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BATCH ORDERING INVENTORY MANAGEMENT UNDER THE MIXED DEMAND INFORMATION: A CASE STUDY

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ABSTRACT: This study is concerned with analysing the past demand data and development of an inventory model with demand arising from deterministic which is known in advance and random sources simultaneously. Two different shortages are created for each demand type and in order to prevent model to backlog the deterministic demand, very high shortage cost is given for deterministic demand. The numerical value of the parameters are obtained from a real case which the inventory system of an information and technological organization of a university. The main difference of this study from the previous studies is that the order amount must be in palette quantity for a deterministic and stochastic demand inventory problem. Under this constraint, an inventory model is developed and tested with several datasets. Assuming lead time as constant, the value of deterministic demand present in the system and impact of palette constraint are investigated. These investigations are compared with the status quo in the case study. It has seen that the palette quantity behaves as safety stock for high level random demand. Recommendations based on the impacts of advance demand information, lead time and pallet quantity are presented in terms of changing in ordering costs, holding costs and service level.

Key Words: *Inventory model, batch ordering, deterministic and stochastic demand, mix integer programming*

Karışık Talep Bilgisi Kapsamında Toplu Sipariş Envanter Yönetimi: Bir Durum Çalışması

ÖZ: Bu çalışma, geçmiş dönem talep bilgisinin ve önceden bilinen deterministik ve rassal talep bilgisinin birlikte bulunduğu stok sistemlerinin analizini konu almaktadır. Herbir talep bilgisi için iki farklı talebi karşılayamama maliyeti belirlenmiş olup deterministik talebe verilen yüksek talep karşılayamama maliyeti bu tip talebin zamanında karşılanmamasını oldukça güç hale getirmektedir. Kullanılan veriler bir üniversitenin bilgi teknolojilerinden sorumlu olan birimden alınmıştır. Bu çalışmanın literatürdeki diğer çalışmalardan farkı aynı anda hem deterministik hem de rassal talep altında sipariş miktarının palet cinsinden olmasıdır. Bu kısıt altında, bir stok modeli geliştirilmiş ve farklı veriler altında sayısal olarak test edilmiştir. Sabit tedarik süresi varsayımı altında, deterministik talebin değeri ve paletle sipariş kısıtının etkileri ölçülmüştür. Bu ölçümler, mevcut durumla kıyaslanmıştır. Paletin içerik miktarının yüksek seviyedeki rassal talep için güvenli stok olarak davrandığı gözlemlenmiştir. Değişen sipariş maliyeti, stok tutma maliyeti ve hizmet seviyeleri altında ön talep bilgisi, tedarik süresi ve palet miktarının etkileri üzerine önerilerde bulunulmuştur.

Anahtar Kelimeler: *Envanter modelleme, yığın sipariş kısıtı, deteministik ve rassal talep, matematiksel modelleme*

1. INTRODUCTION

In many competitive business environments, inventory management plays an important role in managing the trade-off between maximising the service level of customers while minimising the operational costs. In order to meet the customer demands within a reasonable time, most businesses need to keep some amount in stock since the time it takes to order products from suppliers or produce the products from raw materials is too long in comparison. Another factor that leads to keep stock is that ordering or producing products efficiently often involves batches of (identical) products which are much larger that individual customer orders. Inventory management is defined as the control of amounts of products kept in stock over time. The principle purpose of inventory management is to answer the following two questions:

1. When do we need to place an order (or produce) for a given type of product?
2. How much of this product should we order?

Inventory management can lead to better results if the future demand is known. In real life at least some part of the future demand is not known with certainty beforehand, but needs to be estimated. Forecasting methods are required in order to avoid unwelcome surprises. According to Bon and Leng (2009), forecasting product demand is one of the most important issues in inventory management in both short and long term planning activities. The most appropriate forecasting method is to be chosen based on a good insight into what drives future demand. Observing seasonal patterns and trends from past data can be very helpful in certain situations, but may still lead to disastrous results if the assumption that the future is going to be very similar to the past does not hold. It may sometimes be more useful to investigate the processes that customers use to place their orders.

During the decision process in inventory management, costs and lead times are typically important considerations. Lead time is the time needed between placing the order at the supplier (or manufacturing floor) and the time the products requested become fully functionally available in the warehouse to meet customer demand. The relevant costs in an inventory model most often include the following four terms: holding cost, ordering cost, unit product cost and unit shortage cost. The shortage cost occurs when a demand does not met on time which the demand is called backorder. In this study, we have such a situation of backorders. It is still one of the difficult problems in inventory management theory to arrive at accurate estimates for the shortage cost. One way around this problem is to use an estimated value for this cost, and then to observe the service level achieved in the inventory model. If this service level achieved is too low, one can iterate by increasing this shortage cost until the service level has achieved a desirable level.

How to measure the service level is very dependent on the context. A simple measure is to count the number of orders delivered by the requested due date of the customer per unit of time (say in one month) and divide this number by the total number of orders delivered. A variation to this is to measure to count the total number of units of products that are delivered by the due date divided by the total number of units delivered. More refined measures of service level will also look at the lateness (the length of time between the due date and the actual delivery date) of orders.

Due to significant period-to-period or even day-to-day changes in demand levels, seasonality effects, trends, and constrained storage space, inventory management is a challenging task at the university's IT department, but also critical for delivering a good service to the university. In the current situation, the inventory is controlled by the providence of staff and none of the economical trade-off analysis is being considered in the day-to-day decision making on the inventory. The main concern of the planners at the present is to be able to meet demand. Some automation is already in place to capture customer requests and keep a status of inventory records. The issues of when and how much to order from the suppliers, however, is still a decision unsupported by a computerised decision aiding model.

In this study, past demand data is going to be analysed to observe the demand pattern. This is complemented by an analysis of the potential difference in customer types as to investigation of the potential value of demand classification. It is then complemented by an analysis of the supply side by investigating the conditions under which the company can order from suppliers. Finally, we will investigate the internal processes undertaken to prepare a product for release to the customer. A set of alternative inventory models is then to be developed and its performance evaluated under different demand profiles as well as compared with the real situation in terms of both service level and costs. Since the IT department delivers many products, this study will have to focus on a specific branch of products only: the high-value and high-volume standard computers/laptops series.

2. LITERATURE REVIEW

This study is mainly related to the fields of inventory management with deterministic and stochastic demand and batch ordering. Thus, we review the literature for demand management and order restrictions in inventory management.

According to Waters (1992), for the inventory control models, future demand is the most important input and has the biggest impact on stocks held. Therefore demand management is considered as the first step of inventory management. The complexity of the inventory model depends on the demand pattern as put by Taha (2007) and mainly the demand can be classified into deterministic demand which can be constant or variable over time and stochastic which can be stationary or non-stationary over time.

Although the inventory model for the first type of demand is the simplest model (classic EOQ model), it has seen in practice not so often. On the other hand, the inventory models are able to deal with the fourth demand type are the most complex although this demand pattern is often likely to occur in real life. In the inventory literature, demand is assumed as deterministic or stochastic (for detailed review see Aloulou *et al.* (2013), Bushuev *et al.* (2015)). There is also a different type which assuming demand as advance demand at which some parts of the demand is known in advance but some part still remains uncertain (Gallego and Özer (2001), Sobel and Zhang (2001)).

Demand is placed in advance of their due dates are called as advance demand information. If customer lead time is less than the supply lead time, this type of demand must be satisfied by using on hand inventory and that’s why it can be classified as stochastic demand. Unlike the classical inventory models treated demand as either deterministic or stochastic, Sobel and Zhang (2001) consider the demand which arrives from a deterministic and stochastic source simultaneously. They mentioned that if deterministic and stochastic demands are considered separately, deterministic demands will not be backordered. However, this will bring higher holding and ordering costs due to keep inventory for both demands separately. Thus, they consider this two types of demand simultaneously. In their study, they consider periodic review inventory systems with demand priority. Deterministic demand is assumed to have non shortages whereas stochastic demand can be backlogged. This demand type is closely related to our problem case. However they assume that if there is stock on hand, the backorders must be satisfied even without considering for future period deterministic demand. However in our case, there must be a possibility of having positive inventory level while having some shortages. This is a result of having two different shortages costs for deterministic and stochastic demand separately. They proved that modified (s, S) policy is optimal for their case.

Similar to Sobel and Zhang (2001), Gallego and Özer (2001) studied the inventory management with advance demand information. They stated that customers have different willingness to pay for the speed of fulfilment of their order. They used dynamic programming (Bellman Equation) to find reorder level and order up to level. One of the interesting result in their study is to prove that for the cases with zero ordering/setup cost, the demand information beyond lead time has no operational value. Özer and Wei (2004) takes this study to an inventory problem with limited storage capacity and advance demand information. They measure the impact of advance demand information on capacitated inventory problem with advance demand. Wang and Toktay (2008) extend these studies by considering flexible delivery options without having a storage capacity. In contrast to the literature, they assumed that customers who placed their order for a due data can accept early delivery. They used some heuristics methods to find a way to making decisions. As a result of their study, they indicate that advance demand information is a powerful tool in reducing inventory costs. Numerical studies mention flexible delivery can contribute significant benefits to the solution.

Beside the demand side, there might also be some restrictions and uncertainties on supply side. One of these restrictions is minimum order quantity which the firm needs to order more than a minimum threshold amount (Kesen *et al.*, 2010). This might be soft which can be relaxed with additional cost or be solid which cannot be relaxed. Another order restriction is batch ordering which allows orders only to be an integer number of a base quantity. Veinott (1965) is one of the first study consider batch ordering in inventory problem. Chen and Zheng (1994) considers the (r, nQ) policies for batch ordering inventory problems and Chen (2000) proves the optimality of (r, nQ) policy. Extention of the problem with lost sales has been considered by Van Woensel (2013). The multiechelon cases of batch ordering has been studied by Chao and Zhou (2009) and Shang and Zhou (2010).

3. PROBLEM DEFINITION

The academic staff and postgraduate students are allowed to request a computer from the university and the university kept stock to satisfy these request within a reasonable time. Some of these requests are placed in advance of the required date. Yet still some of the demand can be known at last minute. The university replenishes its stock from an external company and the company only allows the university to place its order in terms of pallets. The university aims to satisfy all demand within a threshold service time but due to having longer lead time than the service time, they need an effective inventory policy and they need to know the impact of batch ordering so that they can negotiate with the company. In this section, we provide the notation and mathematical formulation to be used to formulate the problem.

3.1. Notation

The variables and parameters used in the formulations are presented in this part. The mathematical model is constructed with the following notation.

D_t	Deterministic demand in period t
R_t	Random demand for period t
E_t	Expected demand in period t
I_t	On hand inventory at the end of period t
y_t	Number of pallets ordered in period t
z_t	Expected amount to be delivered in period t
$B(D)_t$	Number of backorders for deterministic demand in period t
$B(R)_t$	Number of backorders for random demand in period t
$X_t = \begin{cases} 1 \\ 0 \end{cases}$	$\begin{array}{l} if\ an\ order\ placed\ in\ period\ t \\ otherwise \end{array}$
N	Planning Horizon (days)
L	Lead time (days)
h	Holding cost $(\frac{£}{\text{unit}*\text{day}})$
c	Ordering cost $(\frac{£}{\text{order}})$
β_D	Shortage cost for deterministic demand $(\frac{£}{\text{unit} * \text{day}})$
β_R	Shortage cost for random demand $(\frac{£}{\text{unit} * \text{day}})$
Q	Number of computers in a pallette

3.2. Mathematical Formulation

The mathematical formulation of the inventory model with deterministic and stochastic demand and batch ordering is presented. The deterministic demand is known in advance of N days, ($N \geq 3$), whereas stochastic demand is known in advance of 3 days only. At the beginning of period t, deterministic demand over {t, ..., t+N-1} and random demand over {t, ...,t+2} are known. The optimal inventory decisions are made by the on hand information and the decisions are applied for only at the current period. Then, at the end of the period with the new demand information, the demand is updated and the model is run for next N period. The rolling planning horizon approach is applied until reaching the expected time horizon.

