INTRODUCTION

Performance may be defined as the execution of a required function. Performance measures represent, in quantitative or qualitative terms, the extent to which a specific function is executed. As such, transportation performance measures reflect the satisfaction of the transportation service user as well as the concerns of the system owner or operator and other stakeholders.

Performance measures are needed at various stages of the transportation program or project development process for the purposes of decision making and at various hierarchical levels of transportation management and administration. At one extreme (top level), performance measures are used for assessing systemwide plans and programs; at the other extreme (bottom level), they are used to select desirable solutions for a specific localized problem.

The establishment of performance measures has been fostered by various legislative impetuses, particularly the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). The need for meaningful performance measurement in government has also been advocated by several professional organizations over the past decades. These include the 1989 Governmental Accounting Standards Board (GASB) resolution, which encouraged state and local governments to develop indicators in four categories: input, output, outcome and service quality, and efficiency (GASB, 1989).

2.1 TRANSPORTATION SYSTEM GOALS, OBJECTIVES, AND PERFORMANCE MEASURES

The development of performance measures derives from a hierarchy of desired system outcomes. This hierarchy starts with the broad overall goals of efficiency, effectiveness, and equity; under these broad goals are the goals of system preservation, economic development, environmental quality protection, and so on; and under each goal is a set of objectives, and for each objective, performance measures are established (Figure 2.1).

Identification of goals and objectives is a key prerequisite to the establishment of performance measures and therefore influences the evaluation and decision outcome. Diversity in system goals and objectives is desirable because it reflects different expectations (held by various stakeholders) of what the transportation system should be achieving. Goals and objectives are typically developed through extensive examination of top-level agency requirements, by soliciting the perspectives of the users and other stakeholders and by outreach to the general public. Definitions of the various levels of the hierarchy are provided as follows:

- An overall goal is a broad description of what the transportation action is generally meant to achieve. As mentioned in Chapter 1, there are three overall goals: efficiency (is the output worth the input?), effectiveness (is the action producing the desired outcomes?),

Figure 2.1 Hierarchy of desired outcomes for transportation system projects and programs.
and equity (are diverse segments of the population receiving a fair share of the action's benefits?).

A goal is a desired end state toward which effort is directed, and is derived from the overall goals. From the perspective of effectiveness, for example, goals may involve the physical condition, operational characteristics, or external effects of the transportation system. Goals associated with physical condition include system preservation; goals associated with system operations include mobility, accessibility, and safety; and goals associated with external impacts include environmental conservation and economic development.

An objective is a specific statement that evolves from a goal and is geared toward achieving that goal. For example, if a goal is to enhance regional air transportation mobility, a corresponding objective could be to reduce air travel time.

A performance measure is an objective that is stated in measurable terms. Synonyms include performance indicator, performance attribute, or service attribute. For the goal of air transportation mobility enhancement and the objective of reducing air travel time, for example, a performance measure could be the air traveler delay.

A performance criterion is a specific definition attached to a performance measure. For example, a criterion could be to minimize average transfer time for air travelers over the regional network or airports over a given period.

A performance standard is a fixed value of a performance criterion that clearly delineates a desired state from an undesired state. For example, the average passenger transfer time should not exceed 90 minutes. Synonyms include trigger, or minimum level of service. A performance standard therefore specifically defines the least desired level of the performance criterion.

At many transportation agencies, performance measures for improvement projects are generally derived from the agency's overall goals or objectives. For instance, at Delaware's state transportation agency, performance measures are tied to the agency's goals, strategies, policies, and long-range transportation plans in a tiered fashion (Abbott et al., 1998). Literature on performance measures (Cambridge Systematics, 2000; Shaw et al., 2003) provides typical groups or categories of goals and objectives that have been identified by transportation agencies for performance-based management. These include system condition and performance, operational efficiency, accessibility, mobility, economic development, quality of life, safety, and environmental and resource conservation. Examples of typical goals and objectives are shown in Table 2.1.

