National Transportation Operations Coalition

NTOC

National Transportation Operations Coalition (NTOC)

Performance Measurement Initiative

Final Report

July 2005

Acknowledgements

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- American Association of State Highway and Transportation Officials (AASHTO)
- International City/County Management Association (ICMA)
- Transportation Research Board (TRB)
- Association of Metropolitan Planning Organizations (AMPO)
- American Public Works Association (APWA)
- Institute of Transportation Engineers (ITE)

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National Transportation Operations Coalition (NTOC) Operations Performance Measurement Initiative Final Report

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I. Background

Transportation professionals are increasingly pressed to demonstrate sound management decision making and resource allocation. Performance management is a method to quantify and improve performance, and engage and communicate with citizens and other stakeholders. Many jurisdictions and agencies have taken performance data into consideration when measuring progress toward strategic planning and goals for the overall organization, departments, or individuals and have successfully applied the data when making management decisions or considering financial issues.

The National Transportation Operations Coalition (NTOC) Action Team on Performance Measurement conducted an initiative to begin to define and document a few good measures for transportation operations agencies to use in measuring and documenting performance. The initiative was guided by an oversight team consisting of senior transportation professionals from North America with balanced representation from federal, state, and local transportation agencies and Metropolitan Planning Organizations (MPOs) (Appendix 1). The ICMA Center for Performance Measurement and University of Maryland Center for Advanced Transportation Technology served as the primary technical consultants to the initiative.

Initiative's Goal
To identify and begin to define a candidate list of measures —approximately ten—commonly agreed upon by federal, state, and local transportation officials

Oversight Committee
Who: Staff from state DOTs, MPOs, local government agencies
Role: Define measures, provide project evaluation, and input to the process

NTOC Team
Who: Experts in performance measurement, facilitation and transportation operations and management.
Role: Facilitate the identification and definition of measures, provide final reports, and disseminate results.

The oversight team helped to identify and define candidate performance measures and participated in the following activities:

- A one-day meeting in Washington, D.C., on November 8, 2004 (Appendix 2): Identified fourteen measure commonly agreed upon as important among the oversight team members and useful for further study

- A one and one-half day workshop in Las Vegas, Nevada, on March 2-3, 2005 (Appendix 3): Completed the process of selecting the measures and began the process of refining the measures' definitions.

The initiative also included a literature review (Appendix 4) and an electronic survey, which was distributed to transportation officials nationally to gain an understanding of the current use and usefulness of the fourteen measures identified by the oversight committee. (Appendix 5 includes the fourteen measures surveyed, the survey instrument, and the results.)

This initiative is modeled after a process developed and used by ICMA's Center for Performance Measurement to identify and define commonly acceptable and important measures among a range of jurisdictions and agencies. This process ensures that measures are identified and selected by the stakeholders who will collect the measurement data, report the information to their customers (e.g., traveling public,

elected officials, colleagues), and benefit from learning about leading practices used by others in the field.

This *comparative performance measurement* can also help to identify leading practices that can be shared among organizations to improve performance. Essential to comparative measurement is to ensure that the measures are clearly defined among organizations and that descriptors (e.g., demographics, roadway type, etc.) and data collection techniques are identified and commonly understood to put the performance measures into context for comparative purposes and to facilitate identification of effective practices.

The NTOC Team conducted the initiative with support and participation from the U.S. Department of Transportation's Federal Highway Administration. It involved participation from the following organizations:

- American Association of State Highway and Transportation Officials (AASHTO)
- International City/County Management Association (ICMA)
- Transportation Research Board (TRB)
- Association of Metropolitan Planning Organizations (AMPO)
- American Public Works Association (APWA)
- Institute of Transportation Engineers (ITE)
- University of Maryland Center for Advanced Transportation Technology.

II. Summary

Using the results of the literature search, survey, and further deliberations by the oversight committee and NTOC Team, a short list of selected measures has been prepared and defined as the basis for a national set of performance measures that can be used for internal management, external communications, and comparative measurement. Table 1 summarizes these selected measures, which are further detailed in below in IV Detailed Performance Measures Definitions.

Table 1 Summary of Measures

Measure	Definition	Sample Units of Measurement
Customer Satisfaction	A qualitative measure of customers' opinions related to the roadway management and operations services provided in a specified region.	Very satisfied Somewhat satisfied Neutral Somewhat dissatisfied Very dissatisfied Don't know/Not applicable
Extent of Congestion – Spatial	Miles of roadway within a predefined area and time period for which average travel times are 30% longer than unconstrained travel times.	Lane miles of congested conditions or Percent of congested roadways. Calculated as a ratio = 100% x (Congested Lane Miles)/(Total Lane Miles)
Extent of Congestion – Temporal	The time duration during which more than 20% of the roadway sections in a predefined area are congested as defined by the "Extent of Congestion – Spatial" performance measure.	Hours of congestion
Incident Duration	The time elapsed from the notification of an incident until all evidence of the incident has been removed from the incident scene.	Median minutes per incident
Non-Recurring Delay	Vehicle delays in excess of recurring delay for the current time-of-day, day-of-week, and day-type	Vehicle-hours
Recurring Delay	Vehicle delays that are repeatable for the current time-of-day, day-of-week, and day-type.	Vehicle-hours
Speed	The average speed of vehicles measured in a single lane, for a single direction of flow, at a specific location on a roadway	Miles per hour, feet per second, or kilometers per hour
Throughput - Person	Number of persons including vehicle occupants, pedestrians, and bicyclists traversing a roadway section in one direction per unit time. May also be the number of persons traversing a screen line in one direction per unit time.	Persons per hour
Throughput – Vehicle	Number of vehicles traversing a roadway section in one direction per unit time. May also be the number of vehicles traversing a screen line in one direction per unit time.	Vehicles per hour

Measure	Definition	Sample Units of Measurement
Travel Time - Link	The average time required to traverse a section of roadway in a single direction.	Minutes per trip
Travel Time – Reliability (BufferTime)	The Buffer Time is the additional time that must be added to a trip (measured as defined by Travel Time – Trip), to ensure that travelers making the trip will arrive at their destination at, or before, the intended time 95% of the time.	Minutes. This measure may also be expressed as a percent of total trip time or as an index.
Travel Time - Trip	The average time required to travel from an origin to a destination on a trip that might include multiple modes of travel.	Minutes per trip

III. Next Steps

In the near term, the measures summarized in Table 1 and detailed below will be widely distributed to transportation professionals to encourage the use of performance measures in general and to gain additional experience with this initial set of measures. Members of the NTOC will also continue explore ways to solicit interest and experience in the next steps.

However, this effort is just a starting point. The measures identified and the definitions provided need to be tested under real-world conditions in order to evaluate their usefulness, completeness, and accuracy. Specific approaches that could be considered as next steps with the continued input from transportation officials include:

- Identify which performance measures are appropriate for comparative measurement (i.e., to help agencies identify and learn from the processes of others and/or to permit agencies to communicate their relative performance to the public and to city, county, or state leadership)
- Establish a consistent, standard set of definitions and descriptors (collected to inform the data cleaning process and later to assist transportation managers in finding comparable peers), and data collection processes (e.g., sample size and collection techniques for each piece of data to be collected for each measure)

- Determine if data is readily available or can be collected with a reasonable amount of effort by transportation management and operations staff
- Test the data collection, processing, reporting, cleaning, and verification processes.

IV. Detailed Performance Measures Definitions

Performance Measure: Customer Satisfaction

Definition: A qualitative measure of customers' opinions related to the roadway management and operations services provided in a specified region. (See Note 1) A baseline set of questions is provided here as a resource for customer satisfaction surveys related to management and operations. Agencies may select questions from the following list, which can then be supplemented as dictated by local conditions and concerns.

- How satisfied are you with the information available from various sources (radio, TV, 511, websites, etc.) that inform you about the status of alternate routes and transportation modes before you begin a trip?
- How satisfied are you with the information available from various sources (radio, TV, 511, websites, etc.) that enable you to estimate the amount of additional time that must be added to your normal travel time to account for unexpected delays due to traffic accidents and other unusual occurrences?
- How satisfied are you with information available from various sources (radio, 511, dynamic message signs, highway advisory radio, etc.) that inform you about the status of alternate routes and transportation modes while you are traveling to your destination?
- How satisfied are you with the traffic signal operations in your region? In other words, do you feel that the number of stops and delays experienced at traffic signals are reasonable, considering the traffic conditions that exist when you are traveling?
- How satisfied are you that authorities respond and clear roadway emergencies promptly?
- How satisfied are you with the extent of traffic delays caused by work zones in your region?
- How satisfied are you with the time it takes you to commute to work?
- How satisfied are you with the time it takes you to make routine local trips?
- How satisfied are you with the time it takes you to make long-distance trips (greater than 50 miles) within your state/county/region?

Includes: Customer satisfaction with operations on freeways, arterials, corridors and regions.

Excludes: Many agencies regularly conduct customer satisfaction surveys asking questions about the entire range of services they offer. The questions in this survey are specifically restricted to highway management and operations.

Units of Measurement: Respondents should either be provided with the following multiple-choice answers to the questions being asked:

Very satisfied
Somewhat Satisfied
Neutral
Somewhat Dissatisfied
Very Dissatisfied
Don't know/Not Applicable

Or alternatively, the questions contained in this performance measure can be reformatted to elicit Agree/Disagree responses

Processing (or how to measure): It is recommended that responses be processed to provide both the distribution of answers (i.e. percent answering very satisfied, somewhat satisfied, etc.) as well as the average response. Survey results should also be analyzed by travel location and type of customer.

Typical Applications: Agency management and evaluation of the quality of service being provided to its customers. This measure can also be used for outreach to senior agency management and government officials.

Example: Given the inability of financial and personnel resources to accomplish all of the various operations tasks desired by the public, the agency wants to know the relative levels of satisfaction that exist with each of their programs (e.g. traffic incident response, dynamic sign messages, traffic signal operations, etc.)

Notes:

(1) Customers include all transportation system stakeholders (motorists, commercial vehicle operator as well as members of the public affected by transportation services (shippers, fleet operators, first responders, etc.))

Performance Measure: Extent of Congestion – Spatial (See Note 1)

Definition: Miles of roadway within a predefined area and time period, for which average travel times are 30% longer than unconstrained travel times. (See Note 2)

Includes: Individual roadways (arterials or freeways), corridors or regions.

Excludes: N/A

Units of Measurement: Units may be either:
Lane miles or centerline miles of congested conditions
Percent of congested roadways. Calculated as a ratio = 100% x (Congested Lane or Centerline Miles)/(Total Lane or Centerline Miles)

Processing (How to measure):

1. Segment the roadways included in the measurement into sections. (See Note 3)
2. Select the time period during which congestion is to be calculated. This must be a time period during which the unconstrained travel times remain constant.
3. Calculate the unconstrained travel time for the section using one of the definitions provided as Note 2.
4. Determine the average travel times for the time period of interest for each section. (See Note 4)
5. Measure the length of each section for which this calculation is made
6. Congested conditions are then equal to the sum of the lengths of the roadway sections for which the travel times are 30% greater than the unconstrained travel time.
7. The ratio is the sum of the congested roadway sections calculated in step (5) divided by the total lengths of all roadway sections included in the analysis.

