STRATEGIES FOR REAL-TIME OPERATION AND PLANNING OF STOCHASTIC DYNAMIC SYSTEMS

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ABSTRACT
Transportation systems involve complex interactions among multiple resources, such as humans, vehicles, shipments and infrastructure. Transportation systems must increasingly operate in a highly dynamic environment, characterized by considerable stochasticity and unpredictability, to serve customers demanding more exacting service levels.

Real-time information on current state of the system, allows system operators to make on-line decisions on a continuing basis to optimize performance. However, the manner in which this information is used will critically determine its effectiveness; inappropriate use of information, in conjunction with incorrectly formulated models and inadequate algorithms, could result in worse performance. Analysis methods and models developed over the past 25 years to support operation and design decisions in transportation systems have assumed largely static conditions, operating under a long-term equilibrium with presumed known deterministic demands. Optimization of deterministic static representations has become progressively less relevant to the actual operation of increasingly dynamic stochastic systems. In its place has appeared a hodge-podge of largely ad hoc approaches, typical of a domain in transition to the realities of the much-heralded new information economy.

In this paper, we present a conceptual framework for formulating and evaluating strategies for dealing with the inherent stochasticity in many transportation systems, and the uncertainty in the models of these systems, with emphasis on the role of real-time information. It contrasts a priori methods with online decision approaches, including both predictive and reactive methods, as well as global versus local approaches. A hybrid approach that combines a priori robust decisions with on-line adjustment and re-optimization is proposed as a general strategy for the operation and planning of dynamic uncertain systems.

The paper identifies a set of fundamental trade-offs in the design and performance of these approaches, leading to a series of open research questions that arise in conjunction with these problems. Examples of these questions include: (1) How useful is probabilistic information about future demand? (2) Can real-time information and corresponding decisions help in removing uncertainty and volatility due to future demands? (3) How to “divide and conquer” in a dynamic and
uncertain environment? (4) How to assign requests to parallel resources? (5) How to make use of a priori information? (6) How sophisticated do we need to be with local decisions?

The paper draws on our research in two distinct areas: (1) dynamic fleet management, and (2) network traffic operations. Specific examples are presented along with numerical results to illustrate the relative effectiveness of alternative strategies.