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**TESI DI LAUREA**

# "Inventory management and optimization: The Cavallone S.R.L. Business Case"

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Firma dello studente

*Ai miei adorati nonni, Anna e Salvatore… miei angeli custodi e stelle polari...*

*Alla mia famiglia, che con il suo amore incondizionato mi ha accompagnato e sostenuto in questo viaggio.*

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*A Martina, parte integrante della mia esperienza.*

*Alle mie amiche di sempre, Diletta, Giorgia e Lucrezia, mio supporto e carico di energie.*

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# INTRODUCTION

Starting from the concept of the current competitive scenarios, the corporate world is facing a clear revolution in strategies and in its modus operandi. From here, the undeniable importance of business management in issues related to the Supply Chain Management, integrated supply chain management, and in particular, the issue relating to inventory management becomes clear.

In this master thesis, we intend to carry out a detailed analysis on the problems relating to inventory management in the company, through the study of mathematical models as problem solvers applied to a particular company. The aim is therefore to search for techniques and inventory management models that maximize the efficiency and productivity of business processes, thereby limiting unnecessary costs and unnecessary waste.

For all companies, inventory management has become problem, since it is not trivial to find the right trade-off between profit and maintenance costs. It is very difficult, and at the same time, very important to understand when and how much to order.

In particular, our attention will be focused on three main issues related to inventory management: the role of inventory in the company, the costs involved and procurement policies.

In this analysis, the problems relating to the inventory management of the Cavallone srl company will be tackled.

The Cavallone srl is based on distribution of Electrical equipmentm and consists of four different business areas. The first one is based on “Electrical material” distribution, which is the area that lies in the centre of our research. The second one is “Security sector”, that offers specific solutions for each safety-related requirements. The third section, “Keluce”, is the lighting division, and at the end, we have the “switchboards” sector is structured for providing the customer with a finished and certified product ready for installation.

The aim of this study is to optimize reorder quantities, by proposing an inventory management model that blends with the needs and characteristics of the real case. The work is divided into five parts.

In the first chapter, we introduce and define the fundamental concepts of stocks and inventory management. A significant part of this section is devoted to the role they played within every company and, above all, the costs involved; clearness of the latter aspect is essential in order to identify the costs related to inventories in different types of enterprise.

The second chapter presents the most common procurement policies such as Wilson model and its numerous variants; one in particular will be deepened. Wilson's model with quantity discount takes into account unit purchase cost variable depending on quantity ordered. In fact, the greater is the order quantity, the more the discount on unit cost will be.

In the third chapter, we present a real case. After the presentation of the company and its needs, we will delve into the commercial situation of a certain product category. Among the numerous references in stock, the goal will be to detect what could be exposed to high criticalities, and then the attention from the decision maker. We carry out an ABC analysis about a group of items.

Chapter four revolves around the estimation of demand and stock costs.. The demand estimation was conducted using statistical tools and studying the historical series. Concerning other data, the costs were derived from a meticulous analysis of the chain of company operations that allow the stocks to be stored. By observation and the use of data and estimates, we are able to calculate the order and holding costs, which are the necessary variables to develop management models.

In the fifth and final chapter, we present the inexpedient part, i.e. the application of the management model in the real case. The quantity discounts characteristic is a very interesting variable to be analysed, because it allows us to have a huge discounts based on quantity purchased. Unquestionably, multi discount factor was the variable that caught our attention the most.

With respect to a careful analysis carried out with the commercial director, we concentrate on the problem of how much to order based on quantity discounts. The model selection is done by analysing the all-quantity discount models. The model that best reflects this problem is All-units discount model. In the implementation of the model, the used perspective is the one of the buyer; he is the real decision-maker for the procurement process of the Cavallone srl.

Finally, we will provide a summary of the proposed and applied model along with its advantages and shortcomings in the conclusion section.

# 1 CHAPTER - THE FUNCTION OF INVENTORY MANAGEMENT, WHY SHOULD A COMPANY HAVE WAREHOUSE?

The success of a venture depends on its ability to provide services to customers or users and remain financially viable. For an organisation, which is supplying goods to its customers, the major activity is to have suitable products available at an acceptable price within a reasonable timescale. Many parts of a business are involved in setting up this situation. Initially it is the marketing and design departments. Then purchasing, and in some cases, manufacture are involved. For an item that is already in the marketplace, the main activity is providing a continuity of supply for the customers. [Wild, 1997]

Operations managers often have an ambivalent attitude towards inventories. On the one hand, they are costly, sometimes tying up considerable amounts of working capital. They are also risky because items held in stock could deteriorate, become obsolete or just get lost, and, furthermore, they take up valuable space in the operation. On the other hand, they provide some security in an uncertain environment that one can deliver items in stock, should customers demand them. This is the dilemma of inventory management: in spite of the cost and the other disadvantages associated with holding stocks, they do facilitate the smoothing of supply and demand [Slack Alistair Johnston, 2013]. In fact, they only exist because supply and demand are not exactly in harmony with each other.