$$Min \quad h \sum_{t=1}^{N} I_t + c \sum_{t=1}^{N} X_t + \beta_D \sum_{t=1}^{N} B(D)_t + \beta_R \sum_{t=1}^{N} B(R)_t \quad (1)$$

$$I_{t-1} + Z_t - D_t - R_t - B(D)_{t-1} + B(D)_t - B(R)_{t-1} + B(R)_t = I_t \quad \forall\, t = 1,2,3 \quad (2)$$

$$I_{t-1} + Z_t - D_t - E_t - B(D)_{t-1} + B(D)_t - B(R)_{t-1} + B(R)_t = I_t \quad \forall\, t = 4, \dots, N \quad (3)$$

$$B(D)_t \leq B(D)_{t-1} + D_t \quad \forall t = 1, \dots, N \quad (4)$$

$$B(R)_t \leq B(R)_{t-1} + R_t \quad \forall t = 1, \dots, N \quad (5)$$

$$Z_t = Q y_f \ \ where\ f = t - L \quad \forall f = 1, \dots, N \quad (6)$$

$$y_t \leq S\, X_t \quad \forall t = 1, \dots, N \quad (7)$$

The main objective in (1) is to minimize the total expected cost including holding, backorder and setup costs over N period. There are two different backorder costs for deterministic and stochastic demand. The inventory balance equations are presented in (2) for first three periods and (3) for the remaining periods. Constraints (4) and (5) provides that shortage amount for each demand type cannot be greater than that specific demand type. The number of pallets ordered at period f will be supplied after a lead time, L. In this case Q represents the number of computers in a pallet as in (6). If an order does not take place in a period, then the y_f must be zero. In order to have positive y_f, an order must be given at period f and this is guaranteed by (7). All parameters and variables used in the model are nonnegative and integer.

4. NUMERICAL RESULTS

The integer model which is developed in mathematical formulation section, implemented into Visual Basic Application (VBA) in Excel and solved by using Excel solver. Then different scenarios are applied into this model with various parameter settings. Two different cases are presented as Case A which has %80 of deterministic demand and Case B which has 20% of deterministic demand present in the system. The reason for examining these two situations is that more customers can be convinced towards advance demand by offering them some financial incentives. The main purpose here is to reveal the financial effects of increasing the deterministic demand in the system. These demand cases are tested with L=12;6 and Q=42;21 and the values of remaining parameters are obtained based on the real case. The reason to choose the parameter values as 42 and 21 for batch size is that the supplier is able to offer such an option.

The demand information of the previous periods is analysed and we have observed that the demand best fits to triangle distribution. Another reason why we have to use triangular distribution is the lack of accessible past demand data which we could only obtain for past three years. Although we use this distribution, the VBA application developed based on the proposed model can also be modified for different demand distributions. The expected demand is made based on the distribution and at the end of each run the new demand is generated based on the demand distribution.

The model with 80% deterministic demand and 20% stochastic demand has been run for 15 datasets and following results are obtained. The economical results are shown in Table 1.

Table 1. Case A costs with L=12, Q=42;21

	Pallette=42			Pallette=21		
	Ordering Cost	**Holding Cost**	**Total Cost**	**Ordering Cost**	**Holding Cost**	**Total Cost**
DATASET 1	650	7687	8337	1225	3763	4988
DATASET 2	625	7905	8530	1200	4042	5242
DATASET 3	600	7364	7964	1150	3794	4944
DATASET 4	650	7057	7707	1275	3708	4983
DATASET 5	625	7372	7997	1225	3905	5130
DATASET 6	600	7623	8223	1075	4060	5135
DATASET 7	600	7788	8388	1175	3887	5062
DATASET 8	650	7754	8404	1225	3684	4909
DATASET 9	625	7569	8194	1175	3928	5103
DATASET 10	600	7755	8355	1150	4135	5285
DATASET 11	650	7233	7883	1200	3414	4614
DATASET 12	650	7112	7762	1200	3556	4756
DATASET 13	600	7815	8415	1150	3968	5118
DATASET 14	600	7690	8290	1175	3656	4831
DATASET 15	600	7721	8321	1075	4040	5115
AVERAGE	**£621.7**	**£7,563**	**£8,184.1**	**£1,178.3**	**£3,836**	**£5,014.3**

As it is seen in Table 1, the average total cost £8,184 with £621.7 of ordering cost and £7,563 for holding cost with 42 palette quantity. When it is compared to the Q=21 case, it is clearly seen that holding cost is decreasing sharply while there is an increase on ordering cost. The reason of this is that the system keeps more stock on hand and order less when the pallet quantity is large. On overall total cost, there is 39% decrease when the palette quantity is changed to 21 instead of 42. Although, the Q=21 case has better results, performance measures are also required to be considered. Performance measures like service level and average delay are shown in Table 2.

Table 2. Case A costs with L=12, Q=42;21 and service levels

	Deterministic Demand	Random Demand	Q=42,Q=21	Q=42		Q=21	
			Service Level for Det.	Service Level For Random	Average Delay (days)	Service Level For Random	Average Delay (days)
DATASET 1	880	221	100%	90.0%	2.73	79.6%	2.8
DATASET 2	831	206	100%	90.3%	2.85	83.5%	2.95
DATASET 3	797	197	100%	93.4%	2	93.4%	2
DATASET 4	870	219	100%	92.2%	4.2	88.1%	4.04
DATASET 5	850	208	100%	88.5%	4.8	76.9%	3.2
DATASET 6	784	188	100%	89.9%	3.9	89.4%	4.05
DATASET 7	797	196	100%	94.4%	4.6	86.7%	2.96
DATASET 8	877	211	100%	97.2%	2	83.9%	2.3
DATASET 9	829	205	100%	96.6%	2	86.3%	3.2
DATASET 10	787	196	100%	89.8%	3.25	83.2%	3
DATASET 11	850	213	100%	93.4%	2.4	84.0%	2.9
DATASET 12	853	210	100%	89.0%	2.7	80.0%	3.3
DATASET 13	806	201	100%	94.5%	2.6	83.1%	2.6
DATASET 14	778	198	100%	96.0%	2.4	92.9%	2.7
DATASET 15	794	193	100%	95.9%	4.1	91.7%	3
AVERAGE	**825**	**204**	**100%**	**92.7%**	**3.1**	**85.5%**	**3**

As it is seen in Table 2, the service level for deterministic demand is 100% whereas the average service level for stochastic demand is 92.7%. As the uncertainty on demand increases, the service level decreases as expected. On the other hand, the case of Q=21 has 85.5% service level for random demand. The service level is defined as the units that are backordered over total stochastic demand. Since the shortage cost for deterministic demand is very high, the service level is 100% with Q=42 and Q=21. For each unit backordered for stochastic demand is averagely delivered late about 3.1 days for Q=42 whereas it is 3 days for Q=21. When we compare the cases with 42 and 21 pallet quantities, economically the model with pallet 21 performs better. On the other hand, in terms of the service level, the first case has 92.7% while the other one has 85.5% while average delay time is almost same for both.

In case B, demands have inverse percentages for the case A. These results are gained with 20% deterministic demand and 80% stochastic demand with running of 15 datasets. The economical results are illustrated in Table 3.

Table 3. Case B costs with L=12, Q=42;21

	Pallette=42			Pallette=21		
	Ordering Cost	Holding Cost	Total Cost	Ordering Cost	Holding Cost	Total Cost
DATASET 1	675	7742	8417	1325	4362	5687
DATASET 2	625	7891	8516	1225	4374	5599
DATASET 3	600	8778	9378	1200	4694	5894
DATASET 4	650	7323	7973	1250	4434	5684
DATASET 5	625	7962	8587	1250	4517	5767
DATASET 6	600	8628	9228	1150	4581	5731
DATASET 7	575	8216	8791	1150	4882	6032
DATASET 8	650	7261	7911	1300	3707	5007
DATASET 9	625	8105	8730	1250	4084	5334
DATASET 10	600	8969	9569	1175	4945	6120
DATASET 11	650	8128	8778	1275	4629	5904
DATASET 12	650	8733	9383	1225	5081	6306
DATASET 13	600	8128	8728	1200	4469	5669
DATASET 14	575	8186	8761	1150	4758	5908
DATASET 15	600	7731	8331	1125	4339	5464
AVERAGE	£620	£8,118.7	£8,738.7	£1,216.7	£4523.7	£5,740.4

Similar to results in Case A, lower quantity in pallet brings better results in terms of holding cost. Overall, 34% improvements achieved on total cost by reducing number of computers in a pallet. Comparison of Case A and Case B results for the same parameters, about 8% increase on total costs are faced for both Q=42 and Q=21. Only difference between costs does not give a clear idea unless systems performances are not compared. Table 4 demonstrates performance of Case B with a lead time of 12 days in terms of service level and delay time.

Table 4. Case B costs with L=12, Q=42;21 and service levels

			Q=42,Q=21	Q=42		Q=21	
	Deterministic Demand	Random Demand	Service Level for Det.	Service Level For Random	Average Delay (days)	Service Level For Random	Average Delay (days)
DATASET 1	214	864	100%	85.3%	2.3	77.7%	3.4
DATASET 2	204	808	100%	88.9%	2.5	78.2%	2.7
DATASET 3	196	783	100%	93.4%	2.6	81.1%	4.1
DATASET 4	218	859	100%	81.8%	3.6	71.5%	4.4
DATASET 5	212	843	100%	86.8%	2.3	76.9%	2.7
DATASET 6	192	777	100%	89.2%	3.4	80.1%	2.9
DATASET 7	201	796	100%	86.3%	2.7	80.4%	3.2
DATASET 8	215	875	100%	85.5%	2.5	77.7%	3.1
DATASET 9	202	822	100%	87.5%	3.4	75.5%	2.9
DATASET 10	192	765	100%	83.3%	3.3	77.1%	4.6
DATASET 11	203	841	100%	83.0%	2.94	73.0%	2.6
DATASET 12	212	837	100%	82.1%	3.8	71.8%	3.8
DATASET 13	201	806	100%	92.1%	3.4	83.4%	3.5
DATASET 14	196	762	100%	87.9%	2.13	84.0%	3.6
DATASET 15	191	774	100%	85.8%	3.2	74.9%	3.2
AVERAGE	**203**	**830**	**100%**	**86.6%**	**2.92**	**77.6%**	**3.4**

In Table 4, it is seen that higher pallet amount gives higher service level for random demand. However, the service measures are worse than the Case A results under same situation.

When we evaluate the results we obtained from the model, we can see that the results are as expected in general. An important result is that the service level is high for random demand when the pallet quantity is large. This indicates that large pallet quantity works like a safety stock. Thus, the inventory policy is changing by the pallet quantity. For large size pallets we expect to have less safety stocks compared to the lower pallet quantities. The effects of other parameters will be detailed in following sections.

4.1. Current Situation Results

Safety stock is used to manage the inventory system against unexpected demand. In the current situation in the university, reorder level is determined as 20 computers. To see the difference between current system and our model results, the current situation is modelled into VBA. Like the model runs previously, demands are used from Case A and Case B situations. Order amount is always chosen as 1 pallet. If inventory level at the day which is today plus lead time is less than 20, then an order placed on today. Current situation is again run over a year with different data and the average results are presented in Table 5.

Table 5. Current situation average results

Situation	Ordering Cost	Holding Cost	Total Cost	Service Level
Case A with L=12, Q=42	£650.0	£14,977.0	£15,627.0	100.0%
Case A with L=12, Q=21	£1,425.0	£10,903.0	£12,328.0	100.0%
Case A with L=6, Q=42	£700.0	£15,137.7	£15,837.7	100.0%
Case A with L=6, Q=21	£1,375.0	£11,322.7	£12,697.7	100.0%
Case B with L=12, Q=42	£718.8	£14,917.8	£15,636.5	98.8%
Case B with L=12, Q=21	£1,381.3	£11,177.0	£12,551.8	98.0%
Case B with L=6, Q=42	£641.7	£15,255.7	£15,897.3	99.7%
Case B with L=6, Q=21	£1,266.7	£11,206.0	£12,470.7	99.6%

As it is seen, the service level for current situation is nearly perfect. However, the costs are almost double than our model costs. Since the random demand percentage is low in Case A, none of shortages are seen. On the other hand, for the case B very little amount of shortages are observed. Managers need to decide whether it is worthy to keep service level with obtained costs or not. For further research, the optimum reorder level could be investigated which minimizes the cost while keeping the service level on a desirable level.

4.2. Impact of the Parameters

All results are summarized in Table 6 and according to these results; the impacts of parameters are discussed

Table 6. Average results for different situations

Situation	Ordering Cost	Holding Cost	Total Cost	Service Level	Average Delay
Deterministic L=12, Q=42	**£621.7**	**£7,208.5**	**£7,830.2**	**100%**	**0**
Deterministic L=12, Q=21	**£1,106.7**	**£3,646.9**	**£4,753.6**	**100%**	**0**
Case A with L=12, Q=42	**£621.7**	**£7,563**	**£8,184.1**	**92.7%**	**3.1**
Case A with L=12, Q=21	**£1,178.3**	**£3,836**	**£5,014.3**	**85.5%**	**3**
Case A with L=6, Q=42	**£620**	**£7,590.1**	**£8,210.1**	**95.6%**	**1.9**
Case A with L=6, Q=21	**£1,181**	**£3,803.7**	**£4,985.4**	**93%**	**1.7**
Case B with L=12, Q=42	**£620**	**£8,118.7**	**£8,738.7**	**86.6%**	**2.92**
Case B with L=12, Q=21	**£1,216.7**	**£4523.7**	**£5,740.4**	**77.6%**	**3.4**
Case B with L=6, Q=42	**£621.7**	**£7,907.5**	**£8,529.2**	**90.2%**	**1.8**
Case B with L=6, Q=21	**£1,216.7**	**£4,184.7**	**£5,401.4**	**82.4%**	**1.85**

Advance Demand Information

The decreasing on percentage of deterministic demand results an increase on total cost while the service level is getting lower. It is clearly showed in Table 6 that with L=12 and Q=42 parameters, both of optimum total cost and service level can be obtained for fully deterministic (known in advance) demand. Similar to this result, the runs with L=12 and Q=21 proved advance demand information is the best case. It might be seen that there is no big difference on total costs. However, the changing in service level shows us the importance of advance demand information.

Lead Time

Except fully deterministic case, lower costs and better service level are recorded with lower lead times. Similar to the advance demand information, the main differences can be seen on service levels instead of total costs. It is concluded that lower lead time will bring better service levels for less or equal to costs of the higher lead time.

Pallet Quantity/Batch Ordering

With the higher percentage of deterministic demand, the reduction on pallet quantity causes lower costs with lower service level. In the model, according to the observations, the high amount pallet behaves like safety stock and prevent model to make backorders. Therefore the demand with contains high level of random demand is more likely to give better results with higher amount in pallets.

In summary, choosing parameters are an issue which is related to decision of what level of service level is acceptable with what costs.

5. CONCLUSION

The main purpose of this study is to analyse the past demand and develop an inventory model based on the demand pattern. Due to the lack of data, the past demand analysis could only be made partially. Therefore datasets are generated instead of using real data. For the inventory model, a mathematical formulation is developed which allow the university to manage their stock systems. It is realized that some percentage of demand can be known in advance. Seeing the impact of this advance demand information, different cases are tested with different datasets. Mainly, it concluded that advance demand information is improving the inventory system in terms of both decreasing cost and increasing service level. The reduced lead times has no significant impact on inventory model while all demand is deterministic. While the percentage of random demand is getting higher, the reduced lead time has more impact the deterministic cases. For all cases, pallet obligation increases the cost whereas it increases the service level as well.

Integration of the model with the current stock spreadsheet used by the staff in the university will make the decision process easier. As an application, an appropriate software can be updated with the developed model in this paper for the stock system. In this paper, it is assumed that the lead time is constant. For more realistic case, the varying or stochastic lead times need to be considered and further models can be developed. Also the pallet quantity can be considered as a decision variable and another mathematical model developed to find the optimal pallet size.

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