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Development of a Computer Model for Multimodal, Multicriteria Transportation Investment Analysis

This digest summarizes NCHRP Project 20-29(2), "Development of a Computer Model for Multimodal, Multicriteria Transportation Investment Analysis." The Transportation Decision Analysis Software, or TransDec, was developed to provide the transportation practitioner with an easy-to-use tool for performing multimodal, multicriteria investment analysis. This digest is based on a draft final report prepared by Drs. Stephen S. Roop and Sondip K. Mathur of the Texas Transportation Institute.

INTRODUCTION

This digest provides the details on and discusses the concepts of a software package (the Transportation Decision Analysis Software, or TransDec) to assist state and local planners in making alternative decisions on modal investment.

Transportation policies and systems in the United States have developed along modal lines with different patterns of ownership. For example, public agencies plan and maintain the highway infrastructure, and private firms build, operate, and maintain rail lines. Although there have been some variations on this pattern with the construction of private toll roads and the investment of public funds in rail planning and rehabilitation, public planning and investment decisions are usually made independently by mode. Mode-oriented planning and investment have been shown to be economically inefficient and generate fewer social benefits than might have been achieved under a multimodal approach. For example, research has indicated that abandoning rail lines, with the subsequent diversion of traffic from rail to truck, can significantly increase highway infrastructure maintenance costs. Thus, the investment of public funds in rail branch lines not only generates shipper benefits, but also reduces future highway and bridge costs. Since the enactment of the Intermodal Surface Transportation Efficiency Act of 1991, there has been widespread interest in tools to conduct cost-benefit analysis and economic assessments of alternative transportation improvements.

NCHRP Project 20-29, "Development of a Multimodal Framework for Freight Transportation Investment: Consideration of Rail and Highway Trade-Offs," completed research that (a) synthesized good economic principles and practices into a framework for multimodal transportation investment, (b) evaluated various examples of transportation investment trade-offs (focusing on trade-offs between rail and highway), and (c) developed a framework for better decision making for transportation investments. NCHRP Project 20-29(2) expanded the framework developed in NCHRP Project 20-29 and developed a generic software package to facilitate the multimodal, multicriteria transportation investment analysis for both freight and passenger transportation.

Working with multiple investment alternatives, objectives that are often contradictory, and measures that do not lend themselves well to quantification (e.g., the value of "scenic beauty") is a daunting task made even more difficult by the need to demonstrate consideration of multiple effects of policy decisions. To ease the management of this process, the 20-29(2) research team developed specifications for a computer software system that would guide the transportation practitioner through the multimodal, multicriteria analytical frame-

work. This software system, TransDec, systematizes the mechanics of performing multicriteria investment analysis and relieves transportation planners of the computational burden imposed by the framework.

The multicriteria, multimodal analytical framework, along with the TransDec software system, represents an improvement in the state-of-the-art tools available to the transportation practitioner responsible for evaluating and recommending how the agency should allocate its resources to achieve organizational objectives. Conventional cost-benefit approaches focus on evaluating a single investment option at a time. The results are usually computed separately for individual alternatives, and the alternatives are not comparatively ranked. In contrast, the multicriteria analysis evaluates a given set of decision alternatives over a common set of evaluation objectives, and the results of the analysis comparatively rank the alternatives. Transportation planners, engineers, and agency administrators will be able to use this framework and the TransDec software system to design plans, investigate investment strategies, and devise policies to solve selected transportation problems.

This digest summarizes the capabilities of the TransDec software system. The TransDec software and *Introductory User's Manual for Multimodal, Multicriteria Transportation Investment Analysis* may be obtained from the McTrans Center, University of Florida, 512 Weil Hall, P.O. Box 116585, Gainesville, FL 32611-6585. The software system will be listed in the McTrans summer 2001 catalog. The McTrans Center may be reached by phone at (352) 392-0378 or by email at mctrans@ce.ufl.edu.

INTERMODAL VERSUS MULTIMODAL

The terms *intermodal* and *multimodal* have several different meanings depending on the context and, in some cases, are used interchangeably. In an intracity context, intermodalism may be interpreted to describe situations in which two or more intercity modes use a common transportation facility. In an intercity context, intermodalism may be interpreted to describe rail freight movement using trailers, or containers, on flat cars or a double stack of containers on special rail cars. Within a facility context, intermodalism may describe the movement of people or goods within a transportation facility.

Intermodalism focuses on connecting several different modes into a seamless transportation system with efficient intermodal transfer terminals. These connective terminals, or nodes, are perhaps the most important part of an intermodal transportation network. If intermodal transfers are slow or inconvenient, users will resort to what they perceive as the more efficient unimodal system.

