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INVENTORY MANAGEMENT WITH STATISTICAL PROCESS CONTROL: SIMULATION AND EVALUATION

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INTRODUCTION

Over the past few years, logistics costs has gained considerable visibility. According to a survey in Germany, 13.3% of an industrial company's total costs are made up by logistic costs. For commercial companies this figure rises to 21.8%.¹ In fact, these figures emphasize the importance of logistics as one of the company's critical functions its importance is expected to rise significantly in the foreseeable future. This development is due to even higher expectations of customer service and is facilitated by highly sophisticated information and communication systems and highly qualified logisticians.²

In spite of the trend to become more process oriented, inventory costs generally amount to almost half of a company's total distribution dollar expense. Therefore, it is important to focus on these inventory as a means to reduce overall logistic costs. In particular, inventory costs are likely to gain more significance in Europe. This is due to the fact that medium-term transportation costs will probably decrease not only because of further technical improvements in the transportation field but also because of the development of a European common market with open borders and more fierce competition.³

For this reason, companies are looking for new approaches to inventory management. One approach is to develop the logistics competency of "agility" and to avoid the necessity of forecasting as much as possible.⁴ The search for excellence shows that it is never a question of "neither ... nor" but, of "as well ... as" in using management concepts.⁵ Therefore, even in agile companies there are situations where forecasting is needed. Due to this, new approaches in forecasting still are of considerable importance⁶ to optimize the inventory levels and to minimize backorder situations.

The following study introduces an instrument that applies an old methodology to inventory management. It is based on a technique that is very well known and used in quality control management in order to recognize unwelcome changes in product qualities "Statistical Process Control" (SPC). In order to examine this new instrument for inventory management, real inventory levels and quantities of backorder situations of the 3M Medical Products Group European Business Center have been compared with simulated inventory situations using the new system. The focus of the study is on finished goods and in-transit inventory.

This paper introduces the SPC method and presents some of the empirical results of inventory simulations. Finally, there will be an evaluation of the inventory control system showing its possible future uses.

PROBLEMS OF INVENTORY CONTROL

The most difficult problems to solve in connection with inventory of finished goods are the three areas of: excessive stock investment, inadequacy of stock to meet demand and inaccuracy of stock records.⁷

In order to check record accuracy the actual figures gathered by physical count are compared with the quantities on record. This comparison is of enormous importance since inaccurate records do not only result in confusion but also lead to shortages or excessive stocks.⁸

There are different ways to solve the problem of mismatches between supply and demand. The first is distribution and materials requirements planning.⁹ The principle idea of requirements planning is to extrapolate demand requirements by discrete periods into the future. If these period demand levels are taken as given, then acquisition of the goods to meet these demand levels is time-phased based on the lead time. In theory, supply and demand are matched perfectly so that no safety stock is needed. If requirements planning is used when there is lead time or demand uncertainty, some inventory build-up, stock-outs, or both will occur in the long run.¹⁰ This is the main criticism of requirements planning made by inventory controllers. In contrast to assumptions behind the requirement planning, demand and lead time variability are not always known with certainty and must sometimes be treated as random variables. This variability results from many different causes, none of which is dominant. Therefore, the variability can be explained by probability distributions.¹¹ A critical question is how high a product's demand will be during the lead time. If demand and lead time are constant and known in advance, it would be easy to calculate the reorder point (as it is done in requirements planning). But, given that demand, as well as lead time sometimes vary, the first step is to gain some understanding of the likely distribution of demand during the lead time. Specifically, it is necessary to calculate accurate estimates for the mean and standard deviation of demand during lead time.

Another major approach to solve mismatches in supply and demand is improved information sharing and cycle time reduction. This is being used extensively in the computer industry, where actual demand levels are shared on a real-time between distribution centers and supply points.

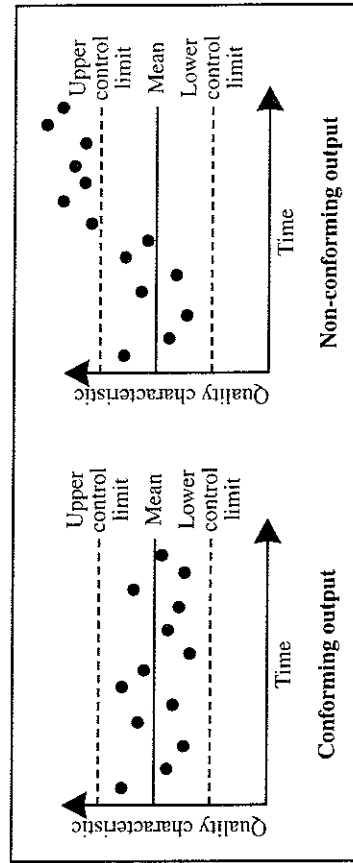
STATISTICAL PROCESS CONTROL: AN INSTRUMENT FOR INVENTORY CONTROL AND REPLENISHMENT ORDER QUANTITY CALCULATION

The Basic Concept

SPC is not a new technique. It is one of the most famous and important tools used for quality control.¹² The technique was first elaborated in a book by Walter A. Shewhart¹³ published in 1931. His ideas were used to solve some quality problems at a company involved in the development and manufacture of telephone systems. This led to the discovery of the basics of what we now refer to as *statistical process control* and to his invention of the associated essential tool known as the *process control chart* (Figure 1) which was first used in 1924.

FIGURE 1

PROCESS CONTROL CHARTS



The popularity of SPC depends on the fact that small samples of data collected on a regular basis from a process can give a statistically determined indication of how the total process is running and whether it is producing conforming outputs or not. This information can then be used to control the process immediately and, thus, prevent non-conforming output.

Variation in outputs from a process can be a result of common causes (e.g. weather, atmospheric pressure, small temperature changes, etc.) or a result of special causes (e.g. malfunctioning machine parts, excessive wear, etc.). Data is collected in a process control chart to help identify any special cause of variation and to establish the capability of the process. This is based upon the range measured values (upper and lower control limit) and the mean (average) value. In order to set up control charts, it is necessary to eliminate the special causes (by problem-solving) so that the process is capable of running in a statistically controllable way. The control limits are calculated from the data

collected using standard statistical formulae and, for processes producing measured data, mean and range charts are set up. In use, constant sized samples are taken at regular intervals and the means and ranges calculated and plotted onto the charts. There are various rules for interpreting the plotted data: points outside of the control limits, trends either up or down, too many consecutive points on either side of the central line, points bunching near the control limits. When characteristics like these appear, action is needed to investigate the cause of abnormal variation because the process is going out of statistical control and may be producing non-conforming outputs.

The application of the SPC technique to inventory management is new. The key objective of SPC inventory management is to use only historical inventory and demand data to optimize replenishment ordering and inventory levels in the future. When calculating the replenishment orders, SPC not only takes into consideration deviation of expected customer demand of the next periods but also variations in lead time.

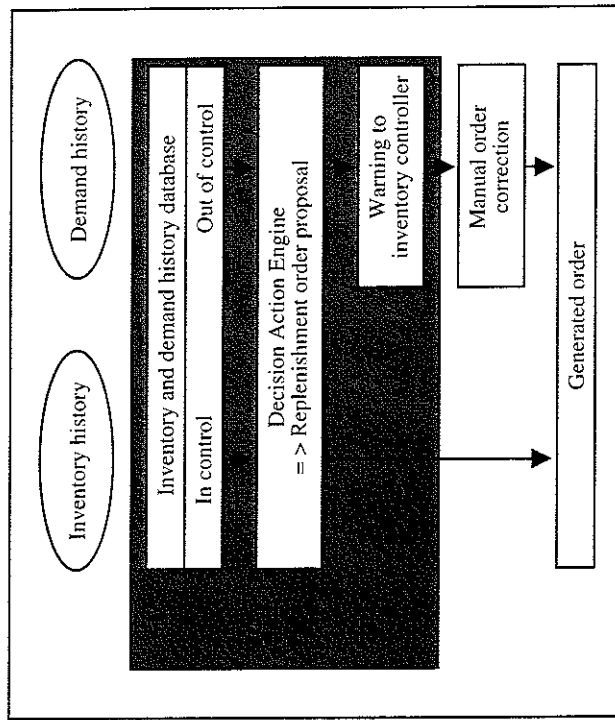
Therefore this technique promises to be a new approach for inventory controllers to complete daily stock management. As with all instruments that employ historical projection, the SPC technique does not rely on demand forecast. It takes both variations in demand and lead time into consideration when calculating a replenishment order. SPC only monitors historically the control of the demand and inventory processes over time in control charts. In this manner it is possible to recognize non-conforming demand or inventory. This reduces the probability of both backorder or excessive inventory situations. When a non-conforming output is detected the special causes can be examined and eliminated in order to avoid further inventory shortages or unnecessary waste of capital and therefore, to guarantee customer satisfaction. But, the question arises how the SPC-system specifically controls inventory.

Figure 2 shows the elements and one typical SPC calculation. At the beginning, a database has to be filled with inventory and demand data. The demand gives information about the quantity of demand over a certain period, (e.g. one or more days, one or more weeks). The inventory data is the inventory balance at the end of this period.

First, the system tests if the demand and inventory processes are in control or out of control. This indicates whether the system can handle the processes or if there are statistical abnormalities in past demand and inventory curves that would make it difficult to make a safe reorder quantity decision using SPC. If the processes are in control, the SPC decision approach can be applied. The support engine examines and interprets the demand and inventory processes. Based on defined rules, the SPC decision support system (DSS) calculates a replenishment order proposal from the information in the database. This order can be generated automatically. In this case the system works without any need for manual inventory controller attention.

If the processes are out of control, the SPC DSS calculates a reorder proposal. However, because there are statistical abnormalities, the DSS indicates a problem and warns the inventory controller that it cannot guarantee safe handling of the situation. In this case, the inventory controller is forced to check the replenishment order proposal. If the inventory controller does not agree with the systems information when examining the demand and inventory history he adjusts the order manually. Finally, an adjusted order will be generated.

FIGURE 2
ELEMENTS AND CALCULATION PROCESS OF SPC



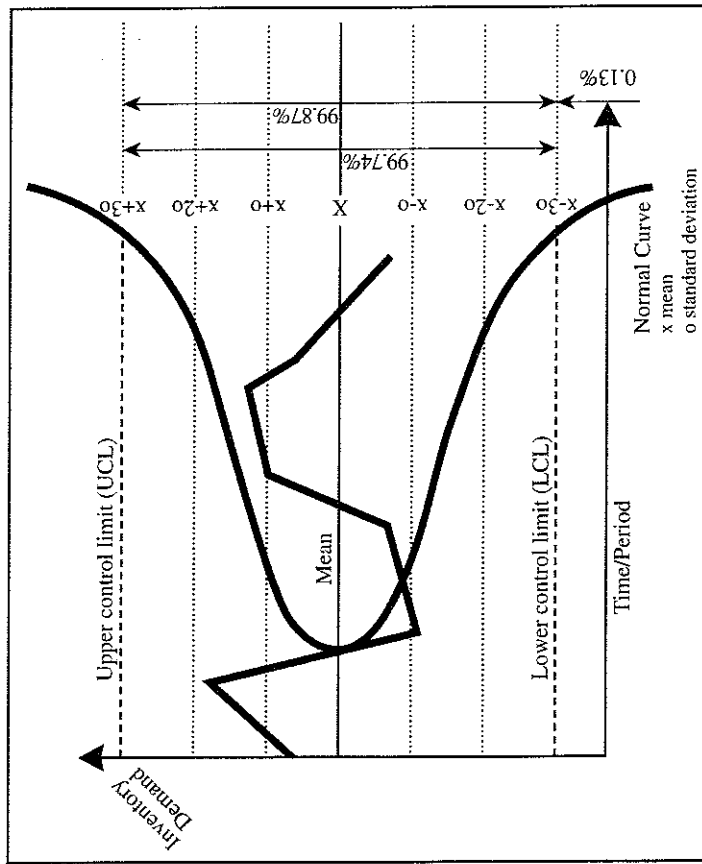
To analyze and understand the results of the SPC calculation it is necessary to explain the different assumptions and rules the SPC DSS determine the quantity of the next replenishment order.

Decision Rules

The decision process relies on the assumption that the amounts of inventory and demand quantity are distributed in the form of a normal curve. On this assumption the system calculates not only the mean demand and inventory levels up to 150 data points but also an "upper control limit" (UCL) and a "lower control limit" (LCL) as 3 standard deviations above and below the mean for historical data (Figure 3). This will guarantee that for more than 99.73% of all cases, the future ordering and inventory needs can be predicted if the process is between the UCL and LCL and is therefore, in statistical control.

As stated above, the DSS first tests if the demand and inventory curve are in statistical control. This is the case when the inventory and demand do not run for more than 3 points in a row above or below the mean. In other words, the demand in the last period was below the UCL and the inventory curve runs between the UCL and the LCL. In this case, the system orders at the end of one period the mean demand.

FIGURE 3



The mean demand is always the base for the replenishment order quantity. The quantity will be adjusted in those cases where the system recognizes an abnormality in the demand or inventory processes. How the system adjusts the order quantity depends on the statistical problem and the rule used to manage this problem.

The next rule requires the SPC to test if the LCL of the inventory chart is in a special range. The limiting values of this range are derived from the work experiences of inventory controllers. In practice, it makes sense to adjust the specific threshold values for each product corresponding to the experience of the warehouse controller. In our example, we determined the limiting values of the range for the LCL to be 3% and 20% of the mean inventory. In some cases, it might make sense to change the 3% line, as well as the 20% line to different values for an acceptable range of the inventory LCL (e.g. 5% and 25%). With this rule, the system insures that the whole range between the UCL and

LCL will be 3% above the mean to guarantee that in more than 99.8 % of all cases the inventory will not run in a backorder situation. The line of 3% can be interpreted as additional safety stock of the system and the 20% line is to prevent an excessive inventory level (overstock). Depending on the products, a change in these values might be useful to insure the availability of products in stock, to prevent backorder situations or to optimize inventory levels. If the inventory LCL is within the range of 3% and 20% of the mean inventory no action will be taken. If the inventory LCL is below 3% of the mean, the order level will be increased by the difference of the 3% of mean line and the current level of the LCL (Figure 4, rule 1). In response, the system will reduce the order quantity by the difference of the current inventory LCL and the 20% line if the LCL is above the 20%.

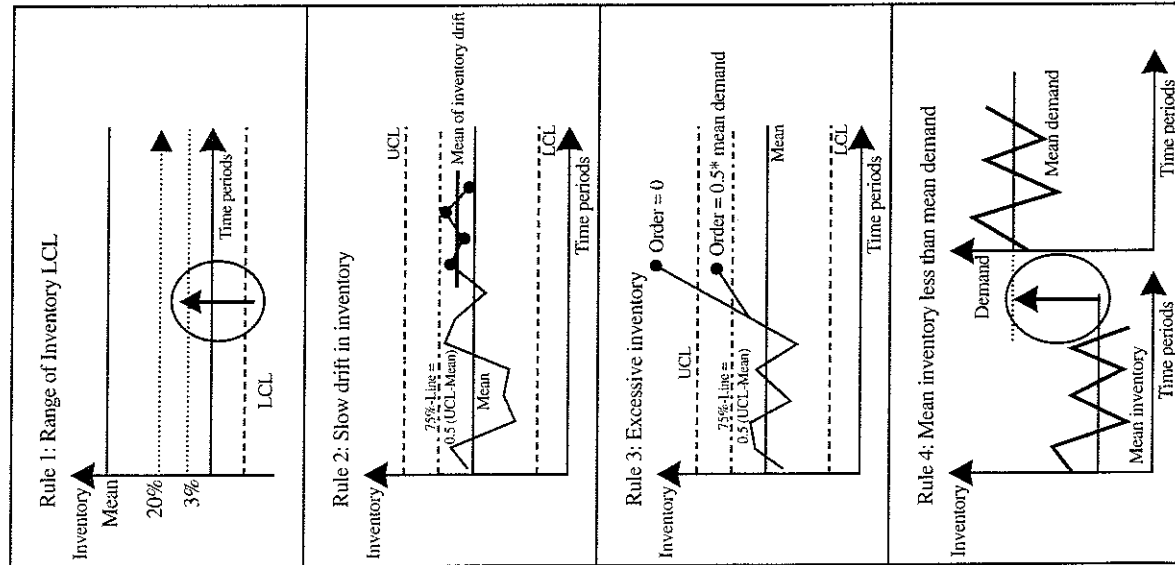
The next rule deals with slow drifts of the inventory curve. The system recognizes a slow drift in inventory when the last four points in a row were above or below the mean inventory and between the 20%-line and a 75% control line which is the mean of the UCL and the mean inventory. If the run is above the mean, the system reduces the order by the difference of the overall inventory mean and the inventory mean of this last row (figure 4, rule 2). When the run is below the mean, the replenishment order proposal will be increased by the amount of the difference of both means.

