable approximation of free flow speed because the change in utility above the speed limit may not be that large. The thresholds for the performance measures for Loop 12 are shown in Table 6.3. Figure 6.2 illustrates the emission index for Loop 12, the emission index lies between 0 and 0.97. The minimum emissions occur from midnight to 5:30 A.M. during low traffic conditions. The emissions greatly increase from 5:30 A.M. to 6:30 A.M. and remain stable until approximately 2:00 P.M.; again, the emissions index decreases during evening peak from 4:00 P.M. to 6:30 P.M.

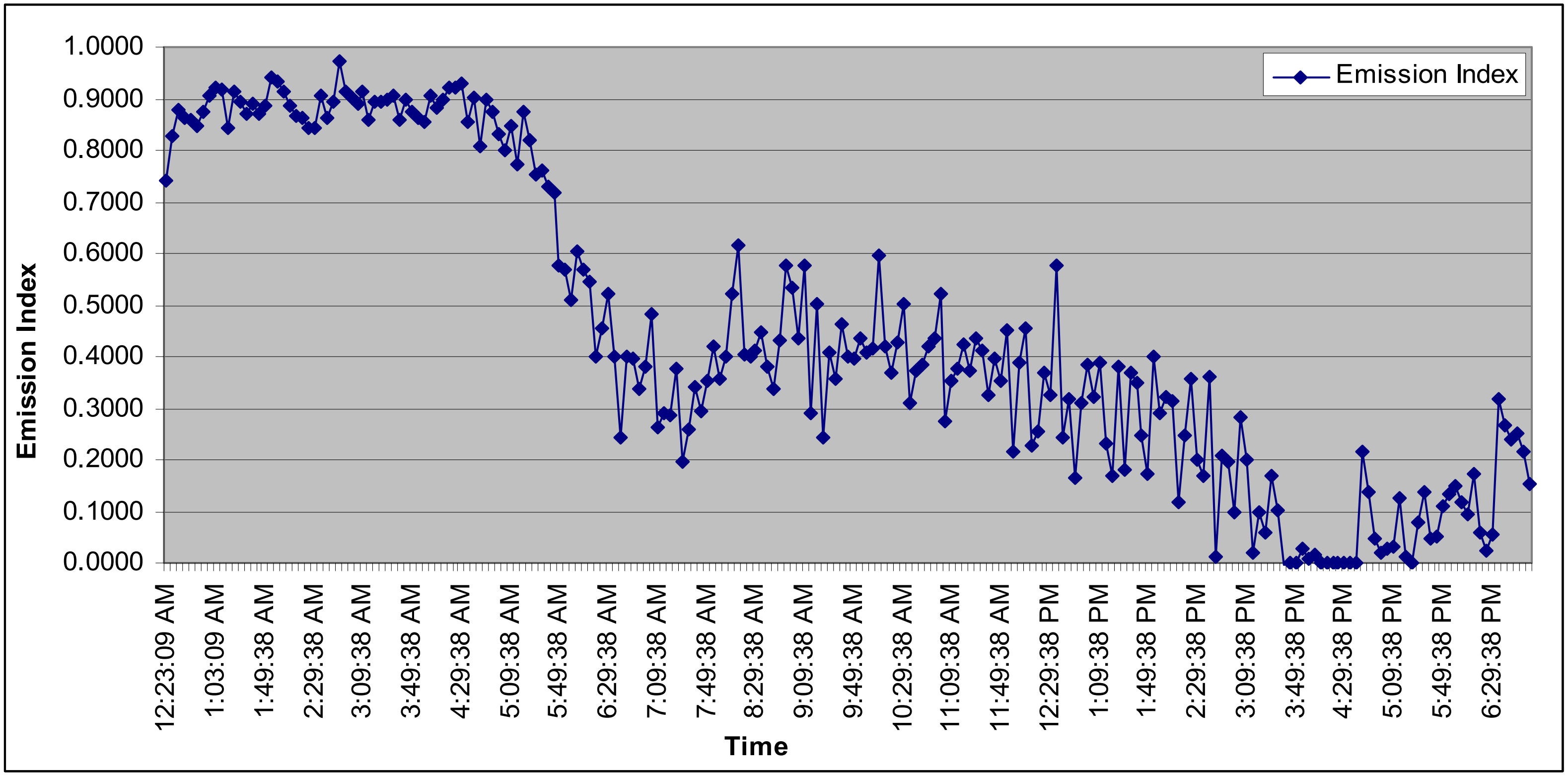


Figure 6.2 Emission index

Table 6.3 Calculated Loop 12 performance measure thresholds

Performance measures	Xmin (minimum)	Xmax (maximum)	Individual Index
Standard deviation of avg. speed	N/A	N/A	C_s = 0 if std. of avg. speed > 6 mph.; otherwise C_s = 1; Where: C_s is safety index
NOx emissions	0	113.48 g/mile	$C_{ee} = (X_{max}-X_i) / (X_{max})$; where Cee is emission and energy index; X_i = NO_x emissions during five minutes.
Avg. speed	52.44 mph.	65 mph.	$C_v = (X_i-X_{min})/(X_{max}-X_{min})$; where C_v = speed index; X_i = avg. speed during five minutes.
Avg. travel time	4.6 mins	5.7 mins	$C_{tt} = (X_{max}-X_i)/(X_{max}-X_{min})$; where C_{tt} = travel time index; X_i = avg. travel time during five minutes.
Total delay (recurring)	0	42.44 mins-veh.	$C_d = (X_{max}-X_i) / (X_{max})$; where C_d = total delay index; X_i = total delay during five minutes.
Extent of congestion	0	5 miles	$C_{ec} = (X_{max}-X_i) / (X_{max})$; where C_{ec} = extent of congestion index; X_i = extent of congestion during five minutes.
Travel time reliability	0	0.53 mins	$C_{ttr} = (X_{max}-X_i) / (X_{max})$; where C_{ttr} = travel time reliability index; X_i = addition travel time.
EFM	0	6980 veh.-mph in five mins interval	$C_{ef} = (X_i) / (X_{max})$; where C_{ef} = efficiency index; X_i = vehicles-mile during five minutes.

Note: All data is assumed at a freeway segment, approximately five miles.

Figure 6.3 illustrates the mobility index for speed, travel time, recurring delay, and extent of congestion. The speed index has a wide variation which ranges between 0.4 and 0.95 before it drops dramatically during the peak. The travel time index ranges between 0.80 and 0.98 before it dramatically decreases during the evening peak. The recurring delay and extent of congestion present the index value above of 0.90 during midnight to 3:30 P.M. before it dramatically drops again during evening peak hour.

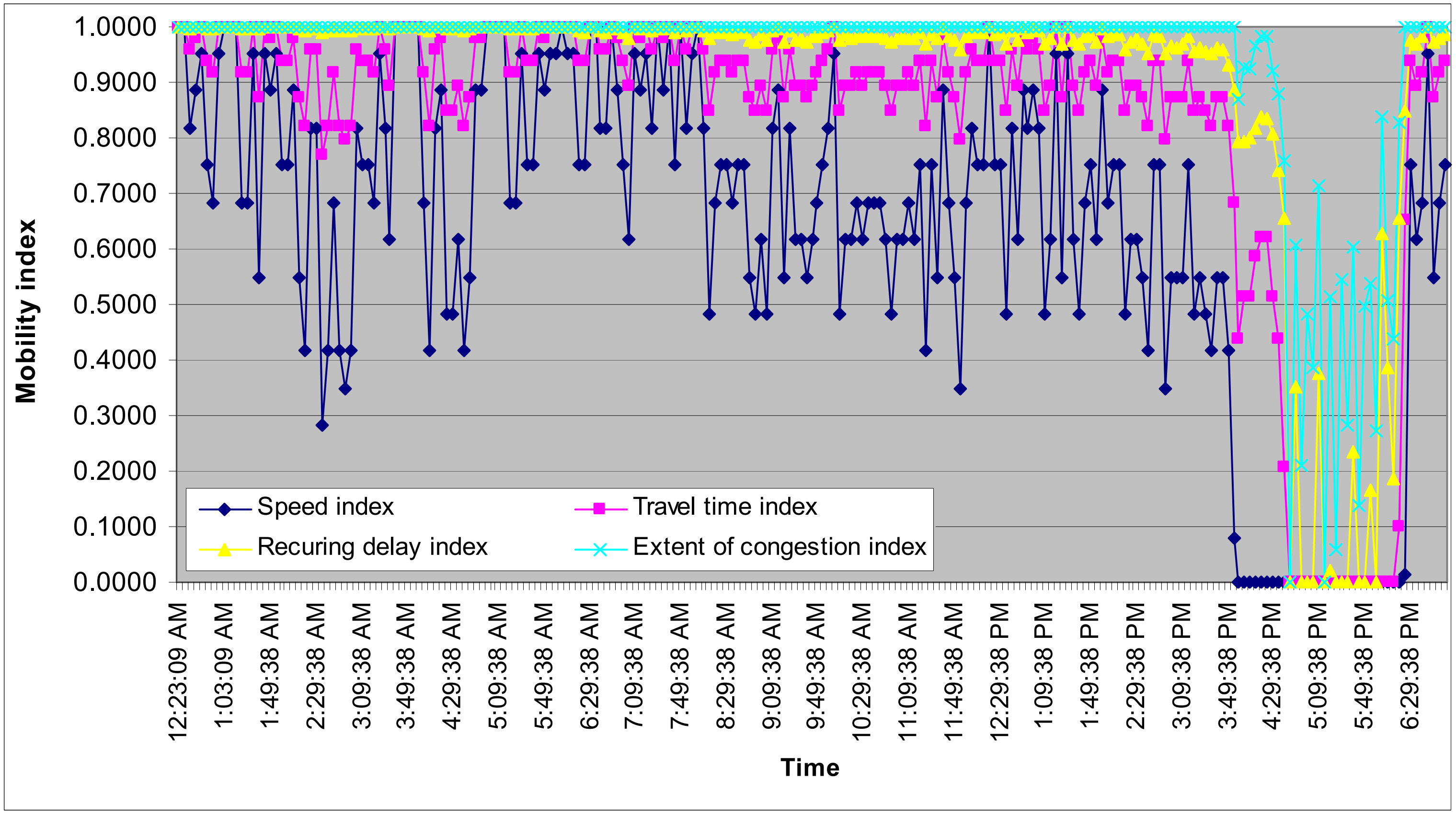


Figure 6.3 Mobility index

Figure 6.4 illustrates the efficiency index (EFM). The freeway efficiency is low from midnight to 5:30 A.M.; the EFM lies between 0.05 and 0.20 during that time period before it dramatically increases during 5:30A.M. to 7:00A.M. from 0.20 to 0.65. The EFM tends to increase from 7:00 A.M. to 4:30 P.M.; then, the maximum EFM occurs before evening peak from 3:00 P.M. to 4:30 P.M.; at 4:30 P.M. efficiency drops because the freeway is not operating a high speed and appears to have entered a constrained flow condition.

This dissertation did not calculate scenarios 1 and 5 due to unavailability of the standard deviation of speed for each five minute interval. Figure 6.5 illustrates the FPI (%) using equations 6.10, 6.11, and 6.12. Comparing among scenarios (2, 3, and 4) provides similar trends. The FPI (%) lies between 20% and 95% for the three scenarios. The FPI (%) is below 60% from midnight to 5:30 P.M. and from 4:00 P.M. to 6:00 P.M. due to the lower speed and flow conditions, while higher than 60% from 6:30 A.M. to 4:00 P.M.; the calculation of FPI is shown in Appendix H.

For the second location, the model in equation (6.9) is applied to one minute interval detector data for all four lanes of SB-I35W at Alta Mesa, Fort Worth, TX. The peak period occurs from 6:00 P.M. to 8:30 P.M.; the maximum five minute traffic volume is 149 vehicles per lane or 595 vehicles per four lanes. The on-road emissions can be also calculated using equation (5.4) with the NO_x emission functions developed by Yerramalla [67] (see in Appendix G), traffic composition from Harris County in 2007 (see in Appendix F), and number of vehicles in that particular freeway. Using equation (6.7) and the proposed objective criteria weights shown in Figure 6.1, the overall Freeway Performance Index (FPI) can be constructed and calculated using equation (6.8). Other candidate scenarios (equations 6.9 - 6.13) are considered for evaluating freeway performance in the absence of data. The additional travel time increment remains at 20% of median travel as described in previous application. The calculation of this application will be based on four lanes for an approximately five miles. The thresholds of the performance measures for this application are shown in Table 6.4.

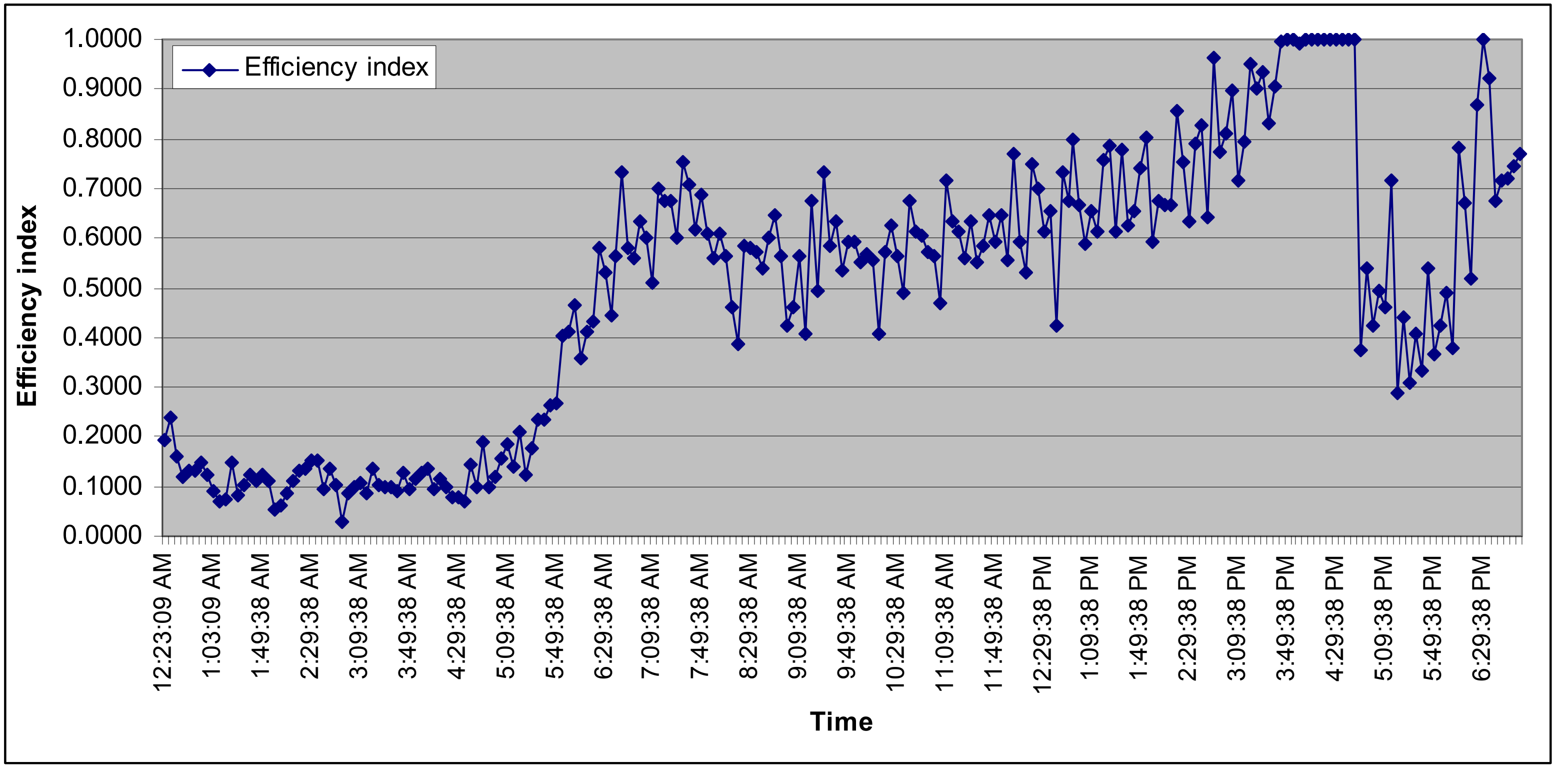


Figure 6.4 Efficiency index

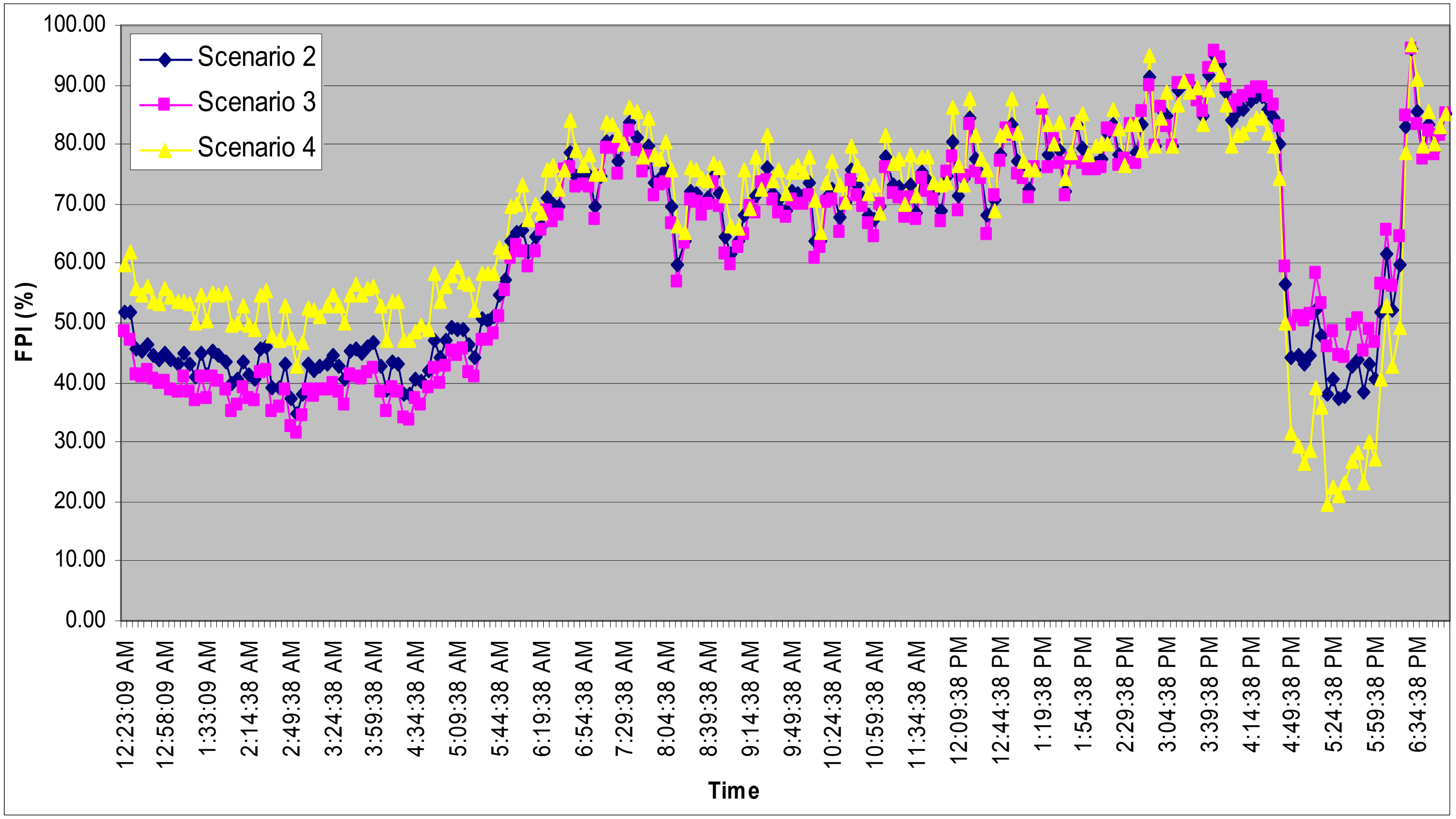


Figure 6.5 Freeways performance index

Table 6.4 Calculated performance measure thresholds

Performance measures	Xmin (minimum)	Xmax (maximum)	Individual Index
Standard deviation of avg. speed	0	6.1	C_s = 0 if std. of avg. speed > 6 mph.; otherwise C_s = 1; Where: C_s is safety index
NOx emissions	0	532.15 g/mile	$C_{ee} = (X_{max}-X_i) / (X_{max})$; where Cee is emission and energy index; X_i = NO_x emissions during five minutes.
Avg. speed	53.4 mph.	65 mph.	$C_v = (X_i-X_{min})/(X_{max}-X_{min})$; where C_v = speed index; X_i = avg. speed during five minutes.
Avg. travel time	4.6 mins	5.6 mins	$C_{tt} = (X_{max}-X_i)/(X_{max}-X_{min})$; where C_{tt} = travel time index; X_i = avg. travel time during five minutes.
Total delay (recurring)	0	163.63 mins-veh.	$C_d = (X_{max}-X_i) / (X_{max})$; where C_d = total delay index; X_i = total delay during five minutes.
Extent of congestion	0	5 miles	$C_{ec} = (X_{max}-X_i) / (X_{max})$; where C_{ec} = extent of congestion index; X_i = extent of congestion during five minutes.
Travel time reliability	0	17.22 mins	$C_{ttr} = (X_{max}-X_i) / (X_{max})$; where C_{ttr} = travel time reliability index; X_i = addition travel time.
EFM	0	32731 veh.-mph in five mins interval	$C_{ef} = (X_i) / (X_{max})$; where C_{ef} = efficiency index; X_i = vehicles-mile during five minutes.

Note: All data is assumed at a freeway segment, approximately five miles for four lanes.

Figure 6.6 illustrates the safety index. The safety index drops almost every hour during the day when the standard deviation of speed is above 6 mph. Figure 6.7 illustrates the emission index, which lies between 0 and 0.96. The minimum emissions occur from midnight to 4:00 A.M. due to low traffic volume. The emission index will dramatically decrease during the morning peak from 6:00 A.M. to 8:30 A.M. before it slightly increases and becomes stable from 9:00 A.M. to 4:00 P.M.; it slightly drops during the evening peak hour and rapidly increases again after evening peak hour to midnight.

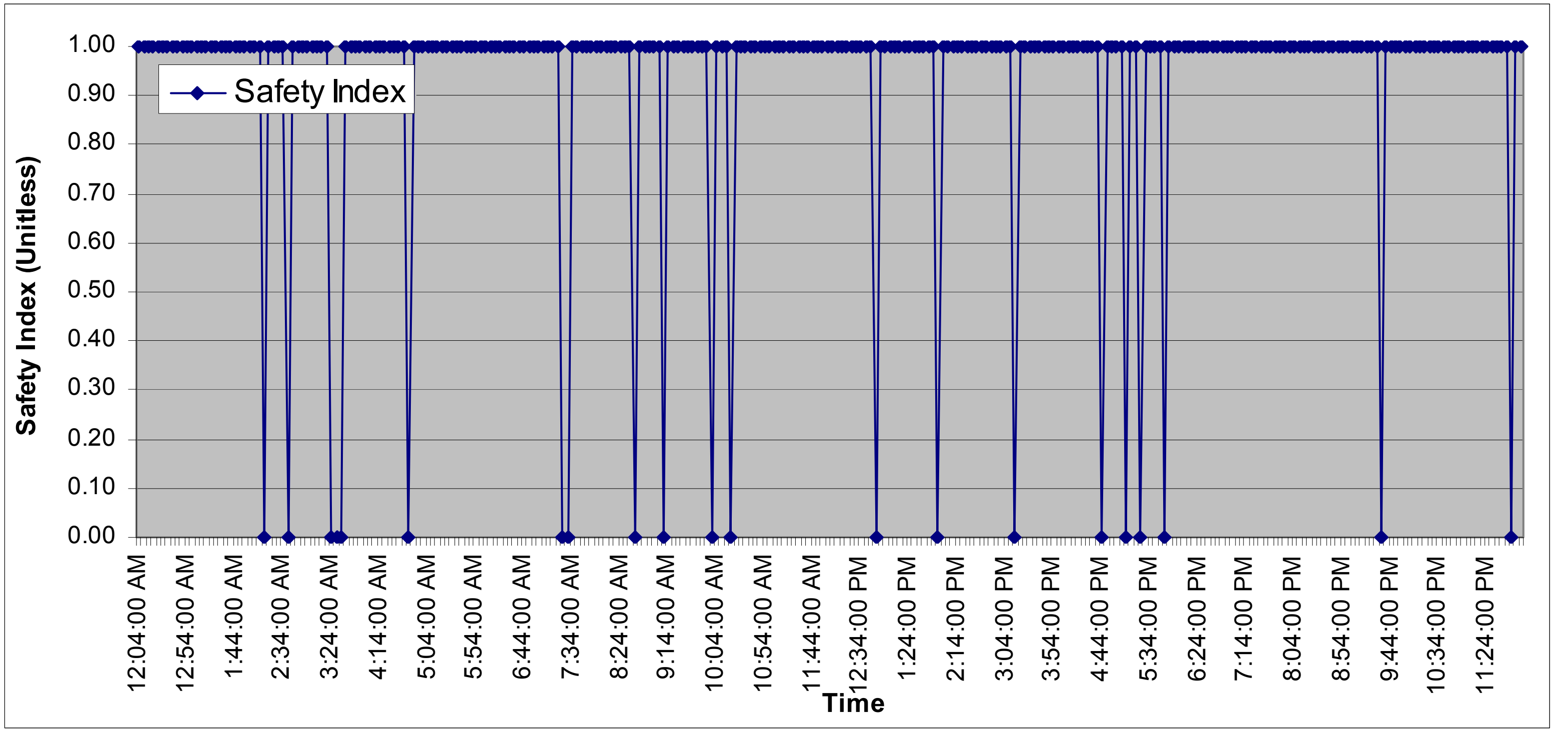


Figure 6.6 Safety index

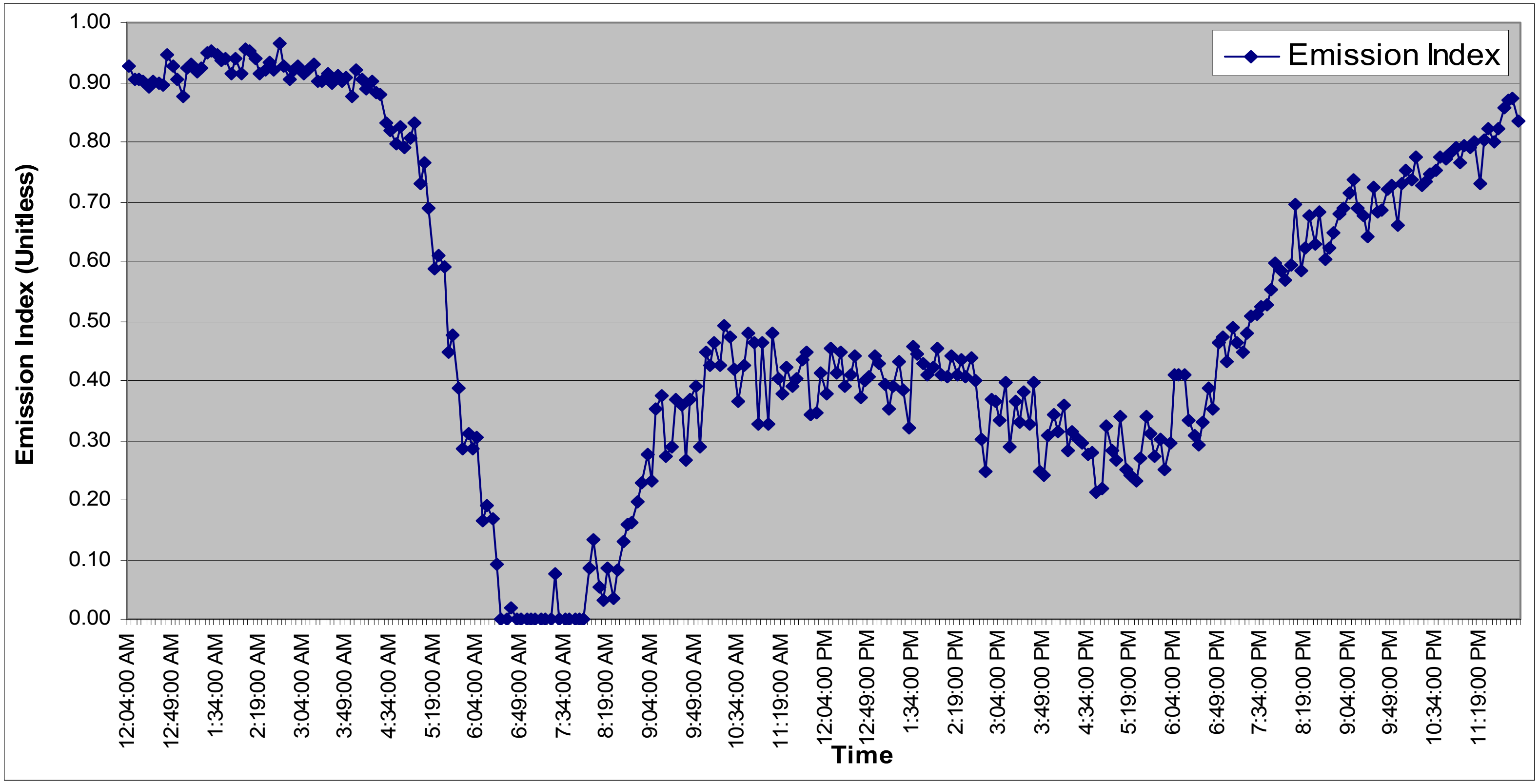


Figure 6.7 Emission index

Figure 6.8 illustrates the mobility index for speed, travel time, recurring delay, and extent of congestion. All mobility indices here show a wide variation which range between 0 and 1.0. The freeway performs worse in terms of speed, travel time, delay, and extent of congestion during morning and evening peak and during midnight to 2:00 A.M.

Figure 6.9 illustrates the efficiency index (EFM), which is low from midnight to 4:30 A.M. before it dramatically increases between 4:30 A.M. and 6:00 A.M. from 0.20 to 1.00. After that the period, EFM slightly decreases and becomes stable between 9:00 P.M. and 3:00 P.M.; the EFM increases again during the evening peak hour between 4:30 P.M. and 6:00 P.M., and then, tends to decrease after evening peak hour to midnight. Comparing the first and second applications, freeway I-35W Alta Mesa at Fort Worth, Texas seems perform better than SB Loop 12 at Irving Boulevard in Irving, Texas during both morning and evening peak hours in terms of the EFM index. The I-35W carries a similar traffic volume as Loop 12 during the peak hour with a higher operating speed.

Figure 6.10 illustrates the FPI (%) using equation (6.9 - 6.13), comparing among scenarios (1, 2, 3, 4, 5, and proposed weights) provide similar trends. The safety index has a significant impact on the change of FPI (%). Whenever the standard deviation of speed is above six mph., the FPI (%) will immediately drop in scenario 1, 2, and 5. This will lead to the future consideration of potential crash on freeways. Either the proposed weight or scenario 4 is suggested for the application. When the safety and emissions are ignored in scenario 4, I-35W Alta Mesa shows a better performance with a higher FPI (%) during the day time. It implies that the emission index is sensitive to the change of FPI (%) approximately 20% compared with the proposed weight scenario.

In summary, the proposed framework in this research can be used to develop the overall performance based on the limitations of the performance measures themselves and data collection strategies as described in Chapter 5. This framework develops both individual performance measures in Chapter 5 and an integration of performance measures (FPI (%)) in

Chapter 6. The real application of models still is based on the data availability for an individual TMC and the decision makers' perspectives where they can set the minimum and maximum threshold differently based on the characteristics of particular freeways or travelers' perceptions of traffic congestion. Instead of using the ideal point concept for developing the safety index, the author considers using only one threshold because impacts of a crash on a freeway are severe. Often, one or more lanes must close and the freeway's performance rapidly drops. Finally, the FPI (%) in this research can be applied by any agencies for evaluating the freeway performance at the planning and operational levels.

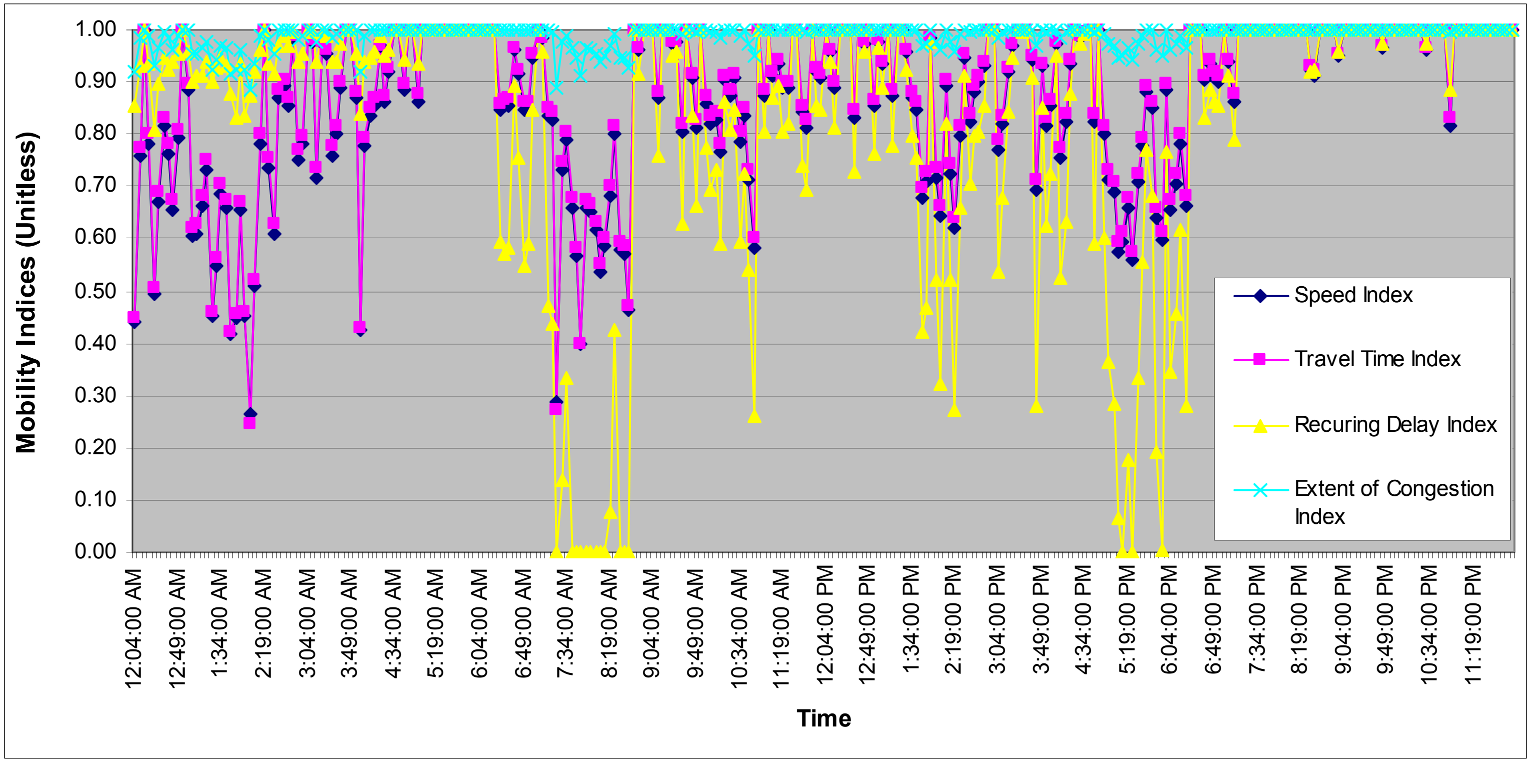


Figure 6.8 Mobility index

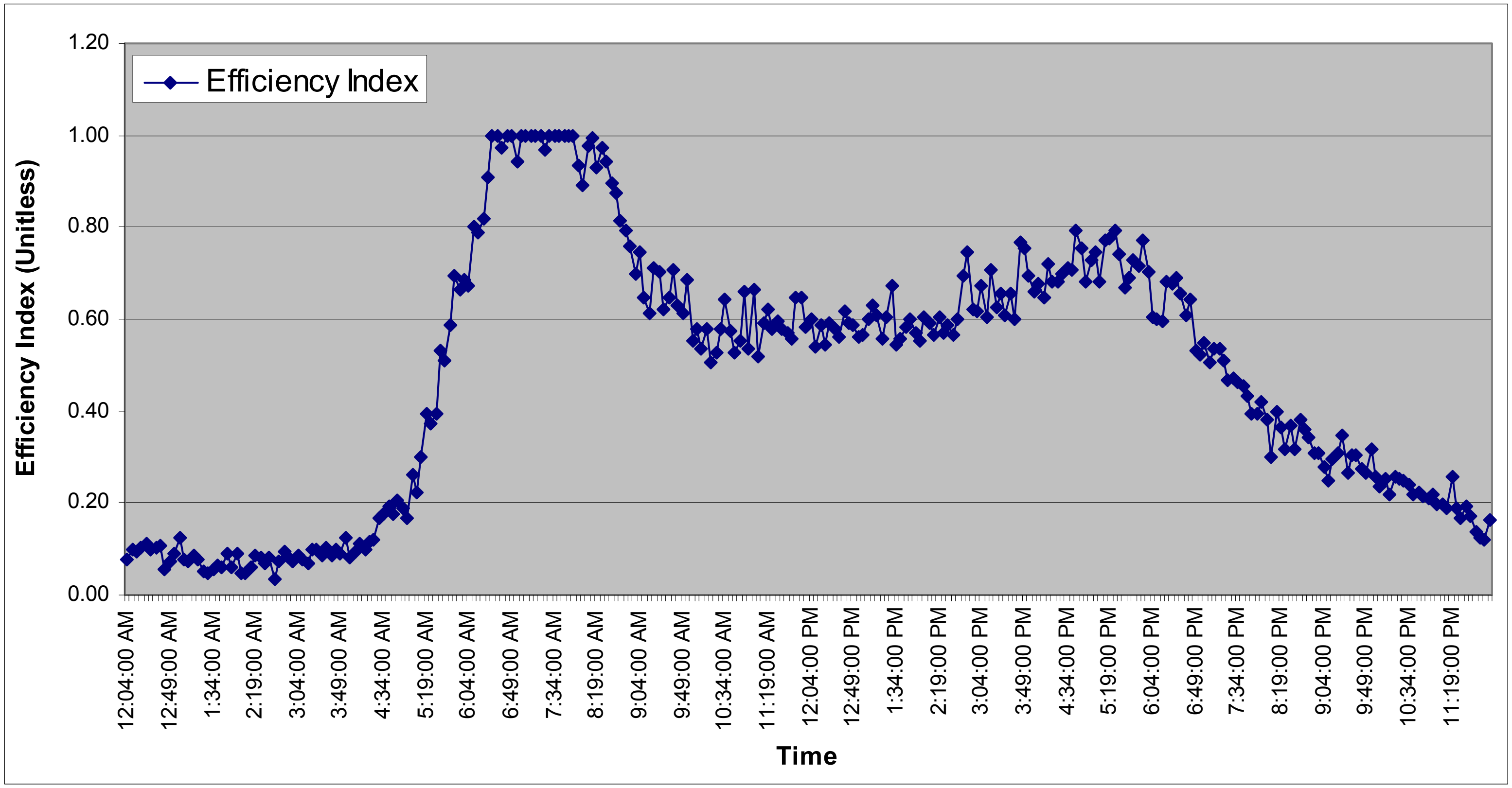


Figure 6.9 Efficiency index

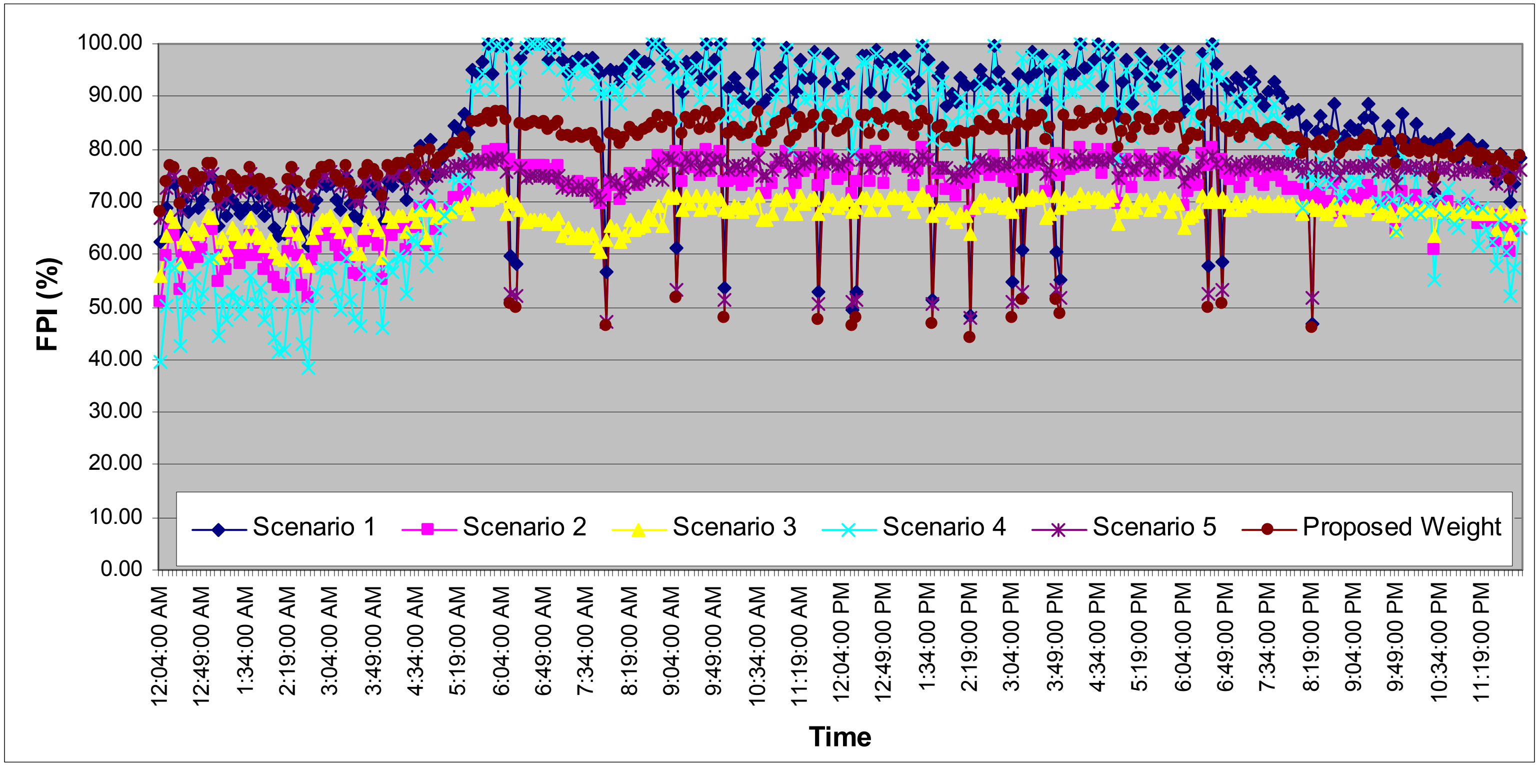


Figure 6.10 Freeways performance index

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 Summary and conclusions

Traffic Management Centers (TMCs) provide many benefits to both traffic operators and on-road travelers. ITS technologies such as closed circuit videos allow traffic operators to monitor and operate freeways; dynamic message signs can provide roadway information so that travelers can properly react to the roadway situation. For long term support of TMCs, this dissertation addressed three separate tasks.

First, this dissertation examines the factors influencing the TMCs' investments, effective methods in persuading the public to support deployment of TMCs, and legal issues involved with making a decision to deploy TMCs. After developing two approaches, which provide the range of criteria weights, this research uses a concordance approach to explain the priority ranking of these criteria. The results indicate that incident management, improved environment and improved safety are the most important factors influencing the TMCs' investment, while newspaper articles and other media are the most effective method in persuading the public to support deployment of TMCs. The rules and regulations are the most important legal issues involved with making a decision to deploy a TMC. These results can guide states when investing or supporting TMCs in long term planning. Furthermore, these criteria weights can be utilized for developing MCDM models such as AHP or PROMETHEE for TMCs' investment.

Second, because the quality of freeways performance assessment is based on the quality of data collection strategies and performance measures, this dissertation develops a framework for selecting the data collection strategies on freeways and performance measures by considering their limitations at the same time. The framework is described step by step in detail. Each step explains the roles of both decision makers and coordinators and the tasks that they should accomplish in order to complete each step. Those steps include establishing "the decision statement", identifying the "set of alternatives or solutions", establishing the "set of criteria" and screening "the set of criteria" using qualitative and quantitative criteria. Results from the surveys can be used to screen the various data collection strategies. The survey's results indicate the requirement that data collection strategies should obtain the performance measures in real time (less five minutes), and their data accuracy and reliability should be above 80%. To make a final decision, the MCDM models such as SAW and ELECTRE III are utilized to find the best data collection strategies. The advantage of using SAW is to provide a complete rank ordering. However, when there is a data uncertainty, the ELECTRE III method can be utilized because it is not as sensitive to data quality. Both methods can be compared to each other and provide a rank order for final decision.

Finally, the issues of daily performance measures are new and require further study. In addition, most TMCs construct their performance measures for analysis at the state level; however, some of these may be applicable in real time. This dissertation proposes a framework for developing a "Freeway Performance Index" (FPI). The FPI will be utilized to evaluate the freeway's performance based on TMC goals. The framework includes indentifying the objective criteria, daily performance measures, the models for integrating the objective criteria, establishing the weights, identifying the methods to calculate and normalize performance measures, and rescale the objective criteria and performance measures into a single comparative scale. The proposed objective criteria from the surveys include safety, environment, mobility, and efficiency. In addition, the respondents do not consider using performance measures for economic criteria based on daily freeway operations. The daily performance measures are proposed and grouped by areas of objective criteria. The proposed daily performance measures includes a crash potential, mass emissions, speed, travel time, recurring delay, extent of congestion, and vehicle-miles of travel during five minute intervals. The weights of the objective criteria are examined and safety is found to be the most important factor for freeway operations with a weight of 35% compared to other factors such as environment, mobility, and efficiency with the weights of 15%, 25%, and 25%, respectively. The reason behind the low weights for emissions may be because air pollutants come from many sources and not from automobiles alone. However, most traffic operators fail to assign the performance measures weights because they currently do not have daily performance measures. As a result, the weights for each daily performance measure are basically given equal importance. Due to the lack of safety and emission data, this dissertation provides an assumption for calculating the index for safety and suggests a surrogate model for NO_x emissions. This research uses the SAW model for developing the FPI index. The SAW model is commonly used for developing indices in many areas such as Transit Serviceability Index provided in Chapter 6. However, the FPI index here requires quantitative data with high accuracy and reliability. For calculating the mobility measures, traffic operators must set the acceptable travel time first based on trip reliability. This value may be set differently based on the travelers' perception, which can be obtained by the surveys. This dissertation provides an innovative efficiency measure, which is slightly different from VMT by multiplying the number of vehicles and their average speed during five-minute intervals. A reason behind developing this measure is because as traffic volume approaches capacity travel speeds decrease. When using vehicles throughput as a performance measure for efficiency where speeds are higher than the acceptable speed, a significant decrease in the efficiency index may occur during a peak period. Thus, using the new efficiency measure (EFM) with "ideal point concept" described in Chapter 5 should minimize this problem. In addition, setting one threshold for safety index seems reasonable due to the fact that when a severe accident occurs on freeways, one or more lanes usually close that lead to immediately decrease of freeway performance.

In summary, this dissertation examines the factors influencing TMCs' investment, effective methods in persuading the public to support deployment of TMCs, and legal issues involved with making a decision to deploy TMCs. In addition, this dissertation proposed a framework to select both data collection strategies and performance measures. This dissertation also provides a framework to develop a Freeway Performance Index. Three types of MCDM models such as PROMETHEE I and II, ELECTRE III, and SAW models can assist with decision making issues in TMCs planning. Two weighting techniques such as ranking and one-hundred point system can be used to establish criteria weights. SAW and ELECTRE III models themselves can be used to validate the results of decision making. In addition, the SAW model can be applied to develop a FPI (%) index for freeway operations. The most important parts in this dissertation are finding the criteria weights, developing a framework for selecting data collection strategies based on performance measures, and a framework for developing the FPI (%) index. The advantage of this framework over conventional methods is it considers the limitations of the data collection strategies and performance measures at the same time. In addition, evaluating freeway operations by considering various operational impacts should lead to better real solution.

7.2 Recommendations for future study

The framework provided in this dissertation for selecting data collection strategies based on performance measures, and developing an FPI index can be applied in other areas (not only freeway operations). A model developed for evaluating good performance measures can also be used in other fields. However, like many research efforts, this study also has limitations and several issues should be addressed in future studies, as follows:

- This research examines the factors influencing TMCs' investment. The significance of those factors can be utilized to develop MCDM models such AHP or PROMETHEE III when the qualitative data are examined for those factors.

- More criteria and their weights as well as the preference and indifference thresholds for selecting the data collection strategies should be examined.
- For developing the FPI (%) index, the maximum and minimum thresholds should be set from the historical traffic data or consultation with traffic operators.
- This research uses proxy measures for safety and emission; however, direct measures should be substituted if real time data becomes available in the future.
- The additional travel time increment should be set based on travelers' experiences. Surveys may be conducted to obtain this data.
- This research does not apply the FPI (%) to investigate the impacts of alternative operational strategies on freeways. However, the FPI (%) can be utilized to evaluate and recommend the alternatives in future studies.

APPENDIX A

ANALYSIS RESULTS OF DECISION MAKING FOR A TMC

Factors involved with TMCs' investment

Texas

Assumption 1

	Reasons	Austin	n-r+1	W	Houston	n-r+1	W	D/FW	n-r+1	W
1	Agency cost saving	2	2	0.333	0	0	0.000	0	0	0.000
2	Incident management	0	0	0.000	1	3	0.500	3	1	0.167
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000	2	2	0.333
5	Improved travel reliability	0	0	0.000	3	1	0.167	0	0	0.000
6	Improved safety	3	1	0.167	2	2	0.333	1	3	0.500
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	Personal face to face interaction	1	3	0.500	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	El Paso	n-r+1	W	San Antonio	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000
2	Incident management	2	2	0.333	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000	3	1	0.167
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	3	1	0.167	0	0	0.000
6	Improved safety	1	3	0.500	2	2	0.333
7	Evacuation management	0	0	0.000	0	0	0.000
8	Personal face to face interaction	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Austin	n-r+1	W	Houston	n-r+1	W	D/FW	n-r+1	W
1	Agency cost saving	2	7	0.194	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	6	3	0.083	1	7	0.250	3	5	0.179
3	Voter or customer satisfaction	6	3	0.083	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	6	3	0.083	5.5	2.5	0.089	2	6	0.214
5	Improved travel reliability	6	3	0.083	3	5	0.179	5.5	2.5	0.089
6	Improved safety	3	6	0.167	2	6	0.214	1	7	0.250
7	Evacuation management	6	3	0.083	5.5	2.5	0.089	5.5	2.5	0.089
8	Personal face to face interaction	1	8	0.222	0	0	0.000	0	0	0.000
			36	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	El Paso	n-r+1	W	San Antonio	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	2	6	0.214	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089	3	5	0.179
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179	5.5	2.5	0.089
6	Improved safety	1	7	0.250	2	6	0.214
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089
8	Personal face to face interaction	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

California

Assumption 1

	Reasons	Dist. 12	n-r+1	W	Dist. 7	n-r+1	W	Dist. 8	n-r+1	W
1	Agency cost saving	0	0	0.000	4.5	3.5	0.125	0	0	0.000
2	Incident management	3	1	0.167	2	6	0.214	2	2	0.333
3	Voter or customer satisfac	0	0	0.000	6.5	1.5	0.054	0	0	0.000
4	Improved environment	0	0	0.000	6.5	1.5	0.054	0	0	0.000
5	Improved travel reliability	2	2	0.333	2	6	0.214	0	0	0.000
6	Improved safety	1	3	0.500	2	6	0.214	1	3	0.500
7	Evacuation management	0	0	0.000	4.5	3.5	0.125	3	1	0.167
8	To maintain an effective transportation system	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**28**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	Bakersfield	n-r+1	W	Fresno	n-r+1	W	Salinas	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000	0	0	0.000
2	Incident management	1	3	0.500	1	3	0.500	1	3	0.500
3	Voter or customer satisfac	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000	0	0	0.000
5	Improved travel reliability	3	1	0.167	3	1	0.167	2	2	0.333
6	Improved safety	2	2	0.333	2	2	0.333	3	1	0.167
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	To maintain an effective transportation system	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	San Diego	n-r+1	W	San Luis Obispo	n-r+1	W	Santa Barbara	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000	0	0	0.000
2	Incident management	3	1	0.167	1	3	0.500	1	3	0.500
3	Voter or customer satisfac	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000	0	0	0.000
5	Improved travel reliability	0	0	0.000	2	2	0.333	2	2	0.333
6	Improved safety	2	2	0.333	3	1	0.167	3	1	0.167
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	To maintain an effective transportation system	1	3	0.500	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Dist. 12	n-r+1	W	Dist. 7	n-r+1	W	Dist. 8	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	4.5	3.5	0.125	5.5	2.5	0.089
2	Incident management	3	5	0.179	2	6	0.214	2	6	0.214
3	Voter or customer satisfac	5.5	2.5	0.089	6.5	1.5	0.054	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	6.5	1.5	0.054	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214	2	6	0.214	5.5	2.5	0.089
6	Improved safety	1	7	0.250	2	6	0.214	1	7	0.250
7	Evacuation management	5.5	2.5	0.089	4.5	3.5	0.125	3	5	0.179
8	To maintain an effective transportation system	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	Bakersfield	n-r+1	W	Fresno	n-r+1	W	Salinas	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	1	7	0.250	1	7	0.250	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179	3	5	0.179	2	6	0.214
6	Improved safety	2	6	0.214	2	6	0.214	3	5	0.179
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	To maintain an effective transportation system	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	San Diego	n-r+1	W	San Luis Obispo	n-r+1	W	Santa Barbara	n-r+1	W
1	Agency cost saving	6	3	0.083	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	3	6	0.167	1	7	0.250	1	7	0.250
3	Voter or customer satisfaction	6	3	0.083	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	6	3	0.083	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	6	3	0.083	2	6	0.214	2	6	0.214
6	Improved safety	2	7	0.194	3	5	0.179	3	5	0.179
7	Evacuation management	6	3	0.083	5.5	2.5	0.089	5.5	2.5	0.089
8	To maintain an effective transportation system	1	8	0.222	0	0	0.000	0	0	0.000
			36	**1.000**		**28**	**1.000**		**28**	**1.000**

Arizona

Assumption 1

	Reasons	Phoenix	n-r+1	W	Tucson	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000
2	Incident management	1	3	0.500	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	2	2	0.333	2	2	0.333
6	Improved safety	3	1	0.167	3	1	0.167
7	Evacuation management	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Phoenix	n-r+1	W	Tucson	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	1	7	0.250	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214	2	6	0.214
6	Improved safety	3	5	0.179	3	5	0.179
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

New Mexico

Assumption 1

	Reasons	Albuquerque	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	3	1	0.167
6	Improved safety	2	2	0.333
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Albuquerque	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179
6	Improved safety	2	6	0.214
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Nevada

Assumption 1

	Reasons	Las Vegas	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	1	3	0.500
6	Improved safety	3	1	0.167
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Las Vegas	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	1	7	0.250
6	Improved safety	3	5	0.179
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Utah

Assumption 1&2

	Reasons	Provo-Orem	n-r+1	W	S.L. City-Reg 1	n-r+1	W	S.L. City-Reg 2	n-r+1	W
1	Agency cost saving	5	3	0.107	5	3	0.107	5	3	0.107
2	Incident management	2	6	0.214	2	6	0.214	2	6	0.214
3	Voter or customer satisfaction	5	3	0.107	5	3	0.107	5	3	0.107
4	Improved environment	5	3	0.107	5	3	0.107	5	3	0.107
5	Improved travel reliability	2	6	0.214	2	6	0.214	2	6	0.214
6	Improved safety	2	6	0.214	2	6	0.214	2	6	0.214
7	Evacuation management	7	1	0.036	7	1	0.036	7	1	0.036
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Colorado

Assumption 1

	Reasons	Denver, Boulder	n-r+1	W
1	Agency cost saving	3	1	0.167
2	Incident management	0	0	0.000
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	2	2	0.333
6	Improved safety	1	3	0.500
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Denver, Boulder	n-r+1	W
1	Agency cost saving	3	5	0.179
2	Incident management	5.5	2.5	0.089
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214
6	Improved safety	1	7	0.250
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Oregon

Assumption 1

	Reasons	Eugene	n-r+1	W	Portland, Vancouver, WA	n-r+1	W
1	Agency cost saving	3	1	0.167	0	0	0.000
2	Incident management	1	3	0.500	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	0	0	0.000	3	1	0.167
6	Improved safety	2	2	0.333	1	3	0.500
7	Evacuation management	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Eugene	n-r+1	W	Portland, Vancouver, WA	n-r+1	W
1	Agency cost saving	3	5	0.179	5.5	2.5	0.089
2	Incident management	1	7	0.250	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	5.5	2.5	0.089	3	5	0.179
6	Improved safety	2	6	0.214	1	7	0.250
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Washington

Assumption 1

	Reasons	Bellingham	n-r+1	W	Seattle NW region	n-r+1	W	Seattle, Olympia region	n-r+1	W
1	Agency cost saving	2	2	0.333	0	0	0.000	0	0	0.000
2	Incident management	3	1	0.167	3	1	0.167	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000	0	0	0.000
5	Improved travel reliability	1	3	0.500	2	2	0.333	1	3	0.500
6	Improved safety	0	0	0.000	1	3	0.500	3	1	0.167
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	Spokane	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	1	3	0.500
6	Improved safety	3	1	0.167
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Bellingham	n-r+1	W	Seattle NW region	n-r+1	W	Seattle, Olympia region	n-r+1	W
1	Agency cost saving	2	6	0.214	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	3	5	0.179	3	5	0.179	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	1	7	0.250	2	6	0.214	1	7	0.250
6	Improved safety	5.5	2.5	0.089	1	7	0.250	3	5	0.179
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	Spokane	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	1	7	0.250
6	Improved safety	3	5	0.179
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Nebraska

Assumption 1

	Reasons	Omaha	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	0	0	0.000
3	Voter or customer satisfaction	1	1	1.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	0	0	0.000
6	Improved safety	0	0	0.000
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			1	**1.000**

Assumption 2

	Reasons	Omaha	n-r+1	W
1	Agency cost saving	4	4	0.129
2	Incident management	4	4	0.129
3	Voter or customer satisfaction	1	7	0.226
4	Improved environment	4	4	0.129
5	Improved travel reliability	4	4	0.129
6	Improved safety	4	4	0.129
7	Evacuation management	4	4	0.129
8	Others	0	0	0.000
			31	**1.000**

Minnesota

Assumption 1

	Reasons	St. Paul	n-r+1	W
1	Agency cost saving	3	1	0.167
2	Incident management	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	2	2	0.333
6	Improved safety	0	0	0.000
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	St. Paul	n-r+1	W
1	Agency cost saving	3	5	0.179
2	Incident management	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214
6	Improved safety	5.5	2.5	0.089
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Iowa

Assumption 1

	Reasons	Des Moines	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	2	2	0.333
6	Improved safety	3	1	0.167
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Des Moines	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214
6	Improved safety	3	5	0.179
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Missouri

Assumption 1

	Reasons	Kansas City, Kansas DOT	n-r+1	W	Kansas City, Missouri DOT	n-r+1	W	Springfield	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000	0	0	0.000
2	Incident management	1	3	0.500	1	3	0.500	3	1	0.167
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000	0	0	0.000
5	Improved travel reliability	3	1	0.167	2	2	0.333	1	3	0.500
6	Improved safety	2	2	0.333	3	1	0.167	2	2	0.333
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	St. Louis, Illinois DOT	n-r+1	W	St. Louis, Missouri DOT	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000
2	Incident management	2	2	0.333	1	3	0.500
3	Voter or customer satisfaction	3	1	0.167	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	0	0	0.000	3	1	0.167
6	Improved safety	1	3	0.500	2	2	0.333
7	Evacuation management	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Kansas City, Kansas DOT	n-r+1	W	Kansas City, Missouri DOT	n-r+1	W	Springfield	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	1	7	0.250	1	7	0.250	3	5	0.179
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179	2	6	0.214	1	7	0.250
6	Improved safety	2	6	0.214	3	5	0.179	2	6	0.214
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	St. Louis, Illinois DOT	n-r+1	W	St. Louis, Missouri DOT	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	2	6	0.214	1	7	0.250
3	Voter or customer satisfaction	3	5	0.179	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	5.5	2.5	0.089	3	5	0.179
6	Improved safety	1	7	0.250	2	6	0.214
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Louisiana

Assumption 1

	Reasons	Baton Rouge	n-r+1	W	New Orleans	n-r+1	W
1	Agency cost saving	1	3	0.500	0	0	0.000
2	Incident management	2	2	0.333	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000	3	1	0.167
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	3	1	0.167	0	0	0.000
6	Improved safety	0	0	0.000	1	3	0.500
7	Evacuation management	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Baton Rouge	n-r+1	W	New Orleans	n-r+1	W
1	Agency cost saving	1	7	0.250	5.5	2.5	0.089
2	Incident management	2	6	0.214	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089	3	5	0.179
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179	5.5	2.5	0.089
6	Improved safety	5.5	2.5	0.089	1	7	0.250
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Michigan

Assumption 1

	Reasons	Detroit, Ann Arbor	n-r+1	W	Grand Rapids	n-r+1	W
1	Agency cost saving	2	2	0.333	0	0	0.000
2	Incident management	3	1	0.167	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	0	0	0.000	3	1	0.167
6	Improved safety	1	3	0.500	1	3	0.500
7	Evacuation management	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Detroit, Ann Arbor	n-r+1	W	Grand Rapids	n-r+1	W
1	Agency cost saving	2	6	0.214	5.5	2.5	0.089
2	Incident management	3	5	0.179	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	5.5	2.5	0.089	3	5	0.179
6	Improved safety	1	7	0.250	1	7	0.250
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Wisconsin

Assumption 1

	Reasons	Janesville-Beloit	n-r+1	W	Milwaukee, Racine	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000
2	Incident management	2	2	0.333	2	2	0.333
3	Voter or customer satisfaction	3	1	0.167	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	0	0	0.000	1	3	0.500
6	Improved safety	1	3	0.500	3	1	0.167
7	Evacuation management	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Janesville-Beloit	n-r+1	W	Milwaukee, Racine	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	2	6	0.214	2	6	0.214
3	Voter or customer satisfaction	3	5	0.179	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	5.5	2.5	0.089	1	7	0.250
6	Improved safety	1	7	0.250	3	5	0.179
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Ilinois

Assumption 1

	Reasons	Gary, Lake County	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	1	3	0.500
6	Improved safety	3	1	0.167
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Gary, Lake County	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	1	7	0.250
6	Improved safety	3	5	0.179
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Indiana

Assumption 1

	Reasons	Indianapolis	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	2	2	0.333
6	Improved safety	3	1	0.167
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Indianapolis	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214
6	Improved safety	3	5	0.179
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Kentucky

Assumption 1

	Reasons	Louisville	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	3	1	0.167
6	Improved safety	1	3	0.500
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Louisville	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179
6	Improved safety	1	7	0.250
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Tennessee

Assumption 1

	Reasons	Chattanooga	n-r+1	W	Knoxville	n-r+1	W	Memphis	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000	0	0	0.000
2	Incident management	1	3	0.500	1	3	0.500	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	3	1	0.167	3	1	0.167	3	1	0.167
5	Improved travel reliability	0	0	0.000	0	0	0.000	0	0	0.000
6	Improved safety	2	2	0.333	2	2	0.333	2	2	0.333
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	Nashville	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	3	1	0.167
5	Improved travel reliability	0	0	0.000
6	Improved safety	2	2	0.333
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Chattanooga	n-r+1	W	Knoxville	n-r+1	W	Memphis	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	1	7	0.250	1	7	0.250	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	3	5	0.179	3	5	0.179	3	5	0.179
5	Improved travel reliability	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
6	Improved safety	2	6	0.214	2	6	0.214	2	6	0.214
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	Nashville	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	3	5	0.179
5	Improved travel reliability	5.5	2.5	0.089
6	Improved safety	2	6	0.214
7	Evacuation management	5.5	2.5	0.089
8	Others	5.5	0	0.000
			28	**1.000**

Alabama

Assumption 1

	Reasons	Louisville	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	3	1	0.167
6	Improved safety	1	3	0.500
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Louisville	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179
6	Improved safety	1	7	0.250
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Ohio

Assumption 1

	Reasons	Cincinnati, Hamilton	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	3	1	0.167
5	Improved travel reliability	0	0	0.000
6	Improved safety	1	3	0.500
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Cincinnati, Hamilton	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	3	5	0.179
5	Improved travel reliability	5.5	2.5	0.089
6	Improved safety	1	7	0.250
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Pennsylvania

Assumption 1

	Reasons	Allentown, Bethlehem, Easton	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	1	2	0.667
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	0	0	0.000
6	Improved safety	2	1	0.333
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			3	**1.000**

Assumption 2

	Reasons	Allentown, Bethlehem, Easton	n-r+1	W
1	Agency cost saving	5	3	0.107
2	Incident management	1	7	0.250
3	Voter or customer satisfaction	5	3	0.107
4	Improved environment	5	3	0.107
5	Improved travel reliability	5	3	0.107
6	Improved safety	2	6	0.214
7	Evacuation management	5	3	0.107
8	Others	0	0	0.000
			28	**1.000**

Georgia

Assumption 1

	Reasons	Atlanta	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	1	3	0.500
6	Improved safety	3	1	0.167
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Atlanta	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	1	7	0.250
6	Improved safety	3	5	0.179
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Florida

Assumption 1

	Reasons	Daytona Beach	n-r+1	W	Jacksonville	n-r+1	W	Miami, Fort Lauderdale, Florida DOT, Turnpike District	n-r+1	W
1	Agency cost saving	0	0	0	0	0	0.000	6.5	1.5	0.054
2	Incident management	1	2	0.333	2	2	0.333	3	5	0.179
3	Voter or customer satisfaction	0	0	0	3	1	0.167	3	5	0.179
4	Improved environment	0	0	0	0	0	0.000	6.5	1.5	0.054
5	Improved travel reliability	0	0	0	1	3	0.500	3	5	0.179
6	Improved safety	1	2	0.333	0	0	0.000	3	5	0.179
7	Evacuation management	1	2	0.333	0	0	0.000	3	5	0.179
8	Others	0	0	0	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**28**	**1.000**

Assumption 1

	Reasons	Miami, Fort Lauderdale, Florida DOT District-6, Sunguide TMC	n-r+1	W	Orlando	n-r+1	W	West Palm Beach, Boca Raton, Delray	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0	0	0	0.000
2	Incident management	1	3	0.500	1	2	0.333	1	2	0.333
3	Voter or customer satisfaction	0	0	0.000	0	0	0	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0	0	0	0.000
5	Improved travel reliability	2	2	0.333	1	0	0	2	0	0.000
6	Improved safety	3	1	0.167	1	2	0.333	3	2	0.333
7	Evacuation management	0	0	0.000	0	2	0.333	0	2	0.333
8	Others	0	0	0.000	0	0	0	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Daytona Beach	n-r+1	W	Jacksonville	n-r+1	W	Miami, Fort Lauderdale, Florida DOT, Turnpike District	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	6.5	1.5	0.054
2	Incident management	1	7	0.250	2	6	0.214	3	5	0.179
3	Voter or customer satisfaction	5.5	2.5	0.089	3	5	0.179	3	5	0.179
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	6.5	1.5	0.054
5	Improved travel reliability	5.5	2.5	0.089	1	7	0.250	3	5	0.179
6	Improved safety	1	7	0.250	5.5	2.5	0.089	3	5	0.179
7	Evacuation management	1	7	0.250	5.5	2.5	0.089	3	5	0.179
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			31	**1.107**		**28**	**1.000**		**28**	**1.000**

	Reasons	Miami, Fort Lauderdale, Florida DOT District-6, Sunguide Transporttaion Mgt. Center	n-r+1	W	Orlando	n-r+1	W	West Palm Beach, Boca Raton, Delray	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	1	7	0.250	1	7	0.250	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214	1	7	0.250	2	6	0.214
6	Improved safety	3	5	0.179	1	7	0.250	3	5	0.179
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**31**	**1.107**		**28**	**1.000**

Massachusetts

Assumption 1

	Reasons	Boston, Lawrence, Salem	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	1	2	0.667
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	0	0	0.000
6	Improved safety	2	1	0.333
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			3	**1.000**

Assumption 2

	Reasons	Boston, Lawrence, Salem	n-r+1	W
1	Agency cost saving	5	3	0.107
2	Incident management	1	7	0.250
3	Voter or customer satisfaction	5	3	0.107
4	Improved environment	5	3	0.107
5	Improved travel reliability	5	3	0.107
6	Improved safety	2	6	0.214
7	Evacuation management	5	3	0.107
8	Others	0	0	0.000
			28	**1.000**

Connecticut

Assumption 1

	Reasons	Hartford, New Britain, Middletown	n-r+1	W	New Haven, Meriden	n-r+1	W	New London	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000	0	0	0.000
2	Incident management	1	3	0.500	1	3	0.500	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000	0	0	0.000
5	Improved travel reliability	2	2	0.333	2	2	0.333	1	3	0.500
6	Improved safety	3	1	0.167	3	1	0.167	3	1	0.167
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Hartford, New Britain, Middletown	n-r+1	W	New Haven, Meriden	n-r+1	W	New London	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	1	7	0.250	1	7	0.250	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214	2	6	0.214	1	7	0.250
6	Improved safety	3	5	0.179	3	5	0.179	3	5	0.179
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

New York

Assumption 1

	Reasons	Albany, Schenectady, Troy, NY Thrust Authority	n-r+1	W	Buffalo, Niagara Falls	n-r+1	W	New York, Northern New Jersey, Southwestern Connecticut, Connecticut DOT	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000	0	0	0.000
2	Incident management	2	2	0.333	2	2	0.333	3	1	0.167
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000	0	0	0.000
5	Improved travel reliability	2	2	0.333	2	2	0.333	1	3	0.500
6	Improved safety	2	2	0.333	2	2	0.333	2	2	0.333
7	Evacuation management	0	0	0.000	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	New York, Northern New Jersey, Southwestern Connecticut, New Jersey DOT	n-r+1	W	New York, Northern New Jersey, Southwestern Connecticut, New York State Thruway Authority	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000
2	Incident management	2.5	2.5	0.250	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	2.5	2.5	0.250	2	2	0.333
6	Improved safety	2.5	2.5	0.250	2	2	0.333
7	Evacuation management	2.5	2.5	0.250	0	0	0.000
8	Others	0	0	0.000	0	0	0.000
			10	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Albany, Schenectady, Troy, NY Thrust Authority	n-r+1	W	Buffalo, Niagara Falls	n-r+1	W	New York, Northern New Jersey, Southwestern Connecticut, Connecticut DOT	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	2	6	0.214	2	6	0.214	3	5	0.179
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214	2	6	0.214	1	7	0.250
6	Improved safety	2	6	0.214	2	6	0.214	2	6	0.214
7	Evacuation management	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	New York, Northern New Jersey, Southwestern Connecticut, New Jersey DOT	n-r+1	W	New York, Northern New Jersey, Southwestern Connecticut, New York State Thruway Authority	n-r+1	W
1	Agency cost saving	6	2	0.071	5.5	2.5	0.089
2	Incident management	2.5	5.5	0.196	2	6	0.214
3	Voter or customer satisfaction	6	2	0.071	5.5	2.5	0.089
4	Improved environment	6	2	0.071	5.5	2.5	0.089
5	Improved travel reliability	2.5	5.5	0.196	2	6	0.214
6	Improved safety	2.5	5.5	0.196	2	6	0.214
7	Evacuation management	2.5	5.5	0.196	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Maryland

Assumption 1

	Reasons	Baltimore	n-r+1	W
1	Agency cost saving	0	0	0.000
2	Incident management	2	2	0.333
3	Voter or customer satisfaction	0	0	0.000
4	Improved environment	0	0	0.000
5	Improved travel reliability	3	1	0.167
6	Improved safety	1	3	0.500
7	Evacuation management	0	0	0.000
8	Others	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Baltimore	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089
2	Incident management	2	6	0.214
3	Voter or customer satisfaction	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179
6	Improved safety	1	7	0.250
7	Evacuation management	5.5	2.5	0.089
8	Others	0	0	0.000
			28	**1.000**

Washington DC

Assumption 1

	Reasons	Washington DC, District of Columbia TMC	n-r+1	W	Washington DC, Maryland Highway Administration	n-r+1	W	Washington DC, Virginia DOT	n-r+1	W
1	Agency cost saving	6.5	1.5	0.054	0	0	0.000	0	0	0.000
2	Incident management	3	5	0.179	2	2	0.333	1	3	0.500
3	Voter or customer satisfaction	3	5	0.179	0	0	0.000	0	0	0.000
4	Improved environment	6.5	1.5	0.054	0	0	0.000	0	0	0.000
5	Improved travel reliability	3	5	0.179	3	1	0.167	3	1	0.167
6	Improved safety	3	5	0.179	1	3	0.500	2	2	0.333
7	Evacuation management	3	5	0.179	0	0	0.000	0	0	0.000
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Washington DC, District of Columbia TMC	n-r+1	W	Washington DC, Maryland Highway Administration	n-r+1	W	Washington DC, Virginia DOT	n-r+1	W
1	Agency cost saving	6.5	1.5	0.054	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	3	5	0.179	2	6	0.214	1	7	0.250
3	Voter or customer satisfaction	3	5	0.179	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	6.5	1.5	0.054	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	3	5	0.179	3	5	0.179	3	5	0.179
6	Improved safety	3	5	0.179	1	7	0.250	2	6	0.214
7	Evacuation management	3	5	0.179	5.5	2.5	0.089	5.5	2.5	0.089
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Virginia

Assumption 1

	Reasons	Hampton Roads	n-r+1	W	Richmond, Petersburg	n-r+1	W
1	Agency cost saving	0	0	0.000	0	0	0.000
2	Incident management	2	2	0.333	1	3	0.500
3	Voter or customer satisfaction	0	0	0.000	0	0	0.000
4	Improved environment	0	0	0.000	0	0	0.000
5	Improved travel reliability	1	3	0.500	0	0	0.000
6	Improved safety	3	1	0.167	2	2	0.333
7	Evacuation management	0	0	0.000	3	1	0.167
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Hampton Roads	n-r+1	W	Richmond, Petersburg	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	5.5	2.5	0.089
2	Incident management	2	6	0.214	1	7	0.250
3	Voter or customer satisfaction	5.5	2.5	0.089	5.5	2.5	0.089
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	1	7	0.250	5.5	2.5	0.089
6	Improved safety	3	5	0.179	2	6	0.214
7	Evacuation management	5.5	2.5	0.089	3	5	0.179
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

North Calorina

Assumption 1

	Reasons	Charlotte, Gastonia, Rock Hill, Metrolina Reginal TMC	n-r+1	W	Charlotte, Gastonia, Rock Hill	n-r+1	W
1	Agency cost saving	0	0	0.000	7	1	0.036
2	Incident management	1	3	0.500	2.5	5.5	0.196
3	Voter or customer satisfaction	0	0	0.000	2.5	5.5	0.196
4	Improved environment	0	0	0.000	5.5	2.5	0.089
5	Improved travel reliability	2	2	0.333	5.5	2.5	0.089
6	Improved safety	3	1	0.167	2.5	5.5	0.196
7	Evacuation management	0	0	0.000	2.5	5.5	0.196
8	Others	0	0	0.000	0	0	0.000
			6	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	Charlotte, Gastonia, Rock Hill, Metrolina Reginal TMC	n-r+1	W	Charlotte, Gastonia, Rock Hill	n-r+1	W
1	Agency cost saving	5.5	2.5	0.089	7	1	0.036
2	Incident management	1	7	0.250	2.5	5.5	0.196
3	Voter or customer satisfaction	5.5	2.5	0.089	2.5	5.5	0.196
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	2	6	0.214	5.5	2.5	0.089
6	Improved safety	3	5	0.179	2.5	5.5	0.196
7	Evacuation management	5.5	2.5	0.089	2.5	5.5	0.196
8	Others	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

South Carolina

Assumption 1

	Reasons	Charleston	n-r+1	W	Columbia	n-r+1	W	Greenville, Spartanburg	n-r+1	W
1	Agency cost saving	7	1	0.036	0	0	0.000	7	1	0.036
2	Incident management	2.5	5.5	0.196	1	3	0.500	2.5	5.5	0.196
3	Voter or customer satisfaction	2.5	5.5	0.196	0	0	0.000	2.5	5.5	0.196
4	Improved environment	5.5	2.5	0.089	0	0	0.000	5.5	2.5	0.089
5	Improved travel reliability	5.5	2.5	0.089	3	1	0.167	5.5	2.5	0.089
6	Improved safety	2.5	5.5	0.196	2	2	0.333	2.5	5.5	0.196
7	Evacuation management	2.5	5.5	0.196	0	0	0.000	2.5	5.5	0.196
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**6**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	Charleston	n-r+1	W	Columbia	n-r+1	W	Greenville, Spartanburg	n-r+1	W
1	Agency cost saving	7	1	0.036	5.5	2.5	0.089	7	1	0.036
2	Incident management	2.5	5.5	0.196	1	7	0.250	2.5	5.5	0.196
3	Voter or customer satisfaction	2.5	5.5	0.196	5.5	2.5	0.089	2.5	5.5	0.196
4	Improved environment	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Improved travel reliability	5.5	2.5	0.089	3	5	0.179	5.5	2.5	0.089
6	Improved safety	2.5	5.5	0.196	2	6	0.214	2.5	5.5	0.196
7	Evacuation management	2.5	5.5	0.196	5.5	2.5	0.089	2.5	5.5	0.196
8	Others	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Effective methods in persuading public to deploy a TMC

Texas

Assumption 1

	Reasons	Austin	n-r+1	W	Houston	n-r+1	W	D/FW	n-r+1	W
1	Open meetings with the public	0	0	0.000	2	2	0.333	2	2	0.333
2	Contractor provided briefings	0	0	0.000	0	0	0.000	0	0	0.000
3	Emergency situation	1	3	0.500	1	3	0.500	0	0	0.000
4	Public involvement	2	2	0.333	0	0	0.000	1	3	0.500
5	Newspaper articles and other local media	0	0	0.000	3	1	0.167	3	1	0.167
6	Scanning tours for elected officials	3	1	0.167	0	0	0.000	0	0	0.000
7	On-line message boards	0	0	0.000	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	El Paso	n-r+1	W	San Antonio	n-r+1	W
1	Open meetings with the public	0	0	0.000	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000
3	Emergency situation	1	3	0.500	1	3	0.500
4	Public involvement	0	0	0.000	0	0	0.000
5	Newspaper articles and other local media	3	1	0.167	2	2	0.333
6	Scanning tours for elected officials	2	2	0.333	3	1	0.167
7	On-line message boards	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Austin	n-r+1	W	Houston	n-r+1	W	D/FW	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	2	6	0.214	2	6	0.214
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	1	7	0.250	1	7	0.250	5.5	2.5	0.089
4	Public involvement	2	6	0.214	5.5	2.5	0.089	1	7	0.250
5	Newspaper articles and other local media	5.5	2.5	0.089	3	5	0.179	3	5	0.179
6	Scanning tours for elected officials	3	5	0.179	5.5	2.5	0.089	5.5	2.5	0.089
7	On-line message boards	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	El Paso	n-r+1	W	San Antonio	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	1	7	0.250	1	7	0.250
4	Public involvement	5.5	2.5	0.089	5.5	2.5	0.089
5	Newspaper articles and other local media	3	5	0.179	2	6	0.214
6	Scanning tours for elected officials	2	6	0.214	3	5	0.179
7	On-line message boards	5.5	2.5	0.089	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

California

Assumption 1

	Reasons	Dist. 12	n-r+1	W	Dist. 7	n-r+1	W	Dist. 8	n-r+1	W
1	Open meetings with the public	2	2	0.333	4	4	0.143	2	2	0.333
2	Contractor provided briefings	0	0	0.000	4	4	0.143	0	0	0.000
3	Emergency situation	0	0	0.000	4	4	0.143	1	3	0.500
4	Public involvement	0	0	0.000	4	4	0.143	0	0	0.000
5	Newspaper articles and other local media	1	3	0.500	4	4	0.143	0	0	0.000
6	Scanning tours for elected officials	0	0	0.000	4	4	0.143	3	1	0.167
7	On-line message boards	3	1	0.167	4	4	0.143	0	0	0.000
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**28**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	Salinas	n-r+1	W	San Diego	n-r+1	W	San Luis Obispo	n-r+1	W
1	Open meetings with the public	0	0	0.000	1	3	0.500	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000	0	0	0.000
3	Emergency situation	0	0	0.000	2	2	0.333	1	3	0.500
4	Public involvement	1	3	0.500	3	1	0.167	2	2	0.333
5	Newspaper articles and other local media	2	2	0.333	0	0	0.000	3	1	0.167
6	Scanning tours for elected officials	3	1	0.167	0	0	0.000	0	0	0.000
7	On-line message boards	0	0	0.000	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	Santa Barbara	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	1	3	0.500
4	Public involvement	2	2	0.333
5	Newspaper articles and other local media	3	1	0.167
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Dist. 12	n-r+1	W	Dist. 7	n-r+1	W	Dist. 8	n-r+1	W
1	Open meetings with the public	2	6	0.214	4	4	0.143	2	6	0.214
2	Contractor provided briefings	5.5	2.5	0.089	4	4	0.143	5.5	2.5	0.089
3	Emergency situation	5.5	2.5	0.089	4	4	0.143	1	7	0.250
4	Public involvement	5.5	2.5	0.089	4	4	0.143	5.5	2.5	0.089
5	Newspaper articles and other local media	1	7	0.250	4	4	0.143	5.5	2.5	0.089
6	Scanning tours for elected officials	5.5	2.5	0.089	4	4	0.143	3	5	0.179
7	On-line message boards	3	5	0.179	4	4	0.143	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	Salinas	n-r+1	W	San Diego	n-r+1	W	San Luis Obispo	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	1	7	0.250	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	5.5	2.5	0.089	2	6	0.214	1	7	0.250
4	Public involvement	1	7	0.250	3	5	0.179	2	6	0.214
5	Newspaper articles and other local media	2	6	0.214	5.5	2.5	0.089	3	5	0.179
6	Scanning tours for elected officials	3	5	0.179	5.5	2.5	0.089	5.5	2.5	0.089
7	On-line message boards	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	Santa Barbara	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	1	7	0.250
4	Public involvement	2	6	0.214
5	Newspaper articles and other local media	3	5	0.179
6	Scanning tours for elected officials	5.5	2.5	0.089
7	On-line message boards	5.5	2.5	0.089
8	Other	0	0	0.000
			28	**1.000**

Arizona

Assumption 1

	Reasons	Phoenix	n-r+1	W	Tucson	n-r+1	W
1	Open meetings with the public	0	0	0.000	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000
3	Emergency situation	1	2	0.667	1	2	0.667
4	Public involvement	0	0	0.000	0	0	0.000
5	Newspaper articles and other local media	2	1	0.333	2	1	0.333
6	Scanning tours for elected officials	0	0	0.000	0	0	0.000
7	On-line message boards	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000
			3	**1.000**		**3**	**1.000**

Assumption 2

	Reasons	Phoenix	n-r+1	W	Tucson	n-r+1	W
1	Open meetings with the public	5	3	0.107	5	3	0.107
2	Contractor provided briefings	5	3	0.107	5	3	0.107
3	Emergency situation	1	7	0.250	1	7	0.250
4	Public involvement	5	3	0.107	5	3	0.107
5	Newspaper articles and other local media	2	6	0.214	2	6	0.214
6	Scanning tours for elected officials	5	3	0.107	5	3	0.107
7	On-line message boards	5	3	0.107	5	3	0.107
8	Other	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

New Mexico

Assumption 1

	Reasons	Albuquerque	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	2	2	0.333
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	1	3	0.500
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Help trucks	3	1	0.167
			6	**1.000**

Assumption 2

	Reasons	Albuquerque	n-r+1	W
1	Open meetings with the public	6	3	0.083
2	Contractor provided briefings	6	3	0.083
3	Emergency situation	2	7	0.194
4	Public involvement	6	3	0.083
5	Newspaper articles and other local media	1	8	0.222
6	Scanning tours for elected officials	6	3	0.083
7	On-line message boards	6	3	0.083
8	Help trucks	3	6	0.167
			36	**1.000**

Nevada

Assumption 1

	Reasons	Las Vegas	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	0	0	0.000
6	Scanning tours for elected officials	1	2	0.667
7	On-line message boards	2	1	0.333
8	Other	0	0	0.000
			3	**1.000**

Assumption 2

	Reasons	Las Vegas	n-r+1	W
1	Open meetings with the public	5	3	0.107
2	Contractor provided briefings	5	3	0.107
3	Emergency situation	5	3	0.107
4	Public involvement	5	3	0.107
5	Newspaper articles and other local media	5	3	0.107
6	Scanning tours for elected officials	1	7	0.250
7	On-line message boards	2	6	0.214
8	Other	0	0	0.000
			28	**1.000**

Utah

Assumption 1

	Reasons	Provo-Orem	n-r+1	W	SL City-Reg 1	n-r+1	W	SL City-Reg 2	n-r+1	W
1	Open meetings with the public	0	0	0.000	0	0	0.000	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000	0	0	0.000
3	Emergency situation	2	2	0.333	2	2	0.333	2	2	0.333
4	Public involvement	0	0	0.000	0	0	0.000	0	0	0.000
5	Newspaper articles and other local media	3	1	0.167	3	1	0.167	3	1	0.167
6	Scanning tours for elected officials	0	0	0.000	0	0	0.000	0	0	0.000
7	On-line message boards	1	3	0.500	1	3	0.500	1	3	0.500
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Provo-Orem	n-r+1	W	SL City-Reg 1	n-r+1	W	SL City-Reg 2	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	2	6	0.214	2	6	0.214	2	6	0.214
4	Public involvement	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
5	Newspaper articles and other local media	3	5	0.179	3	5	0.179	3	5	0.179
6	Scanning tours for elected officials	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
7	On-line message boards	1	7	0.250	1	7	0.250	1	7	0.250
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Oregon

Assumption 1

	Reasons	Eugene	n-r+1	W	Portland, Vancouver, WA	n-r+1	W
1	Open meetings with the public	0	0	0.000	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000
3	Emergency situation	1	3	0.500	1	3	0.500
4	Public involvement	3	1	0.167	2	2	0.333
5	Newspaper articles and other local media	2	2	0.333	3	1	0.167
6	Scanning tours for elected officials	0	0	0.000	0	0	0.000
7	On-line message boards	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Eugene	n-r+1	W	Portland, Vancouver, WA	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	1	7	0.250	1	7	0.250
4	Public involvement	3	5	0.179	2	6	0.214
5	Newspaper articles and other local media	2	6	0.214	3	5	0.179
6	Scanning tours for elected officials	5.5	2.5	0.089	5.5	2.5	0.089
7	On-line message boards	5.5	2.5	0.089	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Washington

Assumption 1

	Reasons	Seattle NW region	n-r+1	W	Seattle, Olympia region	n-r+1	W	Spokane	n-r+1	W
1	Open meetings with the public	0	0	0.000	1	3	0.500	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000	0	0	0.000
3	Emergency situation	0	0	0.000	2	2	0.333	0	0	0.000
4	Public involvement	3	1	0.167	3	1	0.167	0	0	0.000
5	Newspaper articles and other local media	1	3	0.500	0	0	0.000	0	0	0.000
6	Scanning tours for elected officials	2	2	0.333	0	0	0.000	1	1	1.000
7	On-line message boards	0	0	0.000	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**1**	**1.000**

Assumption 2

	Reasons	Seattle NW region	n-r+1	W	Seattle, Olympia region	n-r+1	W	Spokane	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	1	7	0.250	4.5	3.5	0.125
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089	4.5	3.5	0.125
3	Emergency situation	5.5	2.5	0.089	2	6	0.214	4.5	3.5	0.125
4	Public involvement	3	5	0.179	3	5	0.179	4.5	3.5	0.125
5	Newspaper articles and other local media	1	7	0.250	5.5	2.5	0.089	4.5	3.5	0.125
6	Scanning tours for elected officials	2	6	0.214	5.5	2.5	0.089	1	7	0.250
7	On-line message boards	5.5	2.5	0.089	5.5	2.5	0.089	4.5	3.5	0.125
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Nebraska

Assumption 1

	Reasons	Omaha	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	1	1	1.000
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			1	**1.000**

Assumption 2

	Reasons	Omaha	n-r+1	W
1	Open meetings with the public	4.5	3.5	0.125
2	Contractor provided briefings	4.5	3.5	0.125
3	Emergency situation	4.5	3.5	0.125
4	Public involvement	4.5	3.5	0.125
5	Newspaper articles and other local media	1	7	0.250
6	Scanning tours for elected officials	4.5	3.5	0.125
7	On-line message boards	4.5	3.5	0.125
8	Other	0	0	0.000
			28	**1.000**

Minnesota

Assumption 1

	Reasons	St. Paul	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	3	1	0.167
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	1	3	0.500
6	Scanning tours for elected officials	2	2	0.333
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	St. Paul	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	3	5	0.179
4	Public involvement	5.5	2.5	0.089
5	Newspaper articles and other local media	1	7	0.250
6	Scanning tours for elected officials	2	6	0.214
7	On-line message boards	5.5	2.5	0.089
8	Other	0	0	0.000
			28	**1.000**

Iowa

Assumption 1

	Reasons	Des Moines	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	3	1	0.167
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	1	3	0.500
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Do nothing, then they request	2	2	0.333
			6	**1.000**

Assumption 2

	Reasons	Des Moines	n-r+1	W
1	Open meetings with the public	6	3	0.083
2	Contractor provided briefings	6	3	0.083
3	Emergency situation	3	6	0.167
4	Public involvement	6	3	0.083
5	Newspaper articles and other local media	1	8	0.222
6	Scanning tours for elected officials	6	3	0.083
7	On-line message boards	6	3	0.083
8	Do nothing, then they request	2	7	0.194
			36	**1.000**

Missouri

Assumption 1

	Reasons	Kansas City, Kansas DOT	n-r+1	W	Kansas City, Missouri DOT	n-r+1	W	Springfield	n-r+1	W
1	Open meetings with the public	3	1	0.167	0	0	0.000	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000	0	0	0.000
3	Emergency situation	2	2	0.333	0	0	0.000	2	2	0.333
4	Public involvement	1	3	0.500	2	2	0.333	0	0	0.000
5	Newspaper articles and other local media	0	0	0.000	1	3	0.500	1	3	0.500
6	Scanning tours for elected officials	0	0	0.000	3	1	0.167	3	1	0.167
7	On-line message boards	0	0	0.000	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	St. Louis, Illinois DOT	n-r+1	W	St. Louis, Missouri DOT	n-r+1	W
1	Open meetings with the public	0	0	0.000	1	3	0.500
2	Contractor provided briefings	0	0	0.000	0	0	0.000
3	Emergency situation	1	3	0.500	3	1	0.167
4	Public involvement	0	0	0.000	0	0	0.000
5	Newspaper articles and other local media	2	2	0.333	2	2	0.333
6	Scanning tours for elected officials	0	0	0.000	0	0	0.000
7	On-line message boards	3	1	0.167	0	0	0.000
8	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Kansas City, Kansas DOT	n-r+1	W	Kansas City, Missouri DOT	n-r+1	W	Springfield	n-r+1	W
1	Open meetings with the public	3	5	0.179	5.5	2.5	0.089	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	2	6	0.214	5.5	2.5	0.089	2	6	0.214
4	Public involvement	1	7	0.250	2	6	0.214	5.5	2.5	0.089
5	Newspaper articles and other local media	5.5	2.5	0.089	1	7	0.250	1	7	0.250
6	Scanning tours for elected officials	5.5	2.5	0.089	3	5	0.179	3	5	0.179
7	On-line message boards	5.5	2.5	0.089	5.5	2.5	0.089	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**		**28**	**1.000**

Assumption 2

	Reasons	St. Louis, Illinois DOT	n-r+1	W	St. Louis, Missouri DOT	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	1	7	0.250
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	1	7	0.250	3	5	0.179
4	Public involvement	5.5	2.5	0.089	5.5	2.5	0.089
5	Newspaper articles and other local media	2	6	0.214	2	6	0.214
6	Scanning tours for elected officials	5.5	2.5	0.089	5.5	2.5	0.089
7	On-line message boards	3	5	0.179	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Louisiana

