Inventory management: a case study in a small enterprise of the electronics sector

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The achievement of a better customer service level drives companies to structure their inventory management. High levels of inventory can cause an increase in operational expenses. However, maintaining reduced inventory levels tend to reduce the customer service level, resulting in losses and damaging the company’s image in the business. This work aims at developing and implementing a proposal to standardize the decision-making regarding the management of finished goods inventory in a small electronics sector company. The main result of this work is presented as the development of a method from a cause and effect diagram of the company’s problems and the nine steps’ application of the proposed method. Through this inventory management method, it is intended to improve the level of service, reducing the lack of finished goods in order fulfillment.

Gestão de estoques: um estudo de caso em uma pequena empresa do setor de eletrônicos

A obtenção de um nível melhor de serviços leva as empresas a estruturar a sua gestão de estoques. Altos níveis de estoques tendem a reduzir o nível do serviço ao consumidor, resultando em perdas e danos à imagem do negócio da empresa. Este trabalho visa desenvolver e implementar uma proposta para padronizar a tomada de decisão sobre a gestão dos estoques de produtos acabados em uma empresa pequena do setor de eletrônicos. O principal resultado deste trabalho é apresentado como o desenvolvimento de um método a partir do diagrama de causa e efeito dos problemas da empresa e da aplicação dos nove passos do método proposto. Por meio desse método de gestão de estoques, pretende-se melhorar o nível de serviço, reduzindo a falta de produtos acabados no cumprimento dos pedidos.
Production planning and control

According to Slack, Chambers and Johnston (2010), planning and controlling aim to be the bridge between supply and demand, ensuring that the processes are effective and efficient in order to attend the products and services required by customers. The planning and controlling of production requires changes over time. Thus, plans are divided into different levels in the planning horizon: short, medium and long term plans (STEVenson, 2014).

As stated by Tubino (1999), in long term plans, it is formulated a strategic production planning as an estimation of sales, financial and productive availability. Usually this strategic planning is developed by marketing and financial sectors, giving information on resources and targeted markets. The medium term plans are carried out by PPC (planning and production control) department, which develops the production master plan based on medium term demand forecasts and orders already confirmed. Yet in the short term plans, at operational level, the PPC develops the production schedule comprising inventory management, release of purchase orders, manufacturing orders, and, finally, monitoring and control of production.

Regarding the importance of demand, forecasting goes beyond the support to PPC. It guides the organizational strategy embracing multiple industries. Functional areas require future predictions to estimate resources, capacity and policies to be applied for a certain period (FLORES, 2007; LEMOS, 2006), as well as the decision making related to inventory management is mainly based on demand forecast (ELSAYED; BUCHER, 1994). According to Corrêa and Corrêa (2008), one of the main mistakes made by companies is to define the amount of sales needed to reach the financial goals and confound this with demand’s forecast. Forecast is a methodological process that estimates a future demand based on statistical or subjective models (QUEZROZ, 2003; ROCHA et al., 2015). The desired demand concerns the sales’ goals necessary to be achieved in a given time, which may feature the commitment to overcome the forecasts and reach the goal of growth (PIRES, 2004).

As stated by Elsayed and Boucher (1994), any demand forecast follows the same logic: it uses past data to predict the future. To address the information there are two complementary approaches: qualitative and quantitative forecasting techniques. Qualitative techniques are subjective; they admit intuition and experience factors to formulate opinions to determine the forecast. On the other hand, quantitative techniques are objective and based on historical data projected for the future (CORRÊA; CORRÊA, 2008). Quantitative techniques unfold themselves in causal methods, which use historical data on independent variables, and time series analysis, which are based on historical data to project future demand and analyze trends and seasonality patterns (KRAJEWSKI; MALHOTRA; RITZMAN, 2015). Despite the method, there will always be distortions between the actual demand and demand’s forecasting, as these variations are inherent to the process of estimating or making future projections (GARCIA; LACERDA; BENÍCIO, 2001). The assessment of demand uncertainty is important in order to perform analysis, monitoring and measurement of errors (DONK; SOUMAN; GAALMAN, 2005).

Another important aspect to be considered in production planning and control is related to inventory management, which aims to balance the availability of costumer products and costs related to the maintenance of stocks. The challenge is to minimize these inventory costs for each level of target service (BALLOU, 2003). Inventory is defined as raw material, work-in-process parts and finished goods, which are in the production system during a certain time (SILV
Further, among the existent inventory control systems, the continuous review system (Q) and the periodic review (P) stand out as the most applied ones. According to Krajewski, Malhotra and Ritzman (2015), the continuous review system makes inventory revisions continuously, in every withdrawal of stock of the product in order to define the need of placing a new purchasing order. When the inventory level reaches the replenishment point, which is the minimum level, a fixed batch quantity of the item is placed on request (STEVenson, 2014). The periodic review system (P) makes the inventory review periodically and a new purchase order is placed after each review, and the time between orders is fixed. Thus, only the batch size can be changed. The main advantages of the periodic review system are the low cost of application (as the applications for multiple items are performed only once) and the reduction of inventory revisions (due to the fixed period).