Inventory Management, in the last twenty years, has assumed a significance such that it should be brought to the attention of all corporate managers. Many companies, especially medium and big enterprises, created a new function to its management: as director of logistics, that is, the one who follows the flow of the material from their origins at suppliers to the end customer. [Wild, 1997]

In that chapter we will analyse how can inventory management helps the company to make an accurate forecast and, then, planning of the activities inside the organization. We will also explain the main tool of inventory management, ABC analysis, which helps company to focus on the items that are most important and that has wrong management.

## 1.1 MAIN OBJECTIVES OF INVENTORY MANAGEMENT

Inventory is a term we use to describe the accumulations of materials, customers or information as they flow through processes or networks. Physical inventory (called ‘stock’) is the accumulation of physical materials such as components, parts, finished goods or physical (paper) information records. Queues are accumulations of customers, physical as in a queuing line or people in an airport departure lounge. Database are stores for accumulations of digital information. Managing these accumulations is what we call ‘inventory management’, it is very important. [Slack Alistair Johnston, 2013]

Material inventories in a factory can represents a substantial proportion of cash tied up in working capital. Reducing them can release large quantities of cash. However, reducing them too far can lead to customers’ orders not being fulfilled. [Slack Alistair Johnston, 2013]

The task of an optimal policy of inventories, as well as identified by Magee and Boodman [1992], is the realization of a management decision that allows to achieve a balance between savings related to operational benefits, and costs and commitments capital that are associated with an increase in inventories. Bruno [2003] Note also that such decisions should be taken based on the specific business objectives, which vary according to the characteristics of the company and the overall context in which the formation of stocks is inserted. As we may think, the dilemma is not only to minimize the level of inventory at various stages, resulting in cost reduction. Such a solution would lead to an over-simplification. It 'important that the stock is maintained those minimum levels necessary to ensure the highest turnover rate (economic management) and the lowest risk of missing materials (security management) [Donini, 1983]. A good inventory management thus aims to ensure a better functioning of the organization and possibly an increase in profits.

Stock control exists at a crossroads in the activities of a company. Many of the activities depend on the correct level of stock being held, but the definition of the term 'correct level' varies depending upon which activity is defining the stock. Stock control is definitely a balancing act between the conflicting requirements of the company, and the prime reason for the development of inventory management is to resolve this conflict in the best interest of the business. A conventional supply organisation will have many departments including sales, purchasing, finance, and general administration. Each of these has a particular view of the role of stock control. [Slack Alistair Johnston, 2013]

Sales consider that good stock control enables the company to have available any item that will meet immediate sales for as large a quantity as demanded: this requires large stock. For service companies where parts service is involved, the control of stock at the customer interface is traditionally left with the person carrying out the service, and this has led to overstocking and poor control. [Slack Alistair Johnston, 2013]

Similarly, in distribution, the effect of bulking up shipments will lead to high stock levels and a compromise has to be reached. Purchasing consider that stock control provides the opportunity for goods to be purchased so that optimum prices can be obtained. Buying items in bulk often reduces the purchase price and it improves the efficiency within the purchasing department. The stores is a means of keeping the bulk purchase items after buying advantageously.

Finance departments have a problem with stock because it consumes vast amounts of working capital and upsets the cash flow. One benefit of stock from a financial standpoint is that provisions can be made in case the stock turns out to be unsaleable, and this value can be adjusted to modify the profit figure in times of good or bad financial results. However, the existence of these provisions in the first place is detrimental to the finances of the company. [Wild 1997]

Inventories are often the result of uneven flows. If there is a difference between the timing of the rate of supply and demand at any point in a process or network then accumulations will occur. If, over time, the rate of supply of water to the tank differs from the rate at which it is the demanded, a tank of water (inventory) will be needed to maintain supply. When the rate of supply exceeds the rate of demand, inventory increase; when the rate of demand exceeds the rate of supply, inventory decrease. So if an operation or process can match demand and supply rates, it will also succeed in reducing its inventory levels. Most organizations must cope with unequal supply and demand, at least at some points in their supply chain. [Slack Alistair Johnston, 2013]

There is a complication when using this 'water flow' analogy to represent flows and accumulations (inventories) of information, of information can either be stored because of uneven flow, in the same way as material or people, or stored because the operations needs to use the information to process something in the future. [Slack Alistair Johnston, 2013]

There are plenty of reasons to avoid accumulating inventory where possible. Particularly those concerned with cