Abstract

In this paper, we analyze a model that states that investing in progressive manufacturing programs, combined with a modern approach to supplier issues, has a direct effect on inventory level and structure, which in turn directly affects delivery service and delivery related competitive advantages. The model was tested on data from the Global Manufacturing Research Group. This data was broken up into three groups: the United States, Western Europe and Transitional Economies of Central and Eastern Europe. The results of a set correlation analysis showed that in all three groups of countries: (1) investing in progressive manufacturing programs and using modern approaches in dealing with suppliers were significantly linked to inventory level and structure; (2) inventory level and structure were linked to delivery service; (3) delivery service was related to competitive advantage. Companies from the transitional economies differed from the other two groups in that they did not show a relationship between inventory structure and competitiveness. This may demonstrate that management in transitional economies may still be working to achieve a more successful linkage between inventory structure and competitiveness. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Inventory management; Comparative studies; Customer service; Competitiveness

1. Introduction

This paper presents a cross-country comparison of inventories in specific manufacturing industries. More specifically, we take a look at the idea of "inventory structure", which is the relative levels of raw materials, work in process and finished goods in the total inventory. We use this to compare the market economy of the United States, Western European market economies, and "transitional" economies (i.e., formerly communist countries in Eastern Europe). Issues of customer service in these countries are also discussed. What we are asking in this paper is, first, whether inventory structure is related to competitiveness. Then, we investigate if the formerly centrally planned economies implemented progressive management concepts, would they succeed in producing an inventory structure similar to that of the market economies, which in turn would lead to greater customer service and thus, competitiveness.

This study tested hypotheses that previous research has attempted to answer, with the intent if
seeing of the conclusions drawn in previous studies still hold. Dubin [1] discussed the importance of replication, yet this is not something that is commonly observed in our field. It is hoped that this paper will show the usefulness of replication, and lead to further insights into the inventory structures and customer service levels that exist at a country level.

As noted by Chikan [2], the general theory of inventories is still mostly unexplored from the viewpoint of cross-country comparison. Since that article, there has not been much additional research in this area. This is somewhat disappointing, as we had a very interesting development over this period of time, namely the conversion of a number of economies from being centrally planned to being market-based. As Chikan [3] stated in a later article, formerly centrally planned economies underwent three dramatic changes:

1. Paternalistic state behavior stopped. That is, government subsidies were reduced or stopped altogether.
2. Extended privatization started. In essence, this is the ultimate stoppage of government subsidies, as formerly government-controlled firms moved toward market control.
3. Restructuring of production was necessary. As firms would more and more have to answer to the consumer, and not to the central planner, a new paradigm of production was required in the formerly centrally planned economies.

Each country went about this change differently, as has been well documented by the popular business press. For instance, Poland went through what has been described as "shock therapy", while on the other end of the scale, Hungary started market reforms in the 1960s. Russia's transition has been somewhere in between.

The operations management community has had not much to say about the issue of transition economies and the inventory structures of these countries. As an example, using the search term "transition economy and inventory" on the popular ABI Inform database yielded three hits when done in mid-1999. This paper should thus help fill a gap in the literature.

2. Literature review

In the case of the transition economies, Chikan [2] noted that there is a distinct difference in the inventory structures between market and centrally planned economies. Centrally planned economies tend to have a greater proportion of raw materials inventory and a lower proportion of finished goods than is found in market economies. He attributed this to the lack of "intercompany cooperation" in centrally planned economies. Chikan explained that this situation was caused by the lack of reliable relationships between firms in centrally planned economies. In effect, firms in centrally planned economies were "hoarding" materials to mitigate the effects of shortages.

This issue of firms hoarding goods leads to another issue. If firms in centrally planned economies are hoarding raw materials and not holding much in the way of finished goods, they are acting in a sellers' market. Getting goods is difficult, and selling them is easy as demand is exceeding supply. Chikan and Demeter [4] used the term "permanent overdemand" to describe this situation. Thus, a firm in this situation has no particular need to be responsive to its customers, but must beg and plead with its vendors (or central planners) to get needed materials. By way of contrast, it is a staple of introductory business classes how beholden market economy firms are to their customers.

Kisperska-Moron [5] studied the particular case of Poland's transition. The article's findings appear to be at odds with Chikan's. Specifically, it was found that the proportion of finished goods inventory was actually dropping as Poland was going through the transition to a market economy. Further, the proportion of work-in-process inventory was decreasing. The first finding appears to be in direct conflict with the trend that Chikan had noted. In the particular case of Poland, however, Kisperska-Moron noted that the most likely reason for the decline of finished goods inventory was the high interest rates Poland was experiencing at the time. It should be noted that these interest rates were the result of the "shock therapy" transition plan mentioned earlier. The second finding was attributed to poor managerial practices, which one
could surmise might have been left over from the days of central planning. In particular, Kisperska-Moron noted that concepts such as JIT, MRP and CIM were not well known in Poland at the time of the study.

Radovilsky [6] also noted that firms in the Commonwealth of Independent States (as the former Soviet Union was known at the time) appeared to lack knowledge of “Western” techniques of operations management. Because of this, he prescribed a major overhaul of the production systems found in these countries, including everything from relaying out the shop floor to the overall use of more automation.

Similarly, Chikan and Demeter [4] noted that Hungarian firms have had to move from a resource orientation to a customer orientation. This is reflected in the firms’ efforts to move to what the authors describe as “more developed and sophisticated methodology”. Specifically, they noted that resource issues accounted for the majority of problems in the centrally planned economy that Hungary had; now the problems are due to customer demands, so firms have shifted their focus to the output side in order to meet these demands.

3. Model and hypotheses

The model used in the analysis is shown in Fig. 1. The left-hand side of the figure shows new manufacturing concepts, that to a varying degree can be found in all countries of the world. The new manufacturing concepts box consists of two parts. The supplier concepts box addresses issues related to the performance measurements of suppliers (the basis of retaining suppliers), the extent of outsourcing (the new trend is to increase the level of outsourcing) and the sourcing strategy (the current conventional wisdom is reduce the number of suppliers). It is conceivable that all these factors influence the inventory level and structure.

The investments in manufacturing programs box identifies those programs where the company invested resources in order to improve its operations and competitiveness. These programs represent techniques that have become quite popular over the last twenty or thirty years. Three of these programs are primarily related to manufacturing: materials requirements planning (MRP) and its variations, just-in-time (JIT) and cellular manufacturing. Two of these programs are related to

![Fig. 1. Conceptual model.](image-url)
quality: total quality management (TQM) and statistical process control (SPC).

All these factors have an influence on inventory level and structure. However, it is logical to assume that the inventory level and structure are also influenced by other variables. We partialed out the influence of two other factors: size and product complexity. Generally speaking, bigger companies and companies with complex product structures have more inventories. Therefore, these effects have to be partialed out to control for these sources of variance.

The inventory level and structure have a direct influence on the delivery-related dimensions of customer service, particularly on those that are related to speed. In the next step, delivery service influences competitive advantage of the company. We also want to test the idea that competitive advantage is directly associated with inventories.

As noted by Chikán [2], inventory structures that have a higher finished goods to raw materials ratio are associated with market economies. As he explained, market economies are more oriented towards the customer (i.e. a “buyer’s market”), and thus need greater levels of finished goods in order to provide the required level of customer service. Based on this model we formulate the following hypotheses. All hypotheses are given in null form.

H01: There is no relationship between inventory level/structure and customer service.

This is the centerpiece of this paper. Rejection of this hypothesis would mean that inventory level and structure are associated with delivery service, which is an important message for transitional economies.

H02: There is no relationship between supplier concepts and inventory level and structure.

Chikán and Demeter [4], in their discussion of the sophistication of transition economy firms, specifically mention the use of MRP, JIT, and computers as a means of measuring the sophistication of the firms in an economy. Radovilsky [6] used “the West” as his base point for discussing how formerly Soviet firms needed to become more sophisticated. Thus, we include in our model the idea of “Investments in Progressive Manufacturing Programs”. Further, based on Radovilsky, we posit that this construct will directly affect inventory level/structure.

H03: There is no relationship between investment in progressive manufacturing concepts and inventory level and structure.

All things being equal, the firm that is able to deliver a higher level of customer service via faster delivery times will have a competitive advantage. We test this in our model with the following hypothesis:

H04: There is no relationship between customer service and competitive advantage.

Further, we wish to test the direct effect of inventory level and structure upon competitive advantage.

H05: There is no relationship between inventory level and structure and competitive advantage.

This hypothesis will allow us to test the direct effects of inventory structure on competitiveness. The existence of this relationship has many important managerial implications, not the least of which could be a prescription for gaining competitiveness.

4. Data and method of analysis

Obviously, gathering the data necessary to do a cross-country analysis can be quite difficult. Previous literature has described the two primary methods for data gathering of this type. The first is to use statistics provided by various governmental bodies, such as West [7] or Chikán [2] did. This method has the benefit of being relatively inexpensive. In both of these studies, the data was of a financial or accounting nature. Unfortunately, trying to adjust each country’s information so that it is calculated on the same basis can be a daunting, if not impossible task, as each country may have different accounting rules. Bentson [8] contains a useful discussion of the difficulty of reconciling accounting numbers across countries. The second method for gathering this type of data is to gather the data yourself, possibly using scales that are not solely focused on financial or accounting measurements. The Global Manufacturing Research Group
(GMRG) has carried out two worldwide surveys [9], first in the late 1980s and then in the mid-1990s. This group has attempted a far-reaching effort to capture a broad base of information about a number of manufacturing firms in countries all over the world. Note that in his later studies, Chikán [4], 1995 with Demeter) used the GMRG data.

The US data used in this study was gather primarily in 1994 and 1995. The data for the Western European countries was collected in the same time frame. Finally, the data for the transitional economies was gathered in 1994.

Having chosen to use data collected by the Global Manufacturing Research Group, a secondary data source from the point of view of this research, the frame of the research needs to be specified further. Similar to Chikán [2], this paper will look at inventory by the stage of fabrication. Thus, we will focus on the three most basic breakdowns of inventory: raw materials, work-in-process and finished goods. The GMRG database contains information on primarily machine tool and non-fashion textile firms, so those will be the specific industries at which we will look. As noted by Whybark and Rho [10], by concentrating on two industries, problems associated with trying to gather data on every industry in multiple countries are mitigated.

To measure investments in progressive manufacturing programs, we have used the five-point Likert scales representing investments in cellular manufacturing, just-in-time, materials requirements planning, total quality management and statistical process control programs. Supplier issues were measured by supplier performance (percent of purchase orders delivered early, on-time or late and average lateness of late purchase orders), extent of outsourcing (percent of parts made in-house), and the use of single or multiple sourcing (average number of suppliers per purchased part).

In order to measure inventory level and structure, we used the total value of inventory and the percentages of inventory invested in raw materials, work in process and finished goods. This is similar to previous work done by Chikán [2].

Chikán and Demeter [4] used delivery promised, number of deliveries late and the late time to discuss the idea of market reorientation. By this, they meant the idea that transition economies had to reorient themselves to be customer focused. Thus, these measures will be used as part of the "customer service" construct. We add to these the characteristics of lead time, which were collected as minimum, average and maximum customer order lead time.

Competitive advantage was measured by using five-point Likert scales which compared the firm's unit cost of manufacturing, delivery speed and delivery as compared to its competitors.

