CHAPTER 2

Performance Measures in Transportation Evaluation

Give no decision till both sides thou'st heard.
—Phocylides, sixth century B.C.

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?),

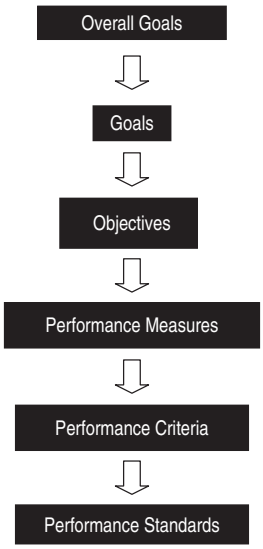

Figure 2.1 Hierarchy of desired outcomes for transportation system projects and programs.

Transportation Decision Making: Principles of Project Evaluation and Programming. Kumares C. Sinha and Samuel Labi

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 *threshold, 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 (Abbot et al., 1998). Literature on performance measures (Cambridge Systematics, 2000; Shaw, 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.

2.2 PERFORMANCE MEASURES AT THE NETWORK AND PROJECT LEVELS

The application of performance measures to transportation systems evaluation can occur at two levels:

1. *Network level* or *system level*. At this level, evaluation is used in programming and priority setting (determining the optimal use of limited funds for the entire network of transportation facilities), estimating funding levels needed to achieve specified systemwide targets (such as average facility condition or average user delay), and estimating the systemwide performance impacts of alternative funding levels, investment strategies, or policies.
2. *Project level* or *facility level*. Here, the intent is to select an optimum policy, physical design, or preservation strategy for a specific transportation facility, much as a pavement section, bridge, or transit terminal, at a given time or over the facility life cycle. Project-level evaluation is typically more comprehensive, deals with technical variables and design issues, and requires more detailed information than at the network level.

Performance measures used at the network level are typically used in a context that differs from those at the project level. For air transportation, for example, a project-level goal may be to assess the change in average plane delay in response to a specific project such as expansion of runway capacity; while at the network level, the goal may be to assess the average plane delay (averaged across an entire network of airports) in response to changes in nationwide transportation security policies. However, it must be noted that network- and project-level evaluation are often interdependent: Depending on its internal practices, an agency may carry out evaluation using a top-down approach (from network level to project level) or a bottom-up approach (from project level to network level). In the top-down approach, for example, performance targets can be established for the entire network, and then using project-level performance measures, specific projects can be identified to achieve network-level performance targets. In the bottom-up approach, project-level performance measures are first used to estimate the impacts of alternative actions (and their respective timings) at each facility, and then the corresponding impact of each set of actions at the network level is determined. It must be recognized that the optimal decisions

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

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

(*continued overleaf*)

Table 2.1 (*continued*)

Overall Goals	Goals	Objectives	Performance Measures	Performance Criteria
	Environmental quality and resource conservation	Minimize adverse environmental impacts or enhance environmental quality, including ecology, water quality and quantity, air pollution, noise, and privacy Reduce energy use or enhance energy efficiency Minimize damage to cultural heritage, such as historical sites and archeological treasures	Reduce air and noise pollution Reduce environmental degradation Improve aesthetics and general environmental quality Avoid damage to sites of cultural interest	Tons of carbon monoxide emitted per year Average energy consumed per vehicle per mile per year Percentage of green space, open space, and parkland Intrusion of cultural treasures sites
Equity	Improve quality of life	Enhance general quality of life and community well-being Promote social equity Promote environmental justice	Enhance community cohesion Enhance accessibility to social services Provide transportation opportunities for handicapped and other socially disadvantaged groups Increase recreational opportunities	Number of displaced persons, farms, businesses, and homes Benefits per income group

Source: Adapted from Cambridge Systematics (2000).

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.
- *Realistic*. It should be possible to collect, generate or extract reliable data relating to the performance measure without excessive effort, cost, or time.
- *Defensible*. The performance measure should be clear and concise so that the manner of assessing and interpreting its levels can be communicated effectively within a circle of decision makers and to the stakeholders and general public. This is often possible when the performance measure is clear and simple in its definition and method of computation.
- *Forecastable*. For planning purposes, it should be possible to determine the levels of the performance measure reliably at a future time using existing forecasting tools.

It is important that the list of selected measures be comprehensive, yet manageable, to facilitate a meaningful analysis. Transportation agencies that seek to select performance measures are concerned particularly with

the practicality of performance measures in terms of their usefulness, data availability and forecasting ability, flexibility across modes, data precision, dimensions, and other attributes. Poister (1997) and Shaw (2003) provided examples of performance indicators that have been used in past evaluation of highway projects, while Cambridge Systematics (2000) presented a perspective of how performance measures could be formulated and used in project evaluation.