### Table 2.1 Typical Goals, Objectives, Performance Measures, and Performance Criteria

<table>
<thead>
<tr>
<th>Overall Goals</th>
<th>Goals</th>
<th>Objectives</th>
<th>Performance Measures</th>
<th>Performance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Improve system financial performance</td>
<td>Enhance economic attributes of the system</td>
<td>Reduce initial or life cycle costs for agency or users or both</td>
<td>Initial cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enhance economic viability (financial feasibility) of the system</td>
<td>Maximize benefit cost ratio or net present value</td>
<td>Life cycle agency cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximize economic efficiency</td>
<td>Life cycle user cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enhance financial feasibility of project construction and preservation</td>
<td>Cost per new person-trip per mile</td>
<td></td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Improve system physical condition</td>
<td>Maintain condition of physical transportation infrastructure at a certain minimum level</td>
<td>Improve construction techniques and materials to minimize construction delays and improve service life of transportation improvements</td>
<td>Feasibility of funding project construction (yest/no)</td>
</tr>
<tr>
<td></td>
<td>Improve system operational performance</td>
<td>Improve technical feasibility (operational effectiveness) so that transportation system provides desired service that maximizes mobility, accessibility, and intermodalism</td>
<td>Mobility: decrease congestion and delay at arterials, freeways, and intersections</td>
<td>Average facility condition index (either for each facility or average for all facilities in network)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accessibility: improve transit frequency and reduce waiting times and walking distance</td>
<td>Average travel time and modal delay in intermodal transfers</td>
<td>Average total delay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intermodal connectivity</td>
<td>Fatal crashes per 100 million vehicle-miles traveled</td>
<td></td>
</tr>
<tr>
<td>Safety of system users and nonusers</td>
<td>Enhance safe use of the transportation system for the benefit of road users (drivers and pedestrians) and nonusers</td>
<td>Reduce the frequency and payment amounts associated with tort liability</td>
<td>Number of injury or property-damage crash rates</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimize the incidence of tort liability associated with use of the transportation system</td>
<td>Annual safety-related tort payments (amounts and frequency)</td>
<td></td>
</tr>
<tr>
<td>Economic development and land-use impacts of the system</td>
<td>Improve transportation services to enhance economic competitiveness of a region, thus attracting new businesses or retaining existing businesses</td>
<td>Increase employment</td>
<td>Number of jobs created</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Promote land-use patterns that foster progressive community development</td>
<td>Increase in gross regional product</td>
<td></td>
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</tbody>
</table>

(continued overleaf)
for project-level evaluation may not necessarily translate to optimal decisions at the network level.

### 2.3 PROPERTIES OF A GOOD PERFORMANCE MEASURE

Generally, a suitable performance measure should have the following properties (Turner et al., 1996; Cambridge Systematics, 2000):

- **Appropriateness:** The performance measure should be an adequate reflection of at least one goal or objective of the transportation system action. It should be applicable to an individual mode or a combination of modes. The appropriateness of a performance measure helps guarantee its relevance because its reporting would provide the needed information to decision makers.

- **Measurability:** It should be possible (and easy) to measure the performance measure in an objective manner and to generate the performance measure levels with available analytical tools and resources. Measurement results should be within an acceptable degree of accuracy and reliability.

- **Dimensionality:** The performance measure should be able to capture the required level of each dimension associated with the evaluation problem. For example, it should be of the appropriate spatial and temporal scales associated with the transportation action and should address the perspectives of the parties affected. The performance measure should be comparable across time periods or geographic regions.

### 2.4 DIMENSIONS OF PERFORMANCE MEASURES

Performance measures can be viewed from the perspective of several dimensions, such as the goals or objectives, transportation mode, facility type, temporal scope, spatial scope, and so on. For example, performance measures may be classified by their applicability to multimodal vs. single-mode evaluations or to freight vs. passenger transportation. Also, performance measures may differ by facility type. For example, the impact of transit guideway projects are measured using specific performance measures that differ from those used for transit terminals, even though the overall goals may be the same. Also, performance measures that are used when evaluation is being carried out over a short time frame may differ from those that are used for a long time frame. For example, performance jump (immediate improvement in facility performance) could be used for the short-term evaluation of physical, policy, or operational interventions, while deterioration rate reduction or extension in facility life may be used to measure the effectiveness of interventions over relatively longer evaluation periods. With regard to spatial scope, the measures of performance for a given impact type may differ, depending on whether the analysis is being carried out at project level, state level, network level, or even regional level. A case in point is air pollution impacts: pollutant types and parameters used to evaluate local pollution differ from those used to evaluate regional pollution. Performance measures may also be categorized by the planning and programming jurisdiction to which they are most relevant, and by the perspective of user, agency, or operator. A classification of possible dimensions of performance measures is shown as Table 2.2.

#### 2.5 PERFORMANCE MEASURES ASSOCIATED WITH EACH DIMENSION

For the transportation program or project under evaluation, the analyst should identify the appropriate dimensions for the evaluation, and should then establish the relevant performance measures associated with each dimension. A discussion of performance measures based on various dimensions is presented below.

#### 2.5.1 Overall Goals

Efficiency-related performance measures involve an assessment of how much return can be achieved for a given input. Examples include the savings in travel costs per dollar of investment, benefit-cost ratio, and net present value. Performance measures for the overall goal of effectiveness are used to assess the degree to which operational goals are being attained. Equity-related performance measures help assess the extent to which specific benefits and/or costs (monetary or nonmonetary) are being shared across

<table>
<thead>
<tr>
<th>Table 2.2 Dimensions of Performance Measures</th>
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<tbody>
<tr>
<td>Dimension</td>
</tr>
<tr>
<td>Overall goals</td>
</tr>
<tr>
<td>Objectives</td>
</tr>
<tr>
<td>Sector concerns</td>
</tr>
<tr>
<td>Flow entity</td>
</tr>
<tr>
<td>Modal scope</td>
</tr>
<tr>
<td>Specific mode</td>
</tr>
<tr>
<td>Entity and stakeholder affected</td>
</tr>
<tr>
<td>Spatial scope</td>
</tr>
<tr>
<td>Level of agency responsibility</td>
</tr>
<tr>
<td>Time frame</td>
</tr>
<tr>
<td>Level of refinement</td>
</tr>
<tr>
<td>Intended use</td>
</tr>
<tr>
<td>Level of use of information</td>
</tr>
</tbody>
</table>
2.5.2 System Objectives
Most transportation agencies have established a portfolio of performance measures for their agency goals (which generally include objectives involving system preservation, agency cost, operational efficiency, mobility, safety, and environmental preservation). Network-level performance measures that are based on overall system goals and objectives are presented in Table 2.3.

(a) Preservation of the System Physical Condition System preservation refers to the set of activities geared toward ensuring a minimum level of physical condition of transportation stock and its generally considered to be a vital aspect of transportation management. For an assessment of the extent to which this goal is being achieved, the following general performance measures can be used:

- Percentage of system units or segments that have been maintained at or a certain minimum or target level of condition or that are operating above a certain specified level of service threshold
- Average level of service, physical condition, or structural or functional sufficiency of the system

General Appendix 2 presents specific examples of these performance measures.

Data on system physical condition and operation, which can be used to derive levels of established performance measures, are generally available at most transportation agencies.

(b) System Operational Efficiency This includes operational effectiveness (the degree to which the transportation system provides a desired service that maximizes mobility, accessibility, and intermodalism; and operational efficiency (the extent to which the resources are used to produce a given level of transportation output). The public sector is typically interested in operational effectiveness, whereas the private sector (comprising shippers and carriers and other businesses whose operations are heavily linked to the transportation system) is interested in operational efficiency, particularly from a monetary standpoint. Operational efficiency could be viewed in the flow entity dimension; as such, its performance measures may be grouped into those applicable to passenger or freight movement, or both.

Accessibility: An important function of any transportation system is to provide for people accessibility to residences, places for employment, recreation, shopping, and so on; and for goods and services, accessibility to points of production and distribution. Any performance measure for accessibility should reflect the ease with which passengers and goods reach their destinations. Performance measures or accessibility as illustrated in General Appendix 2, include:

- The ability of a facility to handle specific types of passengers or freight
- The capacity of specific intermodal facilities for freight and passengers
- The ease of access to the transportation system
- The ease of connecting at transfer facilities
- The percentage of the population or freight-generating businesses located within a certain distance or travel time from a specific transportation facility

Mobility: Performance measures associated with mobility may apply to passenger or freight transportation. As illustrated in General Appendix 2, these may include:

- The travel time, level of service, travel speed, delay, congestion
- The average speed vs. peak-hour speed
- The transfer time at intermodal transfer terminals, hours of delay
- The percentage of a facility that is not heavily congested during peak hours

Data on travel time and congestion-related measures are typically estimated with existing analytical or simulation models, while mode shares and levels of service (intermodal connecting times) can be ascertained using surveys of individual facility users or businesses.

(c) System Financial Performance Transportation systems aim to enhance accessibility and mobility at a reasonable cost to both agencies and users. Benefits could be expressed in terms of the reduction in agency or user costs or tools, relative to a base case (which is typically the do-nothing scenario). Performance measures for system financial performance may include:

- The initial cost per unit dimension of transportation facility
- The preservation cost per unit dimension of transportation system

<table>
<thead>
<tr>
<th>Objective</th>
<th>Facility or Category</th>
<th>Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>System preservation</td>
<td>Pavement</td>
<td>Percentage of highways built to target design</td>
</tr>
<tr>
<td>Bridge</td>
<td>Average roughness or overall pavement index value for state highways, by functional class</td>
<td></td>
</tr>
<tr>
<td>Percentage of highways rated good to excellent</td>
<td>Percentage of roads with score of 80 or higher on overall highway maintenance rating scale</td>
<td></td>
</tr>
<tr>
<td>Miles of highway that need to be reconstructed or rehabilitated</td>
<td>Percentage of highway bridges rated good or better</td>
<td></td>
</tr>
<tr>
<td>Number of bridges that need to be reconstructed or rehabilitated</td>
<td>Cost per unit of highway maintenance work completed; labor cost per unit completed</td>
<td></td>
</tr>
<tr>
<td>Cost per percentage point increase in lane-miles rated fair or better on pavement condition</td>
<td>Cost per crash avoided by safety projects</td>
<td></td>
</tr>
<tr>
<td>Percentage of population residing within 10 minutes or 5 miles of public roads</td>
<td>Percentage of bridges with weight restrictions</td>
<td></td>
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<tr>
<td>Miles of bicycle-compatible highways rated good or fair</td>
<td>Average speed vs. peak-hour speed</td>
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<tr>
<td>Hrs of delay</td>
<td>Percentage of limited-access highways in urban areas not heavily congested during peak hours</td>
<td></td>
</tr>
<tr>
<td>Vehicle-miles of travel (VMT) on highways</td>
<td>Percentage of VMT at specific road classes</td>
<td></td>
</tr>
<tr>
<td>Percentage of traveler-miles traveled (PMT) in private vehicles and public transit buses at specific road classes</td>
<td>Percentage of wholesale and retail sales occurring in significant economic centers served by unrestricted market artery routes</td>
<td></td>
</tr>
<tr>
<td>Percentage of motorists satisfied with travel times for work and other trips</td>
<td>Vehicular crashes per 100 million VMT</td>
<td></td>
</tr>
<tr>
<td>Fatality or injury rates per 100 million VMT</td>
<td>Crashes involving injuries per 1000 passengers</td>
<td></td>
</tr>
<tr>
<td>Number of pedestrians killed on highways</td>
<td>Percent change in miles in high-accident locations</td>
<td></td>
</tr>
<tr>
<td>Percent crash reduction due to highway construction or reconstruction projects</td>
<td>Reduction in highway crash due to safety improvement projects</td>
<td></td>
</tr>
<tr>
<td>Number of railroad-crossing accidents</td>
<td>Percentage of motorists satisfied with snow and ice removal or roadside appearance</td>
<td></td>
</tr>
<tr>
<td>Risk (vulnerability) and consequence of facility element failure</td>
<td>Number of crashes in highway work zones</td>
<td></td>
</tr>
<tr>
<td>Highway VMT per gallon of fuel</td>
<td>Source: Adapted from Poirier (1997).</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Resource and environment</th>
<th>Construction-related</th>
<th>Fuel use</th>
<th>Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of system units that have been maintained at a certain minimum or target level of condition</td>
<td>Cost per unit of highway maintenance work completed; labor cost per unit completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average level of service, physical condition, or structural or functional sufficiency of the system</td>
<td>Cost per percentage point increase in lane-miles rated fair or better on pavement condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data on travel time and congestion-related measures are typically estimated with existing analytical or simulation models</td>
<td>Cost per crash avoided by safety projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>While mode shares and levels of service (intermodal connecting times) can be ascertained using surveys of individual facility users or businesses</td>
<td>Percentage of population residing within 10 minutes or 5 miles of public roads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data on system physical condition and operation, which can be used to derive levels of established performance measures, are generally available at most transportation agencies</td>
<td>Percentage of bridges with weight restrictions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The public sector is typically interested in operational effectiveness, whereas the private sector (comprising shippers and carriers and other businesses whose operations are heavily linked to the transportation system) is interested in operational efficiency, particularly from a monetary standpoint</td>
<td>Percentage of limited-access highways in urban areas not heavily congested during peak hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational efficiency includes operational effectiveness (the degree to which the transportation system provides a desired service that maximizes mobility, accessibility, and intermodalism; and operational efficiency (the extent to which the resources are used to produce a given level of transportation output)</td>
<td>Data on travel time and congestion-related measures are typically estimated with existing analytical or simulation models, while mode shares and levels of service (intermodal connecting times) can be ascertained using surveys of individual facility users or businesses.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The total life-cycle agency costs
The user cost per unit dimension or per unit use (travel volume) of transportation system
The total life-cycle user costs and benefits

To enable equitable comparison across time, these performance measures are expressed in constant rather than current dollars after daily correcting for inflationary effects. Furthermore, in assessing system financial performance, some analysts may combine agency costs with user costs to obtain an overall picture of the monetary costs.