The data for sales level were determined by adding up domestic and export sales. Product complexity was measured using number of stock keeping units (SKUs) in raw materials, work in process and finished goods inventory. We consider these numbers to be a reasonable proxy for product complexity, as it is intuitive that the more SKUs a firm has, the greater their level of possible combinations of those SKUs, which leads to a greater level of product complexity.

The questionnaire used in this survey is available in [9]. In this paper, we used responses from firms in the United States, Western Europe (Northern Ireland, Ireland, England, Wales, Spain, and Sweden), and Central and Eastern Europe (Bulgaria, Hungary, Poland, and Russia). The survey focused on two industries: small machine tools and non-fashion textile manufacturing. Details of the data gathering process are discussed in [11], so we will only give a brief discussion here. Directories of trade association members from these industries were used to select a random sample of firms. The top manufacturing executive from each of the companies was contacted by telephone. The executive was made aware of the trade association support and was invited to participate in the study. As an incentive, firms were told if they participated in the project, the average of typical responses for firms in their industry would be provided for them. Follow-up telephone calls were made to answer questions and remind the participants to complete and return the questionnaires. A second wave of mailing was done to increase the sample size. The data collection was carried out between 1993 and 1996, most of the data came from 1994 and 1995. In the United States, the data collection included Arizona, Illinois, Indiana, New Hampshire, Texas, Utah,
and Washington states and resulted in 253 responses. There were 186 responses from Western Europe, 283 responses from Central and Eastern Europe. A listwise deletion of missing values reduced the number of observations considerably. Considering the large number of variables (28) used in the analysis, this drop was expected. Nonetheless, we further investigated the nature of missing values using Little’s MCAR (missing completely at random) test [12] for each block of variables in Fig. 1. In most cases, the test had a probability of less than 0.05 indicating that we cannot reject the hypothesis that the missing values are randomly missing.

Given the previous research, we should expect to notice the following things:

- The use of Western management ideas is higher in the market economies. Radovilsky [6] discussed this idea.
- The ratio of output to input inventories is higher in market economics. Chikán [2] has discussed this.
- Customer service is better in market economies. The authors in the previous two points have discussed this.

These comparisons can be analyzed using t-tests as Maier [13] did. In this paper, however, the more sophisticated method of set correlation is used to gain new insights into the relationships between the proposed constructs in the model. Set correlation (see Cohen and Cohen [14], for a discussion) is an extension of canonical correlation and it addresses two shortcomings of canonical analysis. First, canonical correlation does not provide one single measure of association between the two data sets; instead it gives multiple canonical correlations. Second, understanding the nature of the relationship between the two sets through factor loadings is not straightforward. Set correlation corrects these shortcomings, provides a single general framework for the study of association and partitions the variance in terms of the original variables.

In testing hypotheses, we can make two types of errors. We commit a Type I error when we reject a true null hypothesis; in other words, we find things that are not there. Choosing a low p-value guards against this type of error. Power analysis, a very much neglected topic in operations management (see [15] for further details), seeks to control the Type II error, the error of failing to reject a false null hypothesis and therefore failing to find things that are there. Consequently, statistical power is the probability that an empirical test will detect a relationship when a relationship in fact exists. In this paper we relied on Cohen [16] to compute the power of the main associations in Fig. 1. After testing the main hypotheses between sets of variables, we also tested the influence of the individual variables. To guard against Type I error inflation when testing multiple hypotheses, we followed Cohen and Cohen’s [14] suggestions. We required that the association between the larger sets of variables be statistically significant as a condition of testing the associations between the individual variables that belonged to these sets. This approach employs the same logic as the Fisher protected (LSD) test.