Assumption 1

	Reasons	Baton Rouge	n-r+1	W	New Orleans	n-r+1	W
1	Open meetings with the public	0	0	0.000	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000
3	Emergency situation	2	2	0.333	1	3	0.500
4	Public involvement	0	0	0.000	3	1	0.167
5	Newspaper articles and other local media	3	1	0.167	2	2	0.333
6	Scanning tours for elected officials	1	3	0.500	0	0	0.000
7	On-line message boards	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Baton Rouge	n-r+1	W	New Orleans	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089	5.5	2.5	0.089
3	Emergency situation	2	6	0.214	1	7	0.250
4	Public involvement	5.5	2.5	0.089	3	5	0.179
5	Newspaper articles and other local media	3	5	0.179	2	6	0.214
6	Scanning tours for elected officials	1	7	0.250	5.5	2.5	0.089
7	On-line message boards	5.5	2.5	0.089	5.5	2.5	0.089
8	Other	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Michigan

Assumption 1

	Reasons	Detroit, Ann Arbor	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	3	1	0.167
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	2	2	0.333
6	Scanning tours for elected officials	1	3	0.500
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Detroit, Ann Arbor	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	3	5	0.179
4	Public involvement	5.5	2.5	0.089
5	Newspaper articles and other local media	2	6	0.214
6	Scanning tours for elected officials	1	7	0.250
7	On-line message boards	5.5	2.5	0.089
8	Other	0	0	0.000
			28	**1.000**

Wisconsin

Assumption 1

	Reasons	Janesville-Beloit	n-r+1	W	Milwaukee, Racine	n-r+1	W
1	Open meetings with the public	6.5	1.5	0.054	0	0	0.000
2	Contractor provided briefings	6.5	1.5	0.054	0	0	0.000
3	Emergency situation	2.5	5.5	0.196	1	2	0.667
4	Public involvement	2.5	5.5	0.196	0	0	0.000
5	Newspaper articles and other local media	2.5	5.5	0.196	0	0	0.000
6	Scanning tours for elected officials	5	3	0.107	0	0	0.000
7	On-line message boards	2.5	5.5	0.196	0	0	0.000
8	Success of the Gateway Patrol Program	0	0	0.000	2	1	0.333
			28	**1.000**		**3**	**1.000**

Assumption 2

	Reasons	Janesville-Beloit	n-r+1	W	Milwaukee, Racine	n-r+1	W
1	Open meetings with the public	6.5	1.5	0.054	5.5	3.5	0.097
2	Contractor provided briefings	6.5	1.5	0.054	5.5	3.5	0.097
3	Emergency situation	2.5	5.5	0.196	1	8	0.222
4	Public involvement	2.5	5.5	0.196	5.5	3.5	0.097
5	Newspaper articles and other local media	2.5	5.5	0.196	5.5	3.5	0.097
6	Scanning tours for elected officials	5	3	0.107	5.5	3.5	0.097
7	On-line message boards	2.5	5.5	0.196	5.5	3.5	0.097
8	Success of the Gateway Patrol Program	0	0	0.000	2	7	0.194
			28	**1.000**		**36**	**1.000**

Illinois

Assumption 1

	Reasons	Gary, Lake County	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	1	3	0.500
6	Scanning tours for elected officials	3	1	0.167
7	On-line message boards	2	2	0.333
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Gary, Lake County	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	5.5	2.5	0.089
4	Public involvement	5.5	2.5	0.089
5	Newspaper articles and other local media	1	7	0.250
6	Scanning tours for elected officials	3	5	0.179
7	On-line message boards	2	6	0.214
8	Other	0	0	0.000
			28	**1.000**

Indiana

Assumption 1

	Reasons	Indianapolis	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	3	1	0.167
4	Public involvement	0	0	0.000
5	Newspaper articles and other local media	2	2	0.333
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Improved incident mgmt. and traveler inform	1	3	0.500
			6	**1.000**

Assumption 2

	Reasons	Indianapolis	n-r+1	W
1	Open meetings with the public	6	3	0.083
2	Contractor provided briefings	6	3	0.083
3	Emergency situation	3	6	0.167
4	Public involvement	6	3	0.083
5	Newspaper articles and other local media	2	7	0.194
6	Scanning tours for elected officials	6	3	0.083
7	On-line message boards	6	3	0.083
8	Improved incident mgmt. and traveler inform	1	8	0.222
			36	**1.000**

Kentucky

Assumption 1

	Reasons	Louisville	n-r+1	W
1	Open meetings with the public	3	1	0.167
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	2	2	0.333
5	Newspaper articles and other local media	1	3	0.500
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Louisville	n-r+1	W
1	Open meetings with the public	3	5	0.179
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	5.5	2.5	0.089
4	Public involvement	2	6	0.214
5	Newspaper articles and other local media	1	7	0.250
6	Scanning tours for elected officials	5.5	2.5	0.089
7	On-line message boards	5.5	2.5	0.089
8	Other	0	0	0.000
			28	**1.000**

Tennessee

Assumption 1

	Reasons	Chattanooga	n-r+1	W	Memphis	n-r+1	W
1	Open meetings with the public	0	0	0.000	0	0	0.000
2	Contractor provided briefings	0	0	0.000	0	0	0.000
3	Emergency situation	0	0	0.000	0	0	0.000
4	Public involvement	3	1	0.167	0	0	0.000
5	Newspaper articles and other local media	1	3	0.500	1	1	1.000
6	Scanning tours for elected officials	2	2	0.333	0	0	0.000
7	On-line message boards	0	0	0.000	0	0	0.000
8	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**1**	**1.000**

Assumption 2

	Reasons	Chattanooga	n-r+1	W	Memphis	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089	4.5	3.5	0.125
2	Contractor provided briefings	5.5	2.5	0.089	4.5	3.5	0.125
3	Emergency situation	5.5	2.5	0.089	4.5	3.5	0.125
4	Public involvement	3	5	0.179	4.5	3.5	0.125
5	Newspaper articles and other local media	1	7	0.250	1	7	0.250
6	Scanning tours for elected officials	2	6	0.214	4.5	3.5	0.125
7	On-line message boards	5.5	2.5	0.089	4.5	3.5	0.125
8	Other	0	0	0.000	0	0	0.000
			28	**1.000**		**28**	**1.000**

Alabama

Assumption 1

	Reasons	Birmingham	n-r+1	W
1	Open meetings with the public	3	1	0.167
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	2	2	0.333
5	Newspaper articles and other local media	1	3	0.500
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Birmingham	n-r+1	W
1	Open meetings with the public	3	5	0.179
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	5.5	2.5	0.089
4	Public involvement	2	6	0.214
5	Newspaper articles and other local media	1	7	0.250
6	Scanning tours for elected officials	5.5	2.5	0.089
7	On-line message boards	5.5	2.5	0.089
8	Other	0	0	0.000
			28	**1.000**

Ohio

Assumption 1

	Reasons	Cincinnati, Hamilton	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	1	3	0.500
5	Newspaper articles and other local media	2	2	0.333
6	Scanning tours for elected officials	3	1	0.167
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Cincinnati, Hamilton	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	5.5	2.5	0.089
4	Public involvement	1	7	0.250
5	Newspaper articles and other local media	2	6	0.214
6	Scanning tours for elected officials	3	5	0.179
7	On-line message boards	5.5	2.5	0.089
8	Other	0	0	0.000
			28	**1.000**

Pennsylvania

Assumption 1

	Reasons	Allentown, Bethlehem, Easton	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	1	2	0.667
5	Newspaper articles and other local media	2	1	0.333
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	0	0	0.000
8	Other	0	0	0.000
			3	**1.000**

Assumption 2

	Reasons	Allentown, Bethlehem, Easton	n-r+1	W
1	Open meetings with the public	5	3	0.107
2	Contractor provided briefings	5	3	0.107
3	Emergency situation	5	3	0.107
4	Public involvement	1	7	0.250
5	Newspaper articles and other local media	2	6	0.214
6	Scanning tours for elected officials	5	3	0.107
7	On-line message boards	5	3	0.107
8	Other	5	0	0.000
			28	**1.000**

Georgia

Assumption 1

	Reasons	Atlanta	n-r+1	W
1	Open meetings with the public	0	0	0.000
2	Contractor provided briefings	0	0	0.000
3	Emergency situation	0	0	0.000
4	Public involvement	2	2	0.333
5	Newspaper articles and other local media	1	3	0.500
6	Scanning tours for elected officials	0	0	0.000
7	On-line message boards	3	1	0.167
8	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Atlanta	n-r+1	W
1	Open meetings with the public	5.5	2.5	0.089
2	Contractor provided briefings	5.5	2.5	0.089
3	Emergency situation	5.5	2.5	0.089
4	Public involvement	2	6	0.214
5	Newspaper articles and other local media	1	7	0.250
6	Scanning tours for elected officials	5.5	2.5	0.089
7	On-line message boards	3	5	0.179
8	Other	0	0	0.000
			28	**1.000**

Legal issues involved with making a decision to deploy a TMC

Texas

Assumption 1

	Reasons	Austin	n-r+1	W	Houston	n-r+1	W	D/FW	n-r+1	W
1	Rules and regulations	1	3	0.500	0	0	0.000	3	1	0.167
2	Contract disputes and claims	0	0	0.000	0	0	0.000	0	0	0.000
3	Intellect	3	1	0.167	1	3	0.500	1	3	0.500
4	Liability	2	2	0.333	3	1	0.167	2	2	0.333
5	Privacy	0	0	0.000	2	2	0.333	0	0	0.000
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	San Antonio	n-r+1	W
1	Rules and regulations	2	2	0.333
2	Contract disputes and claims	0	0	0.000
3	Intellect	3	1	0.167
4	Liability	0	0	0.000
5	Privacy	1	3	0.500
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Austin	n-r+1	W	Houston	n-r+1	W	D/FW	n-r+1	W
1	Rules and regulations	1	5	0.333	4.5	1.5	0.100	3	3	0.200
2	Contract disputes and claims	4.5	1.5	0.100	4.5	1.5	0.100	4.5	1.5	0.100
3	Intellect	3	3	0.200	1	5	0.333	1	5	0.333
4	Liability	2	4	0.267	3	3	0.200	2	4	0.267
5	Privacy	4.5	1.5	0.100	2	4	0.267	4.5	1.5	0.100
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**		**15**	**1.000**

Assumption 2

	Reasons	San Antonio	n-r+1	W
1	Rules and regulations	2	4	0.267
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	3	3	0.200
4	Liability	4.5	1.5	0.100
5	Privacy	1	5	0.333
6	Other	0	0	0.000
			15	**1.000**

California

Assumption 1

	Reasons	Dist. 12	n-r+1	W	Dist. 7	n-r+1	W	Dist. 8	n-r+1	W
1	Rules and regulations	1	3	0.500	1.5	4.5	0.300	1	3	0.500
2	Contract disputes and claims	0	0	0.000	4.5	1.5	0.100	3	1	0.167
3	Intellect	3	1	0.167	4.5	1.5	0.100	0	0	0.000
4	Liability	2	2	0.333	1.5	4.5	0.300	0	0	0.000
5	Privacy	0	0	0.000	3	3	0.200	0	0	0.000
6	Inter-agency agreements	0	0	0.000	0	0	0.000	2	2	0.333
			6	**1.000**		**15**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	Salinas	n-r+1	W	San Diego	n-r+1	W	San Luis Obispo	n-r+1	W
1	Rules and regulations	3	1	0.167	0	0	0.000	3	1	0.167
2	Contract disputes and claims	0	0	0.000	3	1	0.167	0	0	0.000
3	Intellect	0	0	0.000	2	2	0.333	0	0	0.000
4	Liability	1	3	0.500	1	3	0.500	1	3	0.500
5	Privacy	2	2	0.333	0	0	0.000	2	2	0.333
6	Inter-agency agreements	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	Santa Barbara	n-r+1	W
1	Rules and regulations	3	1	0.167
2	Contract disputes and claims	0	0	0.000
3	Intellect	0	0	0.000
4	Liability	1	3	0.500
5	Privacy	2	2	0.333
6	Inter-agency agreements	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Dist. 12	n-r+1	W	Dist. 7	n-r+1	W	Dist. 8	n-r+1	W
1	Rules and regulations	1	5	0.333	1.5	4.5	0.300	1	6	0.286
2	Contract disputes and claims	4.5	1.5	0.100	4.5	1.5	0.100	3	4	0.190
3	Intellect	3	3	0.200	4.5	1.5	0.100	5	2	0.095
4	Liability	2	4	0.267	1.5	4.5	0.300	5	2	0.095
5	Privacy	4.5	1.5	0.100	3	3	0.200	5	2	0.095
6	Inter-agency agreements	0	0	0.000	0	0	0.000	2	5	0.238
			15	**1.000**		**15**	**1.000**		**21**	**1.000**

Assumption 2

	Reasons	Salinas	n-r+1	W	San Diego	n-r+1	W	San Luis Obispo	n-r+1	W
1	Rules and regulations	1.5	4.5	0.300	1.5	4.5	0.300	1.5	4.5	0.300
2	Contract disputes and claims	4.5	1.5	0.100	4.5	1.5	0.100	4.5	1.5	0.100
3	Intellect	4.5	1.5	0.100	4.5	1.5	0.100	4.5	1.5	0.100
4	Liability	1.5	4.5	0.300	1.5	4.5	0.300	1.5	4.5	0.300
5	Privacy	3	3	0.200	3	3	0.200	3	3	0.200
6	Inter-agency agreements	0	0	0.000	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**		**15**	**1.000**

Assumption 2

	Reasons	Santa Barbara	n-r+1	W
1	Rules and regulations	1.5	4.5	0.300
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	4.5	1.5	0.100
4	Liability	1.5	4.5	0.300
5	Privacy	3	3	0.200
6	Inter-agency agreements	0	0	0.000
			15	**1.000**

New Mexico

Assumption 1

	Reasons	Albuquerque	n-r+1	W
1	Rules and regulations	2	1	0.333
2	Contract disputes and claims	0	0	0.000
3	Intellect	0	0	0.000
4	Liability	0	0	0.000
5	Privacy	0	0	0.000
6	Public safety	1	2	0.667
			3	**1.000**

Assumption 2

	Reasons	Albuquerque	n-r+1	W
1	Rules and regulations	2	5	0.238
2	Contract disputes and claims	4.5	2.5	0.119
3	Intellect	4.5	2.5	0.119
4	Liability	4.5	2.5	0.119
5	Privacy	4.5	2.5	0.119
6	Public safety	1	6	0.286
			21	**1.000**

Nevada

Assumption 1

	Reasons	Las Vegas	n-r+1	W
1	Rules and regulations	1	3	0.500
2	Contract disputes and claims	2	2	0.333
3	Intellect	3	1	0.167
4	Liability	0	0	0.000
5	Privacy	0	0	0.000
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Las Vegas	n-r+1	W
1	Rules and regulations	1	5	0.333
2	Contract disputes and claims	2	4	0.267
3	Intellect	3	3	0.200
4	Liability	4.5	1.5	0.100
5	Privacy	4.5	1.5	0.100
6	Other	0	0	0.000
			15	**1.000**

Colorado

Assumption 1

	Reasons	Denver, Boulder	n-r+1	W
1	Rules and regulations	1	1	1.000
2	Contract disputes and claims	0	0	0.000
3	Intellect	0	0	0.000
4	Liability	0	0	0.000
5	Privacy	0	0	0.000
6	Other	0	0	0.000
			1	**1.000**

Assumption 2

	Reasons	Denver, Boulder	n-r+1	W
1	Rules and regulations	1	5	0.333
2	Contract disputes and claims	3.5	2.5	0.167
3	Intellect	3.5	2.5	0.167
4	Liability	3.5	2.5	0.167
5	Privacy	3.5	2.5	0.167
6	Other	0	0	0.000
			15	**1.000**

Oregon

Assumption 1

	Reasons	Portland, Vancouver, WA	n-r+1	W
1	Rules and regulations	2	2	0.333
2	Contract disputes and claims	0	0	0.000
3	Intellect	3	1	0.167
4	Liability	1	3	0.500
5	Privacy	0	0	0.000
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Portland, Vancouver, WA	n-r+1	W
1	Rules and regulations	2	4	0.267
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	3	3	0.200
4	Liability	1	5	0.333
5	Privacy	4.5	1.5	0.100
6	Other	0	0	0.000
			15	**1.000**

Washington

Assumption 1

	Reasons	Seattle NW region	n-r+1	W	Seattle, Olympia region	n-r+1	W	Spokane	n-r+1	W
1	Rules and regulations	3	1	0.167	2	2	0.333	1	3	0.500
2	Contract disputes and claims	0	0	0.000	3	1	0.167	0	0	0.000
3	Intellect	0	0	0.000	0	0	0.000	3	1	0.167
4	Liability	2	2	0.333	1	3	0.500	2	2	0.333
5	Privacy	1	3	0.500	0	0	0.000	0	0	0.000
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Seattle NW region	n-r+1	W	Seattle, Olympia region	n-r+1	W	Spokane	n-r+1	W
1	Rules and regulations	3	3	0.200	2	4	0.267	1	5	0.333
2	Contract disputes and claims	4.5	1.5	0.100	3	3	0.200	4.5	1.5	0.100
3	Intellect	4.5	1.5	0.100	4.5	1.5	0.100	3	3	0.200
4	Liability	2	4	0.267	1	5	0.333	2	4	0.267
5	Privacy	1	5	0.333	4.5	1.5	0.100	4.5	1.5	0.100
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**		**15**	**1.000**

Iowa

Assumption 1

	Reasons	Des Moines	n-r+1	W
1	Rules and regulations	1	3	0.500
2	Contract disputes and claims	0	0	0.000
3	Intellect	0	0	0.000
4	Liability	3	1	0.167
5	Privacy	2	2	0.333
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Des Moines	n-r+1	W
1	Rules and regulations	1	5	0.333
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	4.5	1.5	0.100
4	Liability	3	3	0.200
5	Privacy	2	4	0.267
6	Other	0	0	0.000
			15	**1.000**

Missouri

Assumption 1

	Reasons	Kansas City, Kansas DOT	n-r+1	W	Kansas City, Missouri DOT	n-r+1	W	Springfield	n-r+1	W
1	Rules and regulations	0	0	0.000	3	1	0.167	2	2	0.333
2	Contract disputes and claims	0	0	0.000	0	0	0.000	3	1	0.167
3	Intellect	1	3	0.500	1	3	0.500	1	3	0.500
4	Liability	3	1	0.167	0	0	0.000	0	0	0.000
5	Privacy	2	2	0.333	2	2	0.333	0	0	0.000
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 1

	Reasons	St. Louis, Illinois DOT	n-r+1	W	St. Louis, Missouri DOT	n-r+1	W
1	Rules and regulations	1	3	0.500	2	2	0.333
2	Contract disputes and claims	2	2	0.333	0	0	0.000
3	Intellect	3	1	0.167	3	1	0.167
4	Liability	0	0	0.000	1	3	0.500
5	Privacy	0	0	0.000	0	0	0.000
6	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Kansas City, Kansas DOT	n-r+1	W	Kansas City, Missouri DOT	n-r+1	W	Springfield	n-r+1	W
1	Rules and regulations	4.5	1.5	0.100	3	3	0.200	2	4	0.267
2	Contract disputes and claims	4.5	1.5	0.100	4.5	1.5	0.100	3	3	0.200
3	Intellect	1	5	0.333	1	5	0.333	1	5	0.333
4	Liability	3	3	0.200	4.5	1.5	0.100	4.5	1.5	0.100
5	Privacy	2	4	0.267	2	4	0.267	4.5	1.5	0.100
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**		**15**	**1.000**

Assumption 2

	Reasons	St. Louis, Illinois DOT	n-r+1	W	St. Louis, Missouri DOT	n-r+1	W
1	Rules and regulations	1	5	0.333	2	4	0.267
2	Contract disputes and claims	2	4	0.267	4.5	1.5	0.100
3	Intellect	3	3	0.200	3	3	0.200
4	Liability	4.5	1.5	0.100	1	5	0.333
5	Privacy	4.5	1.5	0.100	4.5	1.5	0.100
6	Other	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**

Louisiana

Assumption 1

	Reasons	Baton Rouge	n-r+1	W	New Orleans	n-r+1	W
1	Rules and regulations	1	3	0.500	2	2	0.333
2	Contract disputes and claims	2	2	0.333	3	1	0.167
3	Intellect	0	0	0.000	0	0	0.000
4	Liability	3	1	0.167	1	3	0.500
5	Privacy	0	0	0.000	0	0	0.000
6	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Baton Rouge	n-r+1	W	New Orleans	n-r+1	W
1	Rules and regulations	1	5	0.333	2	4	0.267
2	Contract disputes and claims	2	4	0.267	3	3	0.200
3	Intellect	4.5	1.5	0.100	4.5	1.5	0.100
4	Liability	3	3	0.200	1	5	0.333
5	Privacy	4.5	1.5	0.100	4.5	1.5	0.100
6	Other	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**

Michigan

Assumption 1

	Reasons	Detroit, Ann Arbor	n-r+1	W	Grand Rapids	n-r+1	W
1	Rules and regulations	1	3	0.500	2	2	0.333
2	Contract disputes and claims	3	1	0.167	0	0	0.000
3	Intellect	2	2	0.333	0	0	0.000
4	Liability	0	0	0.000	3	1	0.167
5	Privacy	0	0	0.000	1	3	0.500
6	Other	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Detroit, Ann Arbor	n-r+1	W	Grand Rapids	n-r+1	W
1	Rules and regulations	1	5	0.333	2	4	0.267
2	Contract disputes and claims	3	3	0.200	4.5	1.5	0.100
3	Intellect	2	4	0.267	4.5	1.5	0.100
4	Liability	4.5	1.5	0.100	3	3	0.200
5	Privacy	4.5	1.5	0.100	1	5	0.333
6	Other	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**

Wisconsin

Assumption 1

	Reasons	Janesville-Beloit	n-r+1	W	Milwaukee, Racine	n-r+1	W
1	Rules and regulations	4.5	1.5	0.100	1	3	0.500
2	Contract disputes and claims	2.5	3.5	0.233	0	0	0.000
3	Intellect	4.5	1.5	0.100	0	0	0.000
4	Liability	2.5	3.5	0.233	2	2	0.333
5	Privacy	1	5	0.333	3	1	0.167
6	Other	0	0	0.000	0	0	0.000
			15	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Janesville-Beloit	n-r+1	W	Milwaukee, Racine	n-r+1	W
1	Rules and regulations	4.5	1.5	0.100	1	5	0.333
2	Contract disputes and claims	2.5	3.5	0.233	4.5	1.5	0.100
3	Intellect	4.5	1.5	0.100	4.5	1.5	0.100
4	Liability	2.5	3.5	0.233	2	4	0.267
5	Privacy	1	5	0.333	3	3	0.200
6	Other	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**

Illinois

Assumption 1

	Reasons	Gary, Lake County	n-r+1	W
1	Rules and regulations	2	1	0.333
2	Contract disputes and claims	0	0	0.000
3	Intellect	0	0	0.000
4	Liability	1	2	0.667
5	Privacy	0	0	0.000
6	Other	0	0	0.000
			3	**1.000**

Assumption 2

	Reasons	Gary, Lake County	n-r+1	W
1	Rules and regulations	2	4	0.267
2	Contract disputes and claims	4	2	0.133
3	Intellect	4	2	0.133
4	Liability	1	5	0.333
5	Privacy	4	2	0.133
6	Other	0	0	0.000
			15	**1.000**

Indiana

Assumption 1

	Reasons	Indianapolis	n-r+1	W
1	Rules and regulations	1	3	0.500
2	Contract disputes and claims	0	0	0.000
3	Intellect	2	2	0.333
4	Liability	0	0	0.000
5	Privacy	3	1	0.167
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Indianapolis	n-r+1	W
1	Rules and regulations	1	5	0.333
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	2	4	0.267
4	Liability	4.5	1.5	0.100
5	Privacy	3	3	0.200
6	Other	0	0	0.000
			15	**1.000**

Kentucky

Assumption 1

	Reasons	Louisville	n-r+1	W
1	Rules and regulations	1	3	0.500
2	Contract disputes and claims	0	0	0.000
3	Intellect	0	0	0.000
4	Liability	3	1	0.167
5	Privacy	2	2	0.333
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Louisville	n-r+1	W
1	Rules and regulations	1	5	0.333
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	4.5	1.5	0.100
4	Liability	3	3	0.200
5	Privacy	2	4	0.267
6	Other	0	0	0.000
			15	**1.000**

Tennessee

Assumption 1

	Reasons	Chattanooga	n-r+1	W
1	Rules and regulations	1	1	1.000
2	Contract disputes and claims	0	0	0.000
3	Intellect	0	0	0.000
4	Liability	0	0	0.000
5	Privacy	0	0	0.000
6	Other	0	0	0.000
			1	**1.000**

Assumption 2

	Reasons	Chattanooga	n-r+1	W
1	Rules and regulations	1	5	0.333
2	Contract disputes and claims	3.5	2.5	0.167
3	Intellect	3.5	2.5	0.167
4	Liability	3.5	2.5	0.167
5	Privacy	3.5	2.5	0.167
6	Other	0	0	0.000
			15	**1.000**

Alabama

Assumption 1

	Reasons	Birmingham	n-r+1	W
1	Rules and regulations	0	0	0.000
2	Contract disputes and claims	0	0	0.000
3	Intellect	3	1	0.167
4	Liability	1	3	0.500
5	Privacy	2	2	0.333
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Birmingham	n-r+1	W
1	Rules and regulations	4.5	1.5	0.100
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	3	3	0.200
4	Liability	1	5	0.333
5	Privacy	2	4	0.267
6	Other	0	0	0.000
			15	**1.000**

Ohio

Assumption 1

	Reasons	Cincinnati, Hamilton	n-r+1	W
1	Rules and regulations	2	2	0.333
2	Contract disputes and claims	0	0	0.000
3	Intellect	1	3	0.500
4	Liability	3	1	0.167
5	Privacy	0	0	0.000
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Cincinnati, Hamilton	n-r+1	W
1	Rules and regulations	2	4	0.267
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	1	5	0.333
4	Liability	3	3	0.200
5	Privacy	4.5	1.5	0.100
6	Other	0	0	0.000
			15	**1.000**

Georgia

Assumption 1

	Reasons	Atlanta	n-r+1	W
1	Rules and regulations	0	0	0.000
2	Contract disputes and claims	3	1	0.167
3	Intellect	1	3	0.500
4	Liability	0	0	0.000
5	Privacy	2	2	0.333
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Atlanta	n-r+1	W
1	Rules and regulations	4.5	1.5	0.100
2	Contract disputes and claims	3	3	0.200
3	Intellect	1	5	0.333
4	Liability	4.5	1.5	0.100
5	Privacy	2	4	0.267
6	Other	0	0	0.000
			15	**1.000**

Florida

Assumption 1

	Reasons	Daytona Beach	n-r+1	W	Jacksonville	n-r+1	W	West Palm Beach, Boca Raton, Delray	n-r+1	W
1	Rules and regulations	1	1	1.000	3	1	0.167	2	1.000	0.333
2	Contract disputes and claims	0	0	0.000	0	0	0.000	0	0.000	0.000
3	Intellect	0	0	0.000	0	0	0.000	0	0.000	0.000
4	Liability	0	0	0.000	1	3	0.500	0	0.000	0.000
5	Privacy	0	0	0.000	2	2	0.333	0	0.000	0.000
6	Funding	0	0	0.000	0	0	0.000	1	2.000	0.667
			1	**1.000**		**6**	**1.000**		**3**	**1.000**

Assumption 2

	Reasons	Daytona Beach	n-r+1	W	Jacksonville	n-r+1	W	West Palm Beach, Boca Raton, Delray	n-r+1	W
1	Rules and regulations	1	5	0.333	3	3	0.200	2	5	0.238
2	Contract disputes and claims	3.5	2.5	0.167	4.5	1.5	0.100	4.5	2.5	0.119
3	Intellect	3.5	2.5	0.167	4.5	1.5	0.100	4.5	2.5	0.119
4	Liability	3.5	2.5	0.167	1	5	0.333	4.5	2.5	0.119
5	Privacy	3.5	2.5	0.167	2	4	0.267	4.5	2.5	0.119
6	Funding	0	0	0.000	0	0	0.000	1	6	0.286
			15	**1.000**		**15**	**1.000**		**21**	**1.000**

Connecticut

Assumption 1

	Reasons	Hartford, New Britain, Middle-town	n-r+1	W	New Haven, Meriden	n-r+1	W	New London	n-r+1	W
1	Rules and regulations	0	0	0.000	0	0	0.000	0	0	0.000
2	Contract disputes and claims	3	1	0.167	3	1	0.167	3	1	0.167
3	Intellect	0	0	0.000	0	0	0.000	0	0	0.000
4	Liability	2	2	0.333	2	2	0.333	2	2	0.333
5	Privacy	1	3	0.500	1	3	0.500	1	3	0.500
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**6**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Hartford, New Britain, Middle-town	n-r+1	W	New Haven, Meriden	n-r+1	W	New London	n-r+1	W
1	Rules and regulations	4.5	1.5	0.100	4.5	1.5	0.100	4.5	1.5	0.100
2	Contract disputes and claims	3	3	0.200	3	3	0.200	3	3	0.200
3	Intellect	4.5	1.5	0.100	4.5	1.5	0.100	4.5	1.5	0.100
4	Liability	2	4	0.267	2	4	0.267	2	4	0.267
5	Privacy	1	5	0.333	1	5	0.333	1	5	0.333
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**		**15**	**1.000**

NewYork

Assumption 1

	Reasons	New York, Northern New Jersey, Southwestern Connecticut, Connecticut DOT	n-r+1	W
1	Rules and regulations	0	0	0.000
2	Contract disputes and claims	3	1	0.167
3	Intellect	0	0	0.000
4	Liability	2	2	0.333
5	Privacy	1	3	0.500
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	New York, Northern New Jersey, Southwestern Connecticut, Connecticut DOT	n-r+1	W
1	Rules and regulations	4.5	1.5	0.100
2	Contract disputes and claims	3	3	0.200
3	Intellect	4.5	1.5	0.100
4	Liability	2	4	0.267
5	Privacy	1	5	0.333
6	Other	0	0	0.000
			15	**1.000**

Marryland

Assumption 1

	Reasons	Baltimore	n-r+1	W
1	Rules and regulations	1	2.000	0.667
2	Contract disputes and claims	0	0.000	0.000
3	Intellect	0	0.000	0.000
4	Liability	2	1.000	0.333
5	Privacy	0	0.000	0.000
6	Other	0	0.000	0.000
			3	**1.000**

Assumption 2

	Reasons	Baltimore	n-r+1	W
1	Rules and regulations	1	5	0.333
2	Contract disputes and claims	4	2	0.133
3	Intellect	4	2	0.133
4	Liability	2	4	0.267
5	Privacy	4	2	0.133
6	Other	0	0	0.000
			15	**1.000**

Washington DC

Assumption 1

	Reasons	Washington DC, District of Columbia TMC	n-r+1	W	Washington DC, Maryland Highway Administration	n-r+1	W	Washington DC, Virginia DOT	n-r+1	W
1	Rules and regulations	2	2	0.333	1	2	0.667	1	3	0.500
2	Contract disputes and claims	0	0	0.000	0	0	0.000	0	0	0.000
3	Intellect	0	0	0.000	0	0	0.000	2	2	0.333
4	Liability	2	2	0.333	2	1	0.333	0	0	0.000
5	Privacy	2	2	0.333	0	0	0.000	3	1	0.167
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			6	**1.000**		**3**	**1.000**		**6**	**1.000**

Assumption 2

	Reasons	Washington DC, District of Columbia TMC	n-r+1	W	Washington DC, Maryland Highway Administration	n-r+1	W	Washington DC, Virginia DOT	n-r+1	W
1	Rules and regulations	2	4	0.267	1	5	0.333	1	5	0.333
2	Contract disputes and claims	4.5	1.5	0.100	4	2	0.133	4.5	1.5	0.100
3	Intellect	4.5	1.5	0.100	4	2	0.133	2	4	0.267
4	Liability	2	4	0.267	2	4	0.267	4.5	1.5	0.100
5	Privacy	2	4	0.267	4	2	0.133	3	3	0.200
6	Other	0	0	0.000	0	0	0.000	0	0	0.000
			15	**1.000**		**15**	**1.000**		**15**	**1.000**

Virginia

Assumption 1

	Reasons	Richmond, Petersburg	n-r+1	W
1	Rules and regulations	2	2	0.333
2	Contract disputes and claims	0	0	0.000
3	Intellect	3	1	0.167
4	Liability	0	0	0.000
5	Privacy	1	3	0.500
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Richmond, Petersburg	n-r+1	W
1	Rules and regulations	2	4	0.267
2	Contract disputes and claims	4.5	1.5	0.100
3	Intellect	3	3	0.200
4	Liability	4.5	1.5	0.100
5	Privacy	1	5	0.333
6	Other	0	0	0.000
			15	**1.000**

North Carolina

Assumption 1

	Reasons	Charlotte, Gastonia, Rock Hill, Metrolina Reginal TMC	n-r+1	W
1	Rules and regulations	3	1	0.167
2	Contract disputes and claims	2	2	0.333
3	Intellect	1	3	0.500
4	Liability	0	0	0.000
5	Privacy	0	0	0.000
6	Other	0	0	0.000
			6	**1.000**

Assumption 2

	Reasons	Charlotte, Gastonia, Rock Hill, Metrolina Reginal TMC	n-r+1	W
1	Rules and regulations	3	3	0.200
2	Contract disputes and claims	2	4	0.267
3	Intellect	1	5	0.333
4	Liability	4.5	1.5	0.100
5	Privacy	4.5	1.5	0.100
6	Other	0	0	0.000
			15	**1.000**

APPENDIX B

SURVEY QUESTIONNAIRE

Performance Measures Questionnaire

Multi-Criteria Assessment for Supporting Freeway Operations and Management Systems

The following survey is part of a Research developed at The School of Civil and Environmental Engineering at The University of Texas at Arlington.

The purposes of this task include:

1. Summarize the practices with respect to performance measures and how performance measurement is used to support freeway operational decisions.

2. Assess the factors influencing decision makers for selecting the existing or the new operational performance measures for freeways and data collection strategies.

3. Determine the importance of program goal and performance measures criteria that decision makers consider are significant for supporting freeway operational decisions.

Your answers will help us to develop the tool for selecting the operational performance measures and data collection strategies according to an innovative operational performance measurement index for freeways, methodology and policy recommendations which can support the freeway operational decisions in the future.

The questionnaire should take no more than 25 minutes to complete. For the participant respondents, the researchers will make a follow up call to schedule the date and time for interview. Otherwise, the participant respondents can also return the results of survey by email, mail, or fax them to us.

This survey should be completed by those in your agency who are involved in freeway operations and performance measures. The researchers will not disclose your personal information in any way throughout the study or report. Your participation is completely voluntary. If you are not interested in participating in this research, please let us know and no further communication will be made. Your responses are important regardless of the current use of performance measures in your agency. Please let us know if you need further information.

Please respond to the survey by April 15, 2008 or provide any comments or queries to:

Auttawit Upayokin

Principal Investigator

Department of Civil and Environmental Engineering

University of Texas at Arlington

Ph: (817) 272-3592 (Office), (817) 891-7312 (Mobile)

Fax: (817) 272-2630

Email: aupayokin@uta.edu

Section 1. Background Information

Personal Information

Name:		
Address:		
Phone:	Fax:	Email:

1. Can we contact you for additional information? Yes ….. No ….

Agency Information

2. What type of organization, agency and firm do you work at?
State Department of Transportation…. Metropolitan Planning Organization…. City or County…. Other (Specify)………………………………………...

3. Is your agency responsible for (please check all available):
Freeways….. Toll roads…. Traffic data collection systems…. Intelligent Transportation Systems (ITS)…..Other (Specify) ……………………………………………

4. How many employees are working in your agency? Approximately………………………

5. How many centerline-miles of roadways are present in your agency's jurisdiction?…… miles

6. Do you currently use performance measures for assessing freeways operational strategies?
Yes….. No …….
   - If, the answer is "no", please skip to ***section 2***.
   - If, the answer is "yes"

6.1) How long have you used the performance measures for assessing the freeway operations?
Less than one year….. 1-2 years….. 2-5 years….. 5-10 years…… More than 10 years…..

6.2) Are the performance measures used to assess <u>daily</u> freeway operations?

Yes…. No…..
   - If, the answer is "no", please skip to ***section 2.***
   - If, the answer is "yes"

6.3) What are the performance measures currently used for assessing <u>daily</u> freeway operations at your agency?

Freeway operational strategies	Performance measures
Traffic incident management	
Traveler information	
Managed lanes	
Ramp Management	
Intelligent Transportation System (ITS)	
Weather/ Snow/ Ice management	
Special Event Management	
Other (Specify)	
1.	
2.	
3.	

6.4) What is the main motivation for your agency using performance measures for assessing daily freeway operations?

Section 2: Expected Weight of Good Characteristics for Assessing Performance Measures

7. NCHRP 311 describes the characteristics of good performance measures in Table 1. Using the one hundred point approach, please give one hundred points to distribute amongst those useful characteristics based on their significance for selecting the performance measures.

For example:

Characteristics	Score	Description
Clarity and simplicity	15	It is important for assessing performance measures (PM) for performance measure selection.
Descriptive and predictive ability	25	It is critically important for assessing PM for performance measure selection.
Analysis capability	20	It is very important for assessing PM for performance measure selection.
Accuracy and precision	20	It is very important for assessing PM for performance measure selection.
Flexibility	20	It is very important for assessing PM for performance measure selection.
Total Score	**100**	

Note: in the example, the descriptive and predictive ability is given the highest importance because it can be used to identify the problems.

Table 1: Characteristics of good performance measures

Characteristics	Score
Clarity and simplicity	
Descriptive and predictive ability	
Analysis capability	
Accuracy and precision	
Flexibility	
Total Score	**100**

Description of the Characteristics
Clarity and simplicity ▪ The measure is simple to present, analyze and interpret. ▪ It is unambiguous. ▪ The measure's units are well defined and quantifiable. ▪ The measure has professional credibility. ▪ Technical and nontechnical audiences can easily understand the measure.
Descriptive and predictive ability ▪ The measure describes existing conditions. ▪ It can be used to identify problems. ▪ It can be use to predict change and forecast condition. ▪ It can be calculated easily. ▪ The measure reflects changes in traffic flow conditions only.
Analysis capability ▪ The measure can be calculated with existing field data. ▪ There are techniques available to estimate the measure. ▪ The results are easy to analyze. ▪ The measure achieves consistent results.
Accuracy and precision ▪ The accuracy level of the estimation techniques is acceptable. ▪ The measure is sensitive to significant changes in assumptions. ▪ The precision of the measure is consistent with planning applications. ▪ The precision of the measure is consistent with an operation analysis.
Flexibility ▪ The measure is applicable to multiple modes. ▪ The measure is meaningful at varying scales and settings.

Section 3: Expected Constraints for Data Collection Strategies on Freeways

Various data collection techniques such as loop detectors, video image processing, and acoustic sensors are used to collect the real time data on freeways. Each data collection technique provides different quality of measurements based on their timeframe, cost, accuracy and reliability.

Your agency plans to use another effective data collection technique instead of the existing one. You are one who is involved with the selection process. Please specify the general characteristics of the new data collection technique you expect to use in your agency.

8. What is the time duration required for gathering an appropriate amount of data from field before it is transferred to traffic management centers?

Less than 15 seconds…. Less than 30 seconds…. Less than 60 seconds…. Less than 2 Minutes…..Other (Specify)……………………………

9. What is the time duration required for roadside controllers to transmit the data from question 8 to the traffic management centers?

Less than 15 seconds…. Less than 30 seconds…. Less than 60 seconds…. Less than 2 Minutes…..Other (Specify)……………………………

10. What is the time duration required at TMC to calculate the performance measure? What is the acceptable value you expect?
    Less than 15 seconds…. Less than 30 seconds…. Less than 60 seconds…. Less than 2 Minutes….Others, (specify)……………………………

11. What is the operational and maintenance cost of new data collection technique?
    Less than…………………………. ($ / per month)

12. What do you expect for the accuracy:

Data processing accuracy (%) is the quality of value being estimated or calculated by computable systems compared with the actual value being estimated by reliable computer systems. It should be higher than ………………%
Instrumental accuracy (%) is the quality of value being measured by field equipment compared with the actual value measured by reliable instrument. It should be higher than ………………%
Data aggregation accuracy (%) is the quality of value being gathered by computers or humans compared with the actual value gathered by reliable approach. It should be higher than …………......%

13. What do you expect for the reliability:

The percentage of field equipment failure should be less than …………….%
The percentage of communication failure should be less than ……………..%
The percentage of database failure should be less than …………….%

Section 4. Expected Weight of Performance Measures (PM)

14. Please specify your current PM and expected PM for assessing daily freeway operations according to your agency goal. Using the one hundred point approach, please give one hundred points to distribute amongst those performance measures based on their significance for assessing your agency goal. *The score will be distributed only in the performance measures which you select.*

For example:

Goal 3: Enhance the mobility of persons, freight, etc.
Does your agency currently include this goal? Yes…/.   No…..

Performance Measures	Currently used in your agency	Expected to be used in the future	Score
Extent of congestion: Actual time or percentage of time that traffic on freeways is flowing at less than free-flow speeds.		/	20
Recurring Delay: The difference between actual travel time and travel time at free flow speeds experienced by individuals due to repetitive factors.			
Incident Delay: The increase in travel time experienced by individuals due to incidents.		/	20
Reliability: The amount of additional time that travelers must add to their average trip time in order to be 95% on time to the destination.			
Others (Specify)			
1. Speed: average speed on roadway segment or network.	/		30
2. Travel Time: average travel time on roadway segment or network.	/		30
		Total	**100**

Note: Most performance measures provided in this section come from the National Transportation Operations Coalition (NTOC) and other studies which can be applied for daily freeway operations. NTOC serves as an important foundation for institutionalizing management and operations into the transportation industry.

Goal 1: Improve the safety of transportation system
Does your agency currently include this goal? Yes…. No…..

Performance Measures	Currently used in your agency	Expected to be used in the future	Score
Total number of crashes or stopped vehicles			
Other (Specify)			
1.			
2.			
3.			
		Total	**100**

Goal 2: Reduce the energy and environmental impacts
Does your agency currently include this goal? Yes….. No…..

Performance Measures	Currently used in your agency	Expected to be used in the future	Score
Emissions: The noxious byproducts resulting from the combustion of fuels by vehicles traveling on the freeways			
Other (Specify)			
1.			
2.			
3.			
		Total	**100**

Goal 3: Enhance the mobility of persons, freight, etc.
Does your agency currently include this goal? Yes…. No…..

Performance Measures	Currently used in your agency	Expected to be used in the future	Score
Extent of congestion: Actual time or percentage of time that traffic on freeways is flowing at less than free-flow speeds.			
Recurring Delay: The difference between actual travel time and travel time at free flow speeds experienced by individuals due to repetitive factors.			
Incident Delay: The increase in travel time experienced by individuals due to incidents.			
Reliability: The amount of additional time that travelers must add to their average trip time in order to be 95% on time to the destination.			
Speed: average speed on roadway segment or network.			
Travel Time: average travel time on roadway segment or network.			
Performance Measures	**Currently used in your agency**	**Expected to be used in the future**	**Score**
Others (Specify)			
1.			
2.			
3.			
		Total	**100**

Goal 4: Increase the efficiency of transportation system
Does your agency currently include this goal? Yes….. No…..

Performance Measures	Currently used in your agency	Expected to be used in the future	Score
Throughput per person: The number of people accommodated by a roadway segment or network.			
Throughput per vehicle: The number of vehicles that are being accommodated by a roadway segment or network.			
Customer Satisfaction: A measure of the degree to which roadway users (travelers) are satisfied with their use of the roadway system.			
Others (Specify)			
1.			
2.			
3.			
		Total	**100**

Other goals and performance measures please specify:

Goal 5: …………………………………………………………
Does your agency currently include this goal? Yes….. No…..

Performance Measures	Currently used in your agency	Expected to be used in the future	Score
1.			
2.			
3.			
		Total	**100**

Goal 6: …………………………………………………………..
Does your agency currently include this goal? Yes…… No …..

Performance Measures	Currently used in your agency	Expected to be used in the future	Score
1.			
2.			
3.			
		Total	**100**

Section 5. Expected Weight of Performance Goals

15. Using the one hundred point approach, please give one hundred points to distribute amongst those performance measures in Table 2 based on their significance, reflecting the relative importance of the goal at your agency.

Note: The score will be distributed in the goal which you select.

Table 2 Expected Weight of Performance Goals in Your Agency

Goals	**Score**
Goal 1: Improve the safety of the transportation system	
Goal 2: Reduce the energy and environmental impacts	
Goal 3: Enhance the mobility of persons, freight, etc.	
Goal 4: Increase the efficiency of transportation system	
Other goals in question 14 should be included below:	
Goal 5:	
Goal 6:	
Total	**100**

APPENDIX C

ANALYSIS RESULTS OF WEIGHTS BY PROMETHEE

DATA ANALYSIS
CHARACTERISTICS OF PERFORMANCE MEASURES

1. Scores of characteristics of Performance Measures from the first survey

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8
Clarity and simplicity (C)	10	15	25	15	30	25	20	25
Descriptive and predictive ability (D)	10	15	25	30	15	25	20	25
Analysis capability (A_C)	30	30	20	20	30	15	25	20
Accuracy and precision (A_P)	30	35	20	20	15	25	25	20
Flexibility (F)	20	15	10	15	10	10	10	10

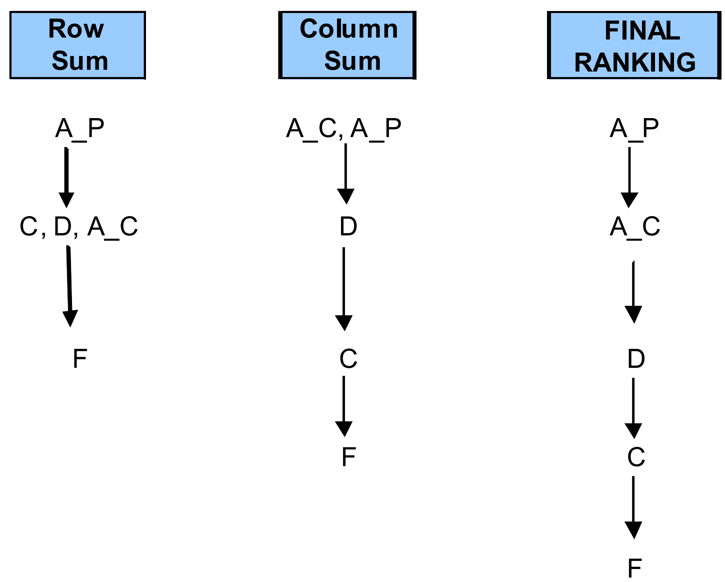
2. Concordance Scores

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Sum
C&D	0.091	0.091	0.091	0.000	0.091	0.091	0.091	0.091	0.000	0.091	0.091	0.818
C&A_C	0.000	0.000	0.091	0.000	0.091	0.091	0.000	0.091	0.000	0.091	0.091	0.545
C&A_P	0.000	0.000	0.091	0.000	0.091	0.091	0.000	0.091	0.091	0.091	0.091	0.636
C&F	0.000	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.909
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Sum
D&C	0.091	0.091	0.091	0.091	0.000	0.091	0.091	0.091	0.091	0.091	0.000	0.818
D&A_C	0.000	0.000	0.091	0.091	0.000	0.091	0.000	0.091	0.091	0.091	0.000	0.545
D&A_P	0.000	0.000	0.091	0.091	0.091	0.091	0.000	0.091	0.091	0.091	0.000	0.636
D&F	0.000	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.909
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Sum
A_C&C	0.091	0.091	0.000	0.091	0.091	0.000	0.091	0.000	0.091	0.000	0.091	0.636
A_C&D	0.091	0.091	0.000	0.000	0.091	0.000	0.091	0.000	0.091	0.000	0.091	0.545
A_C&A_P	0.091	0.000	0.091	0.091	0.091	0.000	0.091	0.091	0.091	0.000	0.091	0.727
A_C&F	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	1.000
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Sum
A_P&C	0.091	0.091	0.000	0.091	0.000	0.091	0.091	0.000	0.091	0.000	0.091	0.636
A_P&D	0.091	0.091	0.000	0.000	0.091	0.091	0.091	0.000	0.000	0.000	0.091	0.545
A_P&A_C	0.091	0.091	0.091	0.091	0.000	0.091	0.091	0.091	0.000	0.091	0.091	0.818
A_P&F	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	1.000
	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	DM11	Sum
F&C	0.091	0.091	0.000	0.091	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.273
F&D	0.091	0.091	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.182
F&A_C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.091	0.000	0.091
F&A_P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

3. Concordance Matrix

	C	D	A_C	A_P	F	Row Sum
Clarity and simplicity	0.000	0.818	0.545	0.636	0.909	**2.909**
Descriptive and predictive ability	0.818	0.000	0.545	0.636	0.909	**2.909**
Analysis capability	0.636	0.545	0.000	0.727	1.000	**2.909**
Accuracy and precision	0.636	0.545	0.818	0.000	1.000	**3.000**
Flexibility	0.273	0.182	0.091	0.000	0.000	**0.545**
Colum Sum	**2.364**	**2.091**	**2.000**	**2.000**	**3.818**	

4. Ranking Results



5. Proposed Weights

	Row Sum (1)	Col Sum (2)	(1)-(2)	Rank Order	Rating n-r+1	Normalised Weight	Avg. Weight	Purposed Weight
Clarity and simplicity (C)	2.909	2.364	0.545	4	2	0.133	0.21	0.200
Descriptive and predictive ability (D)	2.909	2.091	0.818	3	3	0.200	0.21	0.210
Analysis capability (A_C)	2.909	2	0.909	2	4	0.267	0.23	0.240
Accuracy and precision (A_P)	3.000	2	1.000	1	5	0.333	0.23	0.250
Flexibility (F)	0.545	3.818	-3.273	5	1	0.067	0.12	0.100
				sum	15			

DATA ANALYSIS

TRAFFIC MANAGEMENT CENTERS GOALS

1. Scores of traffic management centers goals from the first survey

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9
Safety (S)	100	50	30	30	30	25	25	40	30
Energy and Environment (E_E)	0	0	15	15	15	25	25	0	20
Mobility (M)	0	25	30	25	30	25	25	30	30
Efficiency (E)	0	25	25	30	25	25	25	30	20

2. Concordance Scores

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Sum
S&E_E	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1.000
S&M	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1.000
S&E	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1.000

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Sum
E_E&S	0.000	0.000	0.000	0.000	0.000	0.111	0.111	0.000	0.000	0.222
E_E&M	0.111	0.000	0.000	0.000	0.000	0.111	0.111	0.000	0.000	0.333
E_E&E	0.111	0.000	0.000	0.000	0.000	0.111	0.111	0.000	0.111	0.444

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Sum
M&S	0.000	0.000	0.111	0.000	0.111	0.111	0.111	0.000	0.111	0.556
M&E_E	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1.000
M&E	0.111	0.111	0.111	0.000	0.111	0.111	0.111	0.111	0.111	0.889

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	Sum
E&S	0.000	0.000	0.000	0.111	0.000	0.111	0.111	0.000	0.000	0.333
E&E_E	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1.000
E&E	0.111	0.111	0.000	0.111	0.000	0.111	0.111	0.111	0.000	0.667

3. Concordance Matrix

	S	E_E	M	E	Row Sum
Safety (S)	0.000	1.000	1.000	1.000	3.000
Energy and Environment (E_E)	0.222	0.000	0.333	0.444	1.000
Mobility (M)	0.556	1.000	0.000	0.889	2.444
Efficiency (E)	0.333	1.000	0.667	0.000	2.000
Colum Sum	1.111	3.000	2.000	2.333	

4. Ranking Results

Row Sum	Column Sum	FINAL RANKING
S → M → E → E_E	S → M → E → E_E	S → M → E → E_E

5. Proposed Weights

	Row Sum (1)	Col Sum (2)	(1)-(2)	Rank Order	Rating n-r+1	Normalised Weight	Avg. Weight	Purposed Weight
Safety (S)	3.000	1.111	1.889	1	4	0.400	0.40	0.35
Energy and Environment (E_E)	1.000	3	-2.000	4	1	0.100	0.13	0.15
Mobility (M)	2.444	2	0.444	2	3	0.300	0.24	0.25
Efficiency (E)	2.000	2.333	-0.333	3	2	0.200	0.23	0.25
				sum	10			

APPENDIX D

ANALYSIS OF DATA COLLECTION STRATEGIES

Simple Additive Weight Model

Criteria	Weight	Loop detector	Microwave sensor	Video sensor	Infrared sensor	Acoustic sensor	ITS probe vehicle
Capital cost	0.65	0.91	0.92	0.92	0.85	1.00	0.00
Data accuracy	0.20	1.00	1.00	1.00	0.00	0.00	0.00
Equipment reliability	0.15	0.71	0.71	0.71	0.71	0.00	1.00
	Utility value	0.90	0.91	0.91	0.66	0.65	0.15

ELECTRE III Model

1. Concordance Matrix

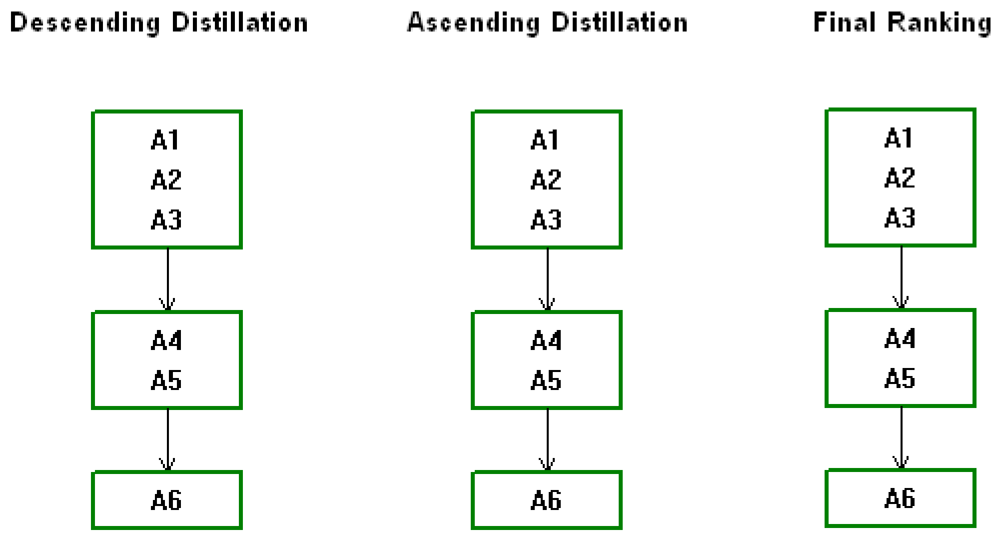
	A1	A2	A3	A4	A5	A6
A1	1	1	1	1	1	0.98
A2	1	1	1	1	1	0.98
A3	1	1	1	1	1	0.98
A4	0.8	0.8	0.8	1	1	0.98
A5	0.65	0.65	0.65	0.85	1	0.85
A6	0.15	0.15	0.15	0.35	0.35	1

Where:
A1 = Loop detector
A2 = Microwave sensor
A3 = Video sensor
A4 = Infrared sensor
A5 = Acoustic sensor
A6 = ITS probe vehicle

2. Credibility Matrix

	A1	A2	A3	A4	A5	A6
A1	1	1	1	1	1	0.98
A2	1	1	1	1	1	0.98
A3	1	1	1	1	1	0.98
A4	0.8	0.8	0.8	1	1	0.98
A5	0.65	0.65	0.65	0.85	1	0.85
A6	0.15	0.15	0.15	0.35	0.35	1

3. Distillations



APPENDIX E

TRAFFIC INFORMATION AND FREEWAY PERFORMANCE INDEX

Traffic composition and FPI (%) in lane 1 SB Loop 12

Time	q in 5 mins	u (mph)	Cee	Cv	Ctt	Cd	Cec	Cefm	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4
12:23:09 AM	21	67	0.7416	1.0000	1.0000	1.0000	1.0000	0.1934	63.02	64.50	59.67
12:28:09 AM	14	67	0.8278	1.0000	1.0000	1.0000	1.0000	0.2400	66.80	68.92	62.00
12:33:09 AM	11	63	0.8774	0.8177	0.9597	0.9982	1.0000	0.1600	62.71	66.04	55.20
12:38:09 AM	12	64	0.8629	0.8847	0.9802	0.9993	1.0000	0.1182	61.62	64.90	54.21
12:43:09 AM	12	65	0.8595	0.9517	1.0000	1.0000	1.0000	0.1310	62.87	65.94	55.95
12:48:09 AM	14	62	0.8477	0.7507	0.9386	0.9976	1.0000	0.1331	60.13	63.41	52.74
12:53:09 AM	12	61	0.8726	0.6836	0.9168	0.9962	1.0000	0.1481	60.42	63.99	52.36
12:58:09 AM	8	65	0.9063	0.9517	1.0000	1.0000	1.0000	0.1249	63.72	67.30	55.64
1:03:09 AM	6	70	0.9204	1.0000	1.0000	1.0000	1.0000	0.0887	63.12	66.96	54.44
1:08:09 AM	6	72	0.9164	1.0000	1.0000	1.0000	1.0000	0.0716	62.37	66.26	53.58
1:13:09 AM	13	66	0.8440	1.0000	1.0000	1.0000	1.0000	0.0737	60.77	63.92	53.68
1:18:09 AM	8	61	0.9150	0.6836	0.9168	0.9965	1.0000	0.1464	61.33	65.35	52.28
1:23:09 AM	10	61	0.8938	0.6836	0.9168	0.9978	1.0000	0.0832	58.43	62.55	49.14
1:28:09 AM	11	65	0.8712	0.9517	1.0000	1.0000	1.0000	0.1041	62.11	65.43	54.60
1:33:09 AM	11	59	0.8886	0.5496	0.8710	0.9954	1.0000	0.1220	58.04	62.15	48.80
1:38:09 AM	11	65	0.8712	0.9517	1.0000	1.0000	1.0000	0.1107	62.36	65.66	54.93
1:49:38 AM	10	64	0.8858	0.8847	0.9802	0.9993	1.0000	0.1220	62.29	65.79	54.40
1:54:38 AM	5	65	0.9415	0.9517	1.0000	1.0000	1.0000	0.1092	63.92	67.95	54.86
1:59:38 AM	6	62	0.9347	0.7507	0.9386	0.9990	1.0000	0.0554	59.17	63.74	48.88
2:04:38 AM	8	62	0.9130	0.7507	0.9386	0.9988	1.0000	0.0635	58.97	63.28	49.27
2:09:38 AM	10	64	0.8858	0.8847	0.9802	0.9995	1.0000	0.0846	60.85	64.54	52.54
2:14:38 AM	13	59	0.8684	0.5496	0.8710	0.9958	1.0000	0.1092	57.09	61.05	48.16
2:19:38 AM	14	57	0.8647	0.4155	0.8220	0.9924	1.0000	0.1308	56.04	60.09	46.92
2:24:38 AM	14	63	0.8440	0.8177	0.9597	0.9982	1.0000	0.1361	61.02	64.13	54.00
2:29:38 AM	14	63	0.8440	0.8177	0.9597	0.9982	1.0000	0.1505	61.57	64.60	54.72
2:34:38 AM	10	55	0.9076	0.2815	0.7694	0.9894	1.0000	0.1505	55.97	60.60	45.53
2:39:38 AM	14	57	0.8647	0.4155	0.8220	0.9942	1.0000	0.0938	54.64	58.87	45.09
2:44:38 AM	10	61	0.8938	0.6836	0.9168	0.9962	1.0000	0.1361	60.45	64.30	51.76
2:49:38 AM	3	57	0.9710	0.4155	0.8220	0.9942	1.0000	0.1041	57.49	62.76	45.60
2:54:38 AM	9	56	0.9150	0.3485	0.7961	0.9980	1.0000	0.0292	52.46	57.65	40.74
2:59:38 AM	10	57	0.9033	0.4155	0.8220	0.9948	1.0000	0.0860	55.23	59.91	44.70
3:04:38 AM	10	63	0.8885	0.8177	0.9597	0.9987	1.0000	0.0972	60.55	64.32	52.06
3:09:38 AM	8	62	0.9130	0.7507	0.9386	0.9980	1.0000	0.1075	60.66	64.74	51.46
3:14:38 AM	13	62	0.8586	0.7507	0.9386	0.9984	1.0000	0.0846	58.53	62.16	50.33
3:19:38 AM	10	61	0.8938	0.6836	0.9168	0.9965	1.0000	0.1375	60.50	64.34	51.84
3:24:38 AM	9	65	0.8946	0.9517	1.0000	1.0000	1.0000	0.1041	62.65	66.21	54.60
3:29:38 AM	9	63	0.8997	0.8177	0.9597	0.9988	1.0000	0.0998	60.91	64.78	52.19
3:34:38 AM	9	60	0.9067	0.6166	0.8943	0.9969	1.0000	0.0967	58.37	62.67	48.68
3:39:38 AM	11	69	0.8577	1.0000	1.0000	1.0000	1.0000	0.0921	61.80	64.99	54.61
3:44:38 AM	8	69	0.8965	1.0000	1.0000	1.0000	1.0000	0.1295	64.13	67.53	56.47
3:49:38 AM	10	68	0.8739	1.0000	1.0000	1.0000	1.0000	0.0942	62.25	65.59	54.71
3:54:38 AM	11	67	0.8647	1.0000	1.0000	1.0000	1.0000	0.1160	62.88	66.02	55.80
3:59:38 AM	12	66	0.8560	1.0000	1.0000	1.0000	1.0000	0.1257	63.05	66.05	56.29
4:04:38 AM	9	61	0.9044	0.6836	0.9168	0.9967	1.0000	0.1351	60.66	64.62	51.72
4:09:38 AM	12	57	0.8840	0.4155	0.8220	0.9948	1.0000	0.0937	55.08	59.52	45.09
4:14:38 AM	9	63	0.8997	0.8177	0.9597	0.9984	1.0000	0.1167	61.56	65.34	53.03
4:19:38 AM	7	64	0.9200	0.8847	0.9802	0.9994	1.0000	0.0967	62.11	66.09	53.14
4:24:38 AM	8	58	0.9209	0.4826	0.8469	0.9965	1.0000	0.0764	56.17	60.95	45.40
4:29:38 AM	7	58	0.9308	0.4826	0.8469	0.9960	1.0000	0.0792	56.50	61.37	45.53
4:34:38 AM	14	60	0.8548	0.6166	0.8943	0.9976	1.0000	0.0693	56.13	60.04	47.32
4:39:38 AM	10	57	0.9033	0.4155	0.8220	0.9919	1.0000	0.1433	57.41	61.79	47.53
4:44:38 AM	19	59	0.8076	0.5496	0.8710	0.9958	1.0000	0.0972	55.23	58.63	47.57
4:49:38 AM	9	64	0.8972	0.8847	0.9802	0.9988	1.0000	0.1912	65.21	68.47	57.86
4:54:38 AM	11	64	0.8743	0.8847	0.9802	0.9994	1.0000	0.0983	61.11	64.62	53.22
4:59:38 AM	14	66	0.8320	1.0000	1.0000	1.0000	1.0000	0.1201	62.28	65.06	56.00
5:04:38 AM	16	68	0.7982	1.0000	1.0000	1.0000	1.0000	0.1576	62.94	65.19	57.88
5:09:38 AM	12	68	0.8486	1.0000	1.0000	1.0000	1.0000	0.1856	65.18	67.80	59.28

Time	q in 5 mins	u (mph)	Cee	Cv	Ctt	Cd	Cec	Cefm	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4
5:14:38 AM	18	68	0.7730	1.0000	1.0000	1.0000	1.0000	0.1392	61.65	63.73	56.96
5:19:38 AM	12	61	0.8726	0.6836	0.9168	0.9951	1.0000	0.2088	63.52	66.68	56.40
5:24:38 AM	17	61	0.8195	0.6836	0.9168	0.9967	1.0000	0.1249	59.08	62.12	52.22
5:29:38 AM	21	65	0.7541	0.9517	1.0000	1.0000	1.0000	0.1769	62.30	64.04	58.36
5:34:38 AM	22	62	0.7607	0.7507	0.9386	0.9958	1.0000	0.2329	62.55	64.35	58.49
5:39:38 AM	25	62	0.7280	0.7507	0.9386	0.9956	1.0000	0.2327	61.79	63.25	58.48
5:44:38 AM	24	65	0.7190	0.9517	1.0000	1.0000	1.0000	0.2644	64.85	65.79	62.74
5:49:38 AM	37	64	0.5774	0.8847	0.9802	0.9984	1.0000	0.2661	60.97	60.53	61.94
5:54:38 AM	37	65	0.5668	0.9517	1.0000	1.0000	1.0000	0.4040	66.71	65.36	69.72
5:59:38 AM	42	65	0.5083	0.9517	1.0000	1.0000	1.0000	0.4103	65.60	63.62	70.03
6:04:38 AM	30	70	0.6022	1.0000	1.0000	1.0000	1.0000	0.4657	70.27	68.92	73.29
6:09:38 AM	37	65	0.5668	0.9517	1.0000	1.0000	1.0000	0.3582	64.95	63.84	67.43
6:14:38 AM	39	65	0.5434	0.9517	1.0000	1.0000	1.0000	0.4103	66.41	64.79	70.03
6:19:38 AM	55	62	0.4017	0.7507	0.9386	0.9922	1.0000	0.4324	61.91	59.01	68.44
6:24:38 AM	50	62	0.4561	0.7507	0.9386	0.9890	1.0000	0.5817	68.88	65.77	75.87
6:29:38 AM	39	67	0.5202	1.0000	1.0000	1.0000	1.0000	0.5288	70.80	68.29	76.44
6:34:38 AM	50	66	0.3999	1.0000	1.0000	1.0000	1.0000	0.4458	64.83	61.52	72.29
6:39:38 AM	68	63	0.2420	0.8177	0.9597	0.9934	1.0000	0.5629	63.93	58.63	75.86
6:44:38 AM	54	63	0.3981	0.8177	0.9597	0.9910	1.0000	0.7308	73.97	69.41	84.23
6:49:38 AM	49	67	0.3971	1.0000	1.0000	1.0000	1.0000	0.5803	69.95	65.91	79.02
6:54:38 AM	58	64	0.3375	0.8847	0.9802	0.9968	1.0000	0.5600	66.72	62.32	76.62
6:59:38 AM	57	62	0.3799	0.7507	0.9386	0.9884	1.0000	0.6332	69.10	64.95	78.44
7:04:38 AM	50	60	0.4816	0.6166	0.8943	0.9803	1.0000	0.6029	68.85	66.08	75.06
7:09:38 AM	63	65	0.2624	0.9517	1.0000	1.0000	1.0000	0.5118	63.83	58.81	75.11
7:14:38 AM	62	64	0.2918	0.8847	0.9802	0.9959	1.0000	0.6986	70.99	65.41	83.54
7:19:38 AM	61	65	0.2858	0.9517	1.0000	1.0000	1.0000	0.6769	70.72	65.10	83.36
7:24:38 AM	56	63	0.3758	0.8177	0.9597	0.9920	1.0000	0.6764	71.37	66.86	81.51
7:29:38 AM	67	66	0.1959	1.0000	1.0000	1.0000	1.0000	0.6018	66.13	59.92	80.09
7:34:38 AM	65	64	0.2575	0.8847	0.9802	0.9957	1.0000	0.7544	72.34	66.13	86.32
7:39:38 AM	55	66	0.3399	1.0000	1.0000	1.0000	1.0000	0.7097	73.60	68.31	85.48
7:44:38 AM	65	62	0.2929	0.7507	0.9386	0.9890	1.0000	0.6192	66.56	61.59	77.74
7:49:38 AM	54	66	0.3519	1.0000	1.0000	1.0000	1.0000	0.6875	73.02	67.97	84.37
7:54:38 AM	52	63	0.4204	0.8177	0.9597	0.9929	1.0000	0.6080	69.78	66.07	78.10
7:59:38 AM	55	65	0.3561	0.9517	1.0000	1.0000	1.0000	0.5589	67.80	63.50	77.46
8:04:38 AM	50	66	0.3999	1.0000	1.0000	1.0000	1.0000	0.6099	71.15	66.99	80.49
8:09:38 AM	43	63	0.5207	0.8177	0.9597	0.9934	1.0000	0.5629	70.37	67.92	75.86
8:14:38 AM	39	58	0.6142	0.4826	0.8469	0.9785	1.0000	0.4621	65.09	64.59	66.19
8:19:38 AM	56	61	0.4053	0.6836	0.9168	0.9894	1.0000	0.3859	59.50	56.97	65.19
8:24:38 AM	55	62	0.4017	0.7507	0.9386	0.9888	1.0000	0.5827	67.67	63.99	75.92
8:29:38 AM	54	62	0.4126	0.7507	0.9386	0.9890	1.0000	0.5817	67.88	64.32	75.87
8:34:38 AM	52	61	0.4478	0.6836	0.9168	0.9853	1.0000	0.5711	67.58	64.53	74.41
8:39:38 AM	57	62	0.3799	0.7507	0.9386	0.9896	1.0000	0.5411	65.57	61.89	73.84
8:44:38 AM	61	62	0.3364	0.7507	0.9386	0.9886	1.0000	0.6029	66.93	62.49	76.92
8:49:38 AM	56	59	0.4330	0.5496	0.8710	0.9743	1.0000	0.6452	68.61	65.23	76.21
8:54:38 AM	43	58	0.5747	0.4826	0.8469	0.9720	1.0000	0.5636	68.03	66.61	71.20
8:59:38 AM	45	60	0.5334	0.6166	0.8943	0.9851	1.0000	0.4255	63.26	61.93	66.23
9:04:38 AM	57	58	0.4362	0.4826	0.8469	0.9775	1.0000	0.4606	60.91	58.60	66.10
9:09:38 AM	38	63	0.5764	0.8177	0.9597	0.9925	1.0000	0.5640	71.68	69.81	75.90
9:14:38 AM	62	64	0.2918	0.8847	0.9802	0.9975	1.0000	0.4084	59.84	55.75	69.04
9:19:38 AM	49	59	0.5038	0.5496	0.8710	0.9739	1.0000	0.6769	71.46	68.65	77.79
9:24:38 AM	68	63	0.2420	0.8177	0.9597	0.9935	1.0000	0.4932	61.25	56.31	72.37
9:29:38 AM	57	60	0.4090	0.6166	0.8943	0.9765	1.0000	0.7308	72.06	67.90	81.41
9:34:38 AM	62	60	0.3572	0.6166	0.8943	0.9803	1.0000	0.5834	65.23	61.29	74.08
9:39:38 AM	53	59	0.4633	0.5496	0.8710	0.9739	1.0000	0.6346	68.90	65.89	75.67
9:44:38 AM	58	60	0.3987	0.6166	0.8943	0.9817	1.0000	0.5334	64.27	61.01	71.60
9:49:38 AM	57	61	0.3947	0.6836	0.9168	0.9842	1.0000	0.5937	67.21	63.50	75.53
9:54:38 AM	52	62	0.4343	0.7507	0.9386	0.9886	1.0000	0.5931	68.82	65.43	76.44

									FPI (%)	FPI (%)	FPI (%)
Time	q in 5 mins	u (mph)	Cee	Cv	Ctt	Cd	Cec	Cefm	Sc2	Sc3	Sc4
9:59:38 AM	53	63	0.4092	0.8177	0.9597	0.9932	1.0000	0.5500	66.85	63.39	74.63
10:04:38 AM	50	65	0.4146	0.9517	1.0000	1.0000	1.0000	0.5696	69.47	65.73	77.88
10:09:38 AM	41	58	0.5944	0.4826	0.8469	0.9750	1.0000	0.5544	66.82	65.83	69.03
10:14:38 AM	56	60	0.4194	0.6166	0.8943	0.9858	1.0000	0.4057	58.90	56.64	63.99
10:19:38 AM	61	60	0.3676	0.6166	0.8943	0.9806	1.0000	0.5732	64.10	60.45	72.30
10:24:38 AM	54	61	0.4266	0.6836	0.9168	0.9834	1.0000	0.6244	68.32	64.89	76.02
10:29:38 AM	48	60	0.5023	0.6166	0.8943	0.9813	1.0000	0.5619	66.78	64.57	71.75
10:34:38 AM	65	61	0.3098	0.6836	0.9168	0.9869	1.0000	0.4913	60.54	56.59	69.41
10:39:38 AM	59	61	0.3735	0.6836	0.9168	0.9823	1.0000	0.6764	69.08	64.85	78.60
10:44:38 AM	58	61	0.3841	0.6836	0.9168	0.9840	1.0000	0.6140	66.94	63.13	75.50
10:49:38 AM	56	60	0.4194	0.6166	0.8943	0.9800	1.0000	0.6035	66.46	63.18	73.81
10:54:38 AM	57	58	0.4362	0.4826	0.8469	0.9720	1.0000	0.5732	63.86	61.15	69.93
10:59:38 AM	46	60	0.5231	0.6166	0.8943	0.9803	1.0000	0.5640	67.33	65.32	71.84
11:04:38 AM	70	60	0.2742	0.6166	0.8943	0.9841	1.0000	0.4708	58.04	53.96	67.23
11:09:38 AM	61	61	0.3522	0.6836	0.9168	0.9810	1.0000	0.7165	70.12	65.46	80.59
11:14:38 AM	60	60	0.3779	0.6166	0.8943	0.9789	1.0000	0.6348	66.69	62.83	75.36
11:19:38 AM	53	62	0.4234	0.7507	0.9386	0.9880	1.0000	0.6141	68.75	65.22	76.67
11:24:38 AM	65	57	0.3717	0.4155	0.8220	0.9692	1.0000	0.5606	60.97	57.79	68.11
11:29:38 AM	52	62	0.4343	0.7507	0.9386	0.9870	1.0000	0.6320	69.68	66.17	77.56
11:34:38 AM	58	59	0.4127	0.5496	0.8710	0.9781	1.0000	0.5500	63.36	60.41	69.98
11:39:38 AM	59	64	0.3261	0.8847	0.9802	0.9962	1.0000	0.5838	67.10	62.50	77.45
11:44:38 AM	57	61	0.3947	0.6836	0.9168	0.9840	1.0000	0.6441	68.35	64.49	77.01
11:49:38 AM	64	59	0.3520	0.5496	0.8710	0.9760	1.0000	0.5931	63.59	59.80	72.11
11:54:38 AM	58	56	0.4519	0.3485	0.7961	0.9573	1.0000	0.6441	65.03	62.38	70.98
11:59:38 AM	74	61	0.2142	0.6836	0.9168	0.9842	1.0000	0.5541	60.72	55.48	72.51
12:04:38 PM	55	63	0.3870	0.8177	0.9597	0.9903	1.0000	0.7700	74.77	69.96	85.60
12:09:38 PM	50	62	0.4561	0.7507	0.9386	0.9890	1.0000	0.5911	68.63	65.55	75.53
12:14:38 PM	71	62	0.2276	0.7507	0.9386	0.9900	1.0000	0.5288	60.97	55.87	72.43
12:19:38 PM	62	66	0.2559	1.0000	1.0000	1.0000	1.0000	0.7509	73.25	66.89	87.55
12:24:38 PM	58	62	0.3691	0.7507	0.9386	0.9876	1.0000	0.6981	70.72	66.20	80.86
12:29:38 PM	62	62	0.3255	0.7507	0.9386	0.9884	1.0000	0.6134	66.47	61.94	76.64
12:34:38 PM	43	58	0.5747	0.4826	0.8469	0.9690	1.0000	0.6557	70.20	68.49	74.02
12:39:38 PM	68	63	0.2420	0.8177	0.9597	0.9943	1.0000	0.4255	58.21	53.68	68.42
12:44:38 PM	66	60	0.3157	0.6166	0.8943	0.9765	1.0000	0.7308	68.93	63.94	80.13
12:49:38 PM	73	64	0.1661	0.8847	0.9802	0.9957	1.0000	0.6755	66.94	60.22	82.03
12:54:38 PM	62	63	0.3089	0.8177	0.9597	0.9904	1.0000	0.7970	74.01	68.26	86.95
12:59:38 PM	54	64	0.3832	0.8847	0.9802	0.9960	1.0000	0.6663	71.59	67.15	81.58
1:04:38 PM	61	63	0.3201	0.8177	0.9597	0.9929	1.0000	0.5896	66.31	61.73	76.61
1:09:38 PM	62	58	0.3867	0.4826	0.8469	0.9695	1.0000	0.6556	65.86	62.23	74.02
1:14:38 PM	74	60	0.2328	0.6166	0.8943	0.9786	1.0000	0.6134	62.52	57.28	74.29
1:19:38 PM	71	65	0.1687	0.9517	1.0000	1.0000	1.0000	0.7574	71.02	63.80	87.27
1:24:38 PM	61	59	0.3823	0.5496	0.8710	0.9701	1.0000	0.7873	71.70	67.24	81.75
1:29:38 PM	70	65	0.1805	0.9517	1.0000	1.0000	1.0000	0.6140	65.77	59.41	80.09
1:34:38 PM	61	60	0.3676	0.6166	0.8943	0.9758	1.0000	0.7762	71.86	67.17	82.39
1:39:38 PM	66	58	0.3471	0.4826	0.8469	0.9695	1.0000	0.6244	63.74	59.87	72.46
1:44:38 PM	71	61	0.2461	0.6836	0.9168	0.9821	1.0000	0.6530	65.24	59.82	77.43
1:49:38 PM	76	62	0.1732	0.7507	0.9386	0.9858	1.0000	0.7388	67.75	61.02	82.88
1:54:38 PM	58	60	0.3987	0.6166	0.8943	0.9737	1.0000	0.8038	73.62	69.11	83.75
1:59:38 PM	62	64	0.2918	0.8847	0.9802	0.9962	1.0000	0.5937	66.69	61.68	77.95
2:04:38 PM	64	61	0.3204	0.6836	0.9168	0.9831	1.0000	0.6769	67.88	63.10	78.64
2:09:38 PM	63	62	0.3147	0.7507	0.9386	0.9872	1.0000	0.6660	68.23	63.32	79.25
2:14:38 PM	81	62	0.1189	0.7507	0.9386	0.9874	1.0000	0.6663	63.72	56.81	79.27
2:19:38 PM	76	58	0.2482	0.4826	0.8469	0.9595	1.0000	0.8567	70.30	64.23	83.95
2:24:38 PM	62	60	0.3572	0.6166	0.8943	0.9737	1.0000	0.7520	70.67	66.00	81.16
2:29:38 PM	77	60	0.2017	0.6166	0.8943	0.9786	1.0000	0.6346	62.61	56.95	75.35
2:34:38 PM	82	59	0.1697	0.5496	0.8710	0.9675	1.0000	0.7881	66.80	60.16	81.76
2:39:38 PM	66	57	0.3620	0.4155	0.8220	0.9523	1.0000	0.8253	70.77	66.15	81.14

Time	q in 5 mins	u (mph)	Cee	Cv	Ctt	Cd	Cec	Cefm	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4
2:44:38 PM	91	62	0.0101	0.7507	0.9386	0.9868	1.0000	0.6418	60.26	52.36	78.04
2:49:38 PM	73	62	0.2059	0.7507	0.9386	0.9817	1.0000	0.9625	77.07	69.53	94.01
2:54:38 PM	85	56	0.1968	0.3485	0.7961	0.9513	1.0000	0.7721	64.00	58.09	77.30
2:59:38 PM	89	59	0.0988	0.5496	0.8710	0.9642	1.0000	0.8120	66.06	58.56	82.91
3:04:38 PM	71	59	0.2811	0.5496	0.8710	0.9625	1.0000	0.8958	73.47	67.41	87.08
3:09:38 PM	79	59	0.2001	0.5496	0.8710	0.9701	1.0000	0.7146	64.70	58.74	78.11
3:14:38 PM	90	62	0.0209	0.7507	0.9386	0.9841	1.0000	0.7951	66.38	57.81	85.67
3:19:38 PM	91	58	0.0999	0.4826	0.8469	0.9550	1.0000	0.9519	70.49	62.42	88.65
3:24:38 PM	93	59	0.0583	0.5496	0.8710	0.9616	1.0000	0.9004	68.49	60.14	87.30
3:29:38 PM	84	58	0.1691	0.4826	0.8469	0.9535	1.0000	0.9360	71.47	64.19	87.84
3:34:38 PM	93	57	0.1010	0.4155	0.8220	0.9511	1.0000	0.8311	64.95	57.64	81.41
3:39:38 PM	99	59	-0.0024	0.5496	0.8710	0.9608	1.0000	0.9043	67.24	58.23	87.48
3:44:38 PM	118	59	0.0000	0.5496	0.8710	0.9582	1.0000	0.9964	70.81	61.36	92.06
3:49:38 PM	111	57	0.0000	0.4155	0.8220	0.9313	1.0000	1.0000	68.93	59.73	89.61
3:54:38 PM	112	52	0.0291	0.0804	0.6829	0.8849	1.0000	1.0000	64.59	56.37	83.10
3:59:38 PM	130	45	0.0072	0.0000	0.4363	0.7936	0.8674	0.9935	58.54	50.83	75.89
4:04:38 PM	125	47	0.0140	0.0000	0.5142	0.7935	0.9278	0.9980	60.20	52.36	77.84
4:09:38 PM	134	47	0.0000	0.0000	0.5142	0.8015	0.9246	1.0000	60.00	52.00	78.00
4:14:38 PM	129	49	0.0000	0.0000	0.5858	0.8185	0.9654	1.0000	61.25	53.08	79.62
4:19:38 PM	133	50	0.0000	0.0000	0.6195	0.8395	0.9839	1.0000	61.95	53.69	80.54
4:24:38 PM	121	50	0.0000	0.0000	0.6195	0.8345	0.9836	1.0000	61.90	53.64	80.47
4:29:38 PM	140	47	0.0000	0.0000	0.5142	0.8078	0.9198	1.0000	60.02	52.01	78.02
4:34:38 PM	133	45	0.0000	0.0000	0.4363	0.7420	0.8801	1.0000	58.25	50.48	75.73
4:39:38 PM	149	40	0.0000	0.0000	0.2073	0.6553	0.7602	1.0000	54.06	46.85	70.28
4:44:38 PM	104	21	0.2156	0.0000	0.0000	0.0000	0.0000	1.0000	43.44	40.52	50.00
4:49:38 PM	122	26	0.1365	0.0000	0.0000	0.3531	0.6054	0.3726	26.70	24.95	30.61
4:54:38 PM	124	20	0.0485	0.0000	0.0000	0.0000	0.2115	0.5411	23.96	21.41	29.70
4:59:38 PM	132	22	0.0199	0.0000	0.0000	0.0000	0.4844	0.4231	21.39	18.80	27.21
5:04:38 PM	129	21	0.0270	0.0000	0.0000	0.0000	0.3852	0.4954	23.38	20.62	29.58
5:09:38 PM	140	30	0.0331	0.0000	0.0000	0.3759	0.7131	0.4621	29.01	25.58	36.72
5:14:38 PM	105	16	0.1235	0.0000	0.0000	0.0000	0.0000	0.7165	30.41	28.00	35.82
5:19:38 PM	129	20	0.0102	0.0000	0.0000	0.0203	0.5148	0.2866	16.40	14.35	21.02
5:24:38 PM	121	15	0.0000	0.0000	0.0000	0.0000	0.0601	0.4401	17.51	15.17	22.76
5:29:38 PM	120	20	0.0792	0.0000	0.0000	0.0000	0.5451	0.3096	18.98	17.50	22.29
5:34:38 PM	108	18	0.1384	0.0000	0.0000	0.0000	0.2823	0.4094	21.66	20.61	24.00
5:39:38 PM	132	24	0.0459	0.0000	0.0000	0.2349	0.6041	0.3316	21.88	19.57	27.07
5:44:38 PM	119	18	0.0507	0.0000	0.0000	0.0000	0.1388	0.5404	23.29	20.86	28.76
5:49:38 PM	118	21	0.1100	0.0000	0.0000	0.0000	0.4970	0.3654	21.37	19.99	24.48
5:54:38 PM	120	24	0.1326	0.0000	0.0000	0.1640	0.5381	0.4227	26.07	24.36	29.91
5:59:38 PM	111	20	0.1483	0.0000	0.0000	0.0000	0.2721	0.4913	24.93	23.58	27.97
6:04:38 PM	127	36	0.1176	0.0000	0.0000	0.6292	0.8379	0.3787	31.39	28.77	37.27
6:09:38 PM	131	30	0.0953	0.0000	0.0000	0.3856	0.5082	0.7799	40.79	36.62	50.17
6:14:38 PM	117	26	0.1719	0.0000	0.0000	0.1851	0.4363	0.6704	35.73	33.25	41.29
6:19:38 PM	134	38	0.0570	0.0000	0.0988	0.6553	0.8273	0.5189	36.48	32.37	45.71
6:24:38 PM	115	51	0.0230	0.0134	0.6518	0.8475	1.0000	0.8686	58.10	50.66	74.84
6:29:38 PM	87	62	0.0536	0.7507	0.9386	0.9769	1.0000	1.0000	74.95	65.66	95.83
6:34:38 PM	66	60	0.3157	0.6166	0.8943	0.9699	1.0000	0.9202	76.14	70.20	89.52
6:39:38 PM	69	61	0.2673	0.6836	0.9168	0.9821	1.0000	0.6755	66.60	61.28	78.56
6:44:38 PM	65	65	0.2390	0.9517	1.0000	1.0000	1.0000	0.7180	71.13	64.82	85.30
6:49:38 PM	74	59	0.2507	0.5496	0.8710	0.9726	1.0000	0.7207	66.13	60.65	78.45
6:54:38 PM	74	61	0.2142	0.6836	0.9168	0.9799	1.0000	0.7448	68.01	61.80	81.99
6:59:38 PM	78	62	0.1515	0.7507	0.9386	0.9852	1.0000	0.7700	68.44	61.33	84.43

Traffic composition and FPI (%) in four lanes SB I-35W

Time	q in 5 mins	u (mph)	Cs	Cee	Cv	Ctt	Cd	Cec	Cttr	Cefm	FPI (%) Sc1	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4	FPI (%) Sc5	Proposed Weights
12:04:00 AM	43	58	1.00	0.93	0.44	0.45	0.85	0.92	0.00	0.08	62.27	50.82	55.77	39.64	66.84	68.03
12:09:00 AM	51	62	1.00	0.90	0.76	0.77	0.93	0.98	0.72	0.10	68.84	59.52	63.67	50.15	72.76	73.68
12:14:00 AM	48	65	1.00	0.90	1.00	1.00	1.00	1.00	1.00	0.10	73.85	64.56	67.39	58.17	75.55	76.96
12:19:00 AM	53	62	1.00	0.90	0.78	0.80	0.93	0.99	0.81	0.10	73.48	63.63	66.31	57.57	74.74	76.36
12:24:00 AM	63	59	1.00	0.89	0.49	0.51	0.81	0.93	0.00	0.11	64.19	53.41	58.16	42.71	68.63	69.72
12:29:00 AM	54	61	1.00	0.90	0.67	0.69	0.90	0.97	0.42	0.10	70.40	59.81	62.99	52.64	72.25	73.88
12:34:00 AM	54	63	1.00	0.90	0.82	0.83	0.94	1.00	0.93	0.10	68.03	58.05	62.14	48.85	71.61	72.73
12:39:00 AM	56	62	1.00	0.90	0.76	0.78	0.92	0.98	0.74	0.11	72.16	61.96	64.85	55.45	73.64	75.27
12:44:00 AM	30	61	1.00	0.95	0.66	0.67	0.94	0.96	0.37	0.06	68.63	59.45	63.72	49.81	72.79	73.64
12:49:00 AM	38	62	1.00	0.93	0.79	0.81	0.96	0.99	0.84	0.07	70.25	60.81	64.53	52.41	73.41	74.52
12:54:00 AM	43	69	1.00	0.90	1.00	1.00	1.00	1.00	1.00	0.09	74.43	64.73	67.22	59.09	75.42	77.07
12:59:00 AM	64	64	1.00	0.88	0.89	0.90	0.96	1.00	1.00	0.12	74.52	64.61	66.99	59.24	75.25	77.00
1:04:00 AM	42	60	1.00	0.92	0.60	0.62	0.90	0.95	0.18	0.08	65.29	54.86	59.47	44.47	69.61	70.66
1:09:00 AM	39	60	1.00	0.93	0.61	0.63	0.91	0.95	0.21	0.07	69.58	59.51	63.15	51.32	72.37	73.68
1:14:00 AM	45	61	1.00	0.92	0.66	0.68	0.91	0.97	0.40	0.08	67.29	56.88	60.96	47.67	70.73	71.97
1:19:00 AM	41	62	1.00	0.92	0.73	0.75	0.94	0.98	0.63	0.08	70.52	61.29	65.05	52.83	73.79	74.84
1:24:00 AM	30	58	1.00	0.95	0.45	0.46	0.90	0.92	0.00	0.05	69.24	59.98	64.06	50.78	73.05	73.98
1:29:00 AM	27	59	1.00	0.95	0.55	0.56	0.93	0.94	0.00	0.05	67.82	58.15	62.42	48.52	71.82	72.80
1:34:00 AM	30	61	1.00	0.95	0.69	0.70	0.95	0.97	0.47	0.06	69.00	59.52	63.57	50.39	72.68	73.69
1:39:00 AM	35	61	1.00	0.94	0.66	0.68	0.93	0.96	0.38	0.06	72.39	63.45	66.83	55.82	75.13	76.24
1:44:00 AM	35	58	1.00	0.94	0.42	0.42	0.88	0.92	0.00	0.06	69.00	59.70	63.82	50.40	72.87	73.80
1:49:00 AM	50	58	1.00	0.91	0.45	0.46	0.83	0.92	0.00	0.09	71.12	60.31	63.20	53.79	72.41	74.20
1:54:00 AM	33	61	1.00	0.94	0.65	0.67	0.93	0.96	0.36	0.06	67.12	57.16	61.49	47.39	71.12	72.15
1:59:00 AM	50	58	1.00	0.91	0.45	0.46	0.83	0.92	0.00	0.09	69.18	59.06	62.77	50.69	72.08	73.39
2:04:00 AM	27	56	1.00	0.96	0.27	0.24	0.87	0.89	0.00	0.05	65.17	55.52	60.51	44.27	70.39	71.09
2:09:00 AM	27	59	1.00	0.95	0.51	0.52	0.92	0.93	0.00	0.05	63.45	53.97	59.49	41.52	69.62	70.08
2:14:00 AM	32	62	0.00	0.94	0.78	0.80	0.96	0.99	0.81	0.06	63.69	53.60	58.79	41.91	69.10	69.84
2:19:00 AM	42	65	1.00	0.91	1.00	1.00	1.00	1.00	1.00	0.08	69.20	60.30	64.54	50.72	73.41	74.19
2:24:00 AM	43	62	1.00	0.92	0.74	0.75	0.94	0.98	0.65	0.08	73.15	63.95	67.01	57.04	75.26	76.57
2:29:00 AM	37	60	1.00	0.93	0.61	0.63	0.92	0.95	0.21	0.07	68.72	59.55	63.80	49.95	72.86	73.70
2:34:00 AM	41	63	1.00	0.92	0.87	0.88	0.97	1.00	1.00	0.08	64.30	54.00	58.94	42.88	69.21	70.10
2:39:00 AM	18	64	0.00	0.96	0.89	0.90	0.99	1.00	1.00	0.04	61.55	51.84	57.77	38.49	68.33	68.70
2:44:00 AM	38	63	1.00	0.93	0.85	0.87	0.97	1.00	1.00	0.07	68.77	59.08	63.10	50.03	72.33	73.40
2:49:00 AM	47	65	1.00	0.91	0.99	0.99	1.00	1.00	1.00	0.09	70.52	61.29	65.05	52.83	73.79	74.84
2:54:00 AM	43	62	1.00	0.92	0.75	0.77	0.94	0.98	0.70	0.08	73.36	63.67	66.45	57.38	74.85	76.38
2:59:00 AM	38	62	1.00	0.93	0.78	0.80	0.95	0.99	0.80	0.07	73.05	63.66	66.66	56.88	75.00	76.38
3:04:00 AM	42	66	1.00	0.91	1.00	1.00	1.00	1.00	1.00	0.08	73.39	64.27	67.31	57.43	75.49	76.78
3:09:00 AM	39	65	1.00	0.92	0.98	0.98	1.00	1.00	1.00	0.08	70.34	61.45	65.40	52.55	74.06	74.94
3:14:00 AM	37	61	1.00	0.93	0.72	0.74	0.94	0.98	0.58	0.07	68.50	59.65	64.11	49.60	73.09	73.77
3:19:00 AM	50	65	1.00	0.90	0.97	0.98	0.99	1.00	1.00	0.10	74.53	64.30	66.53	59.25	74.90	76.79
3:24:00 AM	50	64	0.00	0.90	0.96	0.96	0.99	1.00	1.00	0.10	69.61	59.23	62.71	51.38	72.04	73.50
3:29:00 AM	45	62	0.00	0.92	0.76	0.78	0.94	0.98	0.73	0.09	67.43	56.42	60.20	47.89	70.16	71.67
3:34:00 AM	54	63	0.00	0.90	0.80	0.82	0.94	0.99	0.87	0.10	66.56	55.87	60.03	46.50	70.03	71.31
3:39:00 AM	45	64	1.00	0.91	0.89	0.90	0.97	1.00	1.00	0.09	72.66	62.21	64.84	56.26	73.63	75.43
3:44:00 AM	49	65	1.00	0.90	1.00	1.00	1.00	1.00	1.00	0.10	73.26	64.25	67.37	57.22	75.53	76.76
3:49:00 AM	45	65	1.00	0.91	1.00	1.00	1.00	1.00	1.00	0.09	72.62	63.18	66.27	56.19	74.71	76.06
3:54:00 AM	64	63	1.00	0.88	0.87	0.88	0.95	1.00	1.00	0.12	71.59	61.48	64.56	54.54	73.43	74.96
3:59:00 AM	46	58	1.00	0.92	0.43	0.43	0.84	0.92	0.00	0.08	66.32	55.29	59.36	46.11	69.52	70.94
4:04:00 AM	50	62	1.00	0.91	0.78	0.79	0.94	0.99	0.79	0.10	73.89	64.43	67.17	58.23	75.38	76.88
4:09:00 AM	58	63	1.00	0.89	0.84	0.85	0.95	1.00	0.99	0.11	72.95	63.37	66.32	56.72	74.75	76.19