Method

This case study is categorized as applied research since its goal is to generate knowledge for practical application (DREjer; Gudmundsson, 2002). Additionally, this research has a quantitative approach because it uses as a source of numerical data information. The objective of this research is classified as exploratory due to the fact that it provides greater familiarity with the problem and makes it more explicit (Silva; Menezes, 2001).

This study was conducted in a small enterprise of the electronic sector, more specifically, in the field of monitoring and controlling of electric power equipment. The company's current policy favors the development of new technologies and new products. The focus on innovation is supported by guidelines of the marketing sector and the R&D sector. However, because of the growth in the electronics industry related to energy, highlighted by ABINee (2011), the company needs to improve operational planning to meet the growth of demand. The increased demand for finished goods has resulted in problems in managing the company's operations. There are frequent changes in the production master plan, which results in losses at the production processes and delays in deliveries (DASilva Santos; Bonifácio, 2014). For this reason, this work aims to minimize this problem, managing the inventory system of finished goods of the company. It is proposed the development of an inventory management method applied to the presented case study.

The study's development was motivated by the company's main problem, which is the low level of service offered to customers, resulting in lost orders due to the lack of products for delivery. Thus, a cause and effect relationship was developed for each of the problems.
problems, which resulted in the diagram shown in Figure 1. The development of the method was performed to minimize each of the identified problems. In this way, it was established one or more steps of the method to solve each problem identified in the cause and effect diagram. From the analysis, it was performed a method divided into stages and activities that make the procedure easily applicable. The proposed method of work is divided into 9 stages, namely: (i) collect historical data, (ii) select items, (iii) define the planning horizon, (iv) perform demand forecasting, (v) define system stock, (vi) define desired service level, (vii) scale stock, (viii) define the actions of the production planning, and (ix) monitor the level of service achieved. Figure 2 shows the steps of the proposed method.

Figure 2 - Proposed method

1. Collect historical data
   (sales, billing, profit margin by product)
2. Select items
   (ABC classification and production strategy - MTS and MTO)
3. Set planning horizon
   (strategic, tactical, operational)
4. Define service level
   (strategic assessment based on the criticality of each product)
5. Inventory system
   (definition of what inventory system is best suited for the analyzed items)
6. Stock sizing
   (defining the quantity of finished products to attend the estimated demand forecast)
7. Set the planning actions
   (Defining the planning actions from the information generated by the inventory system)
8. Monitor service level
   (Monitoring the service level provided to the customer)

In the third step it is defined the planning horizon applied to the objective of this work. The planning horizon will be proposed according to the planning level of the CFP and the activities that comprise this horizon. The planning horizon defines the forecasting methods to be used. In the step of performing demand forecast, it was decided to use quantitative techniques to forecasting. Among the options for historical data, the models of exponential smoothing were selected. There will be an analysis on the behavior of demand, and according to this behavior, it will be selected the most appropriate model to conduct the forecast of each product. From the demand forecasting, the stock system is set. This inventory system may be operated through a continuous or periodic review. During this step, it is also established the periodicity of review of the proposed system for sizing the finished goods inventory. The definition of service level for each product is set in accordance with the criticality level of each product. This criticality will be established in accordance with the profit margin of each product. Thus, products with a higher profit margin are expected to present higher level of service.

The stock sizing step holds the definition of inventory levels with regard to the analyzed demand forecast and the level of service. In the step of defining the actions of planning, it is defined the inventory system information that will feed the production planning. Moreover, the decisions regarding the batch size of production orders and the timing of applications are also determined. Finally, the monitoring step of the service level comprises the data monitoring to verify the effectiveness of this method in order to provide feedback to production planning.

Results

The source of data is the ERP software used by the company (Protheus®), in which information such as name, code, quantity, billed amount, cost of raw material, average selling price and billing were collected. The study began in 2014. The sample data comprised 33 previous months, including the years 2014, 2013 and 2012. The sold and invoiced amounts were verified on a monthly basis. The cost of raw material (Cost MP) represents the annual average cost of the item and the billing was a cumulative result of the period. From the collection of such data, it was possible to calculate the average profit and price of each item. This information was gathered for 73 different products, as shown in Table 1. Thirty nine products were chosen according to the presented criteria of MTS strategy. Among these, the 20% most profitable products are shown in Table 2, which account for 7 items, and are equivalent to 41% of total sales of the company with the MTS strategy.
Table 2 - Selected products

<table>
<thead>
<tr>
<th>Product</th>
<th>Code</th>
<th>Strategy</th>
<th>Profit* Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-600</td>
<td>7920050</td>
<td>MTS</td>
<td>$88,951.05</td>
</tr>
<tr>
<td>P-600</td>
<td>7920094</td>
<td>MTS</td>
<td>$75,124.59</td>
</tr>
<tr>
<td>Smart Cap 200-12</td>
<td>7810016</td>
<td>MTS</td>
<td>$63,031.27</td>
</tr>
<tr>
<td>Power Cap 485</td>
<td>7840005</td>
<td>MTS</td>
<td>$58,034.36</td>
</tr>
<tr>
<td>Smart Cap 485 - 12</td>
<td>7900001</td>
<td>MTS</td>
<td>$43,469.95</td>
</tr>
<tr>
<td>P-300</td>
<td>7920040</td>
<td>MTS</td>
<td>$42,870.23</td>
</tr>
<tr>
<td>Smart Cap 200 - 06</td>
<td>7810019</td>
<td>MTS</td>
<td>$32,451.54</td>
</tr>
</tbody>
</table>

Source: Authors (2015)

As the method includes operational level activities such as production planning, inventory management, scheduling and production orders, the planning horizon was defined as a short term view, providing a 3-month forecast and monthly time intervals (time buckets). Further, historical data are analyzed graphically, helping to identify patterns, trends and seasonality in time series. The selection of a better demand forecasting method requires an analysis of the behavior of the time series that can be represented by the following patterns: average seasonality, cyclical and trend (MAKRIDAKIS; WHEELWRIGHT; HYNDMAN, 1998). The patterns in the time series obtained for the products are shown in Figure 3.

A few products, such as “7920094” and “7920040”, have a very limited amount of data, since they have been launched in the market less than two years before the analysis. Moreover, all products demonstrate an irregular demand, also called "lumpy", characterized by high levels of variability, showing a row of peak demand periods of low or null demand (SANTOS; BONIFÁCIO, 2006). The irregular pattern of demand occurs in cases that demand is intermittent, with a high degree of uncertainty and particularly difficult to predict (LEMOS, 2006). In order to establish a demand forecast, this work follows the recommendation of the company’s management, obtaining demand forecast from the past 12 months. Although there are more robust methods for conducting forecasts for this kind of demand, this work does not include in its objectives the modeling of time series data. The selected products have a characteristic of low amount of units sold and the company does not have a reliable system for continuous monitoring of stock levels. In addition, the monitored products have irregular demand. Because of these characteristics, it was decided to use a system periodic review for inventory management.

Figure 3 - Analysis of the seven products’ time series

(a)
To develop this system, it was necessary to estimate the desired revision interval (P), the lead time of products and information. The MTS products have their production schedule for periods of greater slack in the production system. The definition of service level has been established as the criticality of each product, and it was measured by two variables: profitability and sales strategy. From these two criteria, a scale from 1 to 5 was established for each factor, in which one means poor criticality of the variable and 5 high criticality. Table 3 shows the criteria for drawing up the criticality of the products. From the classification of the product on the criticality of profit and the strategy, the criticality of the product is calculated. This criticality is given by the multiplication result between the criticality of profit and strategy, and the obtained value defines the level of service that is shown in Table 4.

Table 3 - Criteria criticality

<table>
<thead>
<tr>
<th>Profit's criticality</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Up to 300% of profit</td>
</tr>
<tr>
<td>2</td>
<td>From 300 to 600%</td>
</tr>
<tr>
<td>3</td>
<td>From 600 to 900%</td>
</tr>
<tr>
<td>4</td>
<td>From 900 to 1200%</td>
</tr>
<tr>
<td>5</td>
<td>Above 1200%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategy's criticality</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Products with more than 5 years in the market</td>
</tr>
<tr>
<td>2</td>
<td>From 5 to 2 years</td>
</tr>
<tr>
<td>3</td>
<td>Products with less than 2 years</td>
</tr>
<tr>
<td>4</td>
<td>Products with less than 2 years + software</td>
</tr>
<tr>
<td>5</td>
<td>New products</td>
</tr>
</tbody>
</table>

Source: Authors (2015)
Table 4 - Analysis of the seven products’ time series

<table>
<thead>
<tr>
<th>Products’ criticality</th>
<th>Service level</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 1 to 5</td>
<td>90%</td>
</tr>
<tr>
<td>From 6 to 16</td>
<td>95%</td>
</tr>
<tr>
<td>From 17 to 25</td>
<td>98%</td>
</tr>
</tbody>
</table>

Source: Authors (2015)

From the calculations proposed it was possible to calculate the level of service desired for each of the products. Among the selected products, the following service levels have been identified:

- Product 7920050 - 20 criticality and service levels 98%;
- Product 7920094 - 08 criticality and service levels 95%;
- Product 7810016 - 02 criticality and service levels 90%;
- Product 7840005 - 10 criticality and service levels 95%;
- Product 7900001 - 03 criticality and service levels 90%;
- Product 7920040 - 04 criticality and service levels 90%; and
- Product 7810019 - 02 criticality and service levels 90%.