According to another rule, the SPC DSS checks whether the current inventory level is above the inventory UCL or between the UCL and the 75% line. In these cases, the system reacts as shown Figure 4, rule 3. As long as the inventory level is above the UCL, the replenishment proposal will be 0. If the inventory level is between the UCL and the 75%-line only half of the mean demand will be ordered. In those cases where there is a slow drift of inventory, which are four points in a row between the 75%-line and the mean inventory, the replenishment proposal will be reduced by the difference of the drifting mean and the total mean of inventory. In addition, the system also tests whether the inventory level is too low and if there is the danger of or currently is a backorder situation. The SPC DSS recognizes this when the current inventory level is less than 20% of the mean. In this situation the replenishment order quantity will be oriented by the replenishment proposal to the demand of that period. For that reason the SPC shall always order the next multiple of half of the mean demand that is more than the current demand but at least 1.5 times the mean demand.

Furthermore, the SPC DSS compares both the inventory mean and the demand mean (Figure 4, rule 4). If the ratio of inventory in demand is less than a determined value the order level will be increased by the difference of both means. This rule prevents the mean inventory in stock below the value that demand that might be met in the next period. The SPC still works with a ratio of 1 but, it is also possible to adjust this figure and keep the ratio of mean inventory and mean demand above 2 or 3.

After examining all inventory rules, the system will then apply three further rules concerning demand. First, the system looks for a slow drift in demand (Figure 5, rule 1). The system recognizes a slow drift in demand if there is a run of 4 or more points above or below the mean demand. In this case, the mean demand is recalculated with the last 4 points of demand only into the next period so that the mean demand as base of the replenishment order proposal will increase or decrease in the next periods' calculation.

FIGURE 4
INVENTORY RULES

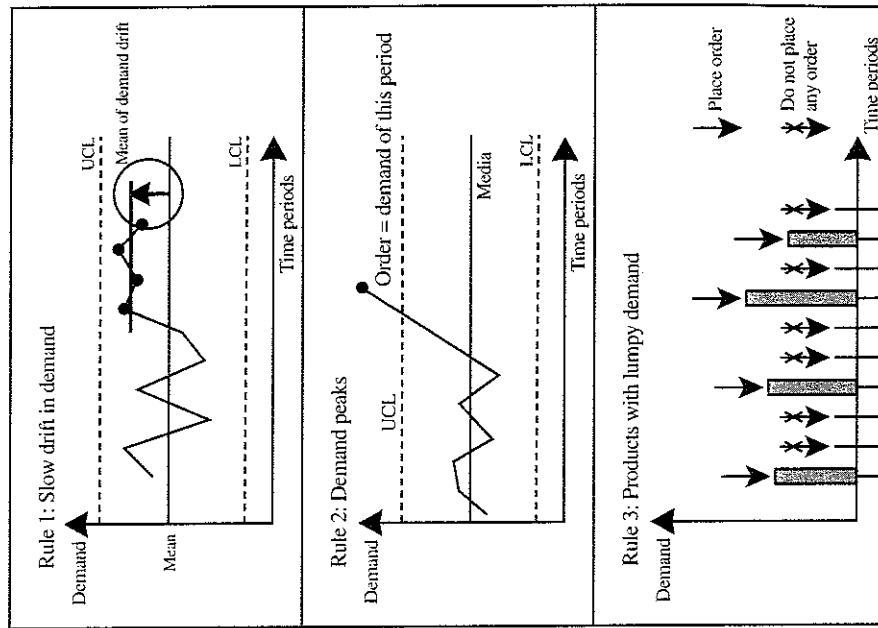


A further rule of the DSS deals with sudden peaks in demand (Figure 5, rule 2). When the demand of the current period is above the UCL, the system interprets the demand curve as out of control. At this point SPC orders the same amount. In addition, the SPC system sends a warning to the inventory controller and asks for manual order intervention.

A last SPC rule is necessary for C-products with lumpy demand and with zero demand in some periods (figure 5, rule 3). Periods with zero demand shall not be considered in the history and, therefore also, not in the calculation. Replenishments are only done in situations with a positive demand. Additionally, for products which have zero demand in more than 75% of all periods, the sum of replenishment proposal and current inventory level may not be higher than the current demand or inventory UCL.