(d) System Safety and Security

Safety of System Use: Transportation system safety includes the safety of those using the system (vehicle operators and passengers), those affected by the use of the system (pedestrians), and those involved in the system preservation and operations (field personnel of the agency or its contractors). Performance measures for transportation safety can be measured in terms of frequencies or rates (per mile, per annual average daily traffic, or per vehicle-mile traveled) of all crashes or various categories of crashes (fatal, injury, or property damage).

For highway, rail, water, or air transportation, performance measures for safety include the number of crashes or rate of crashes (per facility dimension, use, or usage dimension such as VMT); for all crash severity types or patterns, or for each crash severity type or pattern; and for vehicles or pedestrians or both. Additional performance measures for transit safety can include crime and vandalism rates.

Deﬁning performance measures for safety helps agencies to determine the effectiveness of safety related projects; for example, crash reduction due to shoulder or lane widening.

Security from Extraordinary Events: At many agencies, facility vulnerability is increasingly assuming a key role as a performance measure for evaluating projects aimed at enhancing facility resilience to (or recovery from) human-made or natural disasters and for purposes of emergency evacuation planning. A suitable performance measure is the vulnerability rating, which is based on the likelihood and consequence of a harmful event.

1. The likelihood is based on external factors such as the population and the visibility or national importance of the transportation system (for human-made attacks) and water flow rate or seismic histories (for natural disasters such as flood or earthquake failures, respectively).

2. The consequence of failure is evaluated on the basis of the exposure of the facility: for example, the level of usage. It indicates the degree of catastrophe that would result in the event of failure of the transportation facility.

For example, a facility may have a low likelihood of failure but a high consequence of failure (such as a new heavily traveled and well-built city bridge) or a high likelihood of failure but low consequence of failure (such as a lightly used and weak county bridge in a flood- or earthquake-prone area). As illustrated in Figure 2.2, both the event likelihood and its consequence are used to establish the value of the vulnerability rating performance measure. Threat types include human-made attacks, earthquakes, flooding, system fatigue, and major collisions.

(e) Economic Development and Land Use

Most transportation improvements are geared toward enhancing operational effectiveness, but the end goal may be the provision of a top-class transportation infrastructure for the region so as to retain existing businesses or to attract new ones. As illustrated in General Appendix 2, performance measures associated with economic development may include:

- Number of businesses
- Business sales
- Employment (number of jobs)
- Per capita income
- Acreage and proportions of commercial, residential, and agricultural land areas

(f) Environmental Quality and Resource Conservation

Most transportation actions affect the environment and require the consumption of natural resources. Performance measures for environmental impacts are typically expressed in terms of the amount of environmental damage (e.g., pollutant emissions, noise, water quality, habitat degradation). Performance measures for environmental quality and resources conservation may include:

- Acreage of wetlands affected
- Pollutant emissions and concentrations
- Noise and vibration levels
- Energy consumption

(g) Quality of Life: Transportation facilities are expected to contribute to the overall quality of life of residents in a region. Quality of life typically captures attributes such as overall well-being, community spirit, social equity, privacy, aesthetics, and concern for the disadvantaged. General Appendix 2 presents a set of performance measures related to the quality of life in a community.

2.5.3 Sector Concerns and Interests

In the private sector, profit is the primary measure of performance. For example, the operators of a toll facility may be interested primarily in whether the revenue collected provides sufficient return after deducting the costs of operation, maintenance, and debt service. Also, transportation providers, shippers, truckers, and others in the transportation industry ensure that they are providing their transportation services at a reasonable profit. For the public sector, the primary motive is service to the general public, which is typically measured on the basis of operational effectiveness (i.e., mobility, accessibility, safety, and so on). For publicly subsidized transit services, the performance measures may also include such items as the deficit per passenger serviced, the operating rate, and the revenue per vehicle-mile or vehicle hour.

