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Multicriteria Highway Programming Incorporating Risk and Uncertainty: A Methodology for Highway Asset Management System

Introduction

Highway asset management, a systematic process aimed at efficient and cost-effective preservation and operation of highway assets (pavements, bridges, traffic control devices, ITS installations, etc.), necessarily incorporates an analytical tool for rational and integrated decision-making. A key component of any highway asset management system is multicriteria decision-making which involves tradeoff analysis, and project selection and programming. Most existing management systems deal with individual highway assets and also focus primarily on analysis of outcomes that are assumed to be certain. In a departure from such state of practice, this study adopts holistic and probabilistic approaches that incorporate risk and uncertainty towards the management of overall physical highway assets and usage of such assets.

A set of highway asset management system goals was first identified and their relative weights were determined, and a set of performance indicators under each goal were classified. Benefits achieved under asset goals as a result of project implementation are typically measured with non-commensurable units under different goals, but need to be converted into non-dimensional units so that tradeoffs can be carried out under equal footings. Where such conversion processes involve certainty and risk, utility theory was adopted to form the basis of tradeoff analysis under certainty and risk. Due to the limitation of utility theory for situations under uncertainty, an alternative approach based on Shackle's model was introduced. Multiattribute utility functions and standardized focus gain-over-loss ratio functions based on utility theory and Shackle's model were calibrated for each asset management program, respectively, using data collected through a series of questionnaire surveys. Also, a system optimization model and its solution algorithm were formulated to facilitate the selection and programming of constituent (pavement, bridge, safety, and ITS) projects.

Findings

A methodology was developed and utilized in a case study for system-wide project selection based on information on candidate projects proposed for state highway programming in Indiana during 1998-2001.

The study revealed that, regardless of decision-making under certainty, risk, or uncertainty, a higher total number of contracts was selected in the proposed approach under the multiyear budget scenario for the entire analysis period. However, as no constraints were imposed for each year under the multiyear budget scenario, the number of projects selected in each year tended to be less balanced as opposed to that of the carryover budget scenario. For instance, for case under uncertainty the number of contracts selected on the basis of multiyear budget scenario was higher than that on the basis of carryover budget scenario for 1999 and 2000 and was lower for 1998 and 2001. On the other hand, irrespective of budget scenarios, less number of projects was selected under certainty as

compared to number of projects being selected under risk and uncertainty.

The study also revealed that project selection was sensitive to the budget level for a given analysis period. However, the relative weights of the agency and user decision groups appeared to be not as significant, which suggested that the agency and the user maintained consistent perceptions on asset management system goals.

For all given years and regardless of the tradeoff decision under certainty, risk, or uncertainty, using budget scenarios based on annual budget with carryover and multiyear budget for the entire analysis period, the software outputs matched with the results of actual highway programming at least 85 percent of the time.

Implementation

The developed software can be used for programming purposes. The incorporation of risk and uncertainty will assist in an objective evaluation of programming decisions.

However, uncertainty considerations will introduce added complexity. The proposed methodology and study findings can be adopted not only by the Indiana Department of Transportation by also by other transportation agencies for highway asset management practice.

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