"Design of a network of reusable logistic containers: theoretical results"

Short abstract:

In this study, we consider the management of the return flows of empty logistic containers that accumulate at the customer's sites. These containers must be brought back to the factories in order to sustain future expeditions. We consider a network composed of several factories and several customers in which the return flows are independent of the delivery flows. The models and their solutions aim at finding to which factory the containers have to be brought back and at which frequency. These frequencies directly define the volume of logistic containers to hold in the network. We consider fixed transportation costs depending on the locations of the customers and of the factories and linear holding costs for the inventory of logistic containers. The analysis also provides insight on the benefit of pooling the containers among different customers and/or factories.

Long abstract:

In this study, we consider the management of the return flows of empty reusable logistic containers, i.e. any kind of items used to store and send goods (e.g. pallets, kegs, barrels, trestles,…) that must be brought back to the producers for further expeditions. This problem is directly inspired by the distribution of glass. In this real case, the glass is shipped to the customer with special trucks and in special containers. At the customer site, the glass is used according to the local demand. Once the customer has emptied a container, this container can be folded. Later on, the folded containers are brought back, with regular trucks, to the factories. In this example, the return flows are managed independently from the delivery flows because of the differences in the timing of the flows and in the transportation modes (truck specificities). In this paper, we also consider the return flows independently from the delivery flows. The management of the return flows raises several questions like

Q1: to which factory should each customer return the containers?
Q2: at which frequency should they be returned?
Q3: how many containers are needed in the network?

These questions are interdependent. The link between Q3 and Q2 is straightforward. For example, if we have few containers (Q3) then it is clear that they must rotate quickly. This means that the returns will be, at least on short distances, more frequent (Q2). The dependence with Q1 is more complex. But we will show that, given a total inventory in the system (Q3), the optimal allocation of

customers to factories varies with the capacity constraint on the return flows, if any. However, we will also show that in some cases the question (Q1) can be solved independently of (Q2) and (Q3). This problem is, at the same time, a transportation problem (Q1) and an inventory control problem (Q2 and Q3). The objective is to minimize the costs. Here we consider holding costs for the containers and transportation costs for bringing back the containers. The transportation costs are supposed to be independent from the transported quantity. However, a capacity limit may be imposed on the transport. We only consider point-to-point transport and here discard milkruns.

In this study, the problem is studied in a strategic perspective. Such a perspective will allow us to compare the potential benefits associated with different transportation capacity limits, with different holding cost rates. It will also allow us to quantify the benefit of merging different networks by pooling the containers among different customers and/or different factories.

We present a detailed model of the problem with a clear identification of the problem variables, constraints and assumptions. The solutions of the problem for increasingly complex cases are then analyzed. We focus, first, on the "1-factory 1-customer" case then, second, on the "1-factory C-customer" case. Since none of these cases raises the issue of allocating customers to factories, we can simply focus on the analysis of the optimal inventory of containers and on the optimal return frequencies, that is, questions Q2 and Q3. Not only can these two questions be analytically solved but the benefit of pooling the containers among all the customers can be quantified. The benefit is similar in the symmetric "F-factory 1-customer" case which is quickly analyzed. Finally, we deal with the solution of the general "F-factory C-customer" case. We show there under which circumstances question Q1 may (or may not) be solved independently of Q2 and Q3. In each of these sections, we also consider the impact of a potential capacity constraint on transportation. Finally, we will conclude the study by underlining the main contributions by discussing a plan for future work.

References:

[1] Anily S. Multi-item Replenishment and Storage Problems (MIRSP): Heuristics and Bounds. Operations Research 1991; 39; 233-239.

[2] Axsäter S. Economic lot sizes and vehicle scheduling. European Journal of Operational Research 1980; 4; 395-398.

[3] Churchman C W, Ackoff R L, Arnoff E L. Introduction to Operations Research. John Wiley and Sons, New York; 1957.

[4] Dixon P S, Poh C L. Heuristic procedures for multi-item inventory planning with limited storage. IIE Transactions 1990;6; 112-123.

[5] Gallego G, Shaw D,Simchi-Levi D. The Complexity of the Staggering Problem and Other Classical Inventory Problems. Operation Research Letters 1992; 12; 47-52.
[6] Gallego G, Queranne M, Simchi-Levi D. Single resource multi-item inventory systems. Operations Research 1996; 44; 580-595.
[7] Goyal S K.() Optimum ordering policy for a multi-item single supplier system. Operations Research Quaterly 1974; 25; 293.
[8] Günther H-O. Ein Verfahren zur Bestellmengenplanung bei beschränker Lagerkapazität. In Bühler W, Feichtinger G, Hartl R F, Rademacher F J, Stähly P. Operations Research Proceedings. Springer, Berlin Heidelberg; 491-498; 1990.
[9] Hadley G, Whitin T M. Analysis of Inventory Systems. Prentice Hall, Englewood Cli_s, New Jersey; 1963.
[10] Haksever C, Moussourakis J. A model for optimizing multi-product inventory systems with multiple constraints. International Journal of Production Economics 2005; 97; 18-30.
[11] Hall N G. A Multi-Item EOQ Model with Inventory Cycle Balancing. Naval Research Logistics 1988; 35; 319-325.
[12] Hariga M, Jackson P L. The warehouse scheduling problem: Formulations and algorithms. IIE Transactions 1996; 28; 115-127.
[13] Harris F W. What quantity to make at once. The library of factory management 1915; 5; 47-52.
[14] Holt C C. Decision Rules for Allocating Inventory to Lots and Cost Foundations for Making Aggregate Inventory Decisions. Journal of Industrial Engineering 1958; 9; 14-22.
[15] Hommer E D. Space-limited aggregate inventories with phased deliveries. Journal of Industrial Engineering 1966; 17; 327.
[16] Huang W, Romeijn H E, Geunes J. The Continuous-Time Single-Sourcing Problem with Capacity Expansion Opportunities. Naval Research Logistics 2005; 52; 193-211.
[17] Krone L H. A note on economic lot sizes for multi-purpose equipment. Management Science 1964; 10; 461-464.
[18] Maxwell W L. The scheduling of economic lot sizes. Naval Research Logistics Quaterly 1964; 11; 89-124.
[19] Page E, Paul R J. Multi-product Inventory Situation with one Restriction. Journal of the Operational Research Society 1976; 27; 815-834.
[20] Parsons J A. A note on Krone's economic lot-size formulas. Management Science 1965; 12; 314-315.
[21] Parsons J A. Multiproduct lot size determination when certain restrictions are active. Journal of Industrial Engineering 1966; 17; 360-365.