5. Results and discussion

Table 1 shows the results of the analysis. For each group, we report the number of cases the analysis was based on, \( R^2 \), the significance level, shrunken \( R^2 \), and the power of the test at the 5% significance level. The interpretation of the \( R^2 \) is similar to that of used in the multiple correlation analysis and p shows the significance level. The definition of the shrunken \( R^2 \) needs some explanation. Although we may determine from a sample \( R^2 \) and the associated significance level that the population \( R^2 \) is not likely to be zero, it is nevertheless not true that the sample \( R^2 \) is a good estimate of the population \( R^2 \). The population estimate is necessarily smaller than the upwardly biased sample \( R^2 \) and, thus, often referred to as the “shrunken” \( R^2 \). The magnitude of shrinkage will be larger for small values of \( R^2 \) than for large \( R^2 \), other things being equal. Shrinkage will be also larger as the ratio of the number of variables to the number of cases increases. We computed the power of the test using the population estimate of the \( R^2 \), shrunken \( R^2 \). In the literature, 80% is the generally accepted power level, based on the implicit convention of using 5% significance level. In most cases, our power tests exceeded this level.
Looking at the broad-brush picture of the table, the first observation we can make is that all of the hypotheses but one are rejected, meaning that there is a strong association between manufacturing concepts, inventories, delivery service and competitiveness. The only exception is for Hypothesis 5 in the transitional economies group. It means that in the transitional economies, contrary to other country groups, inventory level and structure are not related to competitive advantage in the marketplace, so inventory does not serve as a competitive weapon.

Looking at a more detailed picture, the results showed that in the United States and to a lesser extent in the Western European countries, higher total inventory levels and higher work-in-process inventory percentage make the delivery (customer) service worse. This is consistent with earlier findings that shorter delivery lead time is associated with low work-in-process inventory levels (Vastag and Whybark [17]). In the transitional economies, on the other hand, higher total inventory levels are associated with better customer service. The other area where the results were different for the developed market and transitional economies was the level of outsourcing and approach to single-sourcing. In the United States and in Western Europe the increased levels of outsourcing and single-sourcing were associated with reduced WIP inventories, while in the transitional economies it worked the other way.

As Table 1 shows, all but one hypotheses are rejected, so we will further analyze these relationships at the level of individual variables.

5.1. Relationships between supplier concepts and inventory level/structure

In addition to having a significant association between the two sets of variables, in all three regions, the measures of supplier performance, extent of outsourcing, and sourcing strategy were all significantly related to the percentage of WIP inventories. In the United States, the above mentioned supplier concepts accounted 19.4% of the variation in the WIP inventory level. Data from the United States also showed that increasing the percentage of in-house manufacturing and moving towards multiple-sourcing correlate with increased level of WIP inventories. In the western European data set,
the supplier concepts explained 15.2% of the variation in the WIP level, with in-house manufacturing having a significant beta. In the transitional economy data set, the supplier concepts variable set explained 11.6% and 24.2% of the variation in the raw materials and the WIP inventory levels, respectively. There was significant evidence that in these economies, increased level of in-house manufacturing increases the WIP inventory level (this relationship works exactly the same way as in the developed market economies) and reduces the raw material inventory level. There was no significant relationship between the variables of single-sourcing and the WIP inventories. The suppliers' delivery lateness (the percentage of orders delivered late and the average lateness of late orders), which was not an issue in the other data sets, proved to be significant in these economies in increasing the WIP inventory level. Increased lateness of late orders also contributed to the reduction of raw materials inventories.

5.2. Relationship between investments in progressive manufacturing ideas and inventory level structure

In the data from the United States, no significant associations were found for the individual dependent variables. In the western European group of companies, 17.8% and 18.6% of the variation in the raw and WIP inventory levels, respectively, could be explained by the variation in investments in progressive manufacturing ideas. More specifically, investments in the material requirements planning (MRP) systems were associated with increases in the raw material inventory level, and investments in quality management practices (statistical process control and total quality management) were accompanied with increased finished goods inventory levels. In the transitional economy data set, all three inventory structure variables were significantly related to the investments in progressive manufacturing concepts. The variation in these investments determined 13.5%, 10.0%, and 10.2% of the variation in the raw materials, WIP, and finished goods inventory levels, respectively. Surprisingly though, investments in just-in-time (JIT) manufacturing resulted in increased raw material, reduced WIP and reduced finished goods inventory levels. Investments in SPC were associated with increased finished goods inventory levels.

