A Priority System for Multimodal and Intermodal Transportation Planning

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Abstract

Prioritization is an increasingly important concept for transportation system planning and programming. The resources for capital improvements to state and regional transportation systems are stagnant or declining. AT the same time, population growth, urban development patterns, and travel behaviors are increasing the demands placed on transportation systems. The number and range of interest groups, each with separate sets of transportation objectives, make it increasingly difficult to pinpoint the "public good." ISTEA mandates consideration of multiple modes, but it is difficult to compare the relative benefits of projects across modes. Public trust in the ability of government agencies t make resource allocation decisions can be intense. Given all these factors, planners need to prioritize. They need to make hard choices about which projects to select for funding, and which to scale back, postpone or not fund at all. Formal priority systems can help planners identify and justify the choices that achieve the greatest benefit in this complex environment.

This paper describes an innovative application of formal prioritization principles to intermodal planning. A priority system was constructed as part of the development of Oregon Department of Transportation Intermodal Management System. It is designed to help identify transportation system needs based on quantitative, facility type-specific performance measures; to rank the needs; and to prioritize projects for meeting the needs. In addition, the system provides an opportunity for sensitivity analysis to distinguish which assumptions or uncertainties significantly affect priorities from those that do not. This information can point the way to data collection efforts that are most effective in improving the allocation of investment resources. This work produced a practical and logically defensible system for supporting the ODOT planning process, and generated concepts and models of potential use for other aspects of transportation planning and programming.

The priority system was tested through an application to 25 actual intermodal system needs and proposed projects. For example, the application compared projects to improve truck access to a railway yard, widen a roadway segment, build a railroad overcrossing, and add information kiosks at a passenger terminal. Following the system logic, needs were ranked based on the benefit that would result from eliminating those needs, and projects were ranked based on benefit-to-cost ratio.

Topics addressed in the paper include principles of prioritization, methods of quantifying benefit, models for estimating performance for ten types of intermodal transportation facilities (connector and mainline roadways, bus station, rail passenger stations, air passenger terminals, marine terminals, rail truck facilities, grain, reload facilities, petroleum terminals, truck terminals, and air cargo facilities), ranking methodologies, and software implementation.

Prioritization is an increasingly important concept in transportation system planning. The resources for capital improvements to state and regional transportation systems are stagnant or declining. At the same time, population growth, urban development patterns, and travel behaviors are increasing the demands placed on transportation systems. The number and range of interest groups, each with separate sets of transportation objectives, make it increasingly difficult to pinpoint the "public good." The Intermodal Surface Transportation Efficiency Act (ISTEA) mandates consideration of multiple modes, but it is difficult to compare the relative benefits of

projects across modes. Public trust in the ability of government agencies to make effective and efficient use of public funds is at an all-time low, and public scrutiny of resource allocation decisions can be intense. Given all these factors, planners need to prioritize-they need to make hard choices about which projects to scale back, postpone, or not fund at all. Formal priority systems can help planners identify and justify the choices that achieve the greatest benefit in this complex environment.

This paper describes an innovative application of the formal principles of prioritization to intermodal transportation planning. The project-conducted for the Oregon Department of Transportation (ODOT), Metro (Portland's metropolitan planning organization [MPO]), and the Port of Portland-developed a formal priority system known as the Intermodal Transportation System Prioritization Model (ITSPM). ITSPM is designed to help identify critical needs of the intermodal system, rank those needs, and prioritize projects proposed to meet them. It is important to note that the priority system is not intended to make decisions; rather, it provides information for decisionmakers. This work produced a practical and logically defensible system for supporting the ODOT and MPO planning processes. It also generated concepts and models of potential use for other aspects of transportation planning and programming.

Principles of Prioritization

According to prioritization theory, projects should be prioritized based on the ratio of benefits generated to project costs. If proposed projects are independent of one another and can be either funded or not, then the set of projects offering the greatest possible benefit for the available budget will be that which is produced by ranking the projects by their benefit-to-cost ratios and then funding them from the top down until the budget is exhausted. Another basic prioritization principle is that the prioritizing criteria should be derived from objectives. By definition, any incremental improvement in the achievement of an objective is a benefit.

Following this theory, prioritization criteria for ITSPM were derived from statements of the basic objectives for the ODOT intermodal transportation system. Objectives were defined by an advisory panel of transportation managers and experts assembled for the project and were reality-tested through interviews with facility operators and system users. The following objectives were identified:

- Satisfy the demand for transportation services

- Maximize the quality of service to customers

- Maximize safety

Benefit was defined as an incremental improvement in the achievement of one or more of these objectives; priority system logic is directed at quantifying such benefit.

Quantifying Benefit

Performance measures were defined to quantify the degree to which transportation system objectives are achieved. Facility usage, or throughput of people, vehicles, and freight, was defined as the performance measure for quantifying the satisfaction of demand. Thus, projects were assumed to improve the satisfaction of customer demand if they result in increased facility usage, or throughput. Two measures were defined for quality of service. One is user service time. In the

Figure 1. Priority System Objectives and Performance Measures
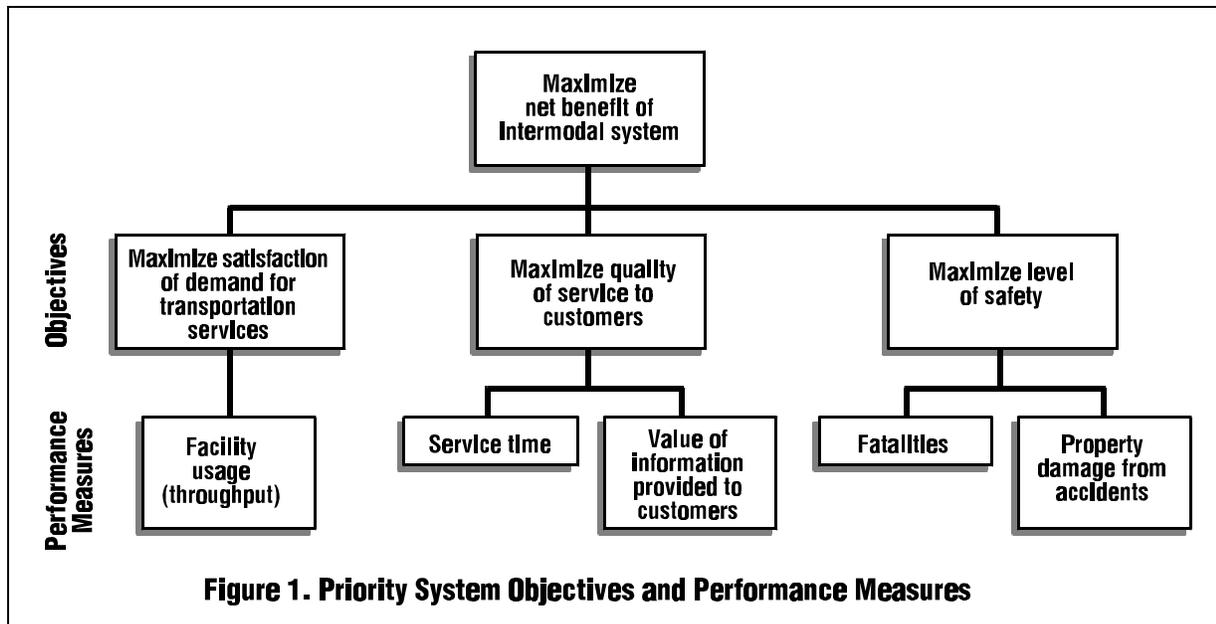
case of roadways, for example, a project may improve the quality of service if it decreases the traffic delays experienced by motorists. The second performance measure for quality of service is the value of information provided to potential customers. Thus, for example, improved signage to facilities on connector roadways and placement of information kiosks in passenger facilities were assumed to improve service to the extent they provide information useful to customers. The level of safety is measured by fatalities and property damage resulting from accidents. Figure 1 summarizes the relationship between performance measures and objectives.

To permit the comparison of projects that improve different performance measures (e.g., a project that reduces traffic accidents versus a project that reduces customer delays), the measures of performance are converted to equivalent dollar values. Thus, the system allows project benefits to be expressed either in the units of system performance (e.g., a reduction in total customer delays, expressed in minutes) or in dollar values. The conversion is accomplished using a set of value weights (e.g., equivalent dollar value per fatality averted, equivalent dollar value per hour of travel time saved). These weights are input parameters for the system. Although the model contains default weights based on surveys, expert judgments, and willingness-to-pay data, users can alter these parameters to reflect their personal value judgments or the value judgments of their organizations.

Models for Estimating Facility Performance

Models were developed to estimate the performance measures for ten types of intermodal transportation facilities. These facilities include bus stations, rail passenger stations, air passenger terminals, marine terminals, rail truck facilities, grain reload facilities, petroleum terminals, truck terminals, air cargo facilities, and connector and mainline roadways to these facilities. The models consider both current levels of service as well as projected future conditions. For example, all of the models allow for input of growth rates to convert current levels of throughput into estimated future levels. This ability to take into account expected future conditions is unusual; most models limit future throughput to the maximum capacity of the existing facility. As usage rates approach

capacities, the models estimate the increased delay times for users.

The models for estimating the value of safety and information are relatively simple. The economic costs of facility accidents are estimated by multiplying the number of accidents by the average dollar loss per accident. The dollar cost per accident includes the average property damage cost plus an equivalent economic cost for injuries and the risk of loss of life. To estimate the value of information from improved signs, for example, a potential user is asked to input a raw estimate of information value based on the usefulness of the information to customer decision-making. This value can be estimated using decision analysis techniques for calculating the value of information. The raw information value is then multiplied by an estimate of the number of users who will receive the information (e.g., the number of people expected to walk past a sign providing instructions) and multiplied by a factor representing the estimated effectiveness of the chosen mode of communication. In some cases, effectiveness is reflected in reduction of service time.

The models for estimating user service times are more complex, but they are based on standard algorithms and straightforward logic. In the case of roadway segments, for example, the model uses peak-hour volumes and assumes that these volumes will occur for 3 hours during a typical weekday. Stoppages (calculated in seconds per vehicle) traditionally associated with volume-to-capacity ratios are used as input to a delay model that also incorporates other factors affecting delay, such as roadway geometrics, barriers (e.g., at grade rail crossings), pavement conditions, and entering driveways. Intersection delay is also calculated using standard algorithms that consider the characteristics of the intersection (e.g., number of lanes, configuration, type of signalization, etc.). The average delay per vehicle is estimated based on the ratio of intersection volume to capacity. For each period, the total delay is the average delay per vehicle times the total number of vehicles entering the intersection. Total intersection or road-segment delay is the sum of the delays over the 20-year planning horizon, taking into account traffic growth projections.

The system allows field data or traffic model outputs to be substituted for estimates provided in the priority system model. In Portland, for example, delay time can be estimated by Metro's traffic model and is likely to be more accurate. However, in many parts of the state no system models are maintained, and even where models exist, many of the local road segments connecting inter-modal facilities to the mainlines are not included. Traffic model outputs can be used over time to refine the priority system delay models.

Identifying Needs, Ranking Needs, and Prioritizing Projects

ITSPM uses available data, user-provided inputs, and its performance models to identify and rank needs and to prioritize projects. To aid in the identification of needs, threshold levels of performance are associated with factors represented in the performance models. For example, for accident rates, the threshold is set at 150 percent of statewide average rates at similar facilities. As another example, if throughput at a passenger or freight terminal is approaching the capacity limit for the terminal, a need to increase terminal capacity is identified.

Needs are quantified by computing the improvement in the facility performance measures that would result if the need were eliminated. Thus, for example, the need to reduce delays is quantified by computing the total user time that could be saved if all drivers could drive at the posted speed limit. Or, at a container port where a need for additional capacity is identified, the volume of additional twenty-foot equivalent units (TEUs) that could be handled over the 20-year time

horizon by expanding the facility is calculated (see Figure 2). From this volume, the estimated improvements in performance measures can be converted to equivalent dollar benefits using the value weights. ITSPM ranks needs in order of the magnitude of the estimated benefits. The need which, if eliminated, would produce the greatest increase in benefit is ranked first.