Time	q in 5 mins	u (mph)	Cs	Cee	Cv	Ctt	Cd	Cec	Cttr	Cefm	FPI (%) Sc1	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4	FPI (%) Sc5	Proposed Weights
4:14:00 AM	51	63	1.00	0.90	0.86	0.87	0.96	1.00	1.00	0.10	74.90	65.13	67.47	59.84	75.61	77.33
4:19:00 AM	59	65	1.00	0.88	0.97	0.97	0.99	1.00	1.00	0.12	74.62	64.93	67.38	59.39	75.54	77.20
4:24:00 AM	62	63	1.00	0.88	0.86	0.87	0.95	1.00	1.00	0.12	70.32	60.71	64.34	52.51	73.26	74.46
4:29:00 AM	86	64	1.00	0.83	0.92	0.93	0.96	1.00	1.00	0.17	76.83	66.13	67.55	62.93	75.67	77.99
4:34:00 AM	87	66	1.00	0.82	1.00	1.00	1.00	1.00	1.00	0.18	76.22	64.87	66.15	61.96	74.62	77.16
4:39:00 AM	94	68	1.00	0.80	1.00	1.00	1.00	1.00	1.00	0.19	80.74	68.66	68.43	69.18	76.33	79.63
4:44:00 AM	90	64	0.00	0.82	0.89	0.90	0.94	1.00	1.00	0.17	73.63	61.60	63.27	57.80	72.46	75.04
4:49:00 AM	102	65	1.00	0.79	1.00	1.00	1.00	1.00	1.00	0.20	81.93	69.15	68.29	71.08	76.22	79.95
4:54:00 AM	92	67	1.00	0.81	1.00	1.00	1.00	1.00	1.00	0.19	75.04	64.69	66.73	60.07	75.06	77.05
4:59:00 AM	87	63	1.00	0.83	0.86	0.88	0.93	1.00	1.00	0.17	77.92	66.82	67.77	64.67	75.83	78.43
5:04:00 AM	128	67	1.00	0.73	1.00	1.00	1.00	1.00	1.00	0.26	79.68	67.48	67.48	67.48	75.61	78.86
5:09:00 AM	108	68	1.00	0.77	1.00	1.00	1.00	1.00	1.00	0.22	80.42	68.30	68.13	68.67	76.11	79.40
5:14:00 AM	147	67	1.00	0.69	1.00	1.00	1.00	1.00	1.00	0.30	84.23	70.75	68.96	74.77	76.73	80.99
5:19:00 AM	189	68	1.00	0.59	1.00	1.00	1.00	1.00	1.00	0.39	83.73	70.51	68.97	73.97	76.73	80.83
5:24:00 AM	178	68	1.00	0.61	1.00	1.00	1.00	1.00	1.00	0.37	86.80	72.38	69.48	78.88	77.12	82.05
5:29:00 AM	195	67	1.00	0.59	1.00	1.00	1.00	1.00	1.00	0.40	83.37	69.35	67.55	73.39	75.67	80.08
5:34:00 AM	258	68	1.00	0.45	1.00	1.00	1.00	1.00	1.00	0.53	94.91	77.06	70.47	91.86	77.86	85.09
5:39:00 AM	251	67	1.00	0.47	1.00	1.00	1.00	1.00	1.00	0.51	94.42	76.96	70.68	91.08	78.02	85.03
5:44:00 AM	282	68	1.00	0.39	1.00	1.00	1.00	1.00	1.00	0.59	96.41	77.60	70.19	94.26	77.65	85.44
5:49:00 AM	342	66	1.00	0.28	1.00	1.00	1.00	1.00	1.00	0.69	100.00	79.45	70.31	100.00	77.74	86.64
5:54:00 AM	325	67	1.00	0.31	1.00	1.00	1.00	1.00	1.00	0.67	94.47	76.97	70.66	91.15	78.00	85.03
5:59:00 AM	332	68	1.00	0.28	1.00	1.00	1.00	1.00	1.00	0.69	99.74	79.82	71.04	99.58	78.28	86.89
6:04:00 AM	330	67	1.00	0.31	1.00	1.00	1.00	1.00	1.00	0.67	99.56	79.94	71.33	99.29	78.50	86.96
6:09:00 AM	388	68	1.00	0.17	1.00	1.00	1.00	1.00	1.00	0.80	100.00	77.63	67.69	100.00	75.77	85.46
6:14:00 AM	390	66	1.00	0.19	1.00	1.00	1.00	1.00	1.00	0.79	59.59	77.83	70.04	95.35	52.54	50.59
6:19:00 AM	409	65	1.00	0.17	1.00	1.00	1.00	1.00	1.00	0.82	58.07	76.74	69.56	92.91	52.17	49.88
6:24:00 AM	472	63	1.00	0.09	0.85	0.86	0.59	1.00	1.00	0.91	97.16	76.82	68.54	95.45	76.41	84.93
6:29:00 AM	530	63	1.00	0.00	0.85	0.87	0.57	1.00	1.00	1.00	99.41	76.22	66.07	99.06	74.56	84.55
6:34:00 AM	518	63	1.00	0.00	0.86	0.87	0.58	1.00	1.00	1.00	99.95	76.86	66.61	99.92	74.96	84.96
6:39:00 AM	493	65	1.00	0.02	0.96	0.97	0.89	1.00	1.00	0.97	100.00	76.92	66.66	100.00	75.00	85.00
6:44:00 AM	532	64	1.00	0.00	0.92	0.92	0.75	1.00	1.00	1.00	99.95	76.86	66.61	99.92	74.96	84.96
6:49:00 AM	532	63	1.00	0.00	0.85	0.86	0.55	1.00	1.00	1.00	100.00	76.92	66.66	100.00	75.00	85.00
6:54:00 AM	490	63	1.00	0.00	0.85	0.86	0.59	1.00	1.00	0.94	97.04	74.95	65.92	95.27	74.44	83.72
6:59:00 AM	524	64	1.00	0.00	0.95	0.95	0.85	1.00	1.00	1.00	99.30	76.06	65.91	98.88	74.44	84.44
7:04:00 AM	492	67	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	100.00	76.97	66.73	100.00	75.05	85.03
7:09:00 AM	505	65	1.00	0.00	0.98	0.99	0.96	1.00	1.00	1.00	97.03	73.26	63.49	95.24	72.62	82.62
7:14:00 AM	572	63	1.00	0.00	0.83	0.85	0.47	1.00	0.98	1.00	94.11	72.81	64.91	90.58	73.69	82.33
7:19:00 AM	583	63	1.00	0.00	0.83	0.84	0.44	1.00	0.96	1.00	96.55	72.67	62.98	94.48	72.24	82.24
7:24:00 AM	566	56	0.00	0.08	0.29	0.27	0.00	0.89	0.00	0.97	97.53	73.87	64.02	96.04	73.02	83.02
7:29:00 AM	558	62	0.00	0.00	0.73	0.75	0.14	0.98	0.63	1.00	96.58	72.71	63.01	94.52	72.26	82.26
7:34:00 AM	559	62	1.00	0.00	0.79	0.81	0.34	0.99	0.83	1.00	96.79	72.97	63.24	94.86	72.43	82.43
7:39:00 AM	577	61	1.00	0.00	0.66	0.68	0.00	0.96	0.39	1.00	97.28	73.57	63.75	95.64	72.82	82.82
7:44:00 AM	574	60	1.00	0.00	0.57	0.58	0.00	0.95	0.05	1.00	95.34	71.19	61.69	92.55	71.28	81.28
7:49:00 AM	595	57	1.00	0.00	0.40	0.40	0.00	0.91	0.00	1.00	94.12	69.69	60.39	90.59	70.30	80.30
7:54:00 AM	571	61	1.00	0.00	0.66	0.68	0.00	0.96	0.38	1.00	56.52	71.27	62.75	90.43	47.07	46.33
7:59:00 AM	504	61	1.00	0.09	0.65	0.67	0.00	0.96	0.35	0.93	94.87	73.53	65.41	91.80	74.06	82.80
8:04:00 AM	484	60	1.00	0.13	0.62	0.63	0.00	0.96	0.23	0.89	94.51	72.90	64.76	91.22	73.58	82.39
8:09:00 AM	540	59	1.00	0.05	0.54	0.55	0.00	0.94	0.00	0.98	92.88	70.48	62.43	88.60	71.83	80.82
8:14:00 AM	545	60	1.00	0.03	0.59	0.60	0.00	0.95	0.12	1.00	95.48	72.60	63.64	92.76	72.73	82.19
8:19:00 AM	500	61	1.00	0.09	0.68	0.70	0.08	0.97	0.46	0.93	97.04	75.35	66.49	95.26	74.88	83.98

Time	q in 5 mins	u (mph)	Cs	Cee	Cv	Ctt	Cd	Cec	Cttr	Cefm	FPI (%) Sc1	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4	FPI (%) Sc5	Proposed Weights
8:24:00 AM	509	62	1.00	0.04	0.80	0.82	0.43	0.99	0.87	0.97	97.87	74.44	64.59	96.59	73.45	83.39
8:29:00 AM	517	60	1.00	0.08	0.58	0.59	0.00	0.95	0.09	0.94	94.45	73.05	65.01	91.12	73.77	82.48
8:34:00 AM	492	60	1.00	0.13	0.57	0.59	0.00	0.95	0.06	0.90	96.72	74.55	65.57	94.75	74.18	83.46
8:39:00 AM	490	58	0.00	0.16	0.46	0.47	0.00	0.93	0.00	0.87	96.30	75.46	67.18	94.09	75.39	84.05
8:44:00 AM	402	66	1.00	0.16	1.00	1.00	1.00	1.00	1.00	0.81	99.97	76.88	66.63	99.95	74.97	84.97
8:49:00 AM	403	65	1.00	0.20	0.96	0.97	0.91	1.00	1.00	0.79	100.00	78.77	69.33	100.00	77.00	86.20
8:54:00 AM	379	65	1.00	0.23	1.00	1.00	1.00	1.00	1.00	0.76	98.72	75.53	65.56	97.95	74.17	84.09
8:59:00 AM	344	67	1.00	0.28	1.00	1.00	1.00	1.00	1.00	0.70	96.50	78.21	71.01	94.40	78.26	85.84
9:04:00 AM	367	66	1.00	0.23	1.00	1.00	1.00	1.00	1.00	0.75	95.47	77.45	70.64	92.75	77.98	85.34
9:09:00 AM	334	63	0.00	0.35	0.87	0.88	0.76	1.00	1.00	0.65	61.12	79.29	71.06	97.79	53.30	51.54
9:14:00 AM	306	65	1.00	0.38	1.00	1.00	1.00	1.00	1.00	0.61	90.96	73.81	68.59	85.54	76.44	82.97
9:19:00 AM	352	66	1.00	0.27	1.00	1.00	1.00	1.00	1.00	0.71	96.62	78.24	70.98	94.59	78.24	85.86
9:24:00 AM	355	65	1.00	0.29	0.97	0.98	0.95	1.00	1.00	0.70	95.09	76.41	69.41	92.14	77.06	84.66
9:29:00 AM	315	65	1.00	0.37	0.98	0.98	0.96	1.00	1.00	0.62	97.34	78.66	71.06	95.74	78.30	86.13
9:34:00 AM	338	63	1.00	0.36	0.80	0.82	0.63	0.99	0.88	0.65	93.26	74.74	68.30	89.22	76.23	83.58
9:39:00 AM	345	67	1.00	0.27	1.00	1.00	1.00	1.00	1.00	0.71	100.00	79.96	71.05	100.00	78.30	86.98
9:44:00 AM	322	64	1.00	0.37	0.91	0.92	0.84	1.00	1.00	0.63	94.47	75.66	68.77	91.15	76.58	84.18
9:49:00 AM	321	63	1.00	0.39	0.81	0.83	0.66	0.99	0.91	0.61	97.11	78.34	70.77	95.37	78.08	85.92
9:54:00 AM	336	67	1.00	0.29	1.00	1.00	1.00	1.00	1.00	0.69	100.00	79.48	70.35	100.00	77.77	86.66
9:59:00 AM	286	63	0.00	0.45	0.86	0.87	0.77	1.00	1.00	0.55	53.77	73.89	68.49	86.04	51.37	48.03
10:04:00 AM	302	63	1.00	0.42	0.82	0.83	0.69	1.00	0.93	0.58	91.63	73.82	68.13	86.61	76.10	82.98
10:09:00 AM	280	63	1.00	0.46	0.83	0.84	0.73	1.00	0.96	0.54	93.41	75.46	69.24	89.46	76.93	84.05
10:14:00 AM	306	62	1.00	0.43	0.76	0.78	0.59	0.99	0.75	0.58	91.57	74.27	68.82	86.51	76.62	83.28
10:19:00 AM	259	64	0.00	0.49	0.90	0.91	0.86	1.00	1.00	0.50	89.68	72.91	68.21	83.48	76.16	82.39
10:24:00 AM	272	63	1.00	0.47	0.87	0.88	0.81	1.00	1.00	0.53	89.06	73.66	69.74	82.49	77.31	82.88
10:29:00 AM	297	64	1.00	0.42	0.91	0.92	0.85	1.00	1.00	0.58	94.16	75.66	68.99	90.65	76.75	84.18
10:34:00 AM	337	62	1.00	0.36	0.79	0.80	0.59	0.99	0.82	0.64	99.96	79.91	71.01	99.93	78.26	86.94
10:39:00 AM	299	63	1.00	0.43	0.84	0.85	0.73	1.00	0.99	0.58	88.76	71.41	66.70	82.02	75.03	81.42
10:44:00 AM	281	61	1.00	0.48	0.71	0.73	0.54	0.98	0.58	0.53	89.29	71.52	66.46	82.87	74.85	81.49
10:49:00 AM	302	60	1.00	0.46	0.58	0.60	0.26	0.95	0.11	0.55	91.18	73.39	67.84	85.88	75.88	82.71
10:54:00 AM	331	65	1.00	0.33	1.00	1.00	1.00	1.00	1.00	0.66	93.73	76.48	70.48	89.97	77.86	84.71
10:59:00 AM	277	63	1.00	0.46	0.87	0.88	0.80	1.00	1.00	0.54	95.38	77.21	70.36	92.61	77.77	85.19
11:04:00 AM	332	65	1.00	0.33	1.00	1.00	1.00	1.00	1.00	0.66	99.21	79.58	71.07	98.73	78.31	86.73
11:09:00 AM	266	64	1.00	0.48	0.91	0.92	0.87	1.00	1.00	0.52	87.48	71.36	67.53	79.97	75.65	81.39
11:14:00 AM	302	64	1.00	0.40	0.94	0.94	0.89	1.00	1.00	0.59	90.94	73.27	67.83	85.50	75.88	82.63
11:19:00 AM	319	64	1.00	0.38	0.89	0.90	0.80	1.00	1.00	0.62	96.86	78.37	70.98	94.97	78.24	85.94
11:24:00 AM	297	64	1.00	0.42	0.89	0.90	0.82	1.00	1.00	0.58	93.35	75.61	69.49	89.36	77.12	84.14
11:29:00 AM	294	66	1.00	0.39	1.00	1.00	1.00	1.00	1.00	0.59	93.52	76.36	70.46	89.64	77.85	84.64
11:34:00 AM	286	66	1.00	0.40	1.00	1.00	1.00	1.00	1.00	0.58	98.66	79.19	70.89	97.85	78.18	86.48
11:39:00 AM	295	63	1.00	0.43	0.84	0.86	0.74	1.00	1.00	0.57	53.00	72.86	67.55	84.79	50.66	47.36
11:44:00 AM	291	63	1.00	0.45	0.81	0.83	0.69	0.99	0.91	0.56	92.87	75.26	69.34	88.59	77.01	83.92
11:49:00 AM	326	65	1.00	0.34	1.00	1.00	1.00	1.00	1.00	0.65	97.92	78.71	70.73	96.67	78.05	86.16
11:54:00 AM	332	64	1.00	0.35	0.92	0.93	0.85	1.00	1.00	0.65	97.17	77.99	70.22	95.48	77.67	85.70
11:59:00 AM	299	64	1.00	0.41	0.91	0.92	0.85	1.00	1.00	0.58	91.62	74.31	68.85	86.59	76.65	83.31
12:04:00 PM	293	67	1.00	0.38	1.00	1.00	1.00	1.00	1.00	0.60	91.94	75.01	69.63	87.10	77.23	83.76
12:09:00 PM	274	64	1.00	0.45	0.96	0.96	0.94	1.00	1.00	0.54	94.32	76.80	70.53	90.91	77.90	84.92
12:14:00 PM	302	64	1.00	0.41	0.89	0.90	0.81	1.00	1.00	0.59	49.42	71.39	67.97	79.07	50.98	46.40
12:19:00 PM	274	65	1.00	0.45	1.00	1.00	1.00	1.00	1.00	0.54	52.88	73.58	68.67	84.61	51.51	47.83
12:24:00 PM	290	67	1.00	0.39	1.00	1.00	1.00	1.00	1.00	0.59	97.89	78.76	70.82	96.63	78.12	86.20
12:29:00 PM	287	66	1.00	0.41	1.00	1.00	1.00	1.00	1.00	0.58	97.85	78.75	70.84	96.55	78.13	86.19

Time	q in 5 mins	u (mph)	Cs	Cee	Cv	Ctt	Cd	Cec	Cttr	Cefm	FPI (%) Sc1	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4	FPI (%) Sc5	Proposed Weights
12:34:00 PM	291	63	1.00	0.44	0.83	0.85	0.73	1.00	0.98	0.56	90.98	73.82	68.60	85.57	76.45	82.98
12:39:00 PM	308	65	1.00	0.37	1.00	1.00	1.00	1.00	1.00	0.62	98.90	79.52	71.19	98.24	78.40	86.69
12:44:00 PM	300	65	1.00	0.40	0.97	0.98	0.96	1.00	1.00	0.59	96.60	77.76	70.29	94.56	77.72	85.55
12:49:00 PM	295	65	0.00	0.41	1.00	1.00	1.00	1.00	1.00	0.59	90.16	73.37	68.53	84.26	76.40	82.69
12:54:00 PM	290	63	1.00	0.44	0.85	0.87	0.76	1.00	1.00	0.56	96.81	78.27	70.88	94.90	78.17	85.88
12:59:00 PM	286	65	1.00	0.43	0.98	0.98	0.97	1.00	1.00	0.57	97.30	78.65	71.08	95.68	78.32	86.13
1:04:00 PM	307	64	1.00	0.39	0.93	0.94	0.89	1.00	1.00	0.60	96.08	77.85	70.79	93.73	78.10	85.60
1:09:00 PM	309	67	1.00	0.35	1.00	1.00	1.00	1.00	1.00	0.63	97.55	78.55	70.76	96.08	78.08	86.06
1:14:00 PM	315	63	1.00	0.39	0.87	0.89	0.78	1.00	1.00	0.61	94.53	76.28	69.63	91.24	77.23	84.58
1:19:00 PM	279	65	1.00	0.43	1.00	1.00	1.00	1.00	1.00	0.56	90.01	72.91	67.97	84.02	75.98	82.39
1:24:00 PM	302	66	1.00	0.38	1.00	1.00	1.00	1.00	1.00	0.60	92.60	75.86	70.39	88.16	77.80	84.31
1:29:00 PM	341	64	1.00	0.32	0.96	0.96	0.92	1.00	1.00	0.67	99.78	80.12	71.43	99.65	78.58	87.08
1:34:00 PM	281	63	1.00	0.46	0.87	0.88	0.80	1.00	1.00	0.54	97.05	78.06	70.41	95.27	77.81	85.74
1:39:00 PM	289	63	1.00	0.44	0.85	0.86	0.75	1.00	1.00	0.56	51.19	71.76	67.25	81.90	50.44	46.65
1:44:00 PM	312	61	1.00	0.43	0.68	0.70	0.42	0.97	0.45	0.58	94.09	75.21	68.40	90.54	76.30	83.89
1:49:00 PM	320	61	1.00	0.41	0.71	0.73	0.47	0.97	0.56	0.60	95.54	75.99	68.48	92.86	76.37	84.39
1:54:00 PM	288	65	0.00	0.42	0.98	0.99	0.98	1.00	1.00	0.57	88.09	72.28	68.43	80.94	76.33	81.99
1:59:00 PM	295	61	1.00	0.45	0.72	0.74	0.52	0.98	0.58	0.55	90.65	72.40	66.78	85.04	75.09	82.06
2:04:00 PM	327	61	1.00	0.41	0.64	0.66	0.32	0.96	0.33	0.60	88.81	71.05	66.14	82.09	74.61	81.18
2:09:00 PM	304	64	1.00	0.41	0.89	0.90	0.82	1.00	1.00	0.59	93.49	74.48	67.76	89.59	75.83	83.41
2:14:00 PM	301	62	1.00	0.44	0.72	0.74	0.52	0.98	0.61	0.57	91.91	73.40	67.32	87.06	75.49	82.71
2:19:00 PM	328	60	1.00	0.41	0.62	0.64	0.27	0.96	0.24	0.60	48.31	68.13	64.06	77.29	48.05	44.29
2:24:00 PM	299	62	1.00	0.43	0.80	0.81	0.66	0.99	0.86	0.57	92.07	74.43	68.70	87.32	76.53	83.38
2:29:00 PM	299	64	1.00	0.41	0.95	0.95	0.91	1.00	1.00	0.59	95.17	77.11	70.37	92.27	77.78	85.12
2:34:00 PM	295	63	1.00	0.44	0.82	0.84	0.71	1.00	0.94	0.57	93.05	75.98	70.24	88.88	77.69	84.39
2:39:00 PM	309	64	1.00	0.40	0.88	0.89	0.80	1.00	1.00	0.60	92.39	74.82	69.04	87.83	76.79	83.64
2:44:00 PM	357	64	1.00	0.30	0.90	0.91	0.80	1.00	1.00	0.70	99.80	78.75	69.44	99.67	77.09	86.19
2:49:00 PM	381	64	1.00	0.25	0.93	0.94	0.85	1.00	1.00	0.75	94.62	76.17	69.41	91.39	77.06	84.51
2:54:00 PM	312	65	1.00	0.37	1.00	1.00	1.00	1.00	1.00	0.62	92.36	74.69	68.87	87.77	76.66	83.55
2:59:00 PM	306	66	1.00	0.37	1.00	1.00	1.00	1.00	1.00	0.62	91.79	74.78	69.41	86.86	77.06	83.61
3:04:00 PM	354	62	1.00	0.33	0.77	0.79	0.54	0.99	0.77	0.67	54.65	73.90	67.88	87.43	50.92	48.04
3:09:00 PM	316	63	1.00	0.40	0.82	0.83	0.68	1.00	0.93	0.61	94.45	76.50	69.99	91.12	77.50	84.72
3:14:00 PM	361	64	0.00	0.29	0.92	0.93	0.84	1.00	1.00	0.71	60.91	78.82	70.53	97.46	52.90	51.23
3:19:00 PM	318	65	1.00	0.37	0.97	0.97	0.95	1.00	1.00	0.63	93.73	76.26	70.16	89.96	77.63	84.57
3:24:00 PM	328	65	1.00	0.33	1.00	1.00	1.00	1.00	1.00	0.66	98.46	79.16	70.98	97.53	78.24	86.45
3:29:00 PM	307	65	1.00	0.38	1.00	1.00	1.00	1.00	1.00	0.61	94.63	76.98	70.57	91.40	77.93	85.04
3:34:00 PM	326	66	1.00	0.33	1.00	1.00	1.00	1.00	1.00	0.66	97.83	78.89	71.05	96.53	78.30	86.28
3:39:00 PM	305	64	1.00	0.40	0.94	0.95	0.91	1.00	1.00	0.60	89.48	71.89	66.88	83.16	75.16	81.73
3:44:00 PM	410	61	1.00	0.25	0.70	0.71	0.28	0.97	0.51	0.77	95.14	75.35	67.85	92.22	75.89	83.98
3:49:00 PM	384	64	1.00	0.24	0.93	0.94	0.85	1.00	1.00	0.75	60.61	79.09	71.14	96.97	53.36	51.41
3:54:00 PM	363	63	1.00	0.31	0.82	0.83	0.62	1.00	0.92	0.70	55.30	74.80	68.72	88.47	51.54	48.62
3:59:00 PM	341	63	1.00	0.34	0.85	0.87	0.72	1.00	1.00	0.66	97.91	78.70	70.72	96.65	78.05	86.16
4:04:00 PM	343	65	1.00	0.31	0.97	0.98	0.95	1.00	1.00	0.68	94.33	76.20	69.65	90.92	77.24	84.53
4:09:00 PM	343	62	1.00	0.36	0.76	0.77	0.52	0.98	0.72	0.65	94.19	76.27	69.85	90.71	77.39	84.58
4:14:00 PM	375	63	1.00	0.28	0.82	0.84	0.63	1.00	0.95	0.72	100.00	80.21	71.41	100.00	78.56	87.14
4:19:00 PM	347	64	1.00	0.31	0.94	0.94	0.88	1.00	1.00	0.68	95.29	76.88	69.94	92.47	77.46	84.97
4:24:00 PM	337	66	1.00	0.30	1.00	1.00	1.00	1.00	1.00	0.68	95.51	77.59	70.83	92.81	78.13	85.44
4:29:00 PM	352	65	1.00	0.29	0.99	0.99	0.97	1.00	1.00	0.70	97.08	78.32	70.75	95.33	78.07	85.91
4:34:00 PM	359	65	1.00	0.28	1.00	1.00	0.99	1.00	1.00	0.71	99.82	79.68	70.77	99.72	78.08	86.79
4:39:00 PM	353	66	1.00	0.28	1.00	1.00	1.00	1.00	1.00	0.71	91.83	75.10	69.84	86.93	77.38	83.82

Time	q in 5 mins	u (mph)	Cs	Cee	Cv	Ctt	Cd	Cec	Cttr	Cefm	FPI (%) Sc1	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4	FPI (%) Sc5	Proposed Weights
4:44:00 PM	413	63	0.00	0.21	0.82	0.84	0.59	1.00	0.94	0.79	97.46	78.33	70.50	95.93	77.88	85.91
4:49:00 PM	369	67	1.00	0.22	1.00	1.00	1.00	1.00	1.00	0.76	99.27	79.74	71.25	98.83	78.44	86.83
4:54:00 PM	357	63	1.00	0.32	0.80	0.82	0.60	0.99	0.87	0.68	86.31	69.68	65.94	78.10	74.46	80.30
4:59:00 PM	388	61	1.00	0.28	0.71	0.73	0.36	0.97	0.57	0.73	92.92	74.33	67.95	88.67	75.97	83.32
5:04:00 PM	400	61	1.00	0.27	0.69	0.71	0.29	0.97	0.49	0.75	96.91	77.94	70.33	95.05	77.75	85.66
5:09:00 PM	373	60	0.00	0.34	0.58	0.59	0.07	0.95	0.08	0.68	88.75	72.47	68.23	82.00	76.17	82.11
5:14:00 PM	421	60	1.00	0.25	0.59	0.61	0.00	0.95	0.15	0.77	94.47	75.56	68.63	91.15	76.48	84.12
5:19:00 PM	418	61	1.00	0.24	0.66	0.68	0.18	0.96	0.39	0.78	98.09	78.62	70.48	96.95	77.86	86.11
5:24:00 PM	436	59	0.00	0.23	0.56	0.57	0.00	0.94	0.02	0.79	96.53	77.70	70.25	94.44	77.69	85.50
5:29:00 PM	396	61	1.00	0.27	0.71	0.73	0.33	0.97	0.55	0.74	93.70	74.95	68.30	89.92	76.23	83.72
5:34:00 PM	351	62	1.00	0.34	0.78	0.79	0.56	0.99	0.79	0.67	92.01	74.78	69.25	87.21	76.94	83.61
5:39:00 PM	355	64	1.00	0.31	0.88	0.89	0.77	1.00	1.00	0.69	96.15	77.85	70.75	93.83	78.06	85.61
5:44:00 PM	378	63	1.00	0.27	0.85	0.86	0.68	1.00	1.00	0.73	98.75	79.21	70.85	98.00	78.14	86.49
5:49:00 PM	386	61	0.00	0.30	0.64	0.66	0.19	0.96	0.32	0.71	94.74	75.34	68.13	91.58	76.10	83.98
5:54:00 PM	420	60	1.00	0.25	0.60	0.61	0.00	0.95	0.16	0.77	97.39	78.10	70.21	95.83	77.67	85.77
5:59:00 PM	362	64	1.00	0.30	0.88	0.90	0.77	1.00	1.00	0.70	98.35	78.22	69.70	97.36	77.28	85.84
6:04:00 PM	325	61	1.00	0.41	0.65	0.67	0.35	0.96	0.36	0.60	86.96	69.27	64.87	79.14	73.66	80.02
6:09:00 PM	321	61	1.00	0.41	0.71	0.72	0.46	0.97	0.54	0.60	89.31	71.94	67.06	82.90	75.30	81.76
6:14:00 PM	313	62	1.00	0.41	0.78	0.80	0.62	0.99	0.81	0.60	92.14	73.61	67.46	87.42	75.60	82.84
6:19:00 PM	366	61	1.00	0.33	0.66	0.68	0.28	0.96	0.39	0.68	90.47	73.13	67.97	84.75	75.98	82.54
6:24:00 PM	338	66	1.00	0.31	1.00	1.00	1.00	1.00	1.00	0.68	98.14	79.19	71.26	97.02	78.45	86.48
6:29:00 PM	344	66	1.00	0.29	1.00	1.00	1.00	1.00	1.00	0.69	57.71	76.90	70.03	92.34	52.53	49.99
6:34:00 PM	328	66	1.00	0.33	1.00	1.00	1.00	1.00	1.00	0.66	99.86	80.13	71.40	99.77	78.56	87.09
6:39:00 PM	313	64	1.00	0.39	0.90	0.91	0.83	1.00	1.00	0.61	96.25	77.26	69.82	94.00	77.37	85.22
6:44:00 PM	327	64	1.00	0.35	0.94	0.94	0.88	1.00	1.00	0.64	58.57	77.86	70.82	93.70	53.12	50.61
6:49:00 PM	273	64	1.00	0.46	0.91	0.92	0.86	1.00	1.00	0.53	92.32	75.44	69.98	87.71	77.49	84.03
6:54:00 PM	269	64	1.00	0.47	0.90	0.91	0.85	1.00	1.00	0.52	91.37	73.98	68.55	86.19	76.42	83.09
6:59:00 PM	271	66	1.00	0.43	1.00	1.00	1.00	1.00	1.00	0.55	93.63	75.96	69.80	89.81	77.36	84.37
7:04:00 PM	258	64	1.00	0.49	0.94	0.94	0.91	1.00	1.00	0.51	89.10	72.69	68.30	82.56	76.23	82.25
7:09:00 PM	278	63	1.00	0.46	0.86	0.88	0.79	1.00	1.00	0.54	92.34	74.87	69.15	87.74	76.87	83.67
7:14:00 PM	265	66	1.00	0.45	1.00	1.00	1.00	1.00	1.00	0.54	94.84	76.74	70.06	91.75	77.55	84.88
7:19:00 PM	257	65	1.00	0.48	1.00	1.00	1.00	1.00	1.00	0.51	92.64	75.71	70.15	88.23	77.62	84.22
7:24:00 PM	224	69	1.00	0.51	1.00	1.00	1.00	1.00	1.00	0.47	89.20	73.69	69.67	82.72	77.26	82.90
7:29:00 PM	227	68	1.00	0.51	1.00	1.00	1.00	1.00	1.00	0.47	88.26	72.93	69.24	81.22	76.94	82.41
7:34:00 PM	227	67	1.00	0.52	1.00	1.00	1.00	1.00	1.00	0.46	90.98	74.82	70.04	85.57	77.54	83.64
7:39:00 PM	221	67	1.00	0.53	1.00	1.00	1.00	1.00	1.00	0.46	92.95	75.33	69.37	88.72	77.03	83.96
7:44:00 PM	211	67	1.00	0.55	1.00	1.00	1.00	1.00	1.00	0.43	90.93	74.73	69.95	85.49	77.47	83.58
7:49:00 PM	196	66	1.00	0.60	1.00	1.00	1.00	1.00	1.00	0.39	89.61	73.91	69.70	83.38	77.28	83.04
7:54:00 PM	190	68	1.00	0.58	1.00	1.00	1.00	1.00	1.00	0.40	86.52	72.14	69.34	78.43	77.01	81.89
7:59:00 PM	210	66	1.00	0.57	1.00	1.00	1.00	1.00	1.00	0.42	87.24	72.58	69.47	79.58	77.10	82.18
8:04:00 PM	180	70	1.00	0.59	1.00	1.00	1.00	1.00	1.00	0.38	87.33	72.32	69.02	79.73	76.77	82.01
8:09:00 PM	149	66	1.00	0.70	1.00	1.00	1.00	1.00	1.00	0.30	80.49	67.90	67.50	68.78	75.63	79.13
8:14:00 PM	193	68	1.00	0.59	1.00	1.00	1.00	1.00	1.00	0.40	84.43	70.93	69.08	75.09	76.81	81.11
8:19:00 PM	181	66	1.00	0.62	1.00	1.00	1.00	1.00	1.00	0.37	46.89	70.92	69.10	75.02	51.83	46.10
8:24:00 PM	158	66	1.00	0.68	1.00	1.00	1.00	1.00	1.00	0.32	83.43	69.92	68.32	73.49	76.25	80.45
8:29:00 PM	188	64	1.00	0.63	0.92	0.93	0.92	1.00	1.00	0.37	86.20	71.40	68.50	77.92	76.38	81.41
8:34:00 PM	162	64	1.00	0.68	0.91	0.92	0.92	1.00	1.00	0.32	83.81	69.54	67.51	74.10	75.64	80.20
8:39:00 PM	185	67	1.00	0.60	1.00	1.00	1.00	1.00	1.00	0.38	83.36	70.09	68.63	73.38	76.47	80.56
8:44:00 PM	171	69	1.00	0.62	1.00	1.00	1.00	1.00	1.00	0.36	88.41	73.26	69.61	81.46	77.21	82.62
8:49:00 PM	167	67	1.00	0.65	1.00	1.00	1.00	1.00	1.00	0.34	81.61	67.70	66.42	70.58	74.82	79.01