5.3. Relationship between inventory level/structure and delivery service

In all three regions, the inventory level and structure are significantly related to the delivery service variables. The underlying individual factors, however, are very much different. In the United States, after accounting for the differences in size and product complexity, the inventory level and structure determine 26.1% of the variation in the average promised delivery time and 23.8% of the variation in the typical shipment times. Moreover, higher inventory levels and higher percentage of work-in-process (WIP) inventories are associated with longer delivery times (both promised and actual). We can summarize this phenomenon as “inventory is bad”. The western European data set showed a very similar picture, the percentages of variation accounted for by the inventory level and structure were even higher (42.9% for the average promised delivery time and 21.7% for the actual shipment time). The results also confirmed the negative impact of the WIP inventories on delivery service. The trend was the same in the transitional economies. The inventory level and structure explained 33.6% and 31.9% of the variation in the average promised and average actual delivery times but no significant relationships among the individual variables were found.

5.4. Relationship between delivery service and competitive advantage

In the American data set, delivery service explained 14.4% and 22.4% of the variation in the delivery speed and delivery-as-promised dimensions of competitive advantage. In both cases, the percentage of late orders was significant, and it negatively influenced both dimensions of delivery competitiveness. In the western European data set, delivery service accounted for 21.6% of the variation in the delivery-as-promised dimension of competitiveness. This dimension was negatively associated with the two variables of delivery lateness.
(the percentage of late orders and the average lateness of late orders). The picture was very similar for the companies in Central and Eastern Europe. Delivery service explained 19.7% and 15.4% of the variation in the delivery speed and delivery-as-promised variables, respectively. In addition to the two delivery lateness variables, the average promised delivery is also negatively influenced the delivery speed dimension of competitiveness. The percentage of late orders was negatively related to the delivery-as-promised variable.

5.5. Relationship between inventory level/structure and competitive advantage

In the developed market economies, the inventory level and structure variables are significantly associated with delivery competitiveness. This is not the case in the transitional economies. This difference may be the best indicator of the gap between the two types of economies.

In the American data set, the inventory level and structure explained 27.3% of the variation in the unit cost competitive advantage, 29.1% of the variation in the delivery speed and 26.9% of the variation in the delivery-as-promised competitiveness measures. Higher total inventory levels reduced the unit cost advantage, while inventory structure was associated with the delivery-related dimensions of competitiveness. The Western European data set showed very similar results. Inventory level and structure explained even higher portion of the variation of the three competitive advantage variables (37.5%, 45.5%, and 43.5% of the unit cost, delivery speed and delivery-as-promised, respectively). The inventory level was not significantly linked to the cost advantage, but the inventory structure was, like in the United States, was tied to the delivery speed and delivery-as-promised measures of competitiveness.

6. Conclusion

In this paper, a cross-country and cross-group analysis of inventory structure and delivery service measures was carried out. One obvious conclusion from our research is the continued importance of inventory management due to its large effects on customer service. We expected to see that transition economies are beginning to resemble market economies more. Although as a group the transitional economies made good progress toward reaching the inventory levels and structures of the market economies, they are not there yet. To a certain extent, the results of this study offer a confirmation of recent trends. The logic behind the recent trends toward moving towards increased outsourcing and single sourcing agreements with suppliers is that these actions reduce the work in process inventory level and through reduced WIP level, the delivery service can be improved.

Further research should include the use of longitudinal data sets. In particular, a data set containing data from before, during and after the fall of the communist governments in the transitional economies would be especially interesting. This type of data set should be able to quite clearly show the effects of centrally planning on inventory structure, and in turn, customer service. Also, the use of such techniques as structural equation modeling would be appropriate for analyzing the concepts and relationships discussed in this study.

References