Tools for Logistics Planning

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Abstract. Automotive industry is at the vanguard of creating a lean supply chain, whose practices are geared toward maintaining minimal inventory and streamlining all facets of the supply chain management process. The strategy includes a constant stream of just-in-time supply to car manufacturers through mixed loading of components with high frequency of pick-up and delivery, which is challenging the logistics operations. Therefore, manufacturers in automotive industry tend to outsource their logistics. Mathematical models and solution procedures are proposed in this paper to support logistics planning in automotive industry when there is constraint on delivery intervals. They may also be used as decision aids to outsource the logistics function, as negotiation tools, as joint planning tools, and/or as evaluation tools for continuous improvement.

Keywords: Mathematical programming, Transportation, Supply Chain Management.

1. INTRODUCTION

Supply chain management (SCM) is not a new concept but is gaining more and more attention since the 1990s. SCM aims at achieving better end customer service level and lower total supply chain cost. This is achieved by the coordination of the activities between business entities in the supply chain, which results in reduced inventory/waste, shorter lead-time and greater flexibility. The focus of SCM is to deliver the right quantity of good quality products to the right place at the right time for all sectors of the supply chain. Within this SCM paradigm, logistics is viewed as “a part of the supply chain that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption in order to meet customer requirement” (Hyland, Oct. 2002).

Automotive industry is at the vanguard of creating a lean supply chain, whose practices are geared toward maintaining minimal inventory and streamlining all facets of the supply chain management process. The strategy includes a constant stream of just-in-time supply to car manufacturers through mixed loading of components with high frequency of pick-up and delivery, which is challenging the logistics operations. Therefore, manufacturers in automotive industry tend to outsource their logistics function to Logistics Service Providers (LSPs) (Hannon, 2003).

There have been extensive literature (Thomas and Griffin 1996, Kelle et al., 2003) that propose mathematical models that support coordination of the activities within and between business entities in the supply chain. Most of these studies are about the development of EOQ (Economic Order Quantity) models, which assume that the delivery can be performed at any time. A different approach, which solves multiple products problem and considers only a given set of feasible delivery intervals, was proposed by Speranza and Ukovich (1994). This approach was extended to more complex multistage, and network problems (Bertazzi and Speranza, 1999, Bertazzi and Speranza, 1999, Bertazzi et al., 1997).

There are also literature (Alp et al., 2003, Henig et al., 1997) that support the design of contract between shippers and LSPs.

In this current paper, mathematical tools are proposed to support logistics planning in automotive indus-

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try. Speranza and Ukovich’s (1994) work is extended to a stochastic single link model by adopting Tyworth and Zeng’s (1998) method. Also, a procedure is proposed to evaluate a hybrid hub-and-spoke network, which consists of multiple suppliers, multiple customers and a single consolidation hub. The approach is compared to EOQ type models. It is then shown how this approach can be modified to solve a stochastic problem. Finally, a simple solution procedure is proposed to evaluate a product postponement strategy. These mathematical tools may be used as decision aids to outsource the logistics function, as contract negotiation tools, as joint planning tools, and/or as strategy evaluation tools.

2. MATHEMATICAL TOOLS

In this section, the definition of the problem, assumptions and constraints that apply to all the models proposed in this paper are introduced. The problem investigated is defined based on the production setting of the automotive industry. However, the models presented may suit other industries as well. The shippers operate a high volume assembly type operation characterized by negligible changeover times in a mixed-model, smoothed production environment. Customers specify a set of feasible delivery intervals, where regular shipments can be performed. Each product has to be assigned a single delivery interval and products with the same delivery interval may be consolidated (Single Frequency Frequency Consolidation - SFFC). The policy is to place the order at equally spaced intervals of time and to order up to a specified level. The shipment may be performed in-house or outsourced to LSPs. For cases where the logistics is outsourced to LSPs, LSPs will be responsible for distribution between suppliers and customers following a set schedule and performance targets. All parties in the supply chain may determine the set schedule and performance targets jointly. The higher the frequency of delivery, the higher the cost that LSPs will incur, but the lower the inventory holding cost that shippers will incur. The quality of service provided by the LSPs might be an important factor in achieving the shipper’s goals. A trade-off between cost (transportation cost and inventory holding cost) and performance level (fill rate, length and consistency of transportation lead-time) has to be made and compared with the trade-off from the perspectives of customers. Models and heuristics involved in evaluating different distribution strategies, which may be facilitated by LSPs, are proposed.

Assumptions:
1) Demand rate is stationary and follows a normal distribution.
2) Supply rate is constant and is the same as the mean demand rate. This is especially true for repetitive manufacturing that implements a mixed model production scheme and produces product just-in-time.
3) Transit time is stationary and follows a gamma distribution.
4) The transportation cost per return trip is constant irrespective of the shipment quantity.

Constraints:
1) All requirements of the customer must be met.
2) The vehicle capacity may not be violated.

2.1 Stochastic Single Link Model

In this section, Speranza and Ukovich’s (Speranza and Ukovich, 1994) model is extended to incorporate stochastic demand and transportation lead-time. To solve the problem, Tyworth and Zeng’s (1998) method can be applied in a straightforward manner. It results in a nonlinear model that quantifies the impact of the length and reliability of transportation lead-time on total variable cost and service level (fill rate) of a single link supply chain consisting of a single supplier and a single customer. The decision variables are order-up-to level, optimal delivery intervals and optimal number of vehicles. The percentage cost penalty of determining optimal delivery intervals and order-up-to level sequentially tends to be quite small. However, even small percentage savings may be attractive for fast moving items (Silver, 1998).

Only a single frequency is assigned to each product and only products shipped at the same frequency (SFFC) are consolidated, as opposed to the more flexible multiple frequency with frequency consolidation (MFFC) strategy discussed by Speranza and Ukovich (1994). SFFC strategy not only has the merit of simplicity in operation planning, it simplifies the model by reducing the number of nonlinear constraints. In this paper, the impact of flexibility in vehicle capacity on total variable cost is discussed as well.

2.1.1 Notation

The Decision variables:

\[ x_{ij} = 1 \text{ if product } i \text{ shipped every interval } t_j, \text{ 0 otherwise; } \]
\[ y_j = \text{ Number of vehicles required at every interval } t_j; \]
\[ S_{ij} = \text{ Order-up-to level for product } i \text{ shipped at every interval } t_j; \]

Given parameters:

\[ I = \text{ The set of product indices (} i \in I); \]
\[ \hat{h}_{ij} = \text{ Mean demand rate of product } i \text{ (quantity per time); } \]
\[ h_i = \text{ The inventory holding cost of product } i \text{ (cost per unit per time); } \]