Analytical Modeling for the Strategic Design of Service Systems

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ABSTRACT

Systems for transportation, business logistics, production, and customer service must be constructed with consideration of economy, efficiency, user-equity, and flexibility. A proper blend of statistical modeling, deterministic optimization, heuristic scheduling procedures, and computer simulation enables the strategic design of such systems while anticipating the complexity of operations. Performance on multiple dimensions may be investigated for alternative physical configurations and operating procedures while accommodating time-varying mixes of traffic and demands for service. This paper illustrates the blending of analytical tools for an inland waterway transportation service system where staged queues provide the conceptual foundation for operations, and it advocates the use of similar modeling approaches for the strategic design and management of other service systems. For airline traffic at a major commercial airport, where systems of staged queues need to be integrated for optimizing flight and ground operations, the authors suggest the data and analytical models that may be deployed in this more complex environment.

Keywords: Analytical Modeling, Service Optimization and Simulation, Strategic Design and Analysis, System Analytics, Transportation and Logistics

INTRODUCTION

Strategic analysis and design of service systems requires a solid conceptual framework, supporting data, analytical models, solution engines, interpretive tools, and creative insight in the application of analytical results. This is especially the case where the strategic choices involve direct impacts on operational processes rather than financing mechanisms or organizational structures and relationships. Consider, for example, a class of managerial...
problems in the field of transportation and business logistics. Transportation service facilities, traffic intersections, port facilities, distribution centers, and production operations often allocate resources to serve arrivals from different streams and need to switch queues periodically while trying to achieve efficiency and equity in traffic or workflow. Further, the entities being served may impose different demands upon a shared resource, and there may be some staging of activity to position or prepare the next entity to be serviced from each queue. Times required for activities may depend upon the sequence in which they occur because personnel or equipment may have to be relocated or reconfigured to support an operation.

Many service systems exhibit these fundamental properties – where the first entity to be serviced from a queue must be the item positioned at its head and where there is flexibility to select the next item to be staged at the head of a queue when the staging position is vacated. These choices are generally made with consideration of equity to users of the system, on the one hand, and efficiency of the overall operation on the other hand. A simple example appeared recently in The Wall Street Journal (Bialik, 2012), which reported how Alfred Blumstein suggested the queuing structure for UK passport control might be changed to reduce queuing times in anticipation of a flood of visitors to the Olympic Games. By staging individuals to be served next close to individual passport control officers, one may eliminate the delays that occur as individuals walk from the head of a single queue to the next available agent. Doing so, however, exposes the travelers to a risk of being stuck behind a person who requires an unduly long processing time while individuals who arrive later proceed through another channel.

Development of optimal service strategies gets more complicated when the queued entities have identifiable characteristics that affect the expected time to service them. In cross-docking facilities (Bartholdi & Gue, 2000; Gue & Kang, 2001) tractor-trailers are positioned for loading and unloading with different mixes of cargo. Manpower and equipment are allocated to unload incoming shipments and load outgoing shipments. In production and maintenance facilities (Guo, Zhibin, Zhang, & Li, 2012; Hung & Chang, 2002) there is often a preparatory step before an operation whereby the next entity to be processed receives a necessary pre-treatment. Port facilities require vessels to be positioned for loading and unloading with land-based resources (Shabayek & Yeung, 2002). In busy urban environments, signaling is used to grant priority to buses and regulate flows of other traffic through intersections (Wu & Hounsell, 1998). Medical facilities perform triage and assign patients to examination rooms, surgical theatres and diagnostic equipment (Oredsson et al., 2011).

The strategic design of service systems requires an effective information infrastructure and can benefit from a proper blend of statistical modeling, deterministic optimization, heuristic scheduling procedures, and computer simulation, anticipating the impact on complex operational processes. This paper summarizes how these analytical elements were effectively employed to investigate alternative strategies for alleviating congestion in the Upper Mississippi River (UMR) navigation system. It includes recent findings from investigations of scheduling methods in the UMR context and proffers related hypotheses that would apply to such systems in general. Finally, using the example of a major US airport, the authors discuss how their analytical approach may be similarly employed in a more complex network of staged queuing systems.

THE UMR STRATEGIC PLANNING PROBLEM

Upstream and downstream lockage operations on the UMR transportation system involve different processing times in fast-flowing water and differential delays as departing entities clear the way for oncoming traffic to enter the lock. Figure 1 shows the actual physical configuration of a 600-foot lock on the UMR navigation system with a towboat and 15 barges departing the lock and two tows upstream awaiting lockage.
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