Typical Applications: Planning and outreach

Example: Communication with the public of changes in roadway transportation system quality of service.

Notes:

(1) Two types of congestion have been defined, spatial (how widespread is the congestion) and temporal (how long does it last). It is possible to combine these two into a composite measure of congestion defined as lane-mile-hours of congestion with units of congested mile-hours.

(2) One of two alternative forms of unconstrained travel time may optionally be used - see definitions.

(3) A roadway section is a length of roadway being analyzed for which conditions including volume/capacity ratio, signal spacing (if applicable), land use characteristics, etc. are relatively homogenous. .

(4) Travel times may be measured either using floating car runs, or calculated based on the length of the section divided by the average speeds for that section.

Performance Measure: Extent of Congestion – Temporal (See Note 1)

Definition: The time duration during which more than 20% of the roadway sections in a predefined area are congested as defined by the "Extent of Congestion – Spatial" performance measure.

Includes: Individual roadways (arterials or freeways), corridors or regions.

Excludes: N/A

Units of Measurement: Hours of congestion

Processing (How to measure)**:**

1. Select the time period to be used for calculating hours of congestion. (The period may be 24 hours.)
2. Divide the time period into five-minute intervals.
3. Execute processing steps one through five of the "Extent of Congestion – Spatial" performance measure.
4. Identify congested sections as those for which the actual travel times are more than 30% greater than the unconstrained travel times. (See Notes 2 and 3)
5. Count the number of time periods for which more than 20% of the sections are identified as having been congested.
6. Calculate the hours of congestion as the total number of congested time periods times 5 (min./measurement) divided by 60 min./hr.

Typical Applications: Planning and outreach

Example: Communication with the public related to changes in roadway transportation system quality of service.

Notes:

(1) Two types of congestion have been defined, spatial (how widespread is the congestion) and temporal (how long does it last). It is possible to combine these two into a composite measure of congestion defined as lane-mile-hours of congestion with units of congested mile-hours.

(2) One of two alternative forms of unconstrained travel time may optionally be used - see definitions

(3) A roadway section is a length of roadway being analyzed for which conditions including volume/capacity ratio, signal spacing (if applicable), land use characteristics, etc. are relatively homogenous.

Performance Measure: Incident Duration

Definition: The time elapsed from the notification of an incident until all evidence of the incident has been removed or until response vehicles have left the the incident scene. (See Notes 1 and 2)

Includes: Localized incidents occurring on any roadway (freeways and arterials) such as crashes, disabled vehicles, and medical emergencies.

Excludes: Non-traffic incidents such as building fires, law enforcement actions. Also excludes planned events (parades, sporting events, etc.) and regional weather incidents.

Units of Measurement: Median minutes per incident

Processing (How to measure)**:** Calculating the time difference between incident notification and incident removal. Average incident durations may be calculated for specific roadway types as the numerical average of incidents occurring at the locations and the times of interest for the analysis period.

Typical Applications: Operations management

Example: Evaluating the effectiveness of service patrol routes, and actions of emergency responsers on incident duration.

Notes:

(1) Incident notification includes receipt of the fact that an incident has occurred by any public agency personnel (dispatcher, field vehicle, traffic operations center operator, etc.)

(2) Evidence of the incident includes service vehicles, emergency vehicles, vehicles and individuals involved with the incident and debris resulting from the incident.

Performance Measure: Non-Recurring Delay

Definition: Vehicle delays in excess of recurring delay for the current time-of-day, day-of-week, and day-type. (See Notes 1 and 2).

Includes: Roadway segments, roadways, selected routes, corridors, and regions.

Excludes: Not applicable

Units of Measurement: Vehicle-hours

Processing:

1. Select roadways on which delay is to be measured
2. Select time period during which delay is to be measured
3. Determine the vehicle demand on the roadway during the selected time period (See Note 3)
4. Measure the delay during the selected time period
5. Calculate the product of the delay and the demand.
6. Calculate the difference between the delay for the measurement period and the recurring delay for the same roadway segment, time-of-day, and day-type.

Typical Applications: Planning, engineering and operations

Example: Calculate the delays caused by incidents and other causes of non-recurring delay, to perform benefit cost analysis of work zone staging, special events traffic management, freeway service patrols and other traffic incident management techniques, etc..

Notes:

(1) Delay is defined as the difference between the travel time actually required to traverse a roadway segment, and the unconstrained travel time. See definitions.

(2) Day type is used to differentiate between the traffic conditions that exist during normal working days, weekends, holidays (major and minor), shopping/sale days, summer season, etc.

(3) Vehicle demand includes sum of the volume of vehicles traveling through the roadway being evaluated and vehicle queue lengths awaiting passage along the roadway. Queues may exist on freeway entrance ramps, and on mainlines during incidents. Queues at signalized intersections entering the roadway being analyzed must also be included in measurement of vehicle delay for arterials.

Performance Measure: Recurring Delay

Definition: Vehicle delays that are repeatable for the current time-of-day, day-of-week, and day-type. (See Notes 1, 2 and 3).

Includes: Roadway segments, roadways, selected routes, corridors, and regions.

Excludes: Not applicable

Units of Measurement: Vehicle-hours

Processing (How to measure):

1. Select roadways on which delay is to be measured
2. Select time period during which delay is to be measured
3. Determine the demand on the roadway during the selected time period. (See Note 3) [no need to repeat Note 3 here]
4. Measure the delay during the selected time period during normal conditions (i.e. when there are no incident or special events)
5. Calculate the product of the delay and the demand.

Typical Applications: Planning, engineering and operations. Also serves as the baseline delay for estimating non-recurring delay.

Example: Determine the reduction in delay resulting from traffic signal retiming.

Notes:

(1) Delay is repeatable when it can be forecasted when the day-of-week, time-of-day, and day-type are known.

(2) Delay is defined as the difference between the travel time actually required to traverse a roadway segment, and the unconstrained travel time. See definitions.

(3) Day type is used to differentiate between the traffic conditions that exist during normal working days, weekends, holidays (major and minor), shopping/sale days, summer season, etc.

(4) Vehicle demand includes sum of the volume of vehicles traveling through the roadway being evaluated and vehicle queue lengths awaiting passage along the roadway. Queues may exist on freeway entrance ramps, and on mainlines during incidents. Queues at signalized intersections entering the roadway being analyzed must also be included in measurement of vehicle delay for arterials.

Performance Measure: Speed (See Note 1)

Definition: The average speed of vehicles measured in a single lane, for a single direction of flow, at a specific location on a roadway (See Note 2)

Includes: Traffic flow on all roadway types, under both recurring and non-recurring traffic conditions.

Units of Measurement: Miles per hour, feet per second or kilometers per hour

Processing (How to measure)**:** The average speed is the summation of the speeds of individual vehicles divided by the number of vehicles whose speeds have been measured during a defined time period.

Typical Applications: Used by agencies for internal applications associated with the planning, engineering and real-time operations for specific segments of roadway. Used to inform the public of existing traffic conditions on websites.

Example: Measurement of speed on an arterial section for calculating traffic signal offsets.

Notes:

(1) This performance measure is designated speed. It is actually the "point mean speed". It is anticipated that this measure will be replaced by space mean speed at the time when the measurement of the latter becomes economical.

(2) The roadway location selected should be representative of speeds existing throughout the roadway. Usually the length is equal to the detection zone of a vehicle detector (single loop, multiple loop speed trap, radar, vision system, etc.)

Performance Measure: Throughput - Person

Definition: Number of persons including vehicle occupants, pedestrians and bicyclists crossing a roadway screen line in one direction per unit time. (See Note 1). May also be the number of persons traversing a screen line in one direction per unit time. (See Note 2)

Includes: People flow on all roadway types under both recurring and non-recurring traffic conditions.

Excludes: Not applicable

Units of Measurement: Persons per hour

Processing (How to measure)**:** Sum of persons carried on all modes traversing the roadway or screen line measured for the period of an hour

Typical Applications: Used by agencies to evaluate the transportation effectiveness of roadways, and to evaluate their person-carrying capacity for planning and operations purposes including evacuation planning.

Example: Person throughput can be used to compare the movement of persons on high occupancy vehicle lanes with the movement of persons on unrestricted lanes.

Notes:

(1) A roadway section is defined as a roadway of any length accommodating the flow of vehicles, pedestrians and/or bicycles, along which there are no entrances or exits that will affect the measurement of throughput.

(2) A screen line is a planning term that defines an imaginary line crossing one or more roadways, across which person flow or traffic flow is measured.

Performance Measure: Throughput - Vehicle

Definition: Number of vehicles traversing a roadway section in one direction per unit time. (See Note 1). May also be the number of vehicles traversing a screen line in one direction per unit time. (See Note 2)

Includes: Traffic flow on all roadway types under both recurring and non-recurring traffic conditions.

Excludes: Not applicable

Units of Measurement: Vehicles per hour

Processing (How to measure)**:** Sum of all types of vehicles traversing the roadway or screen line measured for the period of an hour. Each vehicle of any type both with and without trailers, receives an equal count.

Typical Applications: Used by agencies to evaluate the transportation effectiveness of roadways for planning and operations purposes.

Example: Evaluate the ability of a roadway or corridor to serve the vehicular demand between major transportation origins and destinations, such as two nearby urban regions.

Notes:

(1) A roadway section is defined as a roadway of any length accommodating the flow of all types of vehicles, along which there are no entrances or exits that will affect the measurement of throughput.

(2) A screen line is a planning term that defines an imaginary line crossing one or more roadways, across which person flow or traffic flow is measured.

Performance Measure: Travel Time - Link

Definition: The average time required to traverse a section of roadway in a single direction. (See Note 1)

Includes: Travel times on all roadway types under both recurring and non-recurring traffic conditions.

Excludes: Link travel times are applicable to a single mode and a single facility type. See Travel Time – Trip for multi-modal or multi-facility travel.

Units of Measurement: Minutes per trip

Processing (How to measure) **:** Travel time is collected for multiple of trips, during which the section of roadway is traversed using floating cars or equivalent measurement techniques. The average time is calculated as the sum of the travel times divided by the number of trips. Care must be taken to ensure that prevailing traffic and roadway conditions remain unchanged during the measurement period.

Typical Applications: Planning and operations.

Example: Comparing the travel time on an arterial section before and after the installation of new signal timing. Evaluating the impact of an incident on the travel time of a freeway section.