For the stock calculation, we use the procedure suggested by Krajewski, Malhotra and Ritzman (2015) presented in Equation (1).

\[ T = \mu (P + L) + z \sigma_{P+L} \]  

where:
- \( \mu (P + L) \): average demand at the protection time (period and lead time)
- \( \sigma_{P+L} \): standard deviation of demand over the protection time at \( \sigma_{P+L} = \sigma \sqrt{P + L} \)

After performing the previous steps, production planning is replenished every four weeks with the following information: (i) number of products in the stock, and (ii) target level (T) for each product. Demand forecasts, the classification of the criticality and the design of the target stock level (T) are conducted quarterly by changing the inventory system information. From this information, the stock planning feeds into a database that is used to monitor the service level achieved for customers. This means that many times it will be checked, among the products with monitored MTS strategy, if there is a lack of finished products for delivery to customers. This monitoring helps to identify the effectiveness of the proposed process through a window of the level of service offered to the customer. However, besides the effort to keep inventories to ensure customer service, it is fundamental to address improvements to reduce inventory and, consequently, the storage costs. It is important to improve the collection of historical data and demand forecasting techniques, which may hinder the method due to lack of data.

**Conclusion**

This working method has not been applied in its entirety in the company, so the results could not be measured yet. However, its application has already contributed for the company to organize its decision-making process regarding the level of inventory and production scheduling. The method’s lack of complexity favors its applicability in small enterprises because the method does not require the formulation of complex and difficult calculations, contributing to greater accessibility to production professionals. The high level of inventory obtained from the proposed method is explained both for the variability of demand as for the stipulated service level. However, it is planned improvement actions to reduce the costs of proposed high inventory levels, such as improving data collection and demand fore-

Table 1 - Summary of collected data

<table>
<thead>
<tr>
<th>Code</th>
<th>Average in period (4 weeks)</th>
<th>Deviation in week</th>
<th>Service Level</th>
<th>Z</th>
<th>Period (week)</th>
<th>Lead Time (week)</th>
<th>Protection time (P+L) (week)</th>
<th>Demand at the protection time</th>
<th>Safety Stock</th>
<th>Stock Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>7920050</td>
<td>6,92</td>
<td>6,72</td>
<td>98%</td>
<td>2,05</td>
<td>4</td>
<td>0,5</td>
<td>4,5</td>
<td>7,79</td>
<td>29,27</td>
<td>37,06</td>
</tr>
<tr>
<td>7920094</td>
<td>3,25</td>
<td>1,42</td>
<td>95%</td>
<td>1,64</td>
<td>4</td>
<td>0,5</td>
<td>4,5</td>
<td>3,66</td>
<td>4,95</td>
<td>8,61</td>
</tr>
<tr>
<td>7810016</td>
<td>51,83</td>
<td>24,83</td>
<td>90%</td>
<td>1,28</td>
<td>4</td>
<td>0,5</td>
<td>4,5</td>
<td>58,31</td>
<td>67,50</td>
<td>125,81</td>
</tr>
<tr>
<td>7840005</td>
<td>5,58</td>
<td>2,07</td>
<td>95%</td>
<td>1,64</td>
<td>4</td>
<td>0,5</td>
<td>4,5</td>
<td>6,28</td>
<td>7,22</td>
<td>13,50</td>
</tr>
<tr>
<td>7900001</td>
<td>14,75</td>
<td>6,47</td>
<td>90%</td>
<td>1,28</td>
<td>4</td>
<td>0,5</td>
<td>4,5</td>
<td>16,59</td>
<td>17,58</td>
<td>34,18</td>
</tr>
<tr>
<td>7920040</td>
<td>11,83</td>
<td>15,46</td>
<td>90%</td>
<td>1,28</td>
<td>4</td>
<td>0,5</td>
<td>4,5</td>
<td>13,31</td>
<td>42,02</td>
<td>55,34</td>
</tr>
<tr>
<td>7810019</td>
<td>36</td>
<td>25,47</td>
<td>90%</td>
<td>1,28</td>
<td>4</td>
<td>0,5</td>
<td>4,5</td>
<td>40,50</td>
<td>69,24</td>
<td>109,74</td>
</tr>
</tbody>
</table>

Source: Authors (2015)
casting techniques, referring to steps 1 to 4.

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