Time	q in 5 mins	u (mph)	Cs	Cee	Cv	Ctt	Cd	Cec	Cttr	Cefm	FPI (%) Sc1	FPI (%) Sc2	FPI (%) Sc3	FPI (%) Sc4	FPI (%) Sc5	Proposed Weights
8:54:00 PM	149	68	1.00	0.68	1.00	1.00	1.00	1.00	1.00	0.31	82.37	69.69	68.74	71.79	76.56	80.30
8:59:00 PM	156	64	1.00	0.69	0.95	0.96	0.96	1.00	1.00	0.31	84.40	70.92	69.09	75.03	76.82	81.10
9:04:00 PM	136	67	1.00	0.71	1.00	1.00	1.00	1.00	1.00	0.28	83.77	70.38	68.75	74.03	76.56	80.74
9:09:00 PM	118	69	1.00	0.74	1.00	1.00	1.00	1.00	1.00	0.25	83.59	70.02	68.36	73.74	76.28	80.51
9:14:00 PM	142	68	1.00	0.69	1.00	1.00	1.00	1.00	1.00	0.30	85.97	71.65	69.01	77.56	76.77	81.57
9:19:00 PM	149	68	1.00	0.68	1.00	1.00	1.00	1.00	1.00	0.31	88.59	73.14	69.30	81.75	76.98	82.54
9:24:00 PM	169	67	1.00	0.64	1.00	1.00	1.00	1.00	1.00	0.35	86.00	71.89	69.34	77.60	77.01	81.73
9:29:00 PM	130	67	1.00	0.72	1.00	1.00	1.00	1.00	1.00	0.27	81.16	68.31	67.62	69.86	75.72	79.40
9:34:00 PM	149	67	0.00	0.68	1.00	1.00	1.00	1.00	1.00	0.31	80.96	68.51	68.04	69.54	76.04	79.53
9:39:00 PM	149	67	1.00	0.68	1.00	1.00	1.00	1.00	1.00	0.30	84.35	70.77	68.91	74.96	76.69	81.00
9:44:00 PM	140	65	1.00	0.72	0.97	0.97	0.97	1.00	1.00	0.28	81.42	68.31	67.42	70.28	75.57	79.40
9:49:00 PM	132	66	1.00	0.73	1.00	1.00	1.00	1.00	1.00	0.27	77.78	64.66	64.75	64.45	73.57	77.03
9:54:00 PM	150	70	1.00	0.66	1.00	1.00	1.00	1.00	1.00	0.32	86.62	71.90	68.91	78.60	76.69	81.73
9:59:00 PM	125	68	1.00	0.73	1.00	1.00	1.00	1.00	1.00	0.26	81.38	68.92	68.34	70.21	76.26	79.80
10:04:00 PM	115	68	1.00	0.75	1.00	1.00	1.00	1.00	1.00	0.24	79.91	68.22	68.37	67.86	76.29	79.34
10:09:00 PM	119	69	1.00	0.73	1.00	1.00	1.00	1.00	1.00	0.25	84.91	71.02	68.86	75.85	76.65	81.16
10:14:00 PM	106	67	1.00	0.77	1.00	1.00	1.00	1.00	1.00	0.22	79.73	67.89	68.02	67.57	76.02	79.13
10:19:00 PM	121	69	1.00	0.73	1.00	1.00	1.00	1.00	1.00	0.26	81.21	68.89	68.42	69.94	76.32	79.78
10:24:00 PM	122	68	1.00	0.73	1.00	1.00	1.00	1.00	1.00	0.25	80.91	68.69	68.35	69.46	76.27	79.65
10:29:00 PM	127	65	1.00	0.75	0.96	0.97	0.97	1.00	1.00	0.25	71.98	60.82	63.32	55.18	72.49	74.53
10:34:00 PM	117	67	1.00	0.75	1.00	1.00	1.00	1.00	1.00	0.24	81.60	69.25	68.67	70.56	76.50	80.01
10:39:00 PM	106	67	1.00	0.77	1.00	1.00	1.00	1.00	1.00	0.22	79.38	67.74	68.06	67.02	76.05	79.03
10:44:00 PM	109	67	1.00	0.77	1.00	1.00	1.00	1.00	1.00	0.22	82.93	69.93	68.69	72.69	76.53	80.45
10:49:00 PM	106	66	1.00	0.78	1.00	1.00	1.00	1.00	1.00	0.21	78.63	66.83	67.28	65.81	75.46	78.44
10:54:00 PM	110	63	1.00	0.79	0.82	0.83	0.89	1.00	0.92	0.21	78.19	67.18	68.10	65.10	76.08	78.67
10:59:00 PM	102	70	1.00	0.77	1.00	1.00	1.00	1.00	1.00	0.22	80.78	68.33	67.92	69.24	75.95	79.42
11:04:00 PM	95	68	1.00	0.79	1.00	1.00	1.00	1.00	1.00	0.20	81.93	69.46	68.73	71.08	76.55	80.15
11:09:00 PM	93	70	1.00	0.79	1.00	1.00	1.00	1.00	1.00	0.20	80.43	68.30	68.13	68.69	76.10	79.40
11:14:00 PM	91	68	1.00	0.80	1.00	1.00	1.00	1.00	1.00	0.19	75.97	65.76	67.62	61.55	75.72	77.74
11:19:00 PM	124	68	1.00	0.73	1.00	1.00	1.00	1.00	1.00	0.26	80.56	68.11	67.75	68.90	75.82	79.27
11:24:00 PM	91	68	1.00	0.80	1.00	1.00	1.00	1.00	1.00	0.19	77.81	66.97	68.06	64.50	76.05	78.53
11:29:00 PM	79	70	1.00	0.82	1.00	1.00	1.00	1.00	1.00	0.17	76.57	65.99	67.53	62.51	75.66	77.90
11:34:00 PM	95	67	1.00	0.80	1.00	1.00	1.00	1.00	1.00	0.19	73.63	62.49	64.56	57.81	73.43	75.62
11:39:00 PM	83	68	1.00	0.82	1.00	1.00	1.00	1.00	1.00	0.17	79.01	67.46	67.92	66.41	75.95	78.85
11:44:00 PM	65	69	1.00	0.86	1.00	1.00	1.00	1.00	1.00	0.14	75.37	65.51	67.68	60.59	75.77	77.58
11:49:00 PM	59	68	0.00	0.87	1.00	1.00	1.00	1.00	1.00	0.12	70.11	60.30	63.90	52.18	72.93	74.20
11:54:00 PM	60	66	1.00	0.87	1.00	1.00	1.00	1.00	1.00	0.12	73.45	64.28	67.28	57.52	75.46	76.78
11:59:00 PM	80	66	1.00	0.83	1.00	1.00	1.00	1.00	1.00	0.16	78.15	67.17	68.11	65.04	76.09	78.66

APPENDIX F

TRAFFIC COMPOSITION

Traffic Composition

	Daily Vehicle Miles Travel	% Traffic Composition
LDGV	58012845.9	60.06%
LDGT1	5135561.4	5.32%
LDGT2	17095922.1	17.70%
LDGT3	5225791.7	5.41%
LDGT4	2403207.9	2.49%
HDGV 2B	655359.5	0.68%
HDGV 3	229724.7	0.24%
HDGV 4	90958.2	0.09%
HDGV 5	32650.2	0.03%
HDGV 6	88626.9	0.09%
HDGV 7	29153.1	0.03%
HDGV 8A	33817.9	0.04%
HDGV 8B	5829.2	0.01%
LDDV	58243.1	0.06%
LDDT12	3915.7	0.00%
HDDV2B	1398350.6	1.45%
HDDV3	400025.5	0.41%
HDDV4	240016.1	0.25%
HDDV5	170444.7	0.18%
HDDV6	511337.6	0.53%
HDDV7	250451.1	0.26%
HDDV8A	507856.7	0.53%
HDDV8B	3466171.8	3.59%
MC	96598.8	0.10%
HDGB	31989.9	0.03%
HDDBT	111254.1	0.12%
HDDBS	200225.7	0.21%
LDDT34	112347.6	0.12%

Reference: Lubertino and Smith [39]

APPENDIX G

NITROGEN OXIDE FUNCTIONS

VEHICLE TYPE	REGRESSION MODEL	R^2
LDGV	$EF = 0.1579 + 2.229V^2 + 3.0664E\text{-}05(1/V)$	0.99
LDGT 1	$EF = 0.1827 + 1.9855V^2 + 3.747E\text{-}05(1/V)$	0.98
LDGT 2	$EF = 0.29083 + 2.7069V^2 + 4.904E\text{-}05(1/V)$	0.98
LDGT 3	$EF = 0.2132 + 2.1353V^2 + 4.554E\text{-}05(1/V)$	0.95
LDGT 4	$EF = 0.3422 + 2.878V^2 + 4.9308E\text{-}05(1/V)$	0.98
HDGV 2B	$EF = 0.8548 - 0.00724V + 2.3146E\text{-}05V^2$	0.99
HDGV 3	$EF = 1.8823 - 0.1591V + 5.1308E\text{-}05V^2$	0.99
HDGV 4	$EF = 2.4321 - 0.02062V + 6.5334E\text{-}05V^2$	0.99
HDGV 5	$EF = 3.8222 - 0.3247V + 0.000102228V^2$	0.99
HDGV 6	$EF = 1.8958 - 0.01606V + 5.1098E\text{-}05V^2$	0.99
HDGV 7	$EF = 2.6868 - 0.0228V + 7.19081E\text{-}05V^2$	0.99
HDGV 8A	$EF = 4.0646 - 0.0344V + 0.000109V^2$	0.99
HDGV 8B	$EF = 3.9078 - 0.03320V + 0.0001045V^2$	0.99
LDDV	$EF = 0.5718 - 0.0187V + 0.000291V^2$	0.99
LDDT 12	$EF = 4.012 - 0.1317V + 0.00204V^2$	0.99
HDDV 2B	$EF = 2.8849 - 0.09477V + 0.001471V^2$	0.99

Reference: Yerramalla [67]

APPENDIX H

WEIGHTING SCENARIOS

Scenario 1: without emissions

Criteria objective	Propose weights	S(i)	Normalized Weight = S(i)/ Sum (S(i))		
Improve safety	30	30	30/80	=	0.3750
Decrease on-road emission	15	0	0/80	=	0.0000
Enhance mobility	25	25	25/80	=	0.3125
Improve efficiency	25	25	25/80	=	0.3125
	Sum	80			

Scenario 2: without safety

Criteria objective	Propose weights	S(i)	Normalized Weight = S(i)/ Sum (S(i))		
Improve safety	30	0	0/65	=	0.0000
Decrease on-road emission	15	15	15/65	=	0.2308
Enhance mobility	25	25	25/65	=	0.3846
Improve efficiency	25	25	25/65	=	0.3846
	Sum	65			

Scenario 3: without safety; assuming the weights are equal

Criteria objective	Propose weights	S(i)	Normalized Weight = S(i)/ Sum (S(i))		
Improve safety	0	0	0/75	=	0.0000
Decrease on-road emission	25	25	25/75	=	0.3333
Enhance mobility	25	25	25/75	=	0.3333
Improve efficiency	25	25	25/75	=	0.3333
	Sum	75			

Scenario 4: without emissions and safety

Criteria objective	Propose weights	S(i)	Normalized Weight = S(i)/ Sum (S(i))		
Improve safety	30	0	0/50	=	0.0000
Decrease on-road emission	15	0	0/51	=	0.0000
Enhance mobility	25	25	25/50	=	0.5000
Improve efficiency	25	25	25/50	=	0.5000
	Sum	50			

Scenario 5: assuming the weights are equal

Criteria objective	Propose weights	S(i)	Normalized Weight = S(i)/ Sum (S(i))		
Improve safety	25	25	25/100	=	0.2500
Decrease on-road emission	25	25	25/101	=	0.2500
Enhance mobility	25	25	25/102	=	0.2500
Improve efficiency	25	25	25/103	=	0.2500
	Sum	100			

REFERENCES

[1]. *1998 California Transportation Plan: Transportation System Performance Measures, Final Report*, California Department of Transportation, Sacramento, August, 1998.

[2]. Ababutain, A. Y., *A Multi-Criteria Decision-Making Model for Selection of BOT Toll Road Proposals Within The Public Sector*, PhD thesis, University of Pittsburgh, 2002.

[3]. Ahmed, S., Soliman, M., and Jacko, R. B., A Quantitative Approach to the Traffic Air Quality Problem: The Traffic Air Quality Index, Air & Waste Management Association, 2008, pp. 641-646.

[4]. Ahn, K., Microscopic Fuel Consumption and Emission Modelling, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1998.

[5]. Brans, J. P. and Vincke, P. A., *A preference Organisation Method*, Management Science, 21, No. 6., 1985, pp. 647-656.

[6]. Briglia, Peter, *Freeway Operations in 2000 and Beyond. Washington*, D.C.: TRB Committee on Freeway Operations, Paper presented at the Annual Meeting of the Transportation Research Board, January, 2000.

[7]. Brydia, R. E., Schneider, W. H., Mattingly, S. P., Sattler, M. L., Upayokin, A., *Operations-Oriented Performance Measures for Freeway Management Systems: Year 1 Report*, Technical Report 0-5292-1, 2007, http://tti.tamu.edu/documents/0-5292-1.pdf, Accessed July 29, 2007.

[8]. Cambridge Systematics, *Multimodal corridor and capacity analysis manual: NCHRP Report 399*, Transportation Research Board, National Research Council, Washington, DC., 1998.

[9]. Cambridge Systematics and Texas Transportation Institute, *Traffic Congestion and Reliability: Linking Solutions to Problems: Final Report*, July 19, 2004.

[10]. Camus, R., Longo, G., and Macorini, C., *Estimation of Transit Reliability Level-of-Service Based on Automatic Vehicle Location Data*, Transportation Research Record: Journal of the Transportation Research Board, No. 1927, TRB, National Research Council, Washington D.C., 2005, pp. 277-286.

[11]. Caulfield, B., *The Application of the Transit Capacity and Quality of Service Manual on a Bus Corridor in Dublin*, Transportation Research Record: Journal of the Transportation Research Board, National Research Council, Washington D.C., 2004, CD-ROM.

[12]. Cirillo, J.A*., Interstate System Crash Research; Study II, Interim Report II*, *Public Roads* 35, 3, 1968, pp. 71-76.

[13]. Choocharukul, K., Sinha, K., Mannering, F.,*User Perceptions and Engineering Definitions of Highway Level of Service: an Exploratory Statistical Comparison,* Transportation Research Part A, 38, 2004, pp. 677–689.

[14]. Colyar, J. D., An Empirical Study of the Relationships between Macroscopic Traffic Parameters and Vehicle Emissions, North Carolina State University, Raleigh, NC., 2001

[15]. Cottrell, W. D., *Measurement of the extent and duration of freeway congestion in urbanized areas: ITE compendium of Technical Papers*, Institute of Transportation Engineers 61st Annual Meeting, Milwaukee, WI, September 22-25, 1991, pp. 427-432.

[16]. Cottrell, W. D., *Development of a Set of Measures and Two Surrogate Models of Recurring Freeway Congestion* , PhD thesis, University of Utah, 1997.

[17]. Dakey, N. C. and Helmer, O., *An experimental application of the Delphi method to the use of experts*, Management Science, Vol. 9, 1963, pp. 458-467.

[18]. Epps, A., May, A. D., and Cortelyou, D., *Developing a methodology for quantifying non-recurring freeway congestion delay; phase one: identification of alternative methodologies. Research Report UCB-ITS-RR-93-8,* Institute of Transportation Studies, University of California, Berkeley. Prepared for the California Dept. of Transportation, October, 1993.

[19]. *Federal Register, Wednesday, December 1. Part II*: Department of Transportation, Federal Highway Administration, 23 CFR Parts 500 and 626, and Federal Transit Administration, 49 CFR Part 614. Management and Monitoring Systems: Interim Final Rule.

[20]. Finch, D. J., Kompfner, P., Lockwood, C.R., Maycock, G., *Speed, Speed Limits and Crashes*, *Project Record S211G/RB/Project Report PR 58*, Transport Research Laboratory TRL, Crowthorne, Berkshire, 1994.

[21]. *Freeway Management and operations handbook*, revised in June 2006, http://ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt_handbook/chapter1_01.htm, Accessed August 6, 2007.

[22]. Garber, N. J., Gadiraju, R., *Factors Affecting Speed Variance and its Influence on Accidents*, Transportation Research Record, Washington D.C., 1213, 1989

[23]. Goletsis, Y., Psarras, J., and Samouilisdis, J., *Project Ranking in the Armenian Energy Sector Using a Multicriteria method for Groups*, Annals of Operations Research 120, Vol 135-157, 2003, pp. 135-157.

[24]. Hanks, J. W., Jr. and Lomax, T. J., *Roadway Congestion in Major Urban Areas: 1982 to 1988*, Transportation Research Record 1305: Finance, Planning, Programming, Economic Analysis, and Land Development 1991, Transportation Research Board, National Research Council, Washington, DC, pp. 177-189.

[25]. *Highway Capacity Manual, HCM 1985*, Transportation Research Board Special Report 209, Transportation Research Board, National Research Council, Washington, DC, 1985.

[26]. *Highway Capacity Manual, HCM 2000*, Transportation Research Board, National Research Council, Washington, DC, 2000.

[27]. Hwang, C.L. and Yoon, K., *Multiple Attributes Decision Making – Methods and Applications*, Springer-Verlag, Berlin, 1981.

[28]. Ikhrata, H. and P. Michell, *Technical Report of Southern California Association of Governments' Transportation Performance Indicators*, Transportation Research Record 1606, Transportation Research Board, National Research Council, Washington, D.C., 1998, pp. 103-114.

[29]. Jackson, D. L., T.L. Shaw, G. Morgan, D. McLeod, And A. Vandervalk, *Florida's Reliability Method*, Florida Department of Transportation, Tallahassee, 2000.

[30]. Jiji, D., guide for good performance measure (Beyond S.M.A.R.T.*), October 2005, http://www.i95coalition.org/PDF/Library/PerformanceMeasures/Good%20Measures%20Guide-10-25-05%20from%20Dan%20Jiji.pdf, Accessed June 26, 2007.

[31]. Kangas, A., Kangas, J., and Pykäläinen, J., *Outranking methods as tools in strategic natural resources planning*. Silva Fennica, Vol. 35(2), 2001, pp 215–227. http://www.metla.fi/silvafennica/full/sf35/sf352215.pdf

[32]. Keel, J., *Guide to Performance Measure Management: 2006 Edition*, August 2006, Report No. 06-329, http://www.lbb.state.tx.us/Performance%20Measures/PerformMeasure_ManagementGuide2006_0806.pdf, Accessed August 6, 2007.

[33]. Keeney, R., and Raiffa, H. 1976. *Decision with Multiple Objectives: Preferences and Value Trade-offs*, New York: John Wiley & Sons.

[34]. Kraft, W. H., TRANSPORTATION MANAGEMENT CENTER FUNCTIONS: NCHRP Synthesis 270, Transportation Research Board, National Research Council, Washington, DC., 1998.

[35]. Levinson, H. S., Pratt, R. H., Bay, P. N., and Douglas, G. B., *Quantifying Congestion: interim report,* Texas Transportation Institute, The Texas A&M University System, College Station, TX. Prepared for the National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, DC., 1992.

[36]. Lindley, J. A., *Quantification of Urban Freeway Congestion and Analysis of Remedial Measures, Report No. FHWA/RD-87/052*, Traffic Systems Division, Federal Highway Administration, U.S. Dept. of Transportation, McLean, VA, October, 1986.

[37]. Lomax, T., et al., *Urban Mobility Report: 2001*, Texas Transportation Institute, College Station, 2001.

[38]. Lomax, T., and Schrank, D., *Urban Mobility Study*, Texas Transportation Institute, May 2005, http://mobility.tamu.edu/ums/, Accessed June 26, 2007.

[39]. Lubertino, G. and Smith, C., *Fuel Economy in Harris County*, Houston-Galveston Area Council, March 31, 2008.

[40]. Mattingly, S. P, *Decision Theory for Performance Evaluation of New Technologies Incorporating Institutional Issues: Application to Traffic Control Implementation*, PhD thesis, University of California, Irvine, 2000.

[41]. Middle East Technical University, *Multicriteria Decision Making Analysis*, (2007), http://www.metu.edu.tr/~sbasak/chapters/Chp3_multicriteria%20decision%20analysis.pdf

[42]. Nijkamp, P., Rietveld, P., and Voogd, H., *Multicrteria Evaluation in Physical Planning*, Elsevier, Amsterdam, Netherlands, 1990.

[43]. National Transportation Operations Coalition (NTOC), *Performance Measurement Initiative. Final Report.* July 2005. http://www.ntoctalks.com/ntoc/ntoc_final_report.pdf, Accessed August 7, 2007.

[44]. Nelson/Nygaard Consulting Associates, *Comprehensive Street Classification Performance and Design Standard System. Final Working Paper: City of Seattle*, April 16, 2004, http://www.seattle.gov/transportation/docs/transitplan_3366SeattlePerformanceMeasures0416.pdf

[45]. Nelson/Nygaard Consulting Associates, *Transportation Performance Measures and Street Typoloty*, June 2006, http://www.ci.glendale.ca.us/planning/pdf_files%5CMobilityPlan/GLENDALE_PerfMeasures_StreetsRPT.pdf, Accessed July 29, 2007.

[46]. *Office of Management and Budget, Performance Measurement Challenge and Strategies*, June 2003, http://www.whitehouse.gov/omb/part/challenges_strategies.html, Accessed June 26, 2007.

[47]. Polatidis, H., Haralambopoulos, D. A., Munda, G., and Vreeker, R., *Selecting an Appropriate Multi-Criteria Decision Analysis Technique for Renewable Energy Planning*, Energy Sources, Part B., 1:181-193, 2006.

[48]. Pasarski, A*., Summary of the Recommendations of the Workshop on National Urban Congestion Monitoring, Report No. FHWA-PL-90-029*, Office of Highway Information Management, Federal Highway Administration, U.S. Dept. of Transportation, September, 1990.

[49]. Poister, T. H., *Performance Measurement in State Departments of Transportation*, NCHRP synthesis of Highway Practice 238, Transportation Research Board, National Research Council, Washington, DC., 1997.

[50]. Research and Innovative Technology Administration (RITA), Deployment Statistics, U.S. Department of Transportation, www.itsdeployment.its.dot.gov/metroresults.asp. Accessed November 03, 2008.

[51]. Rogers, M. G., *Engineering Project Appraisal: The Evaluation of Alternative Development Schemes*, Blackwell Science Ltd, 2001.

[52]. Rogers, M. G., and Bruen, M. P., *Non-monetary based decision-aid techniques in EIA – an overview*. Proceedings of the Institution of Civil Engineering. Municipal Engineer. Vol. 109, 1995, pp. 98-103.

[53]. Roy, B., and Vincke, P., *Multicriteria Analysis: Survey and New Directions*, European Journal of Operational Research, 8, 1981, pp. 207-218.

[54]. Saaty, T. L., *A scaling for priorities in hierarchical structures*, Journal of Mathematical Psychology, Vol. 15, 1977, PP. 234-81.

[55]. Sandlin, A. B. and Anderson, M. D., A Serviceability Index to Evaluate Rural Demand Response Transit System Operations, *Transportation Research Record: Journal of the Transportation Research Board,* National Research Council, Washington D.C., 2004, CD-ROM.

[56]. Shaw, T., *Performance Measures of Operational Effectiveness for Highway Segments and Systems: NCHRP Synthesis 311*, Transportation Research Board, National Research Council, Washington, DC., 2003, http://www.trb.org/publications/nchrp/nchrp_syn_311.pdf, Accessed July 29, 2007.

[57]. Skibniewski, M. J., and Chao, L, *Evaluation of Advanced Construction Technology with AHP Method*, Journal of Construction Engineering and Management, Vol. 118, No. 3 (September 1992), pp. 557-591.

[58]. Solomon, D., *Crashes on main rural highways related to speed, driver and vehicle.* In: Bureau of Public Roads, U.S. Department of Commerce, United States Government Printing Office, Washington, D.C., 1964.

[59]. Sriraj, P. S., Minor, M., Thakuriah, P., *Spatial Decision Support System for Low-Income Families: A Relocation Tool for the Chicago-Land Region*, Transportation Research Record: Journal of the Transportation Research Board, National Research Council, Washington D.C., 2006, CD-ROM.

[60]. Tang, T., Roberts, M., and Ho, C., Sensitivity Analysis of Mobile 6, The Federal Highway Administration (FHWA).

[61]. The Institute of Transportation Studies at the University of California at Berkeley and Caltrans, Traffic Management Centers, http://www.calccit.org/itsdecision/serv_and_tech/Traffic_management/TMC/tmc_summary.html. Accessed November 03, 2008.

[62]. Turner, S.M., M.E. Best, and D.L. Schrank*, Measures of Effectiveness for Major Investment Studies, Report SWUTC/96/467106-1*, Southwest Region University Transportation Center, Texas Transportation Institute, College Station, 1996.

[63]. Upayokin, A., Mattingly, S. P., and Lugo-Serrato, S.A., *Decision-Making Procedure for Assessing Performance Measures of Freeway Operations*, Transportation Research Record: Journal of the Transportation Research Board, National Research Council, Washington D.C., 2008, CD-ROM.

[64]. Vincke, P., *Multicriteria Decision Aid*, New York: Wiley, 1992.

[65]. Wang, Z., *Improving ITS Planning with Multicriteria Decision Analysis*, PhD thesis, The University of Texas at Austin, 2005.

[66]. Xin, Y., Fu, L., and Saccomanno, F. F., *Assessing Transit Level of Service along Travel Corridors Using TCQSM – A Case Study*, Transportation Research Record: Journal of the Transportation Research Board, National Research Council, Washington D.C., 2005, CDROM.

[67]. Yerramalla, A., *Vehicular Emissions Models Using Mobile6.2 and Field Data*, The University of Texas at Arlington, MS thesis, August 2007.

BIOGRAPHICAL INFORMATION

Auttawit Upayokin received Bachelor's degree in Civil Engineering from Chiang Mai University, Chiang Mai, Thailand in 1997. He worked as a Civil Engineer at Teda Construction Company, Bangkok, Thailand during 1997-1998, where his main works were assigned to design and revise circuit breakers' foundations of substations in Thailand.

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Auttawit started his studies at the University of Texas at Arlington in 2003. While a student at UTA, he worked as a Graduate Research Assistant during 2004-2008. His works involves in various transportation projects related to on-road emissions, freeway operations, and toll roads from NCTCOG, TARC, and TxDOT projects. He has authored in conference papers and publication in the Transportation Research Board (TRB). He also served as a president of Thai Student Association at UTA during 2005-2006. He was also initiated to National Scholars Honor Society and Chi Epsilon Honor Society in 2007. He worked as an intern in C&M Associates, Inc., Dallas, Texas during Summer 2008. His works was assigned to develop truck models in Hidalgo and Cameron County, Texas. He also served as a Graduate Teacher Assistant during Fall 2008 for Urban Transportation Planning class where he taught the TransCad Lab at UTA.