2.5.4 Flow Entity (Passenger and Freight)

From the perspective of passengers, measures that can be used to assess the performance of a transportation project or policy may include the delay per passenger, out-of-pocket costs, and travel-time reliability. For freight operations, facility performance measures may include loading time and inventory time and cost (which depend on inventory size and type), and travel-time reliability. General Appendix 2 presents performance measures that could be used to evaluate system improvements from the perspective of freight and passenger operational efficiency.

2.5.5 Type of Transportation Mode

Although the general objectives (and associated performance measures) of delay reduction, safety enhancement, system preservation, and other dimensions apply, it must be consistent across the various modes of transportation. There are specific performance measures that may be unique to each mode.

(a) Highway

For highway systems, typical performance measures include the percentage of the highway network that experiences congestion, the percentage of time that a given highway corridor suffers from congestion, and the incident frequency or severity for the network or at a highway segment or intersection. For a given mode, performance measures may vary by the component system type. For example, traffic density is used to evaluate basic freeway sections, weaving areas, ramp junctions, and multilane highways; while delay is often used to evaluate two-lane highways, intersections, and changes, and speed is used for freeway facilities and arterials (Shaw, 2003). In Europe, the OECD (2001b) established a set of performance indicators for the road sector.

General Appendix 2 presents examples of performance measures that could be used to assess the extent to which highway systems help achieve the goals and objectives of operational efficiency, accessibility, mobility and economic development, quality of life, and safety and the environment.

Also, examples of performance measures for specific highway management systems (highway, bridge, congestion, and safety) are provided in General Appendix 2.

(b) Rail and Urban Transit

For rail transportation in North America, the values of the following performance
measures for each regional rail freight carrier are published on a weekly basis: the total cost, average train speed, average mileage per train, and average of the three main transportation modes.

For passenger rail transportation, performance measures include
- On-time arrivals
- Average train speed
- Average mileage per train
- Average of the three main transportation modes.

Performance measurement for urban rail and bus systems has become fairly standardized. For example, in the United States, Federal Transit Administration (FTA) standards are followed. The FTA requires that performance measures be published for each transportation mode, including:
- On-time arrivals
- Average train speed
- Average mileage per train
- Average of the three main transportation modes.

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- On-time arrivals
- Average train speed
- Average mileage per train
- Average of the three main transportation modes.

Environmental and Land-Use Compatibility: It is essential that the operation of airports does not result in environmental degradation or pose a nuisance to abutting land uses. From this perspective, performance measures include:
- The number of takeoffs and landings
- The noise level at nearby residential areas
- The number of special events
- The number of accidents
- The number of spills
- The number of fatalities

Financial Performance: Measures used to evaluate the financial performance of an airport include:
- The number of passengers
- The number of connections
- The number of flights
- The number of revenue
- The number of expenses
- The number of profits

Accessibility: Accessibility standards are set for different types of aircraft and aviation facilities. Intermodal links are important for air transportation of goods, and access to the region's airports via alternative transportation modes is important for passengers. Performance measures to assess the accessibility of an airport include:
- The number of passengers
- The number of connections
- The number of flights
- The number of revenue
- The number of expenses
- The number of profits

Operational Efficiency: Measures used to evaluate the operational efficiency of an airport include:
- The number of takeoffs and landings
- The number of special events
- The number of accidents
- The number of spills
- The number of fatalities

Ridership: Measures used to evaluate the ridership include:
- The number of passengers
- The number of connections
- The number of flights
- The number of revenue
- The number of expenses
- The number of profits

Service Characteristics: Measures used to evaluate the service characteristics include:
- The number of takeoffs and landings
- The number of special events
- The number of accidents
- The number of spills
- The number of fatalities

Facility Characteristics: Measures used to evaluate the facility characteristics include:
- The number of takeoffs and landings
- The number of special events
- The number of accidents
- The number of spills
- The number of fatalities

Physical Adequacy: Measures used to evaluate the physical adequacy include:
- The number of takeoffs and landings
- The number of special events
- The number of accidents
- The number of spills
- The number of fatalities

A performance measure may be associated with only one single mode or with two or more modes. For example, the delay encountered in freight transfer from rail to track transportation is a multimodal performance measure, whereas the delay encountered from one rail terminal to another is a single-mode performance measure. General Appendix 2 presents possible performance measures that could be used to evaluate the effectiveness of transportation systems.
Table 2.4 (continued)

