Demand management in a multi-stage distribution chain

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ABSTRACT

In this paper we discuss demand management problems in a multi-stage distribution chain. We focus on demand management in intermediate stages, where high demand variations are inflicted by the way people in the supplying stage and buying stage interact. We suggest two simple procedures that help to smooth demand, thereby achieving significant stock reductions of 40%-50% in practical situations. The quantitative results obtained are based on the analysis of the underlying model related to the two procedures proposed, called large order overflow, applicable if the supplying organization executes a multi-stage distribution chain, and order splitting, applicable to any situation.

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1. Introduction.

Since Forrester's Industrial Dynamics [1] a lot has been published on the control of multi-stage logistics chains. The problems signalled by Forrester with respect to amplification of demand fluctuations upstream in the logistic chain have been understood widely and MRP and DRP systems are used throughout industry to eliminate this amplification as much as possible. Yet a closer look reveals that these systems typically operate within industrial and retail organizations and seldom, if ever, across different organizations in the logistics chain. Therefore still in the nineties component manufacturers complain about the poor quality of orientations provided by the set manufacturers they supply. The orientations of demand lack quality for various reasons. One of the main reasons is that the demand experienced by set manufacturers themselves is erratic, i.e. unpredictable. This unpredictability of set demand is amplified by the use of large order quantities at the component suppliers, whereby the predictability of component demand is even worse. Although it is claimed by various authors, such as Martin [2], that the tight coupling of MRP systems of set manufacturers with DRP systems of component manufacturers should solve or at least alleviate these problems, it turns out to be rare that such an approach is implemented. First of all the IT-capabilities of many manufacturers do not allow such a tight system-to-system coupling using EDI. Secondly, it is quite dangerous to tightly couple information systems if the information in each system is not of adequate, i.e. high, quality. As already stated set manufacturers plan on the basis of poor predictions of demand. This implies frequent correction of previously used and exchanged information. In the case of tight system-to-system coupling with EDI the planners at the component manufacturers loose control of their demand forecast, which changes again and again while often it turns out afterwards that there was no need to change the forecast.

In this paper we address the problem of demand management in multi-stage distribution chains from the point of view that before tight system-to-system coupling can be implemented, conditions must be created that ensure a successful implementation of this approach. We focus on the source of all problems, the unpredictability of demand and try to develop a structural approach towards the creation of a stable flow in the logistic chain derived from an accurate forecast of future demand. We discuss some of the cultural or organizational sources of instability of demand in the logistic chain. Based on this discussion we propose alternative procedures and provide quantitative results illustrating the astonishing impact of this approach compared to the original situation. Related to this approach is the concept of condition management as encountered in sales organizations. We discuss this concept based on a case and illustrate the relation between condition management and the structural approach aimed at making demand more predictable. The organization of the paper is as follows. In section 2 we present a case-study, based on which we discuss the typical cultural behaviour of people negotiating about selling and buying in a supplier-customer relation. Recognizing the impact of this behaviour on predictability of demand we propose two alternative procedures to neutralize this impact. We elaborate on the concept of condition management in section 3. The procedures proposed in section 2 are discussed in more detail in sections 4 and 5. We illustrate the impact of these procedures by giving quantitative results. In particular we show the impact of the procedures on the inventory required to maintain a given service level. In section 6 we summarize our conclusions in relation to the case and discuss further research.

2. A Consumer Electronics Company and its customers.

By the end of 1991 a consultancy group was asked to investigate the possibilities of closer cooperation between a global Consumer Electronics Company (CEC) and a group of customers, the whole-salers in a particular country. The investigation comprised the analysis of order policies at whole-salers, demand processes at both whole-salers and CEC, and the delivery process from CEC-factory to CEC-sales organisation (SO) and from SO to whole-salers. In this paper we focus on the findings of the consultancy group with respect to the demand processes.

At a number of whole-salers historical sales data were collected for a number of representative products. All products showed rather stable demand, i.e. the sample standard deviation was less than 1.5 times the sample mean. Assuming rational behaviour of whole-salers, based on the use of reorder point policies, the consultants derived the expected demand process characteristics at the CEC. Typical ratios of standard deviation over mean of demand to be expected were in the range of 0.2 to 0.7. Next these expected ratio values were compared to the actual ratio values of the demand at the CEC company as derived from historical sales data. A great surprise followed since these ratios were in the range of 1 to 4. We explain this dramatic difference as follows. The rational behaviour from a logistics management point of view differs from the rational behaviour of the two key people involved in the process between CEC and a wholesaler: the salesman and the buyer respectively.

Let us consider the salesman's perspective. Usually the salesman's objective is to meet a turnover target each month. This objective is met by adaptive behaviour leading to high sales in the last week of the month and low sales in the first week of the month. Now let us investigate this "hockey-stick phenomenon" more thoroughly. Picture yourself as the salesman at the beginning of the last week of the month. Only 60% of the required sales has been realized up till then. What is the most efficient (i.e. least effort, most effect) way to achieve the turnover target. In principle there are two extreme courses of action. The one extreme is to increase sales for all products with all wholesalers that are part of the salesman's sales package. This implies that each product must be recommended to all wholesalers. This requires a substantial, if not prohibitive, amount of effort from the part of the salesman as well as substantial time from the buyer of each wholesaler. Therefore this is not a likely course of action. The other extreme is to increase the sales of one product with one particular wholesaler. This requires a minimum amount of effort, yet may not yield the required turnover increase. Based on a "least effort, most effect"-policy it is likely that a salesman selects a particular product, increases the discount and sells up to the budget to a minimum number of whole-salers. In general we expect that through this process a limited number of products is selected of which the sales is increased by extra discounts.

Now we may wonder if it is that easy to persuade buyers at wholesaler to buy a higher quantity than required short-term. Usually the buyers perspective is as follows. The buyer is allocated a fixed budget that should yield as much turnover for the wholesale company as possible. To simplify matters this is usually translated into: buy a product at the lowest possible price. Therefore most buyers act price-driven. Again it is the last week of the month. The buyer expects discounts from his suppliers, since he has been reluctant to sell earlier in order to put pressure on the suppliers. And indeed, prices for particular products are lowered. After judging obsolescence risks the buyer decides to increase sales for some products, one of which is supplied by the CEC. The circle is closed. Hence over many years a negotiation process has developed through which both salesman and buyer achieve their highly local, i.e. personal, objectives.

But what is the result of all this on the demand process at the CEC. The buyer has bought more of a CEC product than is really required short-term. In fact, the buyer has probably overruled buy suggestions from his inventory management system. Even though sales showed a stable pattern, suddenly a purchase of a large quantity is generated. Not by the inventory management system but by the buyer. Through this procedure an unexpected high demand is generated by the whole-salers, and even worse, probably by several whole-salers for the same product. Hence a stable selling-out demand pattern at the whole-saler is "translated" into an erratic selling-in pattern. Obviously, the fact that an unnecessarily high quantity is bought by these whole-salers, implies that they will not need the product for a considerable time. This results in erratic demand at the CEC, in spite of smooth demand at the whole-salers.

The validity of this line of thought has been checked whit a number of people, especially logistics managers, at a number of SO's and was accepted. The next step of course is to see whether change is required or not.

First of all, let us analyze the effect of the process described above. First consider a whole-saler. Since unnecessary purchases are made the stock increases substantially above the level to be expected if the reorder point policies were followed. This has been verified at a number of whole-salers for different types of products. Typically stocks of about three months of future sales were found, whereas one month or less was expected. It is clear that the Return On Investment is decreased substantially compared to the situation where a reorder policy is followed. Also obsolescence risk is increased. The effects of higher holding cost and obsolescence risks should be traded off with the cost benefits from a lower purchase price, yet this is hardly ever done.

Next consider the CEC-SO. Since demand is erratic high stocks are required to ensure high fill rates, defined as fraction of demand satisfied from the shelf. If the behaviour discussed above was not exhibited then demand should have been much more smooth, whereby safety stocks needed to cover demand variability, could be lowered considerably. Moreover, the extra discounts have lowered the gross margin and possibly the effect is faster price erosion than necessary.

The high stocks at the CEC also imply a high obsolescence risk. The more so since the erratic demand is a poor translation of in fact smooth consumer demand. It could happen that a high demand causes the CEC to believe, either based on a forecasting algorithm or not, that sales for the product are expected to increase, whereas no demand will occur anymore.

It is clear from the above discussion that what seemed to be beneficial for the CEC and the wholesaler, as judged by the salesman and buyer, respectively, is in fact disastrous. This is a result of a too local perspective and result of an ultra short-term objective versus a mid-term objective. The above vicious circle should be broken. Yet since both parties do not see the immediate need we need to make our point more clear. The only possible way to persuade people driven by financial objectives is to show them the trade-off between short-term and mid-term objectives in financial terms. And to show the trade-off between local objectives and integral objectives in financial terms. To be able to do so we first propose two alternative approaches. These approaches try to tackle the main consequences of the cultural misbehaviour:

- erratic demand at the CEC;
- large orders initiated without a need by the buyer;

The first approach is aimed at smoothing the demand at the SO of the CEC. The reasoning is as follows. If a large quantity is ordered by a whole-saler it is usually not required to deliver this quantity directly from stock. As explained earlier in most cases there is no immediate need. Therefore it seems reasonable to negotiate about the delivery lead time from CEC to the whole-saler. Assuming that the CEC owns a regional distribution centre (RDC) supplying the SO stock points with a maximum lead time of one week, it is well possible that the large quantity can be delivered from the RDC-stock. Thereby the large demand is filtered from the SO demand, thereby showing a smooth demand pattern at the SO stock point. Although the quantity required is large from the SO's perspective, it is usually a small quantity from the RDC's perspective. Hence the variability of RDC demand is hardly impacted. Of course this needs to be proven, which is done based on simulation modelling. Note that this approach only solves the CEC problem. Still high stocks are to be expected at the whole-saler.

The second approach is based on a more integral approach and tries to tackle the problem of erratic demand as well as the problem of too high stocks at the wholesaler. As stated above the turnover-driveness of the salesman and the price-driveness of the buyer is the main cause of our problems. It therefore seems appropriate to change the criteria on which both people are judged. In practice this usually requires top management involvement and takes a lot of time. On several occasions this line of thought was expressed by logistics professionals from within the CEC without any success. A more operational approach is to make agreements about the delivery schedule of the quantities ordered by the buyer. As already stated there is no immediate need for direct shipment of the whole order. We propose to make an agreement whit the buyer about partial shipments. The first lot shipped is intended to replenish the wholesalers safety stock and the short-term demand for the next two weeks, say. The other part of the buyer's order is shipped in a number of equal lots. This approach does not change the order quantity itself but the need dates of parts of the order, whereby the shipment flow from the CEC to the wholesaler is smoothed in quantity and time, so that safety stocks can be reduced. Moreover, part of future demand is now known beforehand, which should enable to decrease safety stocks even more. The idea of partial shipments is not new, yet no clear insights exist about the quantitative impact of this approach. In this paper we intend to provide some of these insights. Before doing so in section 5 we discuss the general concept of condition management.

3. Condition management.

The order processing function is given more and more attention by logistics professions. Especially the concept of Available-To-Promise (cf. Orlicky [3] and Martin [2]) has stimulated research into ways of changing the order processing function from an administrative function to a function that gives a competitive edge. It has been recognized that information systems are vital in this change process. The information systems have evolved from registration systems that provide information about price and available stock, into decision support systems that provide information about future customer orders, sales plans, links to point-of-sale information systems of customers and future scheduled and planned receipts. The management of all this on-line available information is a non-trivial task.

The idea of condition management is to support the order processing function by system defaults of various sorts based on contracts with customers. The most popular of such system defaults are price matrices, that have been used for several decades. However, other aspects of customer relation management can be dealt with by default as well. In the context of this paper wewould like to mention

- lead time
- delivery date/hour
- shipment quantity
- delivery frequency
- packaging
- service level requirements

By making "customer service agreements" about these points the results of these agreements can be translated into defaults. Since these customer service agreements are made for each customer, this concept gives rise to the notion of Product Customer Combinations (PCC's). This is in line with the trend of tailor-made differentiated logistics services. The resulting complexity can only be handled with information systems that enable to automatically schedule shipments to customers based on the conditions given by the customer service agreement. Also, in case of (expected future) shortages priorities can be given based on service level agreements and past performance with respect to the customers involved. Thereby the order processing function is provided with decision support for critical situations, while routine order processing is dealt with by the system. This approach is stimulated further by system-to-system communication (Videotex, EDI) of purchasing systems of customers and the order processing systems of suppliers, which does not allow human intervention apart from critical situations. It is clear that the development or enrichment of the order processing function into value-adding function is expected to be implemented on a larger scale in the coming five years. However, there is a risk that IT-suppliers will push the implementation of complex order processing systems without real insight into the benefits in terms of cost reduction and service improvement. In this paper we investigate in quantitative terms the impact of the two procedures described in section 2 that are aimed at smoothing the demand process at the CEC stockpoints.

4. Rerouting large orders to upstream stockpoints; large order overflow.

The procedure analyzed in this section assumes that the CEC distribution network consists of a regional distribution centre (RDC), possible near the factory, and 10 local stockpoints, wherefrom customer demand is satisfied. Typically, the RDC holds seasonal stocks and replenishes the local stockpoints (see fig. 4.1).

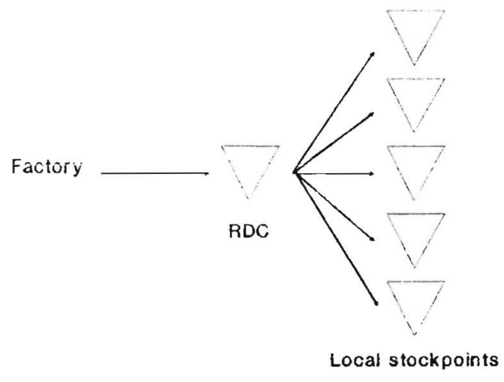

Figure 4.1. Supply chain with RDC and local stockpoints

For sake of simplicity assume that all stockpoints have identical demand processes. We assume that customers arrive according to a Poisson process with rate l. The Poisson process consumption has been shown to hold in most practical situations with regard to customer arrival streams. Each customer has a demand D. We assume that the expected demand E[D] = 100 and the variance of demand $\sigma^2(D)$ are known (e.g. based on historical data).

Furthermore we define the coefficient of variation of D, c_D, as follows.

$$c_D = \frac{\sigma(D)}{E[D]}$$

The coefficient of variation is a measure for the variability of demand. Often it is assumed that if $c_D < 1$, then demand is stable and if $c_D > 1$, then demand is erratic (cf. De Kok [4]). At the CEC local stockpoints we assume that $c_D = \sqrt{3}$, which can be seen as representative based on an extensive analysis of about 10.000 consumer electronics products. This large coefficient of variation is a result of a rather steady stream of small retail orders and lumpy demand of wholesalers and power retailers. If we look at the composition of the stocks at the local stockpoints we find that they are unbalanced, i.e. too low stocks for some products, too high for others. This is typically the result of highly variable demand over time. The main idea for improvement is to reduce the variability by rerouting large orders, the ones that cause the lumpiness, to the RDC. The implementation of this idea is as follows. Determine a maximum customer order size Q_c that is satisfied from local stockpoints. If a customer order exceeds Q_c then this customer order is satisfied from the RDC. This implies that the RDC satisfies big customer orders as well as replenishment orders from the local stockpoints. We assume that the customer asking for a large quantity accepts the additional leadtime of 3 days from the RDC. Of course it may not be easy to persuade customers to accept this new regime. It is likely that additional discounts help. Yet this discount depends on the amount of money that can be saved on stockholding costs.

In figure 4.2. we show the effect on the average stocks needed to satisfy 90%, 95% and 99% of customer demand from stock on hand from the local stockpoints and the RDC for various values of Q_c.

In the simulation we assumed that the lead time to the RDC equals 40 days, representing the sum of planning lead time and distribution lead time for a Far-East factory and a European RDC. We assumed biweekly replenishment of the RDC and weekly replenishment of the local stockpoints. The simulation is based on mathematical modelling. The results have been validated with a discrete simulation model.

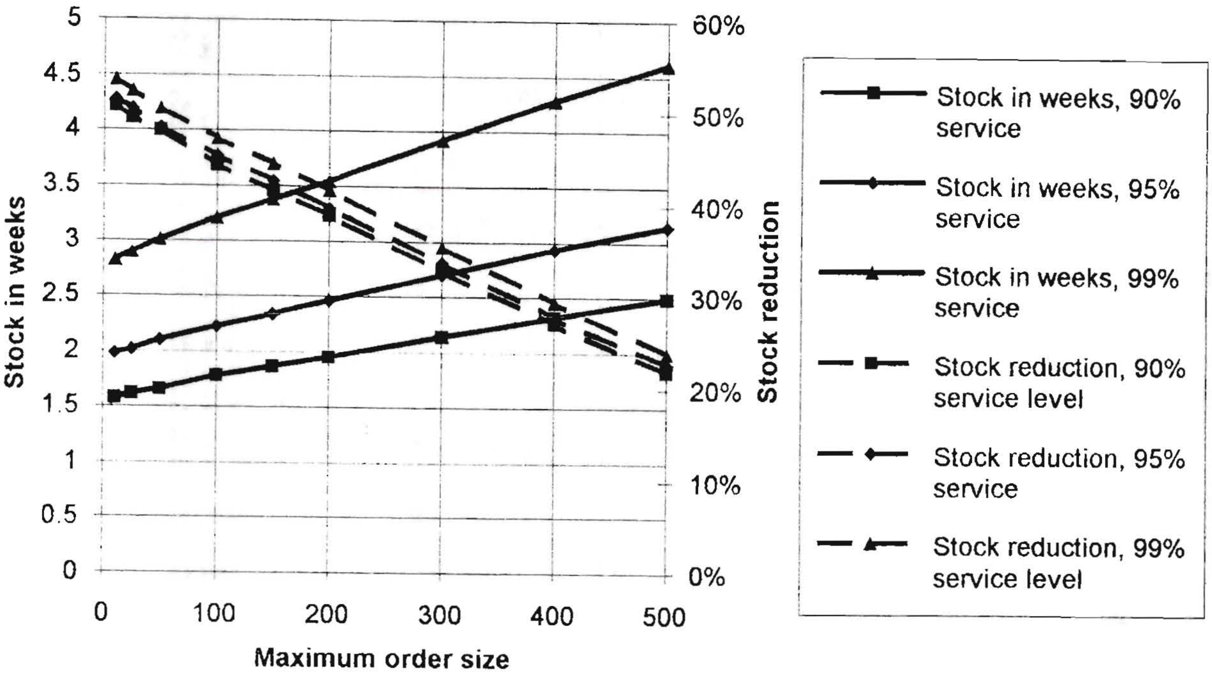

Figure 4.2. Effect of large overflow procedures on stock levels.

First of all we found that without large order overflow we need 3.2 weeks of stock to maintain 90% service level, 4 weeks of stock to maintain 95% service level and 5.8 weeks of stock to maintain 99% service level. We find that by diverting large orders to the RDC we can save about 22% of stock in the pipeline from RDC (inclusive) to the local stockpoints (inclusive) if Q_c equals 5 times the average customer order size to 45% of stock savings if Q_c equals the average order size. The latter situation is not at all unrealistic, since the demand process consists of a lot of small orders, less than 20, say, and some large orders, 500, say. By taking Q_c equal to the average customer order size we indeed discriminate between small and large orders.

The analysis reveals another important point. Without large order overflow we need very high stocks to maintain a 99% service level, as is usually proposed as a standard in the Operations Management literature (cf. Martin [2]). In practice we find such high stocks unacceptable from an economic point of view. Either on accepts a lower service level or one applies procedures such as large order overflow and order splitting, which is discussed in the next section. We found that in practice such procedures (and others) are applied on an ad hoc basis, especially in situations where stock-outs are likely to occur in the near future. However, this usually comes as a surprise to the customer. We advocate the routine use of such procedures, where customers know the conditions, and target stock levels are set taking into account the benefits of the differentiated procedures.

5. Order splitting.

The large order overflow procedure aims at reducing variability of demand to be satisfied from local stockpoints. Indeed, CEC stocks are dramatically reduced by this procedure. Yet, the customer orders are all shipped in one lot. As argued in section 2 this is likely to cause high stocks at the customer. Therefore we propose the following procedure. Determine a maximum shipment lot Q_s. Suppose we get a customer order of size D. Then we ship consecutive lots as follows. Let N be the largest integer value smaller than or equal to D/Q_s. Then the first N lots equal Q_s. The N + 1st lot equals D - N.Q_s. The time between shipments, the intershipment time, is set equal to T, e.g. one week. Of course T should be agreed upon with the customer and may vary from one situation to the other. We assume here that T is fixed and the same for all customers.

Again we have analyzed the quantitative effects of the order splitting procedure. Towards this end we simulated 576 cases as follows. We assumed a single stockpoint that operates a reorder-point/fixed-order-quantity inventory management strategy ((b,Q)-rule). The customer demand was varied as follows. We assumed a weekly demand of 100. The number of customer orders per week was varied as 5, 10 and 25. The squared coefficient of variations of customer demand was varied as 0.25, 0.5, 1 and 4. The lead time of replenishment orders was varied as 2, 4 and 8 weeks. The replenishment order quantity was taken equal to 100 and 200, i.e. weekly and biweekly replenishment, respectively. We varied the service level, defined as fraction of demand satisfied directly from the shelf, as 90% and 99%. The intershipment time T was taken 1 week. The maximum shipment lot was varied as 0.5, 1, 2 and 4 times the average customer demand. The figures below are the consolidation of the results of the 576 cases. We focused on the impact of order splitting on stocks required to maintain the required service level for different values of Q_s and different values of the coefficient of variation of demand. In figure 5.1 we show the stock on hand reduction in the situation where we use a fixed (b,Q)-strategy under the order splitting regime. Again we find substantial reductions of stock on hand, especially when c_D gets large. Note that if c_D is small, $c_D < 1$, say, then order splitting gets only beneficial when Q_s is less than two times the average demand. However, in a stable demand situation order sizes of two times the average demand should be considered normal. In that case order splitting is not allowed. Therefore order splitting has no impact in situations where $c_D < 1$. However, as already argued in section 4, if $c_D \geq 1$ then demand consists of a lot of small orders and a small number of large orders. In that case even taking Q_s equal to the average demand size discriminates between small orders and large orders. In that case we find stock on hand reductions of 30% for $c_D = 1$ and 45% for $c_D = 2$. Clearly the relative stock reductions with order splitting increase as c_D increases.

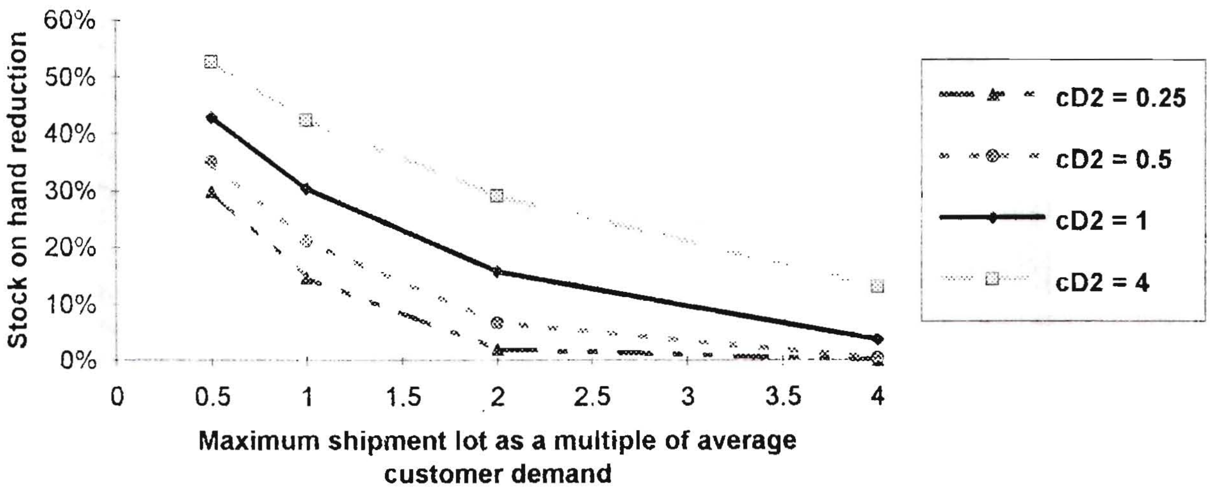

Figure 5.1. Reduction of inventory on hand using partial shipments.

In figure 5.2 we consider the additional stock savings when we use the fact that by shipping demand in subsequent lots we have information about future shipments. In a sense we have now a situation where we have pre-information of customer orders. We expect additional savings by exploiting this information.

It follows from figure 5.2 that again this information is valuable for $c_D > 1$ for realistic values of Q_s. For Q_s equal to the average demand the additional stock savings are 5.5% for $c_D = 1$ and 9% for $c_D = 4$. Again savings increase relatively as c_D increases.

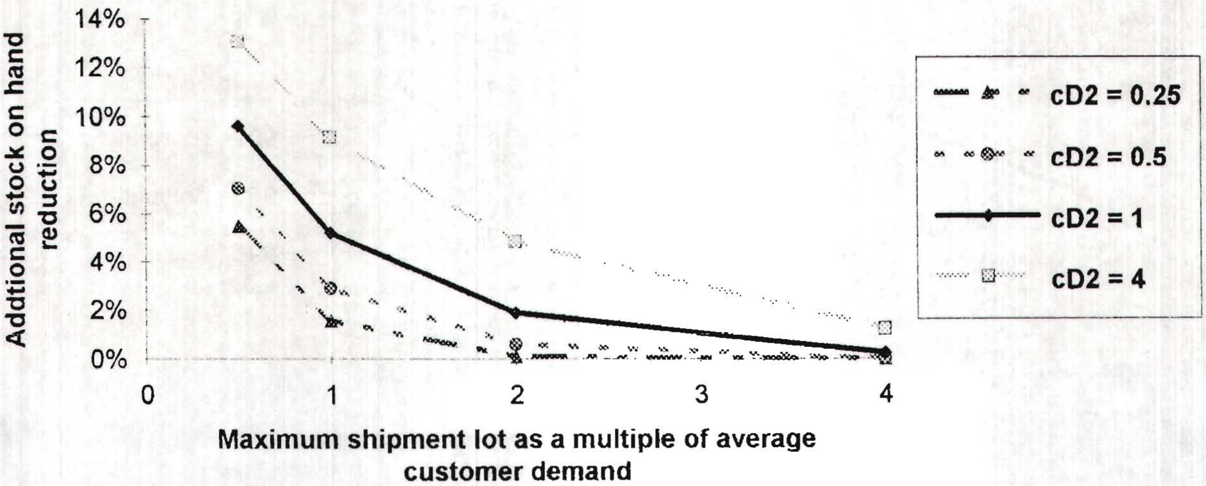

Figure 5.2. Reduction of stock on hand using partial shipments and order information.

In figure 5.3 we take a different perspective, which also applies to the large order overflow procedure. We show the stock on hand requirements for service level 90% and 95% when we do not use order splitting. We also show the relation between Q_s and the stock on hand requirements for service level 99%. We find that a quantum leap in performance is realized by order splitting. By taking Q_s equal to 1.7 times the average demand we can realize a service level of 99% with the same stock on hand level as needed for a 90% service level without order splitting. To achieve a 99% service level with the stock needed to maintain 95% service level without order splitting we must take Q_s equal to 3.2 times the average demand.

Finally note that through the substantial decrease in stock requirements it is economically feasible to offer extra discounts to the customer for allowing partial shipments.

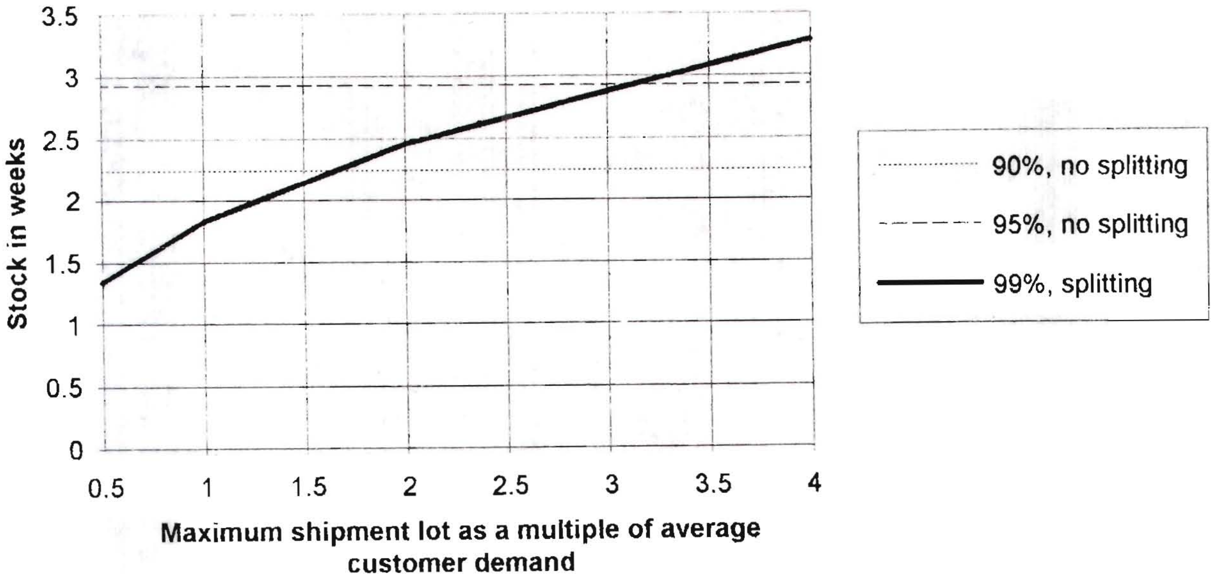

Figure 5.3. Quantum Leap in performance by order splitting.

6. Conclusions.

In this paper we discussed the problem of demand management in a multi-stage distribution chain. We have argued the organizational causes for high demand variations in intermediate stages in spite of stable end-customer demand. This effect is another example of Forrester's findings [1], yet it differs from the usual interpretation of Forrester's conclusions, which are more related to batch sizing and information delays (cf. Silver and Peterson [5]). We discussed ways of resolving the problems caused by these high variations based on the insight that both supplier and customer benefit from stability at intermediate stages by stock reduction. We discussed the concept of condition management as part of the order processing function as a means of implementing procedures that yield more stability. We have introduced and analyzed two simple procedures that could be applied in state-of-the-art order processing systems. We emphasize here that the resulting procedures are customer-oriented yielding to the notion of Product-Customer Combinations (PCC). Our analysis has shown the enormously favourable impact of application of the two procedures from the point of view of the supplying stage, in this case a Customer Electronics Company. We consider this paper as only a first, more quantitative, step towards understanding the impact of operational demand management. In that sense we deliberately use the notion of demand management, which is pro-active, as opposed to inventory management. Further research is required with respect to implementation of the procedures and practical validation of our stock savings predictions. Yet they are in accordance with the savings reported by companies that implemented DRP-systems with Available-To-Promise capabilities. This constitutes another subject of further research, i.e. the relation of the demand management procedures defined in this paper and the ATP-capability.

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