FIGURE 5

DEMAND RULES



In order to handle the inventory with SPC, the preceding rules must be applied in order to prevent excessive inventory and backorder situations. These rules depend on the demand structure of a product and must be adjusted according to the special circumstances of each part number.

This section presented SPC as a decision making system for the management of inventory and replenishment order quantities. The next section describes the process for simulating and testing different products.

Empirical Results of Using SPC

The testing of SPC for the evaluations and simulation has been run over a six month period for 12 different European warehouses. To simulate this period, the data of an entire year was used to seed the SPC demand and inventory database with historical data and provide an adequate database for comparison. Furthermore, for the simulation it was determined that the system would only run once at the end of each week on Sundays. Therefore, it was only necessary to know the aggregated weekly demand per period (for a week from Monday to Sunday) and the inventory levels at the end of each week (on Sundays) as compared to the daily demand and inventory level.

To understand how the system works with different classes of products, (e.g. A, B, and C-products) (and launching products), the simulations were conducted with 20 different part numbers. To simulate the different scenarios with the SPC software, 20 weeks of inventory and demand history of these part numbers was entered into the history database as a basis for the demand and inventory control chart. Since the industry data was input directly into the system, the deterministic simulation exhibited no "randomness." Furthermore, the simulations were based on assumptions that differentiate the simulated results from reality.

The system does not recognize any minimum, maximum or multiple order quantities. Therefore, the system will always order and get the amount of the generated order. Another assumption is that there cannot be any backorder on the production side. Whenever the SPC of any warehouse, that is directly supplied from the plants, places an order, the plants will always be able to supply the warehouses. Knowing the history and the assumptions, the SPC calculation process can be started. The result of each calculation is a proposal for a replenishment order that is filled in on the data sheets.

The simulation also did not consider variations in lead times. It calculated an average lead-time for each specific part number. Due to the lead time, the replenishment orders become physically available in the warehouses after the lead time with each period. As long as no SPC replenishment order has arrived in the meantime, the real order quantity is accepted as replenishment.

Figure 6 shows the example of an A-product with a reorder lead time of two weeks. On the X-axis, you can find the number of each period (week). The Y-axis shows the inventory level of products in each. The columns represent the demand of each period, whereas the grey line gives information about the inventory levels with the real manual inventory control at the end of the last period day. The black line represents the results of the SPC simulation. The black line starts in week 22 which

is the beginning of the simulation. All data on the left side of this line is the history which had been entered into the SPC database to calculate the first proposal for a replenishment order.

Although a backorder situation in week 30 cannot be prevented because of a drift up and additional high peak in demand, the system reacts very fast on the changed demand and on the backorder situation without producing excessive inventory. In this case, the system worked much better than the real inventory controller because shortages in weeks 48, 50, and 51 were avoided.

Figure 7 gives an example of a C-product with a lead time of four months. Though the system does not run in a backorder situation, the average inventory level is just 1 part higher than the inventory curve with manual control.

The SPC system reacts very fast and is flexible to problematic situations. Although the rules work very well, the system cannot prevent all backorder situations. An example of this is shown in Figure 8 using the B-product. The system runs into a backorder situation in week 44 (thin black line). A very high surge in demand is the main cause for the shortage in inventory during that period. Although the system reacts to that problem immediately and adjusts the replenishment order, it is not able to prevent the situation because when looking for the customer demand history such a high peak in demand was not probable. Therefore, the system was not able to anticipate this situation. Furthermore, the earliest point of time when the reaction of the system can have an effect on the inventory level is after the lead time. In this case, the lead time is two weeks after which the inventory level is above zero again.

The problem of lead time could be avoided if some information was available about situations where the future demand and inventory requirements are known, (e.g. special marketing actions where the needed quantity is known). In those cases, the inventory controller could order the required quantity in advance to cover the high demand peak in the future. SPC would only care of that demand which neither the inventory controller nor the marketing department are able to quantify exactly.

As illustrated in Figure 8, the inventory controller received a large replenishment one week before the high surge in demand (grey line). With the achieved level of inventory, it was possible to cover and satisfy the high customer demand peak in week 44. The reason for this could be that the inventory controller knew from the marketing organization that there would be an increase in demand that week. Using this information, he ordered the required quantity just in time. Figure 8 shows what would have happened if the inventory controller had known about this special demand. In this case, the inventory would not have run in the backorder situation (thick black line with data points).

Therefore, it seems to be useful to utilize another inventory control approach for well known demand besides the SPC inventory control program for unknown demand quantities. Only through utilizing both systems, can a minimum of shortages in inventory be achieved.