<table>
<thead>
<tr>
<th>Goal Category</th>
<th>Category</th>
<th>Performance Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic development</td>
<td>Transit</td>
<td>Passengers per capita within urban service area; Number of commuters using transit park-and-ride facilities; Number of demand-responsive trip requests; Percentage of transit demand—response trip requests met; Economic indicator for people movement; Percentage of region’s unemployed or poor who cite transportation access as a principal barrier to seeking employment; Percentage of wholesale and retail sales in the significant economic centers served by market routes.</td>
</tr>
<tr>
<td>Quality of life</td>
<td>Transit accessibility, mobility</td>
<td>Customer satisfaction with commute time; Customer perception of quality of transit service; Transit collisions (injuries or fatalities) per PMT; Transit collisions (injuries or fatalities) per VMT; Number of incidents in bus collisions; Crashes per 1000 passengers; Ratio of number of transit collisions to investment in transit security.</td>
</tr>
<tr>
<td>Safety</td>
<td>Air pollution</td>
<td>Air quality rating; Tons of pollutants generated; Number of days for which air pollution is in an unhealthy range.</td>
</tr>
<tr>
<td>Environmental and resource conservation</td>
<td>Fuel use</td>
<td>Customer perception of satisfaction with air quality; Fuel consumption per VMT.</td>
</tr>
</tbody>
</table>

Source: Adapted from Sinha and Jukins (1978); Poiser (1997); Cambridge Systematics (2000).

of improvements at intermodal facilities. For intermodal connections (also called terminals), including rail-road crossings, rail depots (rail-highway), harbors and water ports (water-rail and water-highway; Figure 2.3), and airports (air-rail and air-highway), performance measures include:

- The percentage of time that congestion is experienced
- The incident frequency or severity
- The average time delay in passengers or freight
- The reliability of time taken for intermodal transfers

2.5.7 Entity or Stakeholder Affected

The perspectives of various affected entities and stakeholders often differ and are not aligned toward evaluating measures. Various economic groups may be interested primarily in facility preservation and financial solvency, whereas users may be more focused on travel time and accessibility. Adjacent businesses and residents may be more concerned with physical and operational impact such as relocation collisions from vehicles, pollution, and accessibility to raw materials, labor, and product distribution points. Environmental groups typically focus on damage to the ecology, wetlands, and water resources. Furthermore, specific advocacy groups may be particularly interested in safety or accessibility for disadvantaged users, for example. For a transportation project or action to be implemented successfully, it is important to consider the perspectives of all affected stakeholders as part of the evaluation process.

2.5.8 Spatial Scope

As explained earlier in Section 2.3, certain performance measures are more appropriate for network-level evaluation, whereas others are more appropriate for project-level evaluation. Even within these levels, performance measures have to be appropriate for specific spatial scales, such as statewide, countrywide, citywide, areawide, or corridorwise, or for a specific segment or intersection of a specific mode or terminal (for multimodal systems).

2.5.9 Level of Agency Responsibility

For a given set of other dimensions, performance measures may differ by the level of agency responsibility: state and local agencies may have different measures, as they typically have different perspectives regarding the intended benefits of transportation system actions. For example, the local economic development effect of a corridor improvement may not be an added benefit at the state level because the gain expected may simply be a shift from one local area to another.

2.5.10 Time Frame and Level of Refinement

There can be some performance measures that relate to immediate consequences (primary impacts) of the transportation action, whereas others are impacts that occur in the wake of the primary impacts: that is, secondary impacts. For example, construction of a new bypass may result in immediate impacts, such as a reduction in travel time, whereas secondary impacts, such as increased business productivity due to the travel-time reduction, will take some time to be noticed.

2.6 LINKING AGENCY GOALS TO PERFORMANCE MEASURES: STATE OF PRACTICE

There is widespread explicit or implicit use of the performance measures concept at transportation agencies all over the world. The current generation of performance measures is outcome oriented, tied to strategic objectives, and is focused on quality and customer service. For example, in the state of Delaware, the highway agency’s performance measures are connected to the agency’s goals, strategies, policies, and long-range transportation plans (Abbott et al., 1998). Also, the state transportation agency of Minnesota uses a performance measures pyramid that has a top layer comprising policy-based system-level performance measures reflecting outcome targets over a 20-year period; a second layer comprising performance measures specific to districts and transportation modes with long-term impacts; a third layer of performance measures specific to business plans, with a planning horizon of approximately two years; and a fourth layer of performance measures for systems operations that are associated with work plans with a planning horizon of one year or less. The fourth layer contains measures for project-level evaluation. The state transportation agency of California (Caltrans) uses a similar pyramid that consists of three tiers of performance measures for the purpose of monitoring the progress of its strategic plan. The apex of the Caltrans pyramid consists of a set of performance measures that are derived from the agency’s strategic goals. The second tier is comprised of performance measures that are performance goals for each program and for each service provided to customers in terms of quality, efficiency, and customer satisfaction. The third tier consists of performance measures for process and output quantities.