ITSPM ranks projects by estimating the changes in facility performance measures that would result if each project were to be implemented. To evaluate a project, the user specifies the data elements that would be changed as a result of the project (e.g., an addition of a lane to a road segment). The facility models are then used to estimate incremental improvements in performance (e.g., reduced delays), and the value weights are used to convert performance improvements to an equivalent dollar benefit.

Figure 2. Capacity Need Calculation for a Container Port over a 20-Year Time Horizon

fit. If a project produces multiple performance improvements, the benefits are summed to obtain the total benefit of the project. That benefit is then compared with estimated project costs, and projects are ranked by their benefit-to-cost ratios.

Note that the ranking of needs requires fewer inputs by users than does the ranking of projects. As indicated above, the system ranks needs by estimating the benefit that would result if each need were eliminated. (i.e., the improvement in the achievement of objectives that would result if a sub-par level of performance could be replaced by a desired or ideal level of performance). Ranking needs is simpler because it does not require inputs describing the characteristics of the project proposed to address the need. However, unlike project ranking, need ranking does not consider the cost-effectiveness or feasibility of eliminating the need.

Software Implementation

A pilot version of ITSPM has been implemented using Microsoft Excel (Version 5.0c). The pilot implementation is a simple spreadsheet model that includes three facility types: lineal roadway segments, intersections, and passenger terminals. The program has four main sheets that perform calculations, plus an "Input" sheet that facilitates data entry and a "Results" sheet that aggregates and summarizes results from the other sheets. The Input sheet requests data to perform the need and benefit calculations-it includes a section for existing facility characteristics and a section for the facility characteristics as they would appear following the execution of a proposed project. The calculation sheets compute the facility performance measures under existing conditions and under the improved conditions resulting from elimination of facility needs and from the implementation of proposed projects. Benefits of candidate project improvements are determined in
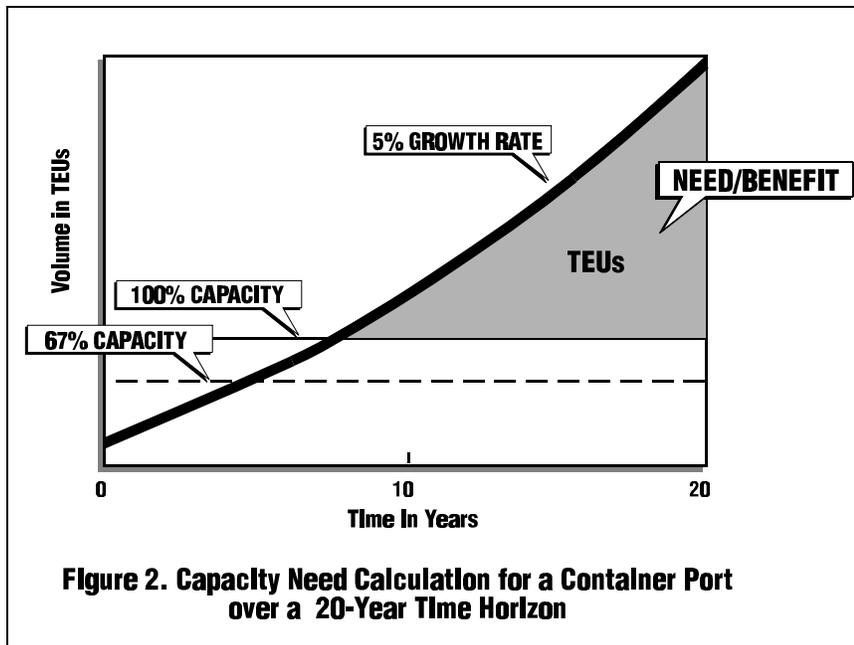
terms of the differences in performance measures between improved and existing conditions. Annual operations and maintenance (O&M) costs are input data; capital costs are debt-service payments calculated under the assumptions that capital costs will be financed over the forecast period on a levelized payment basis. Annual benefits and costs are calculated using a discount rate. The difference between these values is the net present value of the candidate project. The ratio of the present value of benefit to present value of cost is used to rank candidate projects.