SIMULATION RESULT FOR AN A-PRODUCT

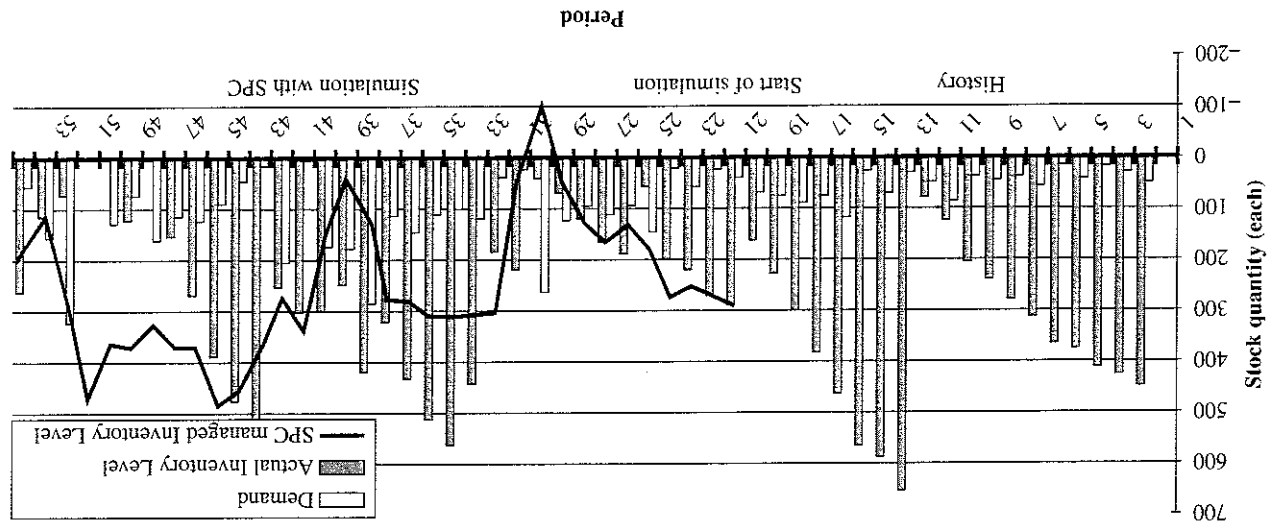


FIGURE 6

SIMULATION OF A C-PRODUCT WITH MODIFIED SPC

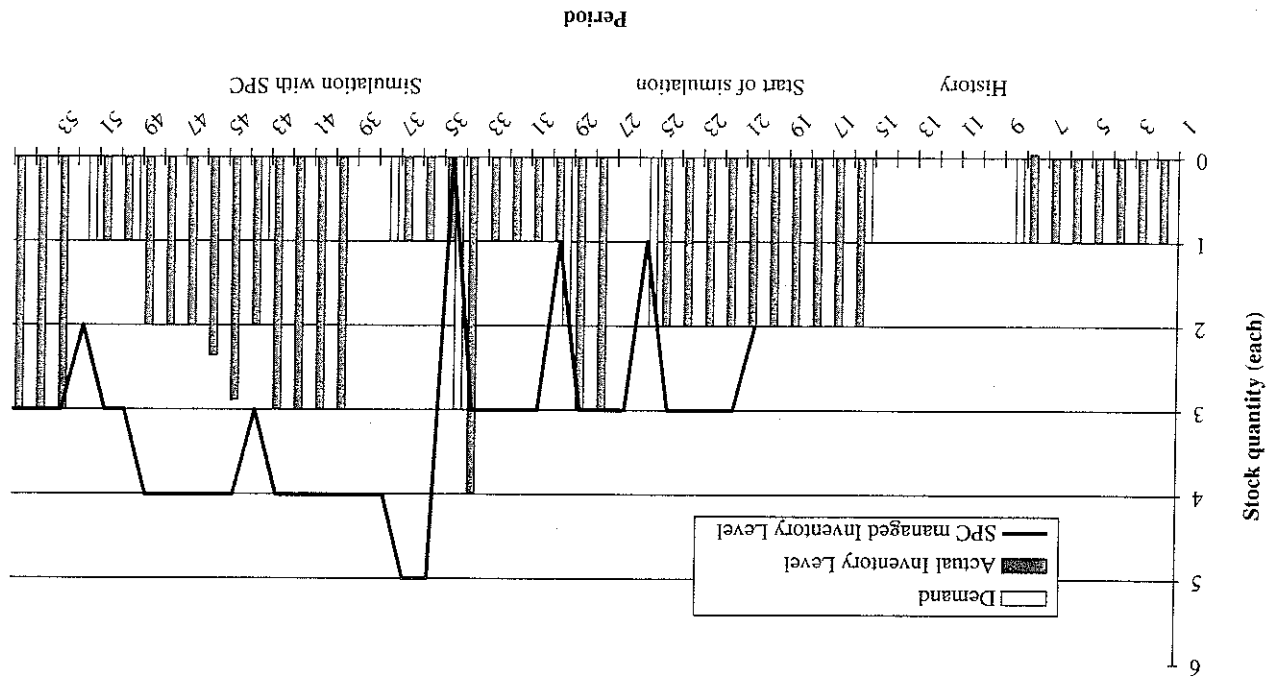


FIGURE 7

SIMULATION OF A B-PRODUCT WITH MARKETING INFORMATION

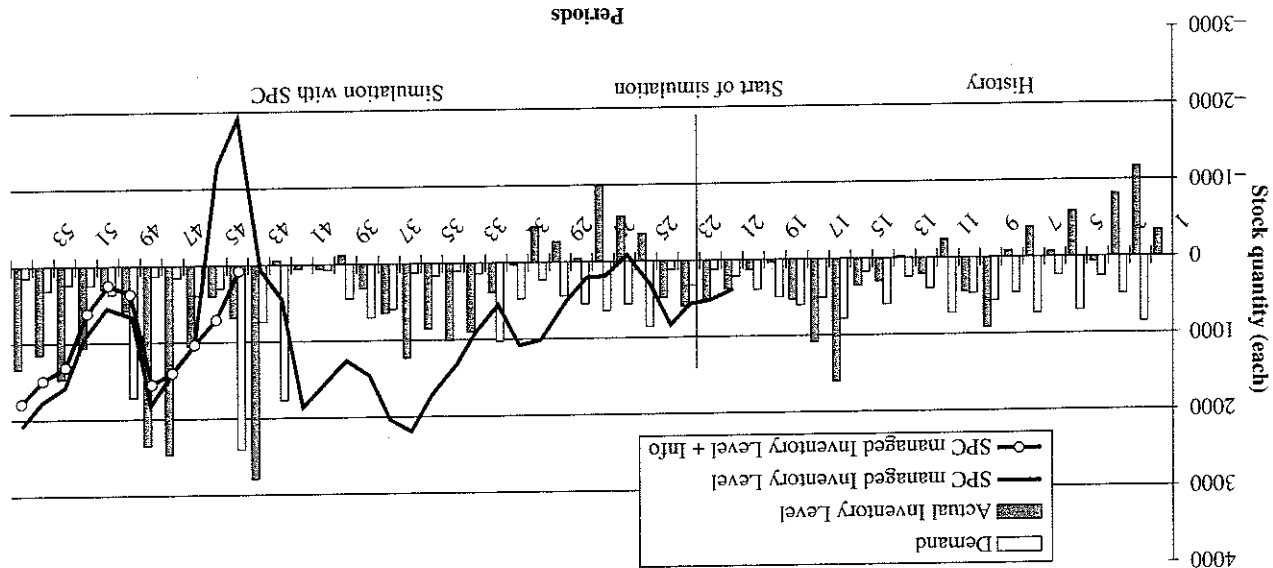


FIGURE 8

After having discussed the problems of SPC and possible improvements, the effects of using SPC in the distribution structure of today can be analyzed.

The overall result is also presented with an A, B, and C-product as characteristic examples of all 20 part-numbers. The SPC DSS overall performance was evaluated using the mean inventory level, which is the average inventory balance over all simulated periods. Table 1 displays the statistics for the inventory levels of the three products. The table shows that an average reduction of 32% for the A-product, 1.5% for the B-product and 32% for the C-product can be achieved by using the SPC instead of manual inventory control. In some warehouses, there is also an increase of the inventory levels. The maximum increase of the mean inventory levels where 11% for the A-product, 46% for the B-product and 50% of the C-product whereas the maximum reductions of inventory were 71%, 31% and 70% respectively.

TABLE 1
INVENTORY EFFECTS OF USING SPC

Changes in inventory levels	A-product	B-product	C-product
Average change per warehouse	-32%	-1.5%	-32%
Max. increase	11%	46%	50%
Max. decrease	-71%	-31%	-70%
Change of the total European inventory (total inventory in all European warehouses)	-58%	-20%	-65%

The sum of the mean inventories of all twelve warehouses is the mean European inventory level. The comparison of the mean European inventory levels of manual inventory management and inventory management when using SPC shows that the technique leads to an overall reduction of the mean European inventory of 58% for the A-product, 20% for the B-product and minus 65% for the C-product.

