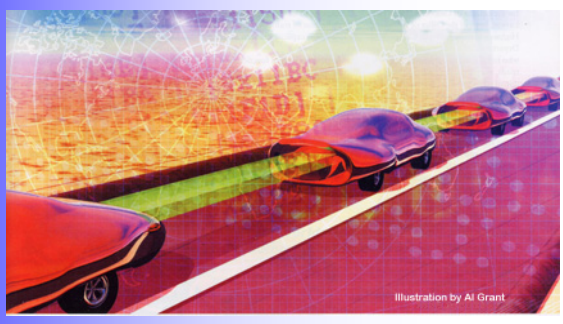
RESEARCH NOTES
TRAFFIC OPERATIONS RESEARCH

Task Order 5329
September 2006

Developing Optimal Planning and Management Strategies for a Robust Highway System

PROJECT DESCRIPTION:

Develop and deliver a proof of concept that optimal planning and management strategies can be formulated through applying robust optimization methodology such that limited resources could be allocated more rationally, and reliability of a highway network improved more efficiently. The report focuses on two applications: the network design problem under demand uncertainty, and fleet allocation for freeway services patrols. Their corresponding decision-makings are formulated as several optimization models. By solving these models robust optimal strategies can be obtained. Numerical examples and simulation tests are presented to demonstrate the validity and usefulness of the proposed models.



Research Project Partners

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

Why We Pursued This Research

The results of the research will help make more efficient use of highway funding to improve the system performance. The research may also lead to the development of new procedures for evaluation of road networking planning, construction, and management with taking reliability issues into account.

Network Design with Demand Uncertainty

Three alternate models, sensitivity-based, scenario-based and min max respectively were presented to determine robust optimal improvement schemes for road networks under demand uncertainty. The usefulness and validity of these three models were demonstrated through numerical examples and simulation tests. It is suggested that if decision makers aim to achieve a mean-variance tradeoff, the sensitivity-based and scenario-based models should be used with particular caution placed on the minimization of the sensitivity of total travel time with respect to demand perturbations or minimization of the variance of total travel times under various demand scenarios. If fluctuations of travel demand are believed to be non-significant, the sensitivity-based model is more appropriate to use, because it is simpler and requires much less computation efforts. Otherwise, the scenario-based model should be used, and additional efforts are needed to generate the demand scenarios and determine the corresponding probabilities of occurrence. On the other hand, if decision makers are more concerned with the worst-case scenarios, the min-max model should be applied.

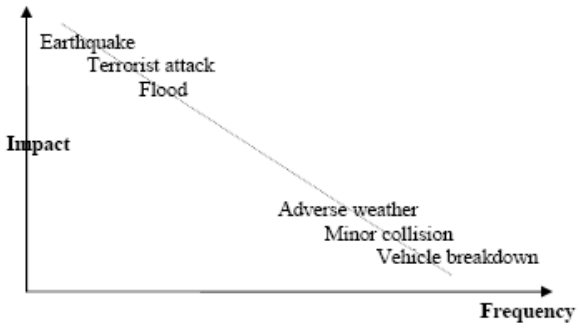


Figure 1 - Disruptive Events with Combinations of Impacts and frequencies

Although only demand uncertainty was of concern in the three models, the proposed modeling framework is quite general and is applicable to accommodate other types of uncertainty, such as incident-induced travel time uncertainty.

Fleet Allocation of Freeway Service Patrols

The report also covers an investigation of how to make use of FSP systems to improve the robustness of the highway systems. It presents a min-max bi-level programming model to determine the optimal fleet allocation strategy for FSP services. A heuristic solution algorithm has been proposed to solve the model. Both the model formulation and the solution algorithm have been validated and demonstrated through a numerical example. It has been observed that the robust optimal fleet allocation always performs better against the worst-case scenarios. Moreover, the performance difference becomes more significant with higher levels of capacity uncertainty or network congestion, suggesting that the model may contribute more in the situations of high frequencies of incidents or high levels of network congestion.

Summary

This report delivered a proof of concept that optimal planning and management strategies can be formulated through applying robust optimization methodology such that limited resources could be allocated more rationally, and reliability of a highway network improved more efficiently.

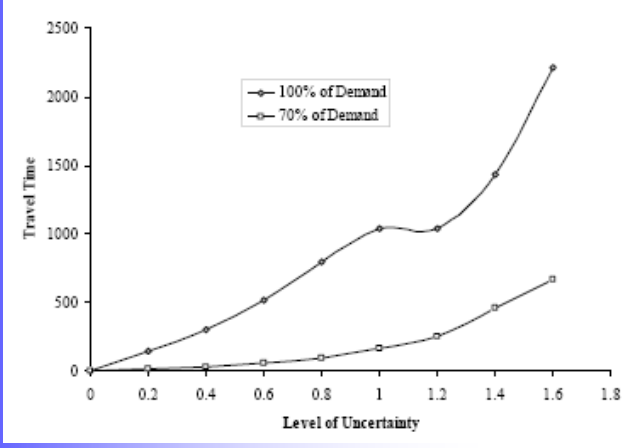


Figure 2 - System Performance Differences between Uniform and Optimal Allocation

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