OPERATIONS PERFORMANCE MEASURES DEFINITIONS

In support of NCHRP 20-7,
Guide to Benchmarking Operations Performance Measures

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Performance Measure: Customer Satisfaction

Definition: A quantitative measure of customers' satisfaction with roadway management and operations services provided in a specified region. (See Notes 1 & 2) A set of guidelines is provided as a resource for customer satisfaction surveys related to management and operations. Agencies should use these guidelines to prepare surveys customized to local conditions and concerns.

- Determine survey objective and information needs:
  - What is the purpose of conducting the survey?
  - What information is needed?
  - How will the results be used?
- Define the targeted study population:
  - Will you sample residents of a geographic area or specific system or service users (e.g., Commuters, recreational, specific users of a route or intersection)?
- Types of services (See Note 3):
  - 511 – telephone access
  - Websites for traffic management resources (Web 511 and other)
  - Changeable message signs (also known as Variable Message Signs and Dynamic Message Signs)
  - Incident management
  - Highway advisory radio
  - Traffic signal operations
  - Variance of travel time
  - Radio traffic alerts
  - Motorist assist
- Types of questions
  - Frequency of access
    - "How many times did you traverse a certain roadway?,"
    - "How often did you access the website?," etc.
  - Satisfaction rating for the service, and various aspects of the service
  - Importance of providing the service
  - Effect of the information or service on traveler choice or behavior (Did you choose an alternate route as a result of the information?)

    - Feedback on improvements or enhancements to the service
    - Socio-demographic characteristics
- Methodology
    - Use professional resources (such as business consultants, customer feedback specialists, or university personnel) to insure robust and rigorous methodology. A robust methodology insures appropriate:
        - Sample Size
        - Response Rate
        - Sample Method (phone, online, mail, etc.)
        - Question structure and balance
- Question Structure
    - Questions requiring a rating scale should be balanced, providing equal number of positive and negative responses (i.e. Very Satisfied, Somewhat satisfied, Not very satisfied, Not at all satisfied)
    - Satisfaction ratings are often on a 5 point scale; however, 7-point or 11-point scales may be appropriate. In general, it is recommended that these scales include a neutral point.

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 operations performance survey are specific to traveler information, highway management and operations.

Units of Measurement:
Utilize rating scales, including Likert scales or other ordinal scales.
In general, ratings should include a “Don’t Know” response category, and a “Not Applicable” response category, as appropriate..

Processing (or how to measure): It is recommended that responses be processed to provide the distribution of responses.. In cases where Likert scales are used, it may be appropriate to provide the mean response. Survey results should also be analyzed by travel location, trip types (commute, school, vacation, freight movement, etc.) and type of customer.

Survey report should contain a full description of the methodology, response rate, and a copy of the survey itself.

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 may include all transportation system stakeholders (motorists and commercial vehicle operators as well as members of the public affected by transportation services (shippers, fleet operators, first responders, etc.)) The definition of the study population may narrow this specific to the objective of the survey.

(2) In instances where the population is limited, funds are limited, or the nature of the effort is the discovery of issues, selected interviews or focus groups with a sub-population may be appropriate. Unlike surveys, these methods provide qualitative data (rather than quantitative) to identify and rate aspects of transportation operations issues (the results can provide valuable insights but are not representative).

(3) Note that customers do not separate roads or services by jurisdiction, nor traffic information by provider. Survey should delineate as appropriate.

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) Congestion is measured separately for opposing directions of traffic flow.

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
- Simple percent of congested roadways. Calculated as a ratio = 100% x Congested Miles / Total Miles. A simple percentage is appropriate when all roadways are of a similar class, for example monitoring congestion on a beltway. If the roadways are of significantly different capacity or AADT, use the AADT weighted average.
- AADT weighted percent of congested roadways. Calculated as a ratio = 100% x AADT weighted Congested Miles / AADT weighted Total Miles. The AADT weighted average is more appropriate to reflect percentage of overall travel occurring on congested roadways. Including lower-volume, lower-capacity roadways will have undue influence when using the simple percent method.

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 travel times remain relatively constant and reflect peak periods of demand.
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. Measure the AADT of each section for which this calculation is made. [For AADT weight calculation only.]
7. 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 (See Note 5)
8. Calculate the percent of congested roadways using one of the following methods.
    a. The simple percent of congested roadways is the sum of the lengths of congested roadway sections divided by the total length of all roadway sections included in the analysis.
    b. For AADT weighted percent of congested roadways:
        i. Multiply each segment length by its AADT to obtain AADT weighted Length for each section.

ii. Sum the AADT weighted Length of all congested roadway sections.
iii. Sum the AADT weighted Length of all roadway sections included in the analysis.
iv. Divide the AADT weighted Length for congested roadways (8bii) by the AADT weighted Length for all roadways (8biii).

Note:
Thresholds other than 30% can be used to denote various levels of congestion, growth and progression of congestion. 30% is used as the basis for comparing various municipalities, regions and road authorities.

Typical Applications: Planning and outreach

Example: Communication with the public in regards 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 such as 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.

(5) A 30% increase is travel time is equivalent to a reduction in speed of approximately 27%. A reduction in speed of 30% is equivalent to an increase in travel time of approximately 43%.

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

Definition: The time duration during which more than 20% of the unidirectional 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 5 to15 minute intervals
3. Execute processing steps 1-8 of the "Extent of Congestion – Spatial" as appropriate to obtain percent of congested roadways for each time interval. Either simple percent of AADT weighted percent may be used. (See Notes 2, 3 and 4)
4. Count the number of time periods for which the percent of congested roadways is greater than or equal to 20%.
5. Calculate the hours of congestion as the total number of congested time periods times the period length (5 to 15 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.

(4) A 30% increase is travel time is equivalent to a reduction in speed of approximately 27%. A reduction in speed of 30% is equivalent to an increase in travel time of approximately 43%.

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 all response vehicles have left the incident scene, whichever is less. (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 and law enforcement actions; Also excludes planned events (parades, sporting events, etc.) and regional weather incidents

Units of Measurement: Mean minutes per incident.

Processing (How to measure)**:**

- Calculate the time difference between incident notification and incident removal
- The mean time of incident duration may be calculated for specific roadway types as the numerical mean of incident duration time for incidents occurring at the locations and the times of interest for the analysis period. Mean incident duration may also be indexed to the number of lanes closed as a result of the incident, and to the type of incident.

Typical Applications: Operations management

Example: Evaluating the effectiveness of service patrol routes and actions of emergency responders 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, tow trucks, vehicles and individuals involved with the incident and debris resulting from the incident.

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: N/A

Units of Measurement: Vehicle-hours

Processing (How to measure)**:**

1. Select roadways on which delay is to be measured (See Note 5)
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)
4. Measure the delay during the selected time period during normal conditions (i.e. when there are no incidents or special events)
5. Calculate the product of the delay and the demand.

Typical Applications: Planning, engineering and operations

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

Notes:

(1) Delay is repeatable when it can be forecast based on the day-of-week, time-of-day and day type.

(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 the 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.

(5) When possible, roadways should be segmented to the lowest level possible. Results for each segment can then be aggregated to obtain delay for roadways and corridors. The low-level results are important for assessing operations of individual such as signal timing, while the aggregated results are more indicative of overall management objectives.

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 specifically the "point mean speed". It is anticipated that this measure will be replaced by space mean speed at the time when probe-based measurements proliferate and become economically viable. Until then, point mean speed is used extensively as a surrogate for space mean speed in order to determine travel time.

(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: N/A

Units of Measurement: Persons per hour

Processing (How to measure)**:**

1. Select the time period during which Throughput – Person is to be calculated.
2. Sum of persons carried on all modes of interest traversing the roadway or screen line measured for the period of study.
3. Divide the sum of persons by the period of study (measured in hours) to get person throughput.

Typical Applications: Used by agencies to evaluate the transportation effectiveness of roadways and other modes 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: N/A

Units of Measurement:

- Total vehicles per hour
- Vehicles per hour by the following classifications:
    - Motorcycle
    - Automobile and Light Truck
    - Buses
    - Heavy Truck
    - Semi Trailer
    - Semi + Multiple Trailers

Processing (How to measure):

1. Select the time period during which Throughput – Vehicle is to be calculated.
2. Tally of all vehicles by specified classifications traversing the roadway or screen line measured for the period of study.
3. Divide the tally of vehicles by the period of study (measured in hours) to get vehicle throughput.

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 - Facility

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: Facility 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 segment

Processing (How to measure)**:**

Direct Measurement Techniques:

Travel time on a facility (See Note 2) is collected for multiple passes 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.

Indirect Measurement Techniques:

Speed is observed and recorded on a facility (See Note 2) at intervals between ¼ mile up to 2 miles. An average speed is calculated as the sum of observed speeds divided by the number of observations. Divide facility length by average speed to obtain an indirect measure of average travel time. Care must be taken to ensure that prevailing traffic and roadway conditions remain unchanged during the measurement period. Indirect methods are only recommended for facilities where spot speed measures are a good estimate of space mean speed. This is generally true for freeways, but not for signal controlled arterials.

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. General guidance for collecting and reporting travel times includes:

- For freeways, report travel times between interchanges, roughly every 2 to 5 miles
- For arterials, report travel times between intersections of major arterials and/or freeways, roughly every 0.5 to 2 miles
- For bus operations, report travel times between major bus stops

(2) When possible, roadways should be segmented to the lowest level possible. Results for each segment can then be aggregated to obtain travel-time for roadways and corridors. The low-level results are important for assessing operations of individual elements such as signal timing, while the aggregated results are more indicative of overall management objectives.

Performance Measure: Travel Time – Reliability (Buffer Time)

Definition: The buffer time describes the additional time that must be planned for in excess of the expected travel time (measured as defined by Travel Time – Facility or Travel Time – Trip) to ensure that travelers 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 between the average travel time and the maximum value of the truncated travel time list
6. If it is desired to express the buffer time as a percent, the calculation is made by dividing the buffer time 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 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 to 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 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.

Lane Miles: Product of the number of lanes and length of a unidirectional roadway segment.

Centerline Miles: The length of a unidirectional roadway segment.

AADT: Annual Average Daily Traffic. AADT is the total volume of vehicle traffic on a facility for a year divided by 365.

Off-Peak Periods: Any time that traffic flow exhibits Level of Service C or better

Unconstrained Travel Time: Unconstrained travel time represents a reasonable estimate of travel time in the absence of congestion during good weather conditions. Methods for estimating unconstrained travel time vary by facility type.

For **Freeways**, two methods may optionally be used as the basis for the appropriate performance measures. The first method is preferred:

- 85^{th} percentile travel time (corresponding to the 85^{th} percentile speed converted to an equivalent travel time) of traffic during off-peak periods (see definition of off-peak periods).
- 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

For **Arterials** Two methods may optionally be used as the basis for the appropriate performance measures:

- Travel time equivalent to the posted speed limit plus 30%.
- 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 AND traffic signals and other traffic control devices are operating as designed for a given time period.