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Near cost-optimal inventory control policies for divergent networks under fill rate constraints

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Abstract

We deal with the optimisation of stock levels in general divergent networks under a periodic review, order-up-to (R, S) policy. The goal is to attain target fill rates, while the total holding costs in the entire network are minimised. To this end, we first present a method for the fast calculation of the control parameters, given central and intermediate stock levels. Next we develop an approximate procedure to determine stock levels sequentially. Extensive numerical experimentation shows that this procedure yields satisfactory results. It also shows that significant stocks at intermediate stockpoints are only useful if unit holding costs in these stockpoints are considerably less than in the end stockpoints that deliver directly to the final customers. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction and literature

The determination of optimal inventory levels in a network of stockpoints is a classical problem. Especially in the last decades this subject has gained interest as a consequence of the increasing attention for integral supply chain management. This is supported by the fast development of information technology, which facilitates the collection and exchange of the information. Appropriate planning and control tools are required to utilise the technological possibilities. These developments have stimulated many research activities. Since the pioneering work of Clark and Scarf [1], many researchers have developed algorithms to analyse various series, assembly and distribution systems (see e.g. [2,3]).

Generally, the effective and efficient control of product flows through a logistic network should be based on cost considerations (holding and ordering costs) on one hand and customer service considerations on the other. Well-known appropriate performance indicators for customer service include the non-stockout probability (= probability that the inventory just before the arrival of a replenishment order is non-negative) and the fill rate (= the fraction of demand satisfied from stock on hand immediately). The latter customer service measure is widely used in practise. However, combining cost and fill rate targets in one model is generally not

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easy. Most research proceeds from one of the two viewpoints, either minimising costs (see [4,5] for an overview) or attaining target service levels (see [6] for an overview).

When minimising costs, customer service is usually included by imposing penalty costs on shortages. The basic work in this field is from Clark and Scarf [1] for a series system with order-up-to policy. Model extensions include the analysis of two-echelon divergent systems by Eppen and Schrage [7] and the analysis of assembly systems by Langenhoff and Zijm [8]. In addition, a lot of work has been done on two-echelon divergent system with lot sizing, see e.g. [9–12]. Recently, Diks and de Kok [13] developed a method to find cost-optimal policies for general N-echelon divergent systems with periodic review and an order-up-to policy. All these models use penalty costs to include customer service considerations. This may cause problems for implementation in practice, because penalty costs might be difficult to establish. In these situations, the problems can be solved if a direct relation between cost parameters and customer service can be given. With respect to the stockout probability, such a relation exists, cf. Diks and de Kok [14] for divergent networks with a periodic review, order-up-to policy. However, an explicit relation between penalty costs and the commonly used fill rate is not available to our knowledge.

When focussing on target service levels, most papers deal with performance evaluation (stock levels, service level) for a given set of control parameters, see e.g. [15–17]. Next, the problem is how to determine the control parameters such, that the target service levels to the final customers are attained. Usually, many sets of control parameters yield the same target service levels. One possible procedure is the calculation of the control parameters given the stock levels at intermediate nodes (i.e. nodes that do *not* deliver directly to the final customers), see e.g. [21]. Next, one can evaluate various scenarios for the intermediate stock levels to find a cost-effective solution. An explicit optimisation is not carried out. A comparable approach is to determine the control parameters given service levels at intermediate nodes, see e.g. [17]. Once more, the next step is scenario evaluation to find a cost-effective set of control parameters, and explicit optimisation is not reported. Only in a few cases stock levels are explicitly optimised under service level constraints, see e.g. [19,20] for approximate analyses of a two-echelon systems under installation stock policies.

Therefore, we deal with explicit stock optimisation under fill rate constraints in this paper. We consider echelon stock, periodic review, order-up-to control policies in general N-echelon divergent systems. That is, each stockpoint in the network has a unique supplier but it may deliver material to multiple other stockpoints. We proceed from the analysis by van der Heijden et al. [21], where the control parameters are determined such that target fill rates are attained, given intermediate stock levels. So in fact we use a fill rate oriented approach. The stock levels required at the end stockpoints are a result of these calculations, so that the total holding costs can be evaluated. Next, some numerical search procedure is required to find a cost optimal solution. In principle, this seems straightforward in the case of two-echelon networks, because the cost function to be optimised has only one parameter (the central stock level). Therefore, a brute force approach is probably adequate then. However, the number of parameters in the cost function may increase considerably when the number of echelons increases. Then a brute force numerical search may require too much computation time, because the evaluation of a single scenario requires some significant effort. Half a second CPU-time for a single function evaluation may seem only little time, but it becomes cumbersome if hundreds or even thousands of function evaluations are required. Besides, it is not assured that the procedure will end in a global optimum.

Therefore, we shall start with a fast approximate method to calculate the control parameters. Numerical experiments will show that we can speed up a single evaluation of the cost function by a factor more than 10 compared to the approach by van der Heijden et al. [21], without significant loss of accuracy. Next, we develop an approximate optimisation procedure, based on an experimental analysis of the cost function structure. It will appear that we can find near cost-optimal control policies for large divergent networks within a reasonable amount of time. The contribution of this