A Simulation Model for LTL Trucking Network

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ABSTRACT

Service network design (SND) is a part of tactical planning activities of transportation companies. Less-than-truckload (LTL) trucking industry has been steadily expanding the market share in the past decades, due to its operational flexibility and high efficiency. In order to provide flexible and robust service schedule for LTL carriers, stochasticity is explicitly taken into account when formulating the SND problem. Service schedules derived from the stochastic model show structural difference with its deterministic counterparts. This research project develops a simulation model of an LTL network, in order to evaluate the system performance of LTL network with the stochastic schedule. A set of experiments shows that the stochastic solution performs very well when it is confronted with random customer demands. Furthermore, the stochastic schedule is much better than the deterministic one in terms of the proportion of undelivered commodities.

Keywords: Less-Than-Truckload (LTL) Trucking, Service Network Design (SND), Simulation Model, Stochastic Customer Demand, Stochastic Schedule

INTRODUCTION

Service network design (SND) is usually a part of tactical planning activities; and it is targeted for operating efficiently to fulfill customer demands and ensure profitability of the transportation firm, e.g., trucking company and railway.

For the less-than-truckload (LTL) trucking problem, stochastic customer demands were explicitly taken into account in service network design problem (Lium, 2006). A stochastic programming model was presented and the schedules were structurally different from those derived from deterministic counterpart. The stochastic solutions have some advantages that the deterministic ones do not have. For instance, the stochastic solution tries to provide many paths for each origin-destination pair in order to gain operational flexibility for LTL carrier to handle uncertain demands. One may ask: how will the new schedules perform in real-world situation? We can trust these new schedules only by validating them by means of a simulation model, since in most cases playing with the real transportation system is quite expensive, sometimes impossible. The simulation package Arena by Rockwell Software Inc. was chosen to develop the simulation model. This product has been used by well-known organizations worldwide as a support tool for their decision-making process (Clavijo & Centeno, 2004).

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The remainder of this paper is divided into four parts. First, we present the basic definition of LTL trucking and review the theoretical aspects of stochastic service network design, which is followed by describing the simulation model employed in afterwards. Then, we describe the experiments and their results with interpretations. Finally, the last section summarizes the study’s findings finally.

SERVICE NETWORK DESIGN FOR LTL TRUCKING NETWORK

Service network design aims at the determination of the routes and types of service to operate, service schedules, vehicle and traffic routing, repositioning of the fleet for future use, which are usually part of tactical planning activities. The selected services and the schedule constitute a load plan. See Crainic (2003) for an overview of the service network design problems applied in the context of freight transportation.

It may be advisable to take uncertainty into account when designing a service network for LTL carriers in order to conduct robust and flexible schedule for truck and freight flow. We say a schedule is robust if it can withstand random changes, while it is flexible if it is capable of accommodating to them. Here we present some primary concepts and perspectives related to service network design and uncertainty inherent in service networks.

Although there is quite a significant body of literature on the service network design problem, stochastic factors are rarely incorporated into service network design model explicitly. The literature and the various software systems implemented at various carriers assume complete knowledge, which means these formulations are deterministic. The deterministic models formulate service network design problem mostly based on point forecast of the future demand, i.e., the expected value. This is not to say the researchers and transportation professionals ignore the uncertainty inherent in actual operations. The load plan is conducted through the deterministic model, while in practical implementation the plan is modified according to the real demands.

For LTL carriers, a variety of key factors may involve randomness. Customer demand may vary from day to day. Transportation times between terminals may be different on each day since vehicle speed may be affected by weather and road condition. Sorting/consolidation times are not fixed since congestion and equipment breakdown are unpredictable at terminal. Other random delays may happen in the network due to truck accident, traffic congestion, etc. The stochastic nature of the transportation system must be explicitly considered in order to have insight into the properties of real-life transportation activities since we know that stochasticity is an inherent characteristic of transportation systems.

For the sake of simplicity, we will only consider dynamic models with stochastic customer demand in this paper. Local customer demands are usually aggregated at the corresponding terminals. In the service network design problem, it is the demands at terminals rather than demands of a specific customer that are incorporated in the model. So here the stochastic demand refers to random aggregated demand at terminal. Furthermore, the stochastic demands are not arbitrarily random, which means the demands must follow some describable statistical distribution.

By solving stochastic models, one may obtain an optimal solution that is structurally different from that of a deterministic model. A few examples can be found in routing and location problems (Louveaux, 1998). In that paper, the author discussed the solution properties of a stochastic model. The simple vehicle routing example demonstrated how the optimal route of a stochastic model is different from that of a deterministic model in which the expected demand is used as parameter inputs. The quality of the solution coming from the deterministic model is significantly worse than the one obtained from the stochastic model in terms of undelivered goods. Furthermore, we know that the expected behavior of the solution of the deterministic model can be arbitrarily worse...
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