Notes:

(1) A section of roadway is defined by the individual or organization performing the travel time measurements. It will typically be a section of roadway between two signalized intersections or between two freeway interchanges, but it can be any desired section of roadway.

Performance Measure: Travel Time – Reliability (Buffer Time)

Definition: The buffer time describes the additional time that must be added to a trip (measured as defined by Travel Time – Trip), to ensure that travelers making the trip will arrive at their destination at, or before, the intended time, 95% of the time.

Includes: Travel times on all roadway and mode types under both recurring and non-recurring traffic conditions.

Excludes: Statistical variations in travel time that might occur due to the fact that travelers are traveling at different times of day when differing levels of traffic demand occur. This measure is intended to apply to a specific time of day, during which repeatable traffic and roadway conditions typically exist.

Units of Measurement: Minutes. This measure may also be expressed as a percent of total trip time or as an index.

Processing (How to measure)**:**

1. Multiple measurements of travel time are made for a given time of day and day of week, for which repeatable traffic and roadway conditions exist.
2. The travel times recorded during step 1 are arranged in ascending order.
3. The average of the distribution is calculated as the sum of the trip durations divided by the number of trips.
4. The top (longest) 5% of the trips is eliminated, leaving a truncated travel time list.
5. The buffer time is calculated as the difference in time between the average travel time, and the longest travel time of the truncated distribution.
6. If it is desired to express the buffer time as a percent, the calculation is made by dividing the buffer index from step (5) by the average calculated in step (3).

Typical Applications: Traveler information, outreach, evaluating the effectiveness of incident management programs.

Example: Buffer time is displayed on a traveler information website, for travelers to evaluate the time required for a rush hour commute, to ensure on-time arrivals.

Performance Measure: Travel Time - Trip

Definition: The average time required to travel from an origin to a destination on a trip that might include multiple modes of travel. (See Note 1)

Includes: Travel times on all roadway and mode types under both recurring and non-recurring traffic conditions.

Units of Measurement: Minutes per trip

Processing (How to measure)**:** Travel time is collected for multiple of trips from origin to destination. Travel time is computed as the sum of the travel time required for each mode used during the trip, including walking times and waiting times from origin to destination. The average time is calculated as the sum of the travel times divided by the number of trips. Care must be taken to ensure that prevailing traffic and roadway conditions remain unchanged during the measurement period.

Typical Applications: Traveler information and outreach.

Example: The total time required to drive to a transit stop, waiting time for a transit vehicle, transit travel time, and walking time to a destination is included in a travel time computation to enable travelers to compare their time from origin destination on alternate travel modes.

Notes:

(1) Trip time is the total elapsed time from origin destination including all modes of transportation included in the trip.

Definitions to Support Performance Measure Descriptions

Floating Car Runs: A data collection technique used to determine representative speeds and/or travel times for a section of roadway. During a floating car run, the driver attempts to drive at a representative speed by passing as many vehicles as have passed the floating car. Speeds and travel times are recorded as required for the performance measure being evaluated.

Unconstrained Speed: Two different definitions of unconstrained speed may optionally be used as the basis for the appropriate performance measures:

- Free-flow speed is the speed that occurs during good weather conditions, and with traffic densities low enough that motorist's speed is unaffected by interactions with other vehicles.
- Target speed occurs when vehicles are traveling at speeds established by operations personnel as the desired speed for a given roadway under prevailing roadway and traffic conditions

Unconstrained Travel Time: Two different definitions of unconstrained travel time may optionally be used as the basis for the appropriate performance measures:

- Free-flow travel time is defined as the time it takes motorists to traverse a roadway section when they are traveling at a speed representative of good weather conditions, and with traffic densities low enough that their speed is not affected by interactions with other vehicles.
- Target travel time is defined as the time it takes motorists to traverse a roadway section when they are traveling at speeds established by operations personnel as the desired speed for a given roadway under prevailing roadway and traffic conditions

V. Appendices

1. Oversight Team Members
2. November 8 Meeting Report
3. March 2-3 Meeting Report
4. Literature Review
5. Survey

National Transportation Operations Coalition
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Appendix 1
Performance Measurement Initiative
Oversight Team Members

Suffix	First Name	Last Name	Title	Organization	City	State
Mr.	Jacob	Snow[1]	General Manager	Regional Transportation Commission of Southern Nevada	Las Vegas	NV
Mr.	Steve	Heminger1	Executive Director	Metropoliatn Transportatin Commission (MTC)	Oakland	CA
Mr.	Rich	Siegel 1	Performance & Outreach Coordinator	City of Bellevue, WA Finance Department	Bellevue	WA
Mr.	Mike	Zezeski[1]	Director, Office of CHART and ITS Development	Maryland State Highway Administration	Hanover	MD
Mr.	Jim	Helmer[1]	Director	City of San Jose, Department of Transportation	San Jose	CA
Mr.	Sarath	Joshua[1]	ITS & Safety Program Manager	Maricopa Assoc. of Governments Business	Phoenix	AZ
Mr.	Wayne	Tanda[1]	General Manager	Los Angeles Department of Transportation	Los Angeles	CA
Mr.	Tim	Lomax[2]	Research Engineer	Texas Transportation Institute (TTI)Texas A&M University	College Station	TX
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Mr.	Toby	Rickman[2]	State Traffic Engineer	Washington State Department of Transportation	Olympia	WA

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Appendix 1
Performance Measurement Initiative
Oversight Team Members

Mr.	Harrison	Rue[3]	Executive Director	Thomas Jefferson Planning Commission	Charlottesville	VA
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Mr.	Eric T.	Hill[3]	Director, Systems Management and Operations	Metroplan Orlando	Orlando	FL
Mr.	John	Thai[3]	Principal Traffic Engineer	City of Anaheim	Anaheim	CA
Ms.	Ekke	Kok[3]	Manager, Transportation Data	Transportation Planning, City of Calgary	Calgary,	Alberta
Mr.	Bill	Kloos[3]	Signals, St. Lighting, and ITS Division Manager	City of Portland	Portland	OR
Mr.	A. Scott	Cothron, P.E.[3]	Traffic Engineer	City of Longview, Texas	Longview,	TX
Ms.	Sandra	Pedigo-Marshall[3]	Traffic Planning and Programming Manager	Washington State Department of Transportation	Olympia	WA
Ms.	Mary	Ameen[3]	Director, Strategic Policy/Planning	New Jersey Turnpike Authority	New Brunswick	NJ
Mr.	Dave	Kinnecom[3]		Utah State Department of Transportation	Salt Lake City	UT
Mr.	Doug	Henderson[3]	DCMS Business Develoment Manager	Econolite Control Products, Inc	Anaheim	CA

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National Transportation Operations Coalition

NTOC

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Introduction

An oversight committee comprised of local, state, and federal transportation and government officials met to identify and begin to define a set of performance measures that would be useful to improve transportation operations (attendee list and meeting agenda attached). This effort is part of the National Transportation Operations Coalition's (NTOC) initiative to research and recommend performance measures that can provide a common basis among federal, state and local agencies for evaluating transportation operations effectiveness. The NTOC Performance Measurement Initiative is supported the U.S. Department of Transportation Federal Highway Administration and includes participation from the members in the following Associations:

- American Association of State Highway and Transportation Officials (AASHTO),
- International City/County Management Association (ICMA)
- Transportation Research Board (TRB)
- Association of Metropolitan Planning Organizations (AMPO)
- American Public Works Association (APWA)
- Institute of Transportation Engineers (ITE)
- American Public Transportation Association (APTA)

At the onset of the meeting, Jeff Lindley, Director, Office of Operations, Federal Highway Administration (FHWA) provided the federal perspective on this initiative. Following Mr. Lindley, Phil Tarnhoff, Director of the Center for Advanced Transportation Technology, University of Maryland (UMD) and the initiative's co-manager, described the meeting's goal and objectives, including (presentation attached):

Meeting goal

A Common Set of Performance Measures for Evaluating the Management and Operations Activities of Participating Agencies

Meeting objectives

1. Define a candidate list of (about 10) performance measures for further study that address:
   - Non-recurring congestion
   - Recurring congestion

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- System-wide performance

2. Agree on high level definitions for selected measures
3. Provide input on a survey that will gain input from transportation officials nationally.

Mike Lawson, Director, ICMA's Center for Performance Measurement, provided an overview of performance measurement to ensure that the group had a common understanding about terminology (see presentation attached). In summary, Mr. Lawson described the following terms:

- Descriptors—Information about the jurisdiction or program, the way services are provided, or how resources are used (e.g., demographics)
- Inputs—Amount of resources used to produce a program or provide a service, generally expressed in expenditure or labor units (e.g., hours paid per staff)
- Outputs—Amount of a service or program provided (which represents completed work activity or effort), expressed in units of service delivered (e.g, number of lane miles swept)
- Efficiency Measures—Indicators of how well the organization is using its resources, expressed as a ratio between the amount of *input* and the amount of *output or outcome* (e.g., cost per work order completed).
- Outcome (Effectiveness) Measures—Indicators of how well a program or service is accomplishing its mission – including quality, cycle time, and customer satisfaction measures (e.g., percent of lane miles in good condition).

Performance Measurement Goals

The oversight committee then provided their input about their goals with respect to the initiative and the criteria that should be considered in selecting specific performance measures for further study and definition through this initiative:

- Focus on outcome measures—i.e., what people really care about
- Apply measures to mobility—the overall goal
- Identify measures that:
  - -Help to achieve success and allocate resources for transportation operations
  - -Help to operate and manage the system better
  - -Demonstrate how effective an agency is using its resources
  - -Identify best performers/best practices

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-Use existing data and data that is currently collected
-Use data that's observable – i.e., not only modeled
-Inform decision making—internally (management) and externally (policy makers and users
-Demonstrate that resources are being used most effectively ("getting the biggest bang for the buck")
-Are linked to the overall agency's and community's goals and objectives

- Consider measures that are comparable and can help operations compete for construction/improvement resources and other resource demands within a jurisdiction
- Consider non-transportation approaches/solutions to achieve outcomes
- Use efficiency measures to demonstrate the value of operations

Literature Review

To assist in the selection of performance measures to be considered in this initiative, a literature review was performed through the University of Maryland's Center for Transportation Technology under the direction of Mr. Tarnhoff (literature review attached). The purpose of the review was to define state-of-the-art performance transportation operations measures and to develop a set of "high level" definitions associated with those measures. The Center reviewed more than 50 relevant references and identified more than 150 different measures (many measures are variations of other, similar measures). The literature review also identified and compiled definitions for each of these measures for consideration by the committee (see Appendix A of the Literature Review)

The information identified through the literature review was compiled, organized, and presented according to roadway type (freeway, arterial and system) and recurring, non-recurring, and area-wide system performance measures. Further, measures were identified from each of the agency and customer perspectives. Tables 1 and 2 demonstrate how the measures were presented to the committee:

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Table 1 Presentation of Measures –Customer Perspective

Roadway Type	Performance Measure		
	Recurring	Non-Recurring	Area-Wide*
Freeway	Delay Metering Rate Percent Time Following Speed Travel time	Incident Characteristics Delay Metering Rate Travel Time Percent Time Following Reliability	
Arterial	Delay Cycle Failures (not in list) Stops (not in list) Travel Time	Delay Cycle Failures (not in list) Stops (not in list) Queue Characteristics Reliability	
System**	Access/Basic LOS Delay Congestion Length of Rush Hour LOS Queue Characteristics Ramps' Effect on Route choice	Access/Basic LOS Delay Queue Characteristics Ramps' Effect on Route choice	B/C Ratios Congestion Customer Satisfaction Fuel Use Noise Reliability Travel Comfort Travel Time Value of Travel Info.