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, statewide 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 2.2 Dimensions of Performance Measures

Dimension	Example
Overall goals	Economic efficiency, effectiveness, and equity
Objectives	Preservation of system condition, operational efficiency, economic development, quality of life, safety, and environment
Sector concerns	Private (profit) and public (service)
Flow entity	Freight and passenger
Modal scope	Multimodal and single mode
Specific mode	Highway, urban transit, railway, waterway, and pipeline intermodal
Entity and stakeholder affected	Agency, user, or nonuser
Spatial scope	Urban, rural, citywide vs. intercity
Level of agency responsibility	State, district, local
Time frame	Long and short terms
Level of refinement	Primary and secondary indicators
Intended use	Policy, programming, implementation, postimplementation review
Level of use of information	Management and operational levels

various particular demographic or geographic groups of the affected population or region and help to ensure that no group suffers a disproportionate level of hardship due to the transportation project. Examples of equity-based performance measures include those that can be related to environmental justice or how well the expected adverse community impacts can be mitigated.

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 facility or rolling stock and is 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 Performance* 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 for 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 both, 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 2.3 Examples of Network-Level Performance Measures Based on Highway System Goals and Objectives

Objective	Facility or Category	Performance Measures
System preservation	Pavement	Percentage of highway miles built to target design
		Average roughness or overall pavement index value for state highways, by functional class
		Percentage of highways rated good to excellent
		Percentage of roads with score of 80 or higher on overall highway maintenance rating scale
		Percentage of total lane miles rated fair or better
		Miles of highway that need to be reconstructed or rehabilitated
	Bridge	Percentage of highway bridges rated good or better
		Percentage of highway mainline bridges rated poor
		Number of bridges that need to be reconstructed or rehabilitated
Operational efficiency	Construction, maintenance, and operation	Cost per lane-mile of highway constructed, by functional class and material type
		Cost per unit of highway maintenance work completed; labor cost per unit completed
	Cost-effectiveness	Cost per percentage point increase in lane-miles rated fair or better on pavement condition
		Cost per crash avoided by safety projects
Accessibility	Roadway	Percentage of population residing within 10 minutes or 5 miles of public roads
		Percentage of bridges with weight restrictions
		Miles of bicycle-compatible highways rated good or fair
Mobility	Travel speed	Average speed vs. peak-hour speed
	Delay, congestion	Hours of delay
		Percentage of limited-access highways in urban areas not heavily congested during peak hours
	Amount of travel	Vehicle-miles of travel (VMT) on highways
		Percentage of VMT at specific road classes
		Percentage passenger-miles traveled (PMT) in private vehicles and public transit buses at specific road classes
Economic development	Support of economy by transportation	Percentage of wholesale and retail sales occurring in significant economic centers served by unrestricted market artery routes
Quality of life	Accessibility, mobility	Percentage of motorists satisfied with travel times for work and other trips
Safety	Number of vehicle collisions	Vehicular crashes per 100 million VMT
		Fatality or injury rates per 100 million VMT
		Crashes involving injuries per 1000 residents
		Crashes involving pedestrians or bicyclists
		Number of pedestrians killed on highways
	Facility condition–related	Percent change in miles in high-accident locations
		Percent crash reduction due to highway construction or reconstruction projects
		Reduction in highway crash due to safety improvement projects
		Number of railroad-crossing accidents
		Percentage of motorists satisfied with snow and ice removal or roadside appearance
		Risk (vulnerability) and consequence of facility element failure
	Construction-related	Number of crashes in highway work zones
Resource and environment	Fuel use	Highway VMT per gallon of fuel

Source: Adapted from Poister (1997).

- 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 duly 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.

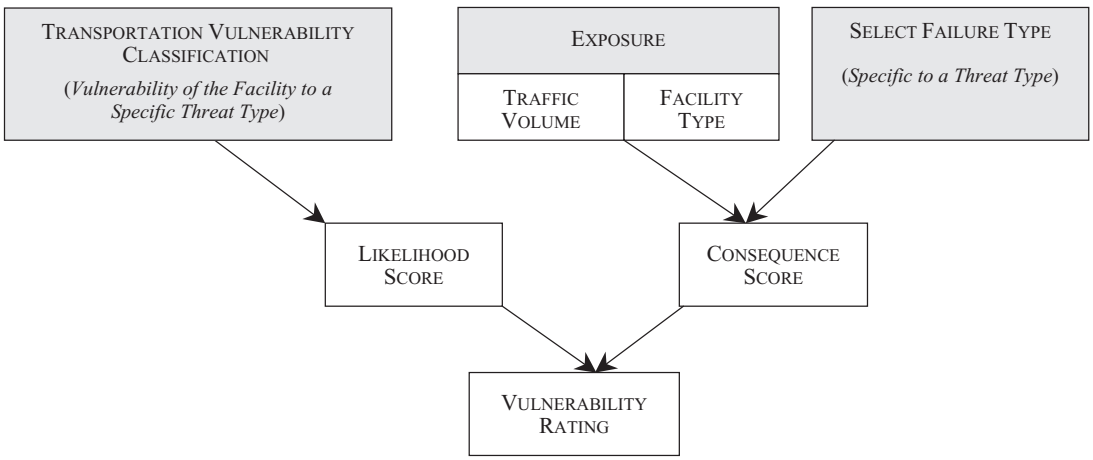

Figure 2.2 Generalized procedure for developing vulnerability ratings. (Adapted from New York State DOT, 1996–2002.)

(*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 ratio, 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 appear to 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 interchanges, 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 cars on line, average train speed, average terminal dwell time, and bill of lading timeliness. For passenger rail transportation, performance measures include on-time arrivals (the number and percentage of on-time rail services that exit or arrive at their destinations within an agreed threshold) and total trip delay (resulting from rail vehicle breakdown, or loading and unloading passengers at terminals). Delay can be expressed in several ways: for example, total delay, delay per vehicle, delay per delayed vehicles, delay per passenger, delay per day, delay per mile, delay per passenger per day, or delay per passenger per mile per day. Other performance measures for rail transportation are the frequency and rate of major incidents, complaints, and trip cancellations. Other rail performance measures can also relate to revenue, cost, or productivity, such as the revenue, cost, or output per resource input (e.g., employee, person-hour, railcar, time).

Performance measurement for urban rail and bus systems has become fairly standardized, due in part to long-standing reporting requirements for transit operators receiving financial assistance from Federal Transit Administration (FTA). Examples and details of performance measures for urban transit are available in the literature (Sinha and Jukins, 1978; Fielding, 1987). A summary of these measures is presented in Table 2.4.

(*c*) *Air* For air transportation, arrival delays are monitored and published routinely for each airline. For airport facilities, typical performance measures can be categorized as described below.

Operational Adequacy: An important item for airport operation is the gate delay, which can be represented by the demand–capacity ratio. Federal Aviation Administration (FAA) guidelines specify the demand–capacity ratio thresholds at which an airport should begin planning to resolve capacity constraints or to implement these plans. At the network level, performance measures related to air transportation capacity include the percentage of system airports that operate at or above a specified level of their annual operational capacity, the percentage of a region (by area, population, or number of business centers) that is within a specified distance or travel time from the nearest system airport, and the percentage of system airports with adequate automobile parking facilities.

Physical Adequacy: Performance measures in this respect include whether the runway and taxiway separations of an airport meet the current FAA guidelines, whether an airport has runway safety areas on its primary runway that meet established standards, whether an airport meets pavement condition standards on its primary runways, whether an airport has shared airspace resulting in operating restrictions, and whether an airport has any obstruction that may affect its operations. At the network level, performance measures involve the percentage of system airports that have the foregoing characteristics.

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 following: whether an airport has worked with surrounding municipalities to adopt height zoning based on federal guidelines, whether an airport is recognized in local comprehensive plans and/or regional vision statements for a community, whether an airport has a noise management plan, and whether the airport complies with state or federal guidelines regarding "airport influence maps" and public disclosure.

Financial Performance: Measures used to evaluate the financial performance of an airport may include the operating ratio, the level of subsidy, and the amount of revenue generated in relation to the number of passengers served. At the network level, performance measures involve the percentage of system airports that have the foregoing characteristics.

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 ability of an airport to provide adequate ground and air access include the extent to which a region, its population, and its major business centers are within a 30-minute drive time of the airport; whether an airport is served by public transportation; and whether an airport has intermodal transfer capabilities. At the network level, performance measures could involve the percentage of system airports that satisfy the characteristics discussed above.

2.5.6 Number of Transportation Modes Involved

A performance measure may be associated with only a single mode or with two or more modes. For example, the delay encountered in freight transfer from rail to truck 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

Table 2.4 Summary of Transit Performance Measures

Goal Category	Category	Performance Measure
System preservation	Transit vehicle	Miles between road calls for transit vehicles
		Age distribution of vehicles
		Capacity or remaining useful life index
Operational efficiency	Financial	Fare recovery rate of urban transit system
		Cost per passenger-mile of travel (PMT) in urban areas
		Cost per VMT in urban areas
		Cost per revenue-mile in urban areas
		Cost per PMT in rural areas
		Cost per VMT in rural areas
		Cost per revenue-mile in rural areas
		Total transit operating expenditure per transit-mile
		Grant dollars per transit trip
	Ridership	Transit ridership per capita
		Transit ridership-to-capacity ratio
		Transit ridership per VMT
		Transit ridership per route-mile
		Transit ridership per revenue-mile
		Transit peak load factor
		PMT on intercity rail and bus service
	Operational	Number of peak-period vehicles
		Revenue vehicle hours per transit employee
		Average wait time to board transit
		Ratio of number of transit incidents to investment in transit security
Accessibility	Access to and amount of transit	Percentage of population with access to (or within a specified distance from) transit service
		Percentage of urban and rural areas with direct access to bus service
		Percent of workforce that can reach work site in transit within a specified time period
		Access time to passenger facility
	Service characteristics	Route-miles (or seat-miles or passenger-miles) of transit service
		Frequency of transit service
		Route spacing
		Percentage of total transit trip time spent out of vehicle
	Facility characteristics	Transfer distance at passenger facility
		Availability of intermodal ticketing and luggage transfer
		Existence of information services and ticketing
	Parking, pickup/delivery	Volume–capacity ratio of parking spaces during daily peak hours for bus or other passenger terminal lots
		Parking spaces per passenger
		Parking spaces available loading and unloading by autos
		Number of pickup and discharge areas for passengers
Mobility	Transit	On-time performance of transit
		Frequency of transit service
		Average wait time to board transit
		Number of public transportation trips

(*continued overleaf*)

Table 2.4 (***continued***)

Goal Category	Category	Performance Measure
		Passengers per capita within urban service area
		Number of commuters using transit park-and-ride facilities
		Number of demand–response trip requests
		Percentage of transit demand–response trip requests met
Economic development	Transit	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
Quality of life	Transit accessibility, mobility	Customer satisfaction with commute time
		Customer perception of quality of transit service
Safety	Transit	Transit collisions (injures or fatalities) per PMT
		Transit collisions (injures or fatalities) per VMT
		Number of intercity bus collisions
		Crimes per 1000 passengers
		Ratio of number of transit collisions to investment in transit security
Environmental and resource conservation	Air pollution	Tons of pollutants generated
		Air quality rating
		Number of days for which air pollution is in an unhealthful range
		Customer perception of satisfaction with air quality
	Fuel use	Fuel consumption per VMT

Source: Adapted from Sinha and Jukins (1978); Poister (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 significantly. For example, an agency 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

Figure 2.3 Multimodal performance measures at intermodal terminals include average delay of freight transfer. (Courtesy of Kevin Walsh, Creative Commons Attribution 2.0.)

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 scopes, such as statewide, countrywide, citywide, areawide, or corridorwide, 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 geared toward evaluating products and services 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. Kassof (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) so as to span the organizational hierarchy and horizontal alignment to span geographical units (such as districts or functional divisions). Poister (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 help provide transportation agencies and transportation project managers with 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,

or policy will be or has been successful in achieving its intended goals and objectives in terms of improved system benefits. In effect, performance measures help transportation agencies 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 reap 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 hierarchical 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 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. They also assist in ensuring internal agency clarity, communications and transparency, internal agency efficiency and effectiveness, and monitoring and improvement of agency business processes. Performance measures therefore not only aid in defining or redefining goals and objectives but are also helpful during the system of facility planning stages of the transportation development process. The identification of goals and objectives is a key prerequisite to the establishment of performance measures and therefore influences the evaluation and decision outcome. Selection of appropriate performance measures depends on the type of transportation facility, the stage of the transportation development process at which evaluation is being carried out, whether the transportation stimulus under investigation is a policy or a physical intervention, whether the evaluation is preimplementation or postimplementation, and whether it is a network-level problem or a project-level problem. A suitable performance measure should be appropriate, measurable, realistic, defensible, and forecastable and should address all dimensionality aspects of the evaluation. It is important that the final set of measures selected be comprehensive, yet manageable, to facilitate meaningful analysis. The current generation of performance measures at most agencies are derived from agency goals that are outcome oriented, tied to strategic objectives, and focused on quality and customer service.

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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