The ITSPM has been incorporated into the ODOT Intermodal Management System (IMS) database. The IMS database and computer program were developed in a user-friendly Windows format that consists of a logical and physical database design and a series of programs to accommodate collection and editing of data. The database also allows updates as well as access and manipulation of the data to support analysis. Users are able to perform queries based on any combination of system attributes, view data on one or multiple IMS elements, calculate performance measures, and produce rankings in user-specified formats.

Sample Application

ITSPM was tested through application to 34 actual transportation system needs and the projects proposed for addressing those needs. For example, the application compared projects to improve truck access to a railway yard, widen a roadway segment, build a railroad overcrossing, and add an information kiosk at a passenger terminal. Input data for the various projects included current facility usage and annual growth rates, times of roadway blockage and facility downtimes, the numbers of lanes and lengths of roadway segments, average roadway speeds and posted speed limits, types of signals at intersections, number of property damage and fatality accidents, information access rates, and estimated project capital costs and ongoing O&M costs. The facility performance models were used to calculate future annual throughput rates, customer services times, information value provided to customers, and fatality and property loss rates. Following the system logic, needs were ranked based on the benefit that would result from eliminating those needs and projects were ranked based on the benefit-to-cost ratios.

The results demonstrate the value of a formal priority system. Given the large number of considerations relevant to assessing the value of proposed projects, it is extremely difficult to evaluate and compare those projects without the aid of formal prioritization logic. Thus, although the resulting ranking was viewed in retrospect to be intuitive, it is unlikely that even experienced planners could have obtained the results without the aid of the system. In general, highly ranked needs tend to be those that (a) significantly detract from the facility's ability to achieve a favorable level of performance and (b) impact a large number of actual or potential facility users. Highly ranked projects tend to be those that (a) are estimated to alleviate substantially one or more highly ranked needs and (b) do so at low to moderate total cost.

In addition to providing an integrated ranking of needs and projects for the whole system, need and project rankings can also be provided by need type (e.g., the facility with the greatest capacity need, or the project that provides the greatest safety benefit), or by facility type (e.g., the marine terminal with the highest aggregate needs of all marine terminals, or the project that provides the highest benefit to air passengers). To respond to geographic equity issues created by metropolitan/rural differences in the sizes and types of facilities, need and project rankings can be prepared for individual regions rather than for the state as a whole.

Conclusions

ITSPM demonstrates the practical value of using formal prioritization logic to aid in transportation system planning. In addition to providing a defensible prioritization of needs and projects, the priority system directly incorporates public values through objectives formulation, allows "apples to apples" comparisons of different types of needs and projects, increases understanding of value trade-offs, provides a mechanism for achieving consensus decisions among diverse stakeholder interests, is auditable and replicable, and fosters efficient use of limited resources.

Another important benefit of the system is its ability to answer "what if" questions. Sensitivity analyses can be conducted wherein importance weights and other value assumptions are varied across a range of values chosen to reflect different opinions. Sensitivity analyses can also be conducted wherein performance measures are varied across their ranges of uncertainty. Those assumptions or uncertainties that significantly affect priorities can be distinguished from those that do not. The identification of critical assumptions points the way to additional analyses and data collection efforts that can most effectively improve the allocation of investment resources.

The cumulative cost/benefit curve provided as an output of this priority system can increase agency credibility by showing the direct linkage between benefits received for particular levels of funding (see Figure 3). The return on investment is much greater on the steeper part of the curve. Showing high multiples of benefits related to cost in this graphic format is often useful for justification of increased allocations.

Other relevant applications for this type of priority system include other ISTEA management systems, as well as project selection for State and Metropolitan Transportation Improvement Programs, Congestion Management Air Quality/enhancement programs, and city/county capital improvement programs.

Figure 3. Cumulative Cost/Benefit Curve