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Incorporating inventory control decisions into a strategic distribution network design model with stochastic demand

Pablo A. Miranda, Rodrigo A. Garrido *

Department of Transport Engineering, Pontificia Universidad Católica de Chile, Santiago, Chile

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Abstract

In this paper, we propose a simultaneous approach to incorporate inventory control decisions—such as economic order quantity and safety stock decisions—into typical facility location models, which are used to solve the distribution network design problem. A simultaneous model is developed considering a stochastic demand, modeling also the risk pooling phenomenon. We present a non-linear-mixed-integer model and a heuristic solution approach, based on Lagrangian relaxation and the sub-gradient method. In a numerical application, we found that the potential cost reduction, compared to the traditional approach, increases when the holding costs and/or the variability of demand are higher.

Keywords: Supply chain management; Distribution network design; Facility location problems; Inventory control; Risk pooling; Lagrangian relaxation

1. Introduction

The standard literature on supply chain management classifies the problems into three hierarchical levels: strategic (long term), tactical (medium term), and operational (short term), though the limits between each level remain unclear. The usual approach to solve these problems has typically been to tackle them in isolation from one another. In practice, strategic decisions are made by top managers, while the tactical and operational decisions are made by bottom level

* Corresponding author. Address. Casilla 306, cod. 105, correo 22, Santiago, Chile. Tel.: +56-2-6864270; fax: +56-2-5530281.

E-mail address: rgarrido@ing.puc.cl (R.A. Garrido).

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managers. This situation tends to promote incompatibilities and incoherence between each level. For instance, facility location problems are considered as strategic, imposing a strong simplification regarding tactical and operational aspects directly related to the optimal location. Examples of these tactical/operational aspects are the inventory control policy, the choice of transportation mode/capacity, warehouse design and management, vehicle routing, among others.

The aim of this paper is to incorporate tactical/operational decisions into to the facility location problem solution scheme. Specifically, inventory management decisions will be simultaneously modeled with the distribution network design. This inclusion acquires especial relevance in the presence of high holding costs (e.g. frozen food industry) and high-variability demands. An example is provided to illustrate the relevance of this issue. Fig. 1 shows a distribution network where a single plant supplies products to regional warehouses, and these distribute products to retailers or customers. The ownership of the chain is assumed to belong to a single decision maker responsible for the holding cost at each facility, as well as all the transportation costs. In Fig. 1, warehouse 1 sends products to retailers 1 and 2, each of which has a stochastic demand with means d_1 and d_2, respectively, and variances u_1 and u_2, respectively. Warehouse 2 supplies products to retailers 3, 4 and 5, and warehouse 3, to retailers 6 and 7. The operation of the warehouses incurs two type of cost: one is proportional to the average supplied demand (made up of holding and handling costs), and the other one is proportional to the standard deviation of supplied demand (due to the safety stock). Under constant lead times and levels of service, the safety stock is proportional to standard deviation of the supplied demand.

Thus, safety stock kept in warehouse 1, must be proportional to $\sqrt{u_1 + u_2}$; safety stock in the warehouse 2 must be proportional to $\sqrt{u_3 + u_4 + u_5}$, and the one in warehouse 3 must be proportional to $\sqrt{u_6 + u_7}$. Clearly the system's cost depends on the retailers assignment scheme. For instance, if we closed warehouse 1 and its clients were assigned to warehouse 2, significant cost changes occur. The fixed-installation cost of the warehouse 1 would be eliminated, and the transportation costs (from plant to warehouses and from warehouses to retailers) would change; safety stock cost would be reduced, because total safety stock kept on warehouse 2 would be

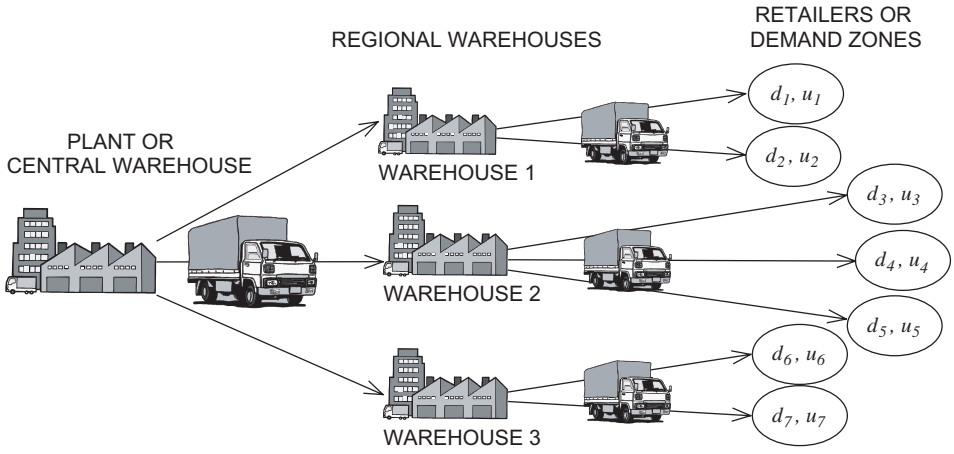

Fig. 1. Graphic representation of the distribution network.