This demonstrates that the SPC technique has the capability of reducing inventory levels from between 20% to 65% in comparison to the current manual inventory control. These reductions of inventory are caused by very aggressive reactions of the SPC to hints of excesses in inventory. The inventory levels are not the only area of importance but also the backorder situations. The statistics of backorder situations for the stated case are presented in Table 2. The average change of backorders per warehouse is +1.3 for the A-product, -0.2 for the B-product and +0.4 for the C-product. The maximum increase of backorders in all warehouses were 5, 2 and 1 respectively. The maximum decrease was 3, 5 and 2. On the European level the total number of backorders increased for the A-, B- and C-product by 17, 2 and 2 when using SPC.

TABLE 2

**BACKORDER EFFECTS OF USING SPC
(MEASURED IN NUMBER OF BACKORDERS)**

Relative changes in backorder sit.; backorders=BOs	A-product	B-product	C-product
Average change per warehouse	1.3 BOs	-0.2 BOs	-0.4 BOs
Max. increase	5 BOs	2 BOs	1 BO
Max. decrease	-3 BOs	-5 BOs	-2 BOs
European inventory level	17 BOs	2 BOs	2 BOs

There is a tendency that more backorder situations will appear when using SPC. The reason for this could be that SPC cannot forecast peaks in demand that are much higher than any peak in the past. Another reason could be that the earliest point of time the reaction of SPC on low inventory or backorder situation can have an effect is the length of lead time. When the inventory level runs in a backorder situation in a country with a lead time of two weeks, the inventory shortages will remain for at least two weeks. The problem of so many backorder situations could be solved with additional information gathering activities by the inventory controller. Backorder situations can be avoided if the inventory controller knows about future additional demand, for example, special marketing actions that could not be recognized and covered by the SPC inventory control.

EFFICIENCY EVALUATION OF THE SPC

The evaluation shall be based on a functional definition of logistics systems.¹⁶ Similar to other functional areas of an enterprise the logistics system shall make a contribution to the improvement of the overall efficiency of the enterprise. This can be transferred to a model for the evaluation of an instrument for inventory control. Without referring to different methods to measure efficiency in general it can be calculated by input-output-relations (I/O-relations). One of the main characteristics of an enterprise has to proceed on the assumption of the limited resources. Therefore, it is fundamental for a company to aspire to an optimal utilization of resources for performance. This can be displayed by the following formula:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

Since SPC is a new method to optimize efficiency of inventory management, the input factors can be defined as all costs for the use of the method. Output performance can be identified as the improvement of replenishment decisions. Performance includes the dimensions of procurement costs, carrying costs, out-of-stock costs, and the service objective. To make a qualitative evaluation of the different factors, it is necessary to explain the items from the classification.

Costs

In contrast to other methods, the SPC inventory control system has two major advantages when looking for operating costs.

First, the costs of collecting all data and information needed for the system to work may be very low. The SPC system only needs information about the demand and inventory history. Normally this data is available and very easy to collect within a company.

Second, a major advantage is the self-contained mode of operation of the SPC software. Based on its decision rules, the SPC DSS can decide without intervention the replenishment order quantity as long as the demand and inventory processes are in control. In these cases, the system can automatically generate orders without the manual routine of an inventory controller. This means that the SPC system releases the inventory controller from the routine manual work of checking and correcting every order proposal, as he has to do when using a conventional inventory control system. According to the management principle "Management by Exception" the SPC system only warns and asks the inventory controller to check the order proposal when it cannot handle a situation safely because of unusual developments in the demand and inventory processes.

The SPC system's ability to work independently increases the productivity of an inventory controller because he can deal with more part numbers than before. This decreases the number of employees needed to control all products on stock thus decreasing operating costs.

Performance

The SPC software is an instrument for inventory management that uses historical projection as its forecasting method. Therefore, the system shows characteristics very similar to other instruments that use historical projection.

As shown, the accuracy that can be achieved for short forecasted time periods is quite good. As other instruments that use historical projection, the SPC system is still weak in forecasting, signaling and reacting to sudden rapid changes in demand that happen the first time. However, the SPC rules concerning slow drifts in demand and inventory cause much faster and better reactions to these fundamental changes in the course of time.

As presented, the SPC inventory control succeeds in decreasing the average level of inventory (in this simulation between 20% and 65%). This reduces the carrying costs, which consist of capital costs, storage space costs, inventory service costs, and inventory risk costs, dramatically. With the assumption that capital costs represent about 25% of the total logistic costs, the overall reduction through savings in capital costs could be significant (in our simulation up to 16.25% of logistic costs).

Despite these improvements, the simulations in this project show that inventory control with the SPC software still leads to more inventory shortages than manual inventory control with conventional instruments. More backorder situations are the reason for an increase of backorder costs and lost-sales costs. These backorder situations could be prevented if the SPC system would not react as aggressive-

sively to excess inventory. Then the reduction of inventory would be less but also the amount of inventory shortages thus reducing the backorder costs and the lost sales costs.

The independent operations of the SPC system also has a positive impact on the out-of-stock costs. As cited, the inventory controller is released from a large part of his manual workload. The saved time could be used to manage additional part numbers and also to deal with inventory problems (e.g. stock shortages) more intensively and carefully. In this way, inventory shortages might be eliminated much more quickly. Therefore, SPC helps to reduce backorder and lost sales costs.

Since the SPC inventory management, DSS produces inventory levels that are comparable or even better than those of conventional systems and simultaneously produces a reduced work-load, it can be recommended for further examination and for testing under real conditions.

SUMMARY OF RESULTS

The development of a single European market will create new challenges to the logistics management in Europe. Because of decreasing transportation costs, the inventory carrying costs become more and more important for a company's success. The reduction of inventory levels, as part of an optimal inventory management, is one of the key factors to remain efficient and to survive in the competitive market in the future.

In order to meet the challenges of the new European market, companies must try to develop new instruments for effective inventory control. It was the goal of this article to introduce a new tool for inventory control based on "Statistical Process Control" and to assess its usage for the inventory management of the European warehouses of the medical and pharmaceutical company 3M Health Care Medical. Simulations were carried out in order to examine the effects on the inventory. A thorough process description and empirical analysis of SPC was the major theme of this work.

The new SPC inventory control, DSS, could be an answer to the future challenges in the use of historical projection for demand and inventory forecasting. The SPC inventory management system showed very good results. The average inventory levels could be reduced by 20% to 65% which saves substantial carrying costs. However, the number of inventory shortages increased for some products. This problem may be solved in further examinations by using SPC parameters which reduce the inventory levels less aggressively. The most striking advantage of the system is that it reduces an inventory controller's workload significantly. Replenishment order calculations and their generation are carried out automatically by the SPC system as long as the demand and inventory processes are in statistical control. The inventory controller is asked to intervene only when the system detects problems or abnormalities in the demand and inventory curves. The system supports inventory management in the sense that it helps human inventory controllers supervise a wider range or number of products without extra effort. In addition, it enables inventory controllers to concentrate on the inventory management of those products that have a critical inventory balance.

Although there is still room for further improvement, the SPC can already be classified as a reliable and efficient instrument for inventory management.¹⁸

NOTES

¹CF. H. Baumgarten (1993): *Perspektiven der Logistik - Trend-Analysen und Unternehmensstrategien*, In: BVL (Ed.): *Logistik-Lösungen für die Praxis*, Berichtsbund über den BVL-Logistik-Kongress '93, Vol. 2, München 1993, p. 934.

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