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Inventory service-level optimization within distribution network design problem

Pablo A. Miranda [a,*], Rodrigo A. Garrido [b]

[a] Network Configuration Research Group and School of Industrial Engineering, Pontificia Universidad Católica de Valparaíso Av. Brasil 2241, Casilla 4059, Valparaíso, Chile

[b] Department of Transport Engineering and Logistics, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Macul, Casilla 306, Santiago 22, Código 105, Santiago, Chile

A R T I C L E I N F O

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A B S T R A C T

We propose a sequential heuristic approach to optimize inventory service levels in a two-stage supply chain. The proposed approach deals with service level and inventory decisions, simultaneously with network design decisions, and incorporating unfulfilled demand costs in a previous inventory-location model. A two-step formulation is considered, where the first step optimizes service level and the second step addresses location and inventory decisions. Each algorithm iteration solves an inventory-location model for a fixed service level, and then the service level is updated in order to reach an equilibrium condition between operating system and unfulfilled demand costs. The algorithm converged in three iterations for a set of sample instances, obtaining the same outcome in comparison with a more intuitive, exact, but more time-consuming search procedure.

1. Introduction and literature review

Distribution network design (DND) is a well recognized and widely studied problem in both supply chain management (SCM) and logistics. The problem consists of selecting sites to install plants, warehouses, and distribution centers; assigning customers to serving facilities; and interconnecting facilities by flow assignment. This paper considers the two-level supply chain shown in Fig. 1, where a single plant serves a set of warehouses, the latter serving a set of end customers or retailers.

The DND is typically solved as part of a sequential approach that simplifies or omits related tactical and operational decision issues (e.g. inventory control, fleet design, warehouse design). Then, omitted decisions are addressed once DND has been already solved. Simchi-Levi et al. (2003), Mourits and Evers (1995), Bradley and Arntzen (1999), Miranda (2004), and Miranda and Garrido (2004a), analyze levels of the decision-making problem related to DND and SCM. Thus, the wide family of facility location problems (FLP) is used to solve the DND, where the objective function, parameters, demands and constraints are considered as deterministic. Daskin (1995), Simchi-Levi et al. (2005), and Drezner and Hamacher (2004), present detailed reviews and analysis of FLP. Recent researches on facility location theory consider concave operational cost functions for each installed facility, based on a well-known FLP (Dupont, 2008). Furthermore, Arostegui et al. (2006) present an empirical analysis for different and well-known meta-heuristics applied to several FLP's. Recently, Lin (2009) presents a stochastic formulation for a basic standard FLP, where outbound flow, or served demand, capacity constraints for all selected warehouse are established, with a minimum service-level probability. In terms of multinational distribution network design problems, Bhutta et al. (2003) present a mixed integer linear formulation addressing multinational corporation facility location decisions, including exchange and tariff rates, incorporating production, distribution, and investment decisions.

* Corresponding author.
E-mail addresses: pablo.miranda@ucv.cl (P.A. Miranda), rgarrido@ing.puc.cl (R.A. Garrido).

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Nomenclature

N	number of available sites to install warehouses
M	number of customers which must be served by installed warehouses
FC_i	fixed location cost for a warehouse on site i ($)
TC_{ij}	transportation unit cost from the warehouse on site i to customer j ($/unit)
RC_i	transportation/ordering unit cost from the plant to the warehouse on site i ($/unit)
OC_i	fixed ordering cost for a warehouse on site i ($/order)
HC_i	holding cost per time a warehouse on site i ($/time unit).
$Z_{1-\alpha}$	value of the standard normal distribution, which accumulates a probability of $1-\alpha$
LT_i	deterministic lead time for warehouse i orders (parameter)
X_i	binary variable. It is equal to 1, if a warehouse is installed on site i, and 0 otherwise
Y_{ij}	binary variable. It is equal to 1, if warehouse i serves customer j, and 0 otherwise
d_i	mean daily demand for each customer j (parameter)
v_i	variance of daily demand for each customer j (parameter)
D_i	mean daily demand to be assigned to warehouse i (dependent variable)
V_i	variance of daily demand assigned to warehouse i (dependent variable)
Cap_i	capacity at warehouse i

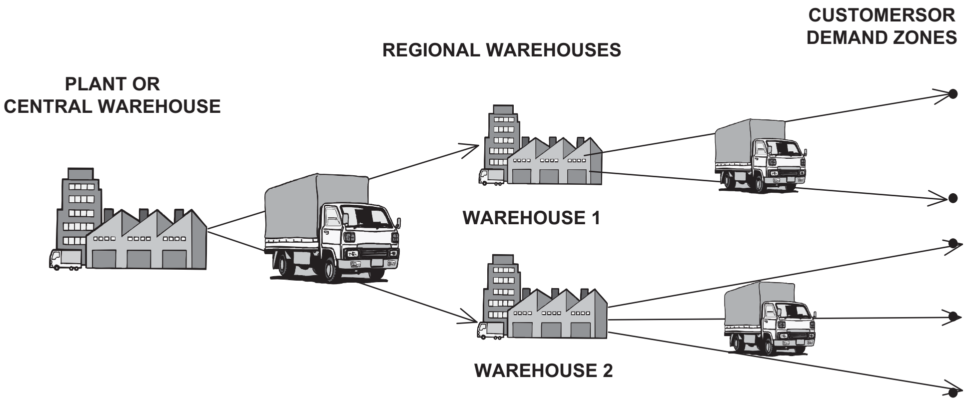

Fig. 1. Two-stage distribution network.

However, the traditional structure of FLP is not quiet useful in considering interactions between facility location and inventory control decisions, as well as the related impacts of the latter into network configuration. For example, the risk pooling effect states total system safety stock is reduced when customers are served by a smaller set of warehouses. This lack of interaction modeling capacity represents a motivation for the present and other recent studies aimed to model simultaneously inventory and location decisions.

In terms of inventory management, Simchi-Levi et al. (2003), Bowersox and Closs (1996), Coyle et al. (1992), among other authors, present the basic models for inventory control. The classic EOQ model and its typical variations (price discounting, continuous production or replenishment rate, etc.) can be found within these references. Porteus (2002) and Porteus (1990) show a selection of models based on the classic Newsvendor Problem, which considers a stochastic demand ruled by a generic probability distribution function and unfulfilled demand penalty cost. The presented models determine ordering quantities, minimizing ordering, holding and unfulfilled demand costs. Furthermore, these models are developed only for a single period, considering initial stock and partial backlogging extensions. All of these researches assume a single location, where demand and service level do not consider the customer assignment scheme as decision variables.

Cachon (2001) and Axsäter (2000) develop exact approaches to evaluate the system cost for a two-echelon supply chain (one-warehouse-multi-retailer system), assuming periodic and continuous review, respectively. These approaches consider order quantities and re-order points as fixed parameters. In addition, Axsäter (2003) approximately optimizes re-order points, and Kochel (2007) optimizes ordering decisions, both authors assuming the same known supply chain structure. Graves and Willems (2000) optimize strategic safety stock decisions in a general multi-stage supply chain, based on bounded stochastic demand and a periodic base-stock inventory control policy. Finally, Ettl et al. (2000), analyze a complex network of supply processes, manufacturing stages and customers, determining re-order points for each location, for a given set of customer service levels. This model