The OECD (2001a) discussed the institutional aspects of intermodal freight transportation, thus laying the groundwork for possible development of measures for assessing the performance of intermodal transportation facilities. Pickrell and Neumann (2000) presented various ways to link performance measures with decision making. Baird and Stammer (2000) developed a model that incorporated an agency’s mission, vision, goals, stakeholder perspectives, and system preservation and outcomes. Kosfis (2001) reinforced the need to amalgamate the several performance measures and stressed the importance of “omnidirectional alignment” of performance management systems (i.e., vertical alignment of goals, strategies, policies, programs, projects, and measures) versus isolated, fragmented, and horizontal alignment to span geographical units (such as districts or functional divisions). Prior (2004) emphasized the importance of performance measures and identified how they can be used in strategic planning at the executive level of an agency. TransTech Management, Inc. (2003) identified modal performance measures that could be used for transportation agencies and transportation project managers to augment the information they need to support transportation-project planning, design, and implementation.

2.7 BENEFITS OF USING PERFORMANCE MEASURES

The establishment of clear performance measures helps agencies to assess the degree to which a program, project,
in terms of improved system benefits. Performance measures therefore enable agencies to monitor facility performance, identify and undertake requisite remedial measures, and plan for future investments. By adopting performance measures for transportation project and program evaluation, an agency can gauge the following benefits:

1. Clarity and transparency of decisions. When the performance measures are objective and unbiased, transportation actions can be evaluated and selected in a rational and unbiased manner, thereby enhancing agency accountability.

2. Attainment of policy goals. The use of performance measures provides a basis upon which attainment of agency goals and objectives can be assessed, and provides a link between the ultimate outcomes of policy decisions and the more immediate actions of the agency. For example, the average waiting time for water vessel unloading for a given year can be compared with established thresholds so that any necessary improvements can be identified and implemented.

3. Internal and external agency communications. The use of performance measures provides a rational and objective language that can be understandable by various stakeholders and can be used to describe the level of progress being made toward the established goals and objectives (Pickrell and Neumann, 2000). For example, the average air traveler delay is a performance measure that is readily understood by the aviation operator, facility owner, air travelers, and the general public.

4. Monitoring and improvement of agency business processes. Performance measures can be used to evaluate the degree to which established strategic or tactical targets (yardsticks or benchmarks) have been achieved (Shaw, 2003). As such, they are useful for decision making regarding continuation of specific operational strategies. Performance measures therefore help not only to define or redefine goals and objectives, but also assist in network performance reviews for program development and for the facility planning stages of the project development process.

**SUMMARY**

Performance measures are needed at various stages of the transportation development process for the purpose of evaluating the various possible courses of action at each stage and also at various levels of transportation management and administration and consequently, for decision making. Performance measures also assess the degree to which the investment program selected has been successful in achieving agency goals and objectives.

**REFERENCES**


GASB 1989). Resolution on Service Efforts and Accomplishments Reporting, Governmental Accounting Standards Board, Norwalk, CT.


**EXERCISES**

2.1. For a proposed rail transit system to connect suburbs to downtown, list the possible goals, objectives, performance measures, and performance criteria.

2.2. What are the attributes of (a) an individual performance measure for purposes of systems evaluation, and (b) a set of performance measures?

2.3. You have been asked to evaluate the performance of a new air terminal that was constructed five years ago. What performance measures would you consider in such an evaluation? Defend your choice of performance measures.

2.4. It is proposed to widen an existing arterial street to make way for an HOV facility. List appropriate performance measures from the point of view of (a) the owner (local highway agency), (b) facility users, and (c) nonusers who are affected by the system.

2.5. An increase in air travel has made it necessary to expand the regional airport in the city of Townsville. You are asked to evaluate the proposed expansion project on behalf of the city. What types of performance measures would you select?

2.6. Consider a transportation company that provides bus transit service to the elderly and handicapped in a rural county in a contract with the county government. Develop a set of performance measures from the perspectives of the transportation company, the county government, and the service users.

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