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An approach to evaluate the impact of interaction between demand forecasting method and stock control policy on the inventory system performances

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ABSTRACT

Usually in stock control studies demand data are considered as an input to the model, without explicitly considering that they are the results of a demand forecasting system. Stock control system is examined independently of the demand forecasting system, and it is assumed that demand data (or forecast errors) have been properly modelled. However, the interactions that may exist between demand forecasting methods and stock control systems, in terms of their effects on global system performances, are not considered. In the paper an approach for evaluating these interactions, based on a comparative simulation test of global system costs using historical data, is presented. The approach is explained through a real case: the replenishment, from different suppliers, of a central depot of tinned food, which supplies more than 700 items to warehouses at the lower echelon. Results of the simulation study show that traditional measures of forecast errors cannot be taken as sole indicators for the choice among different demand forecasting methods. These methods, on the contrary, have to be evaluated on the basis of total costs and service level of the global inventory control system.

1. Introduction

Demand forecasting and stock control are two topics that have been widely studied in the literature. Traditionally, these two phases of inventory control systems are considered in sequence, assuming that there are no interactions between them.

Regarding demand forecasting, the classic approach is to calculate measures of forecast errors (like the mean absolute deviation (MAD) or the mean absolute percentage error (MAPE)) and to consider the minimisation of such indicators as the best practice in order to minimise the part of total costs associated with the forecasting method.

In many stock control studies, the parameters values that lead to total costs minimisation are found on the basis of demand data, which are modelled in a probabilistic way (stationary or non-stationary). Utilising such demand data as inputs to the stock control problem means not to consider that, in practice, a clean distinction between effective demand and forecasted demand does exist, and that in many real cases it is through forecasted demand data that values for stock control parameters have to be assigned. The main limit of traditional approaches is ignoring the possible effects that utilisation of different forecasting methods may have on stock control policies.

The aim of this work is to explore the effects of overcoming this limit, and in particular to point out that the most common procedure for evaluating a demand forecasting method (DFM), that is to compare per period forecast errors (usually measured by the MAD, the MSE or

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Nomenclature

i	product index ($i = 1, \ldots, N$)
j	supplier index ($j = 1, \ldots, M$)
t	period index ($t = 1, \ldots, T$)
$D_{i,t}$	forecasted demand of product i for period t
$d_{i,t}$	effective demand of product i in period t
$s_{i,t}$	order point for product i in period t
$S_{i,t}$	order-up-to level for product i in period t
$I_{i,t}$	starting inventory position of product i in period t
$Q_{i,t}$	number of items i ordered in period t
m	periods covered by a replenishment
c	safety coefficient on the order point
L_i	number of items i that can be arranged in one pallet
$P_{j,t}$	number of pallets ordered from a supplier j in period t
P	carrying capacity of a truckload [number of pallets]
$T_{j,t}$	number of truckloads from supplier j in period t
TC_j	unit freight cost of truckload from supplier j
T	length of the simulation study time horizon [number of periods]
CC	carrying inventory costs over T periods
CT	transportation costs over T periods
C_{tot}	total costs (transportation+carrying inventory) over T periods
$\overline{I_i}$	average inventory level of product i over T periods
v_i	unit variable cost of the item i
r	the annual carrying charge

the MAPE), is not always appropriate. And that, on the contrary, a better way to do this is to analyse the DFM effect on stock control parameters, and to compare resulting system total costs and service level.

To this purpose, a simulation model of a real case, the replenishment of the central depot of a distribution company, has been developed. Features of the case studied are multiple items, highly variable demand patterns (due to seasonality), coordinated replenishment issues (the same supplier furnishes multiple items) and considerable transportation costs. A literature review on studies dealing with these issues is reported in Section 2.

The model development, described in detail in Section 3, includes the implementation of two different DFMs. By using historical demand data, forecasted demand data are obtained from both methods. Then, different stock control and replenishment policies, whose parameters are calculated on the basis of forecasted demand data, are simulated on new effective demand data. The details of the experiment are reported in Section 4. The results obtained (see Section 5) allow to compare total system performances of different "forecasting method/replenishment policy" combinations, and to study the interactions between the two components of the inventory control system.

2. Literature review

As mentioned in Section 1, features of the case studied are multiple items, highly variable demand patterns, coordinated replenishment issues and non-negligible transportation costs.

The class of inventory problems that seems to deal more frequently with these issues is lot-sizing. Under several hypotheses, several approaches (starting from the classical one by Wagner and Whitin, 1958) find optimal solutions in terms of minimisation of replenishment and carrying inventory costs. Many extensions of the basic problem have been studied, and both mathematical models, which find optimal solutions, and heuristic algorithms have been proposed (for surveys see Drexl and Kimms, 1997; Karimi et al., 2003). In particular, most considerable extensions, as far as the applicability of the model to real cases is concerned, regard the consideration of lumpy demand (Blackburn and Millen, 1985; Pujawan and Kingsman, 2003), multiple items (Brown, 1967; Goyal, 1974; Silver, 1976) and quantity discounts (Chung et al., 1996). Although transportation costs can form more than 50% of the total logistics costs of a product (Swenseth and Godfrey, 2002), they are often neglected in lot-sizing research and modelling. In effect, only a minority of dynamic lot-sizing models have considered production–inventory problems incorporating transportation activities. Among the most recent papers of this growing literature, Lee et al. (2005) analyses a dynamic lot-sizing problem, in which the order size of multiple products and a single container type are simultaneously considered, and the total freight cost is proportional to the number of containers used (this model fits quite well to the real case analysed in this paper). Inspired by a real case, Van Norden and Van de Velde (2005) studied a multi-product lot-sizing model where the difference between systematic and spot buying is considered, with consequences on the type of sourcing decisions.

Unfortunately, all these studies assume that demand data, though variable and non-stationary, must be known, and are not obtained as a result of forecasting procedures. In effect, these approaches can be applied on demand data that come from a buyer using a deterministic lot-sizing procedure in an ERP or an MRP system (where, for example, multi-echelon assembly operations lead to production requirements relatively deterministic, though almost always appreciably variable with time).

When demand is no longer assumed to be deterministic (as in many other production and distribution situations), the introduction of uncertainty in the demand pattern significantly complicates the inventory situation. Most of the literature dealing with probabilistic inventory models assumes that the average demand remains approximately constant with time, and hypothesizes a certain demand probability density function. The main