A multimodal system shifts the focus from the transportation system nodes to transportation system links, which connect the nodes. A multimodal system provides system users with a choice of modes along those links. In a nonurban multimodal situation, air routes, highways, and railroads connect cities. In the urban context, a multimodal network might consist of linking the airport with the central business district using public transit, private automobiles, and taxis.

Multimodal planning involves

- A generic definition of a transportation problem,
- Identification of more than one modal option to solve the problem, and
- Evaluation of modal options in an unbiased manner to assess each mode's contribution either individually or in combination.

Intermodal planning, on the other hand, involves

- Identification of key interactions, between one or more modes of transportation, in which the performance or use of one mode affects another;
- Definition of strategies for improving the effectiveness of the modal interactions; and
- Evaluation of the strategies' effectiveness in terms of enhancing overall performance of the system.

Multimodalism refers to the study of modal interactions as they help solve larger problems in the transportation system, whereas intermodalism refers to the study of modal interactions as they affect system performance. Multimodal planning provides the general context within which intermodal planning occurs.

MULTICRITERIA

Multicriteria project analysis allows the transportation practitioner to move beyond the traditional cost-benefit techniques and incorporate into the investment decision process elements that are traditionally not included. Goals and objectives are used to define the criteria.

A goal generally indicates the direction in which one would strive to do better. An example of a broad goal is to "improve mobility." Such a broad goal provides little, if any, insight into which of a number of alternative programs may be best or even worthwhile to pursue. It does, however, provide a useful starting point for specifying related objectives that point toward performance measures that may operationalize policy objectives and goals.

Objectives are measures of policy goals. They represent the quantifiable attribute of an investment policy goal. For example, the goal "enhance mobility" may be detailed into the objectives "decrease volume-to-capacity ratio," "reduce trip time," and "facilitate system usage." For each of these objectives, one can associate a measure (e.g., ratios, units of time, ton-miles) that will indicate the degree to which alternative policies meet the broader goal. Objectives are derived from policy goals and are measurable, thereby making the broad policy goals empirically operational.

The following is an outline of goals and objectives upon which transportation planners may base transportation investment decisions:

- **Improve mobility.** Enhance mobility for all users of a transportation system, including passengers, freight carriers, and other agencies.
- **Improve connectivity.** Facilitate transfer between links and nodes.
- **Increase cost-effectiveness.** Minimize user and societal costs of the transportation system.
- **Increase energy efficiency.** Minimize energy costs of the transportation system.
- **Improve air quality.** Minimize emissions of pollutants from the transportation system.
- **Reduce resource impact.** Minimize degradation and destruction of natural resources due to the transportation system.
- **Reduce noise impact.** Minimize noise impact of the transportation system.
- **Improve accessibility.** Enhance timeliness of the system for users between origins and destinations, including residential, employment, social, commercial, and military locations.
- **Reduce neighborhood impact.** Minimize adverse neighborhood impacts from the transportation system.
- **Improve the economy.** Foster employment, regional economic growth, and interregional trade through transportation system user mobility.

GENERAL SOFTWARE PARAMETERS

TransDec is designed to provide the transportation practitioner with an easy-to-use tool for performing multimodal, multicriteria investment analysis. The software system is written in Microsoft Visual Basic (version 3.0) and operates under Windows 3.1 or higher on any IBM-compatible computer with at least 8 MB of random access memory (RAM). The system also provides the ability to link to Microsoft Excel (if Excel is installed on the host computer), perform complicated data manipulations in the spreadsheet, and then import the resultant calculations back to TransDec. The capability to pass information between TransDec and Excel is provided through a dynamic data exchange.

TransDec is a menu-driven software system designed to allow transportation practitioners to evaluate and provide structure to transportation investment decisions on the basis of multiple goals, objectives, and measures. TransDec guides the decision-making process through a hierarchy of broadly defined project goals tied to specific objectives, with each objective operationalized by a value measure. This organization serves to add consistency and structure to the process of selecting the best of several possible projects or courses of action. The following steps characterize every TransDec investment analysis project:

1. **Identify overall transportation policy goals.** The first step in any TransDec analysis is to define the goals of the project. Project goals assist the transportation practitioner in structuring an analysis that focuses on the results (i.e., what is to be achieved by selecting the best among the investment alternatives being evaluated). An example of a broad goal would be to maintain freight mobility.
2. **Identify project evaluation objectives for each goal.** Objectives are specific, operationally defined categories in which to gauge or support the goals to be achieved in the alternative evaluation and selection process. For example, the goal "maintain urban mobility" might be supported by the objective "reduce freeway congestion."
3. **Assign a measure to each objective.** A measure is a quantifiable component of an objective, or the numeric or verbal value used to compare or evaluate alternatives. An example of a measure for the objective "reduce freeway congestion" would be the congestion index "volume-to-capacity ratio."
4. **Assign a rating scale to each objective's measure.** Rating scales define the form that the values of objective measures may take. The scales employed may be numeric, verbal (e.g., high, medium, or low), binary, ordinal, or anything else that might be developed. The rating scale selected allows the definition of favorable alternatives. Depending on the objective, a low numeric value may be preferred (e.g., for the objective "minimize air pollution," measured by milligrams of nitrogen oxide per ton-mile).
5. **Identify investment alternatives.** Following the assignment of rating scales to project objectives, the next step is to define the investment alternatives to be evaluated. At least two investment alternatives (e.g., purchase rail line or build new track) must be defined in TransDec.
6. **Attach a weight to each of the objectives.** The last step before using TransDec for investment analysis is to assign weights to project objectives. TransDec has four means of assigning weights: direct, pairwise, swing, and standardized.
7. **Normalize the data.** Each of the objectives is normalized onto a 0- to 10-point "value" scale.
8. **Perform sensitivity analysis.** The resultant rankings of the normalized data are submitted to sensitivity analysis to test the rankings' robustness. Sensitivity analysis involves varying each of the objective weights by plus or minus 5 percent and plus or minus 10 percent.

By following the previous steps, TransDec provides a framework within which to define the problem, select measures appropriate to the problem, and evaluate results using the weighted emphasis placed on project objectives.

WAYS TO APPLY THE MULTIMODAL, MULTICRITERIA TRANSPORTATION INVESTMENT ANALYSIS MODEL

To Monitor the System and Identify Weaknesses

Transportation investment decision making can be described as a chain of "principal-agent" relationships, from elected representatives to transportation agency officials who actually deliver to citizens. The use of TransDec can mitigate information problems inherent in the principal-agent relationship by making explicit the values that form the basis for a public agency's decision making. In this regard, the model can be used to conduct threshold analysis, in which thresholds are set for appropriate system elements in order to safeguard national, regional, and local priorities. Functional infrastructure characteristics, regulatory concerns, or other specific needs may determine thresholds.

TransDec aggregates normalized objective measures with their respective weights to generate overall project rankings. Therefore, the project selection process can incorporate more than one baseline alternative among the relevant decision alternatives being evaluated. The baseline may be the existing system (i.e., the "no-action" alternative), or it may be a hypothetical alternative representing ideal or targeted threshold levels of objective performance. The baseline will indicate whether the "best one" among the relevant alternatives is the one to undertake. The overall rankings generated by the investment model provide this information. Projects that are ranked below the baseline are not beneficial, and vice versa. The model normalizes objective performance measures using rating scales. These rating scales should be defined such that they incorporate situation-specific standards and thresholds.

To Address National, Regional, and Local Goals and Objectives

TransDec can be applied to a set of feasible alternatives, defined over relevant goals and objectives, to select the most preferred alternative. The relative weights of the various objectives may vary depending on the nature of the problem, of the policy objective, and of the mode or modes.

To Progress Toward Performance Targets

The model can help track performance of the transportation system over time. It systematically articulates the basis of project selection and makes explicit ground rules of a decision. Thus, a decision-making organization can effectively inform parties affected by the organization's decisions about the decision "values." The ground rules are manifested in the definition of goals and objectives, the associated performance measures, the rating scales, and the weights. In this model, the decision alternatives represent potential solutions for a given transportation problem and manifest achievement on prospective performance targets.

To Support State and MPO Planning

TransDec can aid state and metropolitan planning organization (MPO) planning by encouraging uniformity of data and performance measures and by serving as a planning model in which social policies can be defined and implemented with precision. Furthermore, TransDec can easily be changed in response to new circumstances or changing value systems. Information about such changes can be easily and explicitly disseminated, thereby greatly easing the task of implementing policy change.

FINAL REPORT AVAILABILITY

The full agency report for NCHRP Project 20-29(2) will not be published in the regular NCHRP report series. However, loan copies are available through the Transportation Research Board, National Cooperative Highway Research Program, 2101 Constitution Avenue, NW, Washington, D.C. 20418. As noted previously, the TransDec software and *Introductory User's Manual for Multimodal, Multicriteria Transportation Investment Analysis* may be obtained from the McTrans Center, University of Florida, 512 Weil Hall, P.O. Box 116585, Gainesville, FL 32611-6585.

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