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Table 2 Presentation of Measures –Agency Perspective

Roadway Type	Performance Measure		
	Recurring	Non-Recurring	Area-Wide*
Freeway	Volume Capacity Degree of Saturation Delay Density LOS Metering Rate Congestion Density Safety Speed Traffic Flow Rates	Capacity Delay Density Incident Characteristics Metering Rate Safety Traffic Flow Rates	
Arterial	Cycle Failures Delay LOS Safety Saturation Flow Rate Stops (not in list)	Delay Safety Saturation Flow Rate Stops	
System**	Congestion Delay Congestion Lane Occupancy LOS Queue Characteristics V/C Ratio	Delay Incident Characteristics Lane Occupancy Safety Queue Characteristics V/C Ratio	B/C Ratios Capacity Congestion Characteristics Corridor Mobility Index Customer Satisfaction Delay Emissions Flexibility Fuel Use Noise

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			Reliability Speed Travel Time Vehicle Miles Traveled Vehicle Throughput

Selection of Measures

The oversight committee was then challenged to select one or two measures for each cell of the two matrices (customer and agency). This selection process was accomplished through discussion and a majority vote among the committee. Table 3 summarizes the measures selected by the committee. These measures are applicable to both the agency and customer perspectives, except for those in **bold** which are applicable only to the agency perspective.

Table 3 Selected Measures

Roadway Type	Performance Measures		
	Recurring	Non-Recurring	Area-Wide
Freeway	Delay Speed Travel Time **Throughput***	Travel Time Reliability **Incident Characteristics*** **Delay***	
Arterial	Delay **Throughput*** Travel Time Intersection LOS	Reliability Travel Time **Delay*** Incident Characteristics	
System			Delay Congestion Customer Satisfaction Travel Time **Emissions*** **Safety***

*Applicable to agency perspective only

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High Level Definitions

The crux of this initiative is to identify a set of agreed upon measures by the committee and to clearly define the measures for subsequent data collection and reporting and to identify leading practices. The committee began by determining a "high level definition" for each measure with the understanding that more specific definitions would be developed in a subsequent one and one-half day meeting of the committee. Table 4 summarizes the high level definitions for each measure identified in Table 3:

Table 4 High Level Definitions

Measure	Definition	Facility Type	Comments
Customer Satisfaction	A measure of the degree to which roadway users (travelers) are satisfied with their use of the roadway system	Area-wide	• Qualitative measure based on user opinions • Likely that data collection would use questionnaire survey techniques • The definition is limited to the use of operational factors and would not include considerations such as pavement quality and aesthetics.
Extent of Congestion	Actual time or percentage of time that traffic on freeways and principal arterial streets is flowing at less than free-flow speeds. OR Percentage of travel (vehicle-miles) on freeways and principal arterial streets that is	Area-wide	• Free-flow speeds will be defined during subsequent project activities. They could be defined as either the speed limit or as a percentage of the speed limit.

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Measure	Definition	Facility Type	Comments
	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	Arterials Freeways Area-wide	• Repetitive factors include capacity deficiencies, poor signal operations, etc.
Incident Delay	The increase in travel time experienced by individuals due to incidents	Arterials Freeways	• Used internally only • Incidents are used in the broadest sense here, and include crashes, special events, construction, weather, etc.
Emissions	The noxious byproducts resulting from the combustion of fuels by vehicles traveling on the roadway system	Area-wide	• Used primarily for internal use • Includes carbon monoxide, carbon dioxide, nitrous oxides, hydrocarbons and particulates
Incident Characteristics	The time duration between incident notification, and the completion of incident removal and on-site investigation.	Arterials Freeways	• Used internally for freeways and arterials. • Time for incident identification, and resumption of normal flow conditions intentionally omitted due to difficulties of determining these variables.

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Measure	Definition	Facility Type	Comments
Intersection Level of Service	Operating conditions at an intersection described alphabetically, using "A" (best) to "F" (worst)	Arterial intersections	• As described by the Highway Capacity Manual • Included because of its current widespread use for the definition of developers' responsibilities.
Reliability	The amount of additional time that travelers must add to their average trip time, in order to be on time 95% of the time.	Arterials Freeways	• This is the "buffer index" currently used by FHWA
Safety	Total number of: • Fatalities • Injury accidents(includes fatal accidents • Injuries • Accidents that occur in a given geographic area	Area-wide	• Used internally primarily Should we also use rate (per million vehicle miles)?
Speed	The spot speed measured at a specific point on the roadway	Freeways	• Typically measured by vehicle detectors (loops, radar detectors, etc.) •
Throughput - Person	The number of people per hour that are being accommodated by a roadway segment [for this measure and the next one, if the measure was the	Arterials Freeways	• Used internally primarily • Primarily used for the evaluation of HOV facilities

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Measure	Definition	Facility Type	Comments
	maximum it could not be improved – I think what we want to measure is how much throughput is the facility carrying – operational or other improvements will increase this number]		
Throughput – Vehicle	The number per hour are being accommodated by a roadway segment	Arterials Freeways	• Used internally primarily
Travel Time – Link	The time required to travel between two roadway links	Arterials Freeways	• For arterials, links are the section of roadway between two signalized intersections or between two major intersections • For freeways, links are the section of roadway between an entrance ramp and the next consecutive exit ramp interchanges
Travel Time – OD	The time required to travel between a predefined origin and destination on a roadway network	Area-wide	• Used for evaluation of either an entire roadway facility or a network of roadways

Notes:

(1) Area-wide is defined as a geographical area that includes more than one roadway. The geographical area might be a corridor between two cities, a region that is all or part of an urban area, a central business district, or any other multi-roadway facility

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(2) Unless otherwise noted in the comments column, all of the measures are used both internally and externally. This usage refers to the category of individuals who are likely to make use of the measure. Internal users are agency personnel responsible for the operation of the roadway system. External users include the general public, travelers and elected officials.

(3) Person throughput is not a "maximum" measure. The need is for a measure that shows how many people are moving through a corridor. The maximum vehicle measure is needed to show the target for the productivity-type analyses.

Survey

Another component of the NTOC Performance Measurement Initiative is to gain input from a broader number of transportation officials about the measures identified by the oversight committee. This input would be gained through a survey that asks the degree of usefulness and ease of data collection for each measure. Survey participants would also be asked about other measures that they are using. The survey will be web-based and distributed to members of AASHTO, ITE, AMPO, APWA, and ICMA.

The committee suggested that information be added to the survey to learn if a measure would be useful from a customer or agency perspective.

Next Steps

The initiative's next steps include:

- Finalize the survey and distribute it to members of the organizations identified above
- Compile and report the survey results
- Convene a one and one-half day meeting (March 2-3) with the oversight committee to develop detailed definitions for each measure
- Develop a data collection template that assist agencies to collect and report data for each measure

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Appendix 3
Las Vegas, NV March 2-3, 2005 Meeting Report

On March 2 and 3, 2005, the National Transportation Operations Coalition's Action Team on Performance Measurement met in Las Vegas, NV to further focus and solidify its recommendation for a "few good measures" related to transportation operations. The ultimate goal is to identify approximately 10 performance measures that agencies can use to measure their progress in improving transportation system management and operations (M&O). An equally important objective is to identify measures that are useful and meaningful to the traveling public. The Action Team plans to issue its recommendations for a set of nationally significant M&O performance measures later this spring.

Barbara Yuhas, Program Director from the International City/County Management Association (ICMA), chairs the NTOC Performance Measurement Action Team. The ICMA Center for Performance Measurement and Univ. of Maryland Center for Advanced Transportation Technology serve as the primary technical consultants to the Action Team. The team itself consists of senior transportation professionals from North America, with balanced representation from federal, state and local transportation agencies and Metropolitan Planning Organizations (MPOs).
This initiative is modeled from a process developed and used by ICMA's Center for Performance Measurement to identify and define commonly acceptable and important measures among a range of jurisdictions and agencies. This process ensures that measures are identified and selected by the stakeholders who will collect the measurement data, report the information to their customers (e.g., traveling public, elected officials, colleagues), and benefit from learning others' leading practices.

The March 2005 meeting kicked off with a summary by Phil Tarnoff, Director of the Univ. of Maryland's Center for Advanced Transportation Technology, on the effort's

progress to date. "We want to identify a common set of measures so that everybody is talking the same language," Tarnoff said. Last year, he said, a literature review was conducted to help determine which M&O performance measures were in common use today, which yielded more than 50 relevant references and over 150 different measures. The intent was to identify measures that generally fall within one of three different categories: non-recurring congestion, recurring congestion, and system-wide performance.

Tarnoff said that many of the 150+ measures found in the literature search were variations of one another. In some cases, a single "high-level measure" can have many low-level variations. He cited as an example the measure *speed*, which can include *average speed*, *mainline speed*, *peak speed*, *travel speed*, and several other variants.

Last Fall following the completion of the literature search, the consulting teams met with the Action Team's Steering Committee to develop a so-called "short list" of 14 different high-level M&O measures. A questionnaire was then developed, asking respondents to rate the usefulness of each of those measures, and share whether or not the respondent's agency was currently using that measure to evaluate the effectiveness of the organization's transportation operations. That survey also invited respondents to propose other measures that they felt would be useful, if those preferred measures were not already on the list.

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Breakout Group Analysis

During its recent meeting, the Performance Measures Action Team divided into three separate breakout groups, each of which was tasked by Mike Lawson, Director of the ICMA Center for Performance Measurement, to precisely define each measure and identify practical units of measurement for four different performance measures. (Of the original group of 14 performance measures, the group felt that while "safety" measures were absolutely critical, the consensus was that this group did not have the expertise to precisely define that measure. Discussion on the complex issue of "customer satisfaction" measures was deferred to the second day for the entire group's consideration.)

Each of these groups then presented its own findings and conclusions to the entire Action Team for additional discussion and refinement. Throughout the meeting, much discussion was afforded to considerations of where particular performance measures might apply, and to whom. In several cases, team members acknowledged that current widely used measures among transportation professionals, such as "Level of Service" or "LOS," meant little to the traveling public.

Tarnoff showed examples that illustrated four different categories of interrelated performance measures, related to *input*, *output*, *intermediate outcome* (typically important to transportation agencies) and *outcome to communicate with the public.* For example, an agency's number of signal technicians might be one "input measure" affecting the "output measure" of the number of traffic signals timed every three years. The "intermediate outcome" most often measured by agencies might be either traveler delay or speed or intersection Level of Service (LOS), while the "outcome to communicate with the public" might be a shortening of travel time. One MPO representative summed up the discussion: "If we don't communicate clear and important measures to our residents, we've missed the mark," he said.

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Refining Key Measures

The three breakout groups quickly found out that while some of the measures – such as travel time – were relatively straightforward to nail down, others – including those for *extent of congestion* and *incident delay* – were not only difficult to precisely define, but thought to be potentially difficult to measure, as well. Below is a synopsis of the discussion on many of the measures under consideration.

The Action Team reached very specific definitions for these measures:

- *Throughput per person and per vehicle.* These measures related to the number of people or vehicles in all travel modes traveling through a segment of roadway.
- *Incident characteristics.* For this measure the team preferred the phrase "incident duration," which relates to the time interval between the notification of an incident to the point in time when traffic is again free flowing.
- *Recurring delay.* The team likened this measure to "delay that is predictable on a time-of-day or day-of-week basis."
- *Speed.* The team felt that "spot speed" was currently the measure to use. However, that measure might change in the future as new technologies emerge.
- *Travel time.* The team considered travel time as total trip time using any mode, and each trip could include several segments (each with an associated *segment travel time*).

The Action Team made progress in defining these measures, but acknowledged that more work is required:

- *Extent of congestion.* The team observed that a single measure may be difficult in this area, because it may make sense for it to have both a geographical component as well as a time component. The FHWA is currently supporting work in this area, which may be an appropriate starting point for definitions in this area.
- *Incident delay.* The team agreed to include all types of non-recurring delay – including delay due to incidents as well as other events such as weather conditions – in this measure, so it may be difficult to identify the precise causes of that delay.

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- *Reliability.* The team observed that the so-called *Buffer Index*, which the Mobility Monitoring Program defines as "the extra time (buffer) needed to ensure on-time arrival for most trips" is a good starting point. However, it also felt that more thought was needed about transportation system *predictability*.

The Action Team decided to drop these measures from its consideration:

- *Safety.* The Action Team participants agreed that safety is vitally important, but that it was not an appropriate measure to include in its set of measures because safety measures are actively being developed elsewhere (including NHTSA).
- *Emissions.* The team concluded that emissions measures, much like safety measures, are very important but not appropriate for this group to consider since other groups are much more expert in this area.
- *Intersection level of service.* The team also agreed that while intersection LOS was both useful and needed, it was already well defined in the Highway Capacity Manual. Further, the team felt that "travel time" might be a more useful measure for arterial roadway level of service.

  Note: The above synopsis describes only a small portion of the Action Team's discussions. Detailed definitions of the various measures will be provided in the Team's final product.

A Lively Discussion on "Customer Satisfaction"

Day two of the Action Team meeting included an extensive discussion about the need for a customer satisfaction measure or measures. Many of the team members acknowledged the difficulty in boiling down customer satisfaction to a few measures. "It's tough to get your arms around, because people are satisfied or dissatisfied with a whole range of things," one participant summarized, reflecting the group consensus. The group also felt that many of the other measures under discussion were also, in a real-sense, customer satisfaction measures.

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One participant suggested that any customer satisfaction measures should not be comparative (that is, enabling comparisons between different geographic areas or agencies). Instead, he argued, those measures should be time-based, designed to let agencies see if things are improving or getting worse.

The NTOC Action Team concluded that the issue of customer satisfaction needed to remain part of its deliberations – perhaps not in the form of a single measure but instead as some type of common survey or template. That survey would then take many of the other measures into account. Participants were asked to send to Barbara Yuhas examples of customer satisfaction surveys that their agencies currently used, as source material for this common survey/template.

Next Steps

Mike Lawson then summed up the next tasks of the Action Team. He said that he, Tarnoff, and Yuhas would summarize the results of this meeting and the prior meeting. That summary will include definitions of both those measures that were agreed upon and defined in detail at this meeting, as well as "strawman measures" that were acknowledged at this meeting to require additional thought and work. He said that the three co-authors would then pass the entire set back to the Action Team members for their "scrutiny, comments, and questions." The Action Team's final report, due out later this spring, will take that additional feedback into account, he said.

The Action Team also discussed possible future steps, once it issues its M&O performance measure recommendations. Those steps could include:

1. Pilot testing some subset of these measures in a relatively small numbers of states, cities, or counties.
2. Broadening the set of M&O measures to perhaps include additional measures for transit operations or other modes.

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3. Further refining those measures recommended in the final report – what Tarnoff called "taking them to the next level down and making them more useful" – by looking at such things as collection and measurement techniques and sample size needs.

At the conclusion of the Action Team meeting, the consensus of participants was that real progress had been made in the intensive day-and-a-half meeting. "This initiative will help transportation agencies measure and improve performance, and learn leading practices from their colleagues," Yuhas says. "The Team looks forward to disseminating the results from this part of the initiative and further engaging transportation agencies to use and test its results."

Appendix 4
Performance Measurement Initiative
Literature Review

Prepared by
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October 2004

Background

The literature search described in this report has been performed in support of the performance measures task forces of the National Transportation Operations Coalition (NTOC) and the AASHTO Subcommittee on Systems Operations and Management (SSOM). These task forces share the common objective of identifying and defining a common set of performance measures to be used nationally for the evaluation of traffic operations. This set of performance measures will provide public agencies with a common set of indices that can be used to measure the results of their traffic operations for the purposes of both internal and external communications. The indices can also be used by agencies to benchmark their performance for the purpose of assessing organizational growth, and identification of techniques used by others that might be adapted for local use.

The Performance Measures task force of the SSOM developed a business plan that defines the path to be taken for the development of a common set of measures. Work on this project is a first step toward achieving the first objective of the business plan: "the development of a common set of performance measures for evaluating the management and operations activities of participating state agencies".

Because of the breadth of the subject, this project has been restricted to performance measures associated with:

- Non-recurring congestion (for example, traffic incident management)
- Recurring congestion (for example, arterial management, traffic signal timing)
- System-wide performance (for example, travel time, reliability, congestion)

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Consideration of measures associated with other aspects of traffic operations such as weather, emergency evacuations, work zones and special events have been deferred for later study.

This literature review is one activity of a study being jointly conducted by AASHTO, ICMA (International City/County Management Association) and the University of Maryland with funding support provided by the Federal Highway Administration. The study is to be completed within one year and includes six tasks:

Task 1 – Establish and convene an oversight team
Task 2 – Define a candidate list of performance measures
Task 3 – Conduct surveys and document results
Task 4 – Conduct a literature review and interviews
Task 5 – Develop performance measure metrics and validate through a workshop
Task 6 – Final Report

The literature review identified nearly 200 unique measures. Obviously many of these measures were variations of a common higher level measure. For example, travel time measures identified include:

- Average Travel Time
- Travel Time on Hyperpaths
- Average Travel Speed
- Travel time Reduction
- Time-Dependent Travel Time
- Link Travel Time
- Travel Time Reductions
- Travel Time Predictability
- Travel Time Reliability
- Travel Time Uncertainty
- Random Travel Time
- Travel Time Index

While these measures are closely related, each one is defined in a slightly different manner. Imagine the difficulties experienced by two different agencies comparing their operations when each is using a different definition of travel time.

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Although travel time is the measure with the most variations, there are many measures with multiple definitions. This variation in the definition and use of performance measures provides graphic demonstration of the need for this project.

Results

The results of the literature search have been organized using the following process:

As required by the Contract Statement of Work, a presentation format was established that divided the measures into categories of recurring, non-recurring and area-wide performance. The term area-wide performance was substituted for system-wide performance (as used in the previous section) because of the potential confusion with the types of roadways also used in this analysis.

To reduce the number of measures to be compared, the presentation format has been further subdivided into roadway types. Three types of roadways were defined: freeways, arterials and systems (more than one roadway). Measures applicable to more than one type of facility were repeated in the listing of both facilities.

After these nine categories (three categories of measures and three types of roadways), it became obvious that there one more distinction can be drawn between the measures. That distinction is the manner in which they are used. Some measures are of value to the user (customer) and others are of more value to the agency. As a result, two tables, each containing the nine categories described above were developed. One table is labeled customer perspective and the other agency perspective. This distinction will prove valuable when the list of measures is analyzed and reduced to a smaller set of recommended measures, because it will ensure that the needs of the customer are given equal priority to the agency needs.

The format of the two tables (customer perspective and agency perspective) is shown below as Table 1.

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Table 1. Sample Performance Measure Table

Roadway Type	Performance Measures		
	Recurring	Non-Recurring	Area-Wide
Freeway			
Arterial			
System			

The performance measures identified were then analyzed to identify common characteristics. (For example, all of the performance measures identified as variations of travel time were grouped into the travel time category.) These characteristics were then grouped into the set of higher level measures entered in the table. The results of this process are presented at the end of this report as Tables 2 and 3, for the customer perspective and agency perspective respectively.

The next step was to develop lists of the component measures included in each of the higher level categories. These component measures along with their definitions are contained in Appendix A.

The references identified during the literature search on which this work is based, are listed and summarized in the bibliography contained in Appendix B.

Closing Thoughts

The results presented here will serve as the basis for the discussion to be held during the Oversight Committee meeting of November 8th. The process to be followed will be similar to the process defined here. The committee will be asked to identify the high level measures most appropriate to each of the nine categories of the two tables. The second step of this process will be the identification of the lower level measure(s) that are most representative of the higher level measures. At the conclusion of this work, a survey will be conducted to determine the acceptability and use of these measures by a representative sample of states.

During the meeting and throughout this work, emphasis will be placed on the differentiation of outputs and outcomes. Output measures are typically easier to collect and represent numerical estimates of the resources applied to the solution of a problem. Outcomes represent the end result of the activity. For example,

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incident clearance time is an outcome. This outcome will be influenced by outputs which may include the number of service patrols and the number of CCTV cameras in use. It is the outcomes that are to be emphasized throughout this process. Additional information on this subject will be presented on November 8th.

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Roadway Type	Performance Measures		
	Recurring	**Nonrecurring**	**Area-Wide**
Freeway	Vehicle Volume Delay Metering Rate Percent-Time Following (rural)	Incident Characteristics Delay Metering Rate Percent-Time Following (rural)	Reliability
Arterial	Delay Mean Start-Up Lost Time	Delay Mean Start-Up Lost Time	
System	Access/Basic Levels of Service Delay Congestion Characteristics Length of Rush Hour Level of Service (LOS) Queue Characteristics Ramps' Effect on Route Choice	Access/Basic Levels of Service Delay Level of Service (LOS) Queue Characteristics Ramps' Effect on Route Choice	Benefits & Cost Congestion Characteristics Customer Satisfaction Fuel use Noise Reliability Speed Travel Comfort Travel Time Value of Travel Information

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Table 2. Performance measures from the Customer Perspective

ROADWAY TYPE	PERFORMANCE MEASURES		
	Recurring	**Nonrecurring**	**Area-Wide**
Freeway	Congestion Characteristics Degree of Saturation Delay Density Metering Rate Traffic Flow Rates Vehicle Volume	Capacity Delay Density Incident Characteristics Metering Rate Traffic Flow Rates	Reliability Vehicle Miles Traveled Vehicle Throughput
Arterial	Delay Saturation Flow Rate	Delay Saturation Flow Rate	

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Roadway Type	Performance Measures		
	Recurring	**Nonrecurring**	**Area-Wide**
System	Congestion Characteristics Delay Lane Occupancy Level of Service (LOS) Queue Characteristics Length of Rush Hour Volume to Capacity (V/C) Ratio	Delay Lane Occupancy Level of Service (LOS) Safety Queue Characteristics Volume to Capacity (V/C) ratio	Benefit & Cost Capacity Congestion Characteristics Corridor Mobility Index Customer Satisfaction Delay Emission Evacuation Clearance Time Flexibility Fuel Use Noise Queue Characteristics Reliability Speed Travel Time Vehicle Miles Traveled

Table 3. Performance Measures from the Agency Perspective

Appendix 4
Performance Measurement Initiative
Literature Review

Appendices

Appendix A – Performance Measures and Their Definitions

Appendix B – Bibliography of Performance Measures

APPENDIX A – PERFORMANCE MEASURES AND THEIR DEFINITIONS

Performance Measures	Component Measures	Definitions
Access/Basic Levels of Service	Access/Basic Levels of Service	1. Services provided to meet personal travel and shipping needs, includes • Percentage of people with satisfactory transit options • Miles of trunk highway spring weight restrictions • Percentage of people satisfied with travel information
Benefit & Costs	Benefit to Cost Ratio (BCR)	1. The ratio between the present value of benefits and the present value of countermeasure costs.
Benefit & Costs	Operational Treatment Savings	1. Delay and cost savings by operational treatments, including freeway incident management (i), freeway ramp metering (r) arterial street signal coordination (s) and arterial street access management.
Benefit & Costs	Cost of Highway Crashes	1. Indication of economic costs, including medical bills and property damage, by crash type.
Benefit & Costs	Cost of Transportation	1. Cost of operation, maintenance, etc
Benefit & Costs	Economic Benefit to Cost Ratio	1. Benefit/cost ratio of major state transportation projects
Benefit & Costs	Safety Benefit	1. Economic feasibility of implementing a road safety improvement
Benefit & Costs	Smell's Travel Disutility Cost	1. Measure of disutility associated with a trip by assigning a cost to the duration of travel time and how early or late one reaches one's destination 2. aT +b SDE + 2c(SDE)^2+ dSDL +eD, where T is travel time, SDE is schedule delay early, SDL is schedule delay late, D is late arrival index, & a, b, c, d, e are estimates of cost parameters

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Benefit & Costs	Travel costs	1. Incorporates the value of time, travel time reliability factors, longer travel times, higher vehicle operating costs, congestion related accident cost 2. Value of drivers time during a trip and any expenses incurred during the trip (vehicle ownership and operating expenses, tolls, or tariffs)
Benefit & Costs	User Delay Cost	1. Represented by an average cost per vehicle hour 2. Expressed in dollars per vehicle hour (C/vh)
Benefit & Costs	Work Zone Cost	1. The sum of the user delay, accident, and maintenance costs. The number of lane closures, darkness factor, and seasonal variation travel demand are taken into account
Capacity	Accident capacity	1. Minimum 10-min flow rate measured in the bottleneck area created by an accident.
Capacity	Accident Capacity Reduction	1. The proportion of capacity available under incident conditions.
Capacity	Capacity	1. Maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a given point or uniform section of lane or roadway during a given time period under prevailing roadway, traffic, and control conditions
Capacity	Decongesting Capacity	1. The increasing capacity by reversing lanes on thruways without fixed medians, and creating contra-flow lanes on divided highways.
Capacity	Economic Capacity	1. Volume of traffic or the level of throughput for a given time period so that the difference between total benefits and total costs are maximized 2. Uses probability or cost-benefit analysis to determine optimal capacity
Capacity	Effective Capacity	1. Maximum potential rate at which persons or vehicles may traverse a network under a representative composite of roadway conditions

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Capacity	Evacuation Capacity	1. The capacity that the highway infrastructure can provide to accommodate the movement of larger populations during the evacuation.
Capacity	Mean Capacity Reduction	1. Results from accidents which are beyond the physical blockage of lanes
Capacity	Minor Stream Capacity	1. Capacity of a minor stream merging into a major stream
Capacity	Network Reserve Capacity	1. Additional demand that can be accommodated by a road network without changing the physical characteristics of the road network and without exceeding the capacities of all its links
Congestion Characteristics	Amount of Congested Travel	1. Amount of travel that occurs in congestion 2. Summation of length of a congested segments vehicle traffic or person volume associated with the appropriate time period over all segments
Congestion Characteristics	Average Congestion Levels	1. Measures general purpose lane congestion patterns at different points (mileposts) along each study corridor
Congestion Characteristics	Cost of Congestion	1. The value of the extra time and fuel that is consumed during congested travel. 2. Value of travel time delay (estimated at $13.45 per hour of person travel and $71.05 per hour of truck time) and excess fuel consumption (estimated using state average cost per gallon). 3. Cost imposed on the system as a whole by the additions of a single vehicle to the traffic stream. 4. Estimated by the wasted fuel and time.
Congestion Characteristics	Congestion Frequency	1. Refers to the likelihood that significantly congested traffic will occur at a particular location and time of day, based on data from the entire year
Congestion Characteristics	Congestion Pattern	1. How traffic conditions change from location to location along an HOV lane and GP lane in different traffic periods.

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Congestion Characteristics	Duration of Congestion	1. Period of congestion
Congestion Characteristics	Frequency of Heavy Congestion	1. Tells likelihood of a "slow" trip as measured by the average trip speed 2. Measure describes how often a facility experiences "bad" traffic conditions 3. Likelihood that significantly congested traffic will be encountered at a location at a given time of day
Congestion Characteristics	Freeway congestion levels	1. Below 15,000 ADT/lane (Uncongested), 15,000 to 17,500 ADT/lane (Moderate), 17,501 to 20,000 ADT/lane (Heavy), 20,001 to 25,000 ADT/lane (Severe), and over 25,000 ADT/lane (Extreme)
Congestion Characteristics	Lane-Mile Duration Index (LMDI)	1. A measure of the extent and duration of roadway congestion.
Congestion Characteristics	Misery Index	1. Amount of time beyond the average for some amount of the slowest trips 2. Upper 20 percent of travel rates-average travel rate 3. Average of the travel rates for the longest 20% of the trips – average travel rates for all trips
Congestion Characteristics	Percent of Congested Travel	1. Congested travel is travel on a road section for a time period that is less than the free-flow speed 2. Summation of congested travel/ total travel estimate 3. Percent of vehicle-miles or person-miles traveled 4. VMT under congested conditions / total VMT for the area 5. Percentage of traffic on the freeways and principal arterial streets in urbanized areas moving at less than free-flow speeds
Congestion Characteristics	Percent of Peak-Hour Travel Exceeding V/SF Thresholds	1. Indicator of congestion severity
Congestion Characteristics	Percent of system congested	1. Percent of miles congested (usually defined based on LOS E or F)

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Congestion Characteristics	Percent of congested travel	1. A target speed is used as the benchmark and any travel on a road section for a time period that is at less than the target speed is determined to be congested.
Congestion Characteristics	Principal arterial congestion levels	1. Below 5,500 ADT/lane (Uncongested), 5,501 to 7,000 ADT/lane (Moderate), 7,001 to 8,500 ADT/lane (Heavy), 8,501 to 10,000 ADT/lane (Severe), and over 10,000 ADT/lane (Extreme)
Congestion Characteristics	Roadway Congestion Index	1. RCI=[Freeway DVMT/Ln.-Mi.x Fwy. DVMT+Prin. Art. DVMT/Ln.-Mi.x Prin.Art. DVMT] / [14,000 Fwy. DVMT+5500 Prin. Art. DVMT]
Congestion Characteristics	Vehicle to Saturation Flow (V/SF) Ratio	1. Compares the number of vehicles (V) traveling in a single lane in one hour with the theoretical saturation flow (SF), or the theoretical maximum number of vehicles that could utilize the lane in an hour.
Corridor Mobility Index	Corridor Mobility Index	1. Speed of person movement / some standard value such as one freeway lane operating at nearly peak efficiency with a typical urban vehicle occupancy rate
Customer Satisfaction	Customer Satisfaction	1. Counted and published hundreds of "thank-you" letters received
Customer Satisfaction	Customer Service Index (CSI)	1. Indication of satisfaction in courtesy, responsiveness, effectiveness, knowledge, reliability, and helpfulness.
Customer Satisfaction	Dissatisfaction Over Satisfaction Ratio	1. Ratio of complaints over compliments that monitors the success in making improvements to processes, products, and services.
Customer Satisfaction	Responder Observation, Public Feedback	1. Quantifies discernible outcomes from traffic incident management
Degree of saturation	Degree of Saturation	1. The ratio of minor stream demand flow rate to capacity
Delay	Annual Hours of Traveler Delay	1. Indicator of the total time an individual loses due to traveling under congested conditions in a single year.

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Delay	Annual Person Hours of Delay	1. Daily vehicle hours of delay x 250 working days per year x 1.25 persons per vehicle
Delay	Annual Delay per Traveler	1. Extra travel time for peak period travel during the year divided by the number of travelers who begin a trip during the peak period (6 to 9 a.m. and 4 to 7 p.m.).
Delay	Average Delay Per Incident	1. Indicator of delay, caused by incidents, imposed on other motorists.
Delay	Average Minor Stream Delay	1. The total average delay to an isolated, random merging driver.
Delay	Delay	1. Sum of delays for all vehicles traversing the segment during the time period for which travel time data are available 2. Expressed in vehicle-min or vehicle-hours
Delay	Delay Caused by Incidents	1. Increase in travel time caused by incidents
Delay	Delay Due to Acceleration/Deceleration	1. Estimated by dividing the length of the ramp leading to the toll plaza by this average travel speed.
Delay	Delay Per Person	1. The hours of extra travel time divided by the number of urban area peak period travelers.
Delay	Delay Rate	1. Rate of time loss for vehicles operating in congested conditions for a specified roadway segment or trip 2. Expressed in minutes per mile 3. (actual travel time- acceptable travel time) / segment length 4. Rate of time loss for a specified roadway segment 5. Acceptable travel rate- travel rate
Delay	Delay Ratio	1. Dimensionless measure 2. Delay rate/ actual travel rate
Delay	Delay Time	1. Cost of additional travel time
Delay	Hours of Delay Per 1000 Vehicle Miles	1. Indication that incorporates the effects of congestion throughout the day, not only during the peak hour of travel.

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Delay	Incident Delay	1. Cumulative vehicle hours of delay 2. Estimated by a function of incident duration, prevailing traffic demand, capacity reduction in terms of closed and affected lanes and number of vehicles involved
Delay	Minimum Average Minor Stream Delay	1. Delay that is experienced by an isolated, random merging driver.
Delay	Recurring Delay	1. Travel time increases from congestion, but does not consider incidents
Delay	Reduced Delay	1. Reductions in delay since the inception of the incident response program
Delay	Total Delay	1. Total delay (in person- or vehicle-hours) for a transit or roadway segment is the sum of time lost due to congestion. 2. Expressed in person-or vehicle hours or vehicle-mins 3. Sum of individual segment vehicle or person delays 4. (actual travel time-acceptable travel time) x volume 5. Total delay accumulated by all vehicles by a segment of roadway over a specific length of roadway 6. [actual travel time (min.) – acceptable travel time (min.)] x vehicle volume
Delay	Traffic Delay Associated With Crashes	1. Traveler delay associated with highway crashes.
Delay	Vehicle Delay	1. Measured in seconds or minutes of delay per vehicle. person-hours 2. Time past scheduled arrival 3. Travel time above that needed to complete a trip at free-flow speeds.
Density	Density	1. Indicator of congestion and traffic flow stability 2. Passenger cars per hour per lane
Density	Maneuverability	1. Vehicles per hour per lane in peak hour

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Emission	Emission	1. Measures emissions of noxious byproducts of the combustion of fuels, i.e. carbon monoxide, carbon dioxide, nitrogen oxide, hydrocarbons, particulates 2. Used model calculations of emissions from EPA Mobile 5-a model and traffic field data to compare before and after levels of CO, hydrocarbons, & Nox
Evacuation time	Evacuation time	1. The time required to evacuate a given population within a user defined spatial boundary.
Evacuation time	Evacuation Clearance Time	1. Reaction and travel time for evacuees to leave an area at risk
Flexibility	Flexibility	1. Reserve capacity on system 2. % of person trips that could be accommodated by modes other than auto 3. Number of corridors with reasonable alternatives during closure
Fuel Use	Fuel Use	1. Amount of fuel used to achieve certain demand levels
Fuel Use	Excess Fuel Consumed	1. Increased fuel consumption due to travel in congested conditions rather than free-flow conditions
Incident Characteristics	Detection Clearance Time	1. The monitoring detection clearance time in minutes.
Incident Characteristics	Incident Detection Time	1. Time needed to detect and verify an incident before any other incident management process
Incident Characteristics	Incident Duration	1. The amount of time required for completion of the sequential stages such as detection, initial response, injury attention, emergency vehicle response, accident investigation, debris, cleanup, and recovery 2. The time in which an incident's impact lasted even after it was cleared from the roadway
Incident Characteristics	Incident Rate	1. The number of incidents/traffic exposure i.e., Vehicle Miles Traveled (VMT) e.g. incidents/VMT, Incidents/AADT.

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Incident Characteristics	Number of Incidents	1. Unplanned events that temporarily reduce roadway capacity 2. Traffic interruption caused by a crash or other unscheduled event 3. Vehicle crashes, breakdowns, and other random events that occur on the highway system.
Incident Characteristics	Weather Related Traffic Incidents	1. Period required for an incident to be identified and verified and for an appropriate action to alleviate the interruption to traffic to arrive at the scene
Lane Occupancy	Lane Occupancy	1. Percentage of time a traffic lane is occupied by traffic 2. Measured from vehicle detectors that are part of roadway surveillance and control systems
Length of Rush Hour	Length of Rush Hour	1. The combined periods of time for the A.M. and P.M. travel times when traffic is moving at less than free-flow speeds
Level of Service (LOS)	Level of Service (LOS)	1. Measure of ability of transportation facility to serve the user, usually in terms of its operating conditions and how they are perceived by motorists, shippers, carriers, and others 2. Describes conditions in terms of factors such as speed, travel time, reliability, freedom to maneuver, traffic interruptions, convenience, safety, and avoidance of damage 3. Describes operational conditions within a traffic stream, where LOS A describes free-flow operations to LOS E where the highway reaches capacity and at LOS F there is a breakdown in vehicular flow 4. Qualitative assessment of highway point, segment, or system using "A" (best) to "F" (worst) based on measures of effectiveness
Mean Start-Up Lost Time	Mean Start-Up Lost Time	1. Time required to react to a phase change and accelerate to achieve saturation flow headway

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Metering rate	Metering Rate	1. Expressed in vehicles-per-hour 2. Calculated to correspond to volume capacities found to be available on the mainline
Mobility	Mobility	1. Ability of people and goods to move quickly, easily, and cheaply to where they are destined as a speed that represents free-flow or comparably high-quality conditions
Noise	Noise	1. Measures the number of people exposed to particular noise levels is a good measure 2. Measure of physical turbulence in traffic stream 3. Root-mean square deviation of acceleration of vehicle 4. Quantifies relationship between acceleration noise and traffic volume 5. Must take into account the decibel levels at various distances from the roadway
Percent-Time Following	Percent-Time Following	1. Measure for determining LOS on rural 2-lane highways
Queue Characteristics	Bottlenecks and Impediments	1. Number of design impediments to freight traffic, by mode, by type
Queue Characteristics	Queue Length in Workzone	1. Stationary queue for congested flow in work zone
Queue Characteristics	Queuing	1. Transient phenomenon which grows during the period for which the arrival rate of vehicles is greater than the capacity of the restricted section and shrinks as the arrival rate drops below the capacity of the constricted section
Queue Characteristics	Queuing time	1. Time needed to pass through a bottleneck 2. Dynamic variable that depends on queue length and the bottleneck capacity.
Queue Characteristics	Vertical Queue	1. Vertical queue is defined as vehicle delays through the bottleneck, whereby spillbacks and blockages of adjacent intersections are not considered

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Ramps' Effect on Route Choice	Ramps' Effect on Route Choice	1. Function of multiple factors, including the travel time, simplicity of the route, toll cost, guide signs, driver's income level, and E-Pass use.
Reliability	Buffer Index	1. Amount of extra time needed to be on time 95 percent of the time 2. (95th percentile travel rate- average travel rate) / average travel rate 3. Expressed as percentage
Reliability	Capacity Reliability	1. Probability that the maximum network capacity is greater than or equal to a required demand level when arc capacity is subject to random variations 2. Probability that the network capacity can accommodate a certain traffic demand at a required service level, while accounting for drivers' route choice behavior
Reliability	Connectivity reliability	1. Probability that there exists at least one path without disruption or heavy delay to a given destination within a given time period
Reliability	Reliability Factor	1. Percentage of time that a person's travel time is no more than 10% higher than average
Reliability	Travel Time Reliability	1. Change in average travel time for specific origin-destination pairs, or some measure of variation in average travel time per standard time period such as percent of time that a person's travel time is no more than 10 percent higher than average 2. Measure of variability in travel time 3. Standard deviation for travel time given one has the travel time distribution for the same trip made on numerous occasions 4. Probability that traffic can reach a given destination within a stated time 5. The difference between the 90th percentile travel time and the median travel time.

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Reliability	Travel Time Uncertainty	1. Consists of the individual travel time variance and the mean travel time forecasting error
Safety	Crash Rate	1. Crash rate per mile traveled by freight mode
Safety	Crashes by Age Group	1. The distribution of crashes by age of passengers
Safety	Crashes by Vehicle Type	1. The number of occupant fatalities by vehicle type.
Safety	Intersections-crashes	1. Crashes at or near intersections
Safety	Number of Crashes	1. Number of crashes reduced at signalized intersections because of red light camera enforcement
Safety	Number of Highway-Related Fatalities	1. Rate of highway-related fatalities per 100 million vehicle miles traveled 2. Total number of fatalities due to highway motor vehicle crashes.
Safety	Number of Highway-Related Injuries	1. The number of highway-related injuries per 100 million vehicle miles traveled 2. Total number of injuries as a result of motor vehicle crashes.
Safety	Overall Fatality Rates	1. The annual number of fatalities
Safety	Overall Injury Rates	1. The annual number of injuries
Safety	Response to Weather-Related Incidents	1. Number of traffic interruptions caused by inclement weather
Safety	Single-Vehicle Run-off-the Road (ROR) Crashes	1. Crashes typically caused by inattention, drowsiness, or avoidance maneuvers
Saturation Flow Rate	Saturation Flow Rate	1. Derived from measurements of headway 2. Constant average headway between vehicles occurring after Nth vehicle in queue clears intersection 3. Expressed in vehicles per hour of green time per lane

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Speed	Average Speed	1. Estimated throughout the day for the selected sites 2. Length of the segment/travel time 3. The ratio of the total vehicle-miles of travel to the total vehicle-hours of travel for a specified link for each time interval and is presented as miles per hour.
Speed	Average Transit Vehicle Operating Speeds	1. Based on the number of miles that transit vehicles travel and the number of hours spent transporting passengers. 2. Calculated by dividing vehicle revenue miles by vehicle revenue hours for each type of transit mode.
Speed	Mainline speed	1. Driver speed in the mainline
Speed	Peak Speed	1. Travel speed during the peak time
Speed	Space Mean Speed	1. Function of traffic density to reflect the reduction in traffic speed in a congested freeway segment.
Speed	Speed	1. Distance divided by travel time
Speed	Speed of Person Movement	1. Measure of travel efficiency that could be used to compare the person movement effectiveness of various modes of transportation 2. Passenger volume x average speed for a particular route 3. Expressed in person-miles per hour
Speed	Speed variability	1. Evaluates the use of a variable speed limit system
Speed	Travel Speed	1. Travel speed is defined as HOV lane travel speeds that can be expected for a range of trip start times throughout the day. 2. Distance divided by speed
Traffic Flow Rates	Traffic Flow Rates	1. Used to evaluate the performance of traffic management plans for arriving and departing traffic
Travel Comfort	Travel Comfort	1. An acceptable square or cubic feet of area per vehicle

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Travel Time	Acceptable Travel Time	1. Acceptable travel time (in minutes) is the time that indicates a system or mode is operating according to locally determined performance goals. It focuses on the "door-to-door" trip time from origin to destination.
Travel Time	Anticipated Trip Travel Time	1. Expectation time over the sample space of all trips.
Travel Time	Average Travel Time	1. Estimated between selected origin-destination pairs using specified freeway routes for a range of trip start times throughout an average 24-hour weekday 2. The average travel time on the link in hours averaged during the current time interval.
Travel Time	Individual Travel Time Variance	1. The individual travel time variance means that individual driver may drive may drive faster or slower than the observed mean link travel time for each time of day depending on their own desires and the amount of traffic around them.
Travel Time	Link Travel Time	1. Expressed as a function of a weighted average of the inflow rate at the time it enters and the outflow rate at the time it exits.
Travel Time	Link-Based Travel Time	1. The sum of travel times of vehicles in the consecutive individual links that constitute the whole path.
Travel Time	Path-Based Travel Time	1. The difference between the recorded times when the vehicle was entering and exiting the path.
Travel Time	Percent of Additional Travel Time	1. Indicator of the additional time required to make a trip during the congested peak travel period rather than at other times of the day
Travel Time	Time-Directness	1. Predictable travel time for length of trip 2. Can be measured by percentage of travelers satisfied with trip time

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Travel Time	Travel Rate	1. Rate of motion for a specified roadway segment or vehicle trip analyses 2. Measured directly with a vehicle odometer or scaled from accurate maps 3. Inverse of speed 4. Segment travel time / segment length 5. Actual travel rate (in minutes per mile) is the rate at which a segment is traversed or a trip is completed, expressed in min/km or min/mile.
Travel Time	Travel Time	1. Time required to traverse a segment or complete a trip 2. Measured directly using field studies or can be estimated using empirical relationships with traffic volume and roadway characteristics, computer network models, or intended effects of improvements 3. Time deemed acceptable completion of a trip from origin to destination 4. The total time it would take to travel a segment during expected conditions 5. Estimated for a range of trip start times throughout an average 24-hour weekday 6. Indicates variability in overall travel time from an origin to a destination in the system 7. The "lost" time to the travelers. 8. Difference between the actual time of arrival at the destination and the departure time.

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Travel Time	Travel Time Index	1. Indicates how much more time it takes to travel during a peak period than at other times of day 2. Ratio of travel conditions in the peak period to a target or acceptable travel condition 3. (Freeway travel rate/Freeway free flow rate x Freeway Peak Period VMT) + (Principal Arterial Street travel rate/Principal Arterial Street free flow rate x Principal Arterial Street Peak Period VMT)/(Freeway Peak Period VMT + Principal Arterial Street VMT) 4. (Travel time under congested conditions) / (travel time under uncongested conditions) 5. The ratio of travel time in the peak period to the travel time at free-flow conditions
Travel Time	Travel Time on Hyperpaths	1. Average time taken to travel along a hyperpath, including all of the possible routes the driver may take to reach his destination.
Travel Time	Travel Time Percent Variation	1. Standard deviation of travel time divided by the mean travel time 2. (Standard deviation / Average travel time) × 100%

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Travel Time	Travel Time Predictability	1. Ability to accurately predict travel times, especially short-term travel times 2. Measure of variability in travel time 3. Standard deviation for travel time given one has the given the travel time distribution for the same trip made on numerous occasions 4. Probability that traffic can reach a given destination within a stated time 5. Change in average travel time for specific origin-destination pairs, or some measure of variation in average travel time per standard time period such as percent of time that a person's travel time is no more than 10 percent higher than average 6. Variability of travel times 7. Percent of travelers who arrive at their destination within an acceptable time 8. Range of travel times
Utilization	Traffic Information Utilization	1. The proportion of respondents seeking travel information
Utilization	Utilization	1. Percent of system heavily congested (LOS E or F) 2. Vehicles per lane mile 3. Percentage travel heavily congested 4. Duration of congestion (lane-mile-hours at LOS E or F)
Utilization	Vehicle Utilization	1. Ratio of the total number of vehicles operated in maximum scheduled service, adjusted by a capacity factor, to the total number of passenger miles traveled annually in each mode.
Value of Travel Information	Value of Travel Information	1. Reduces uncertainty on what is causing slowdowns 2. Allows users to know available options

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Vehicle Throughput	Vehicle Throughput	1. Related to the amount of time that a traveler might have to wait to make a trip 2. Also known as interarrival time, time headway 3. Interdeparture time for person transport 4. Number of persons, goods, or vehicles traversing a roadway section or network per unit time
Vehicle Volume	Average Annual Vehicle Volume	1. Estimated total number of vehicles passing a given location during an average 24-hour weekday period (Monday through Friday)
Vehicle Volume	Average Daily Traffic Volume	1. Indication of traffic flow.
Vehicle Volume	Average Peak Vehicle Volume	1. Represent levels of system usage during the traditionally busiest periods of the day • Morning peak period (defined as 6:00 AM to 9:00 AM) • Evening peak period (defined as 3:00 PM to 7:00 PM) • AM peak hour (the one-hour AM interval with the highest vehicle volume) • PM peak hour (the one-hour PM interval with the highest vehicle volume)
Vehicle Volume	Average Traffic Volume Profile	1. Profiles how average traffic conditions at a site vary significantly over the course of a day
Vehicle Volume	Daily Volume Variation	1. The variability in person or vehicle volume from day to day, particularly important in analyses that examine mobility levels on particularly heavy volume days (e.g., Fridays, days before holidays) or days/time periods with different travel patterns (e.g., special events, weekends).
Vehicle Volume	Traffic Volume	1. Annual average daily traffic, peak-hour traffic, or peak-period traffic
Vehicle Volume	Vehicle Count	1. The number of vehicles on a link at the end of a time interval.

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Vehicle-Miles Traveled	Daily Vehicle-Miles Traveled (DVMT)	1. Indication that the demand for travel is growing faster than the supply of highways.
Vehicle-Miles Traveled	Vehicle-Miles Traveled	1. Volume times length
Volume to Capacity (V/C) Ratio	Volume to Capacity (V/C) ratio	1. Volume of traffic on a facility relative to the capacity of the facility 2. Expressed in terms of vehicles, person, and goods movement 3. Measures the relative levels of volume and capacity for a section of roadway.

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APPENDIX B

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Appendix 5
NTOC PERFORMANCE MEASUREMENT INITIATIVE SURVEY

In order to gain broader input from transportation officials nationally regarding the use and usefulness of 14 measures identified as important by the NTOC Performance Measurement Initiative's Oversight Committee (senior transportation professionals from North America, with balanced representation from federal, state, and local transportation agencies and Metropolitan Planning Organizations), an electronic survey was distributed to the members of American Association of State Highway and Transportation Officials, International City/County Management Association, Transportation Research Board, Association of Metropolitan Planning Organizations, American Public Works Association, Institute of Transportation Engineers and Public Technology Institute. Figure 1 is the survey instrument and list of measures surveyed and Tables 1, 2, and 3 summarize the results.

Figure 1
Transportation Operations Performance Measurement Survey Instrument

The survey instrument asked the same two set of questions for each of the 14 measures identified as important by the Oversight Committee (see below), along with several additional questions and the survey participant's contact information.

Measures Surveyed

Measure 1
Customer Satisfaction: A measure of the degree to which roadway users (travelers) are satisfied with their use of the roadway system.

Measure 2
Extent of Congestion: Actual time or percentage of time that traffic on freeways and principal arterial streets is flowing at less than free-flow speeds.

Measure 3

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Recurring Delay: The difference between actual travel time and travel time at free flow speeds experienced by individuals due to repetitive factors

Measure 4
Incident Delay: The increase in travel time experienced by individuals due to incidents

Measure 5
Emissions: The noxious byproducts resulting from the combustion of fuels by vehicles traveling on the roadway system

Measure 6
Incident Characteristics: The time duration between incident notification, and the completion of incident removal and on-site investigation.

Measure 7
Intersection Level of Service: Operating conditions at an intersection are described alphabetically, using "A" (best) to "F" (worst)

Measure 8
Reliability: The amount of additional time that travelers must add to their average trip time, in order to be on time 95% of the time.

Measure 9
Safety: Total number of fatalities, injury accidents, other accidents that occur in a given geographic area during a specified period of time

Measure 10
Speed: The spot speed measured at a specific point on the roadway

Measure 11
Throughput per Person: The number of people per hour that are being accommodated by a roadway segment

Measure 12
Throughput per Vehicle: The number of vehicles per hour that are being accommodated by a roadway segment

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Measure 13
Travel Time – Link: The time required to travel along a given roadway segment.

Measure 14
Travel Time – Origin/Destination: The time required to travel between a predefined origin and destination on a roadway network

Two Questions Asked For Each Measure:

1. Please rank the usefulness of this measure for determining the effectiveness of transportation operations.

Not useful		Useful		Extremely useful	Don't know/no opinion
1	2	3	4	5	
☐	☐	☐	☐	☐	☐

2. Are you currently using this performance measure to evaluate the effectiveness of your organization's transportation operations? _____Yes
_____No

Additional Survey Questions

- Please describe other measures that would be useful to evaluate the effectiveness of transportation operations?

- Provide additional comments (such as ease or difficulty to collect data for these measures)

- Type of organization

☐ City government
☐ County government
☐ Regional council of government
☐ Metropolitan planning organization

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☐ State government
☐ Federal government
☐ Other –Please describe

Survey Results

Table 1 Distribution of Questionnaire Responses

Organization Type	No. of Responses
City Government	171
County Government	28
MPO & Regional COG	47
State Government	15
Federal Government	9
Other (including Consultants)	63
Total	333

Table 2 Usefulness (1 = highest aggregate usefulness)

Measure	Usefulness * (Scale of 1 to 5)	
	All (333) Responses	Local/State Only
Customer Satisfaction	3.41	3.50
Extent of Congestion	3.79	3.88
Recurring Delay	3.49	3.60
Incident Delay	3.24	3.34
Emissions	2.54	2.51

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Incident Characteristics	3.12	3.20
Intersection LOS	3.95	4.11
Reliability	2.97	2.98
Safety	4.06	4.16
Speed	3.08	3.18
Throughput per Person	2.84	2.91
Throughput per Vehicle	3.52	3.61
Travel Time – Link	3.61	3.73
Travel Time – O/D	3.35	3.46

Table 3 Percentage of respondents whose agencies currently use each measure

Rank	Performance Measure	% That Use Each Measure
1	Safety - A family of measures	78%
2	Intersection Level of Service	76%
3	Extent of Congestion	36%
4	Travel Time – Link	46%
5	Throughput per Vehicle	56%
6	Recurring Delay	32%
7	Customer Satisfaction - A family of measures	33%
8	Travel Time – From Origin to Destination	28%
9	Incident Delay	16%

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10	Incident Characteristics	15%
11	Speed	45%
12	Reliability	5%
13	Throughput per Person	13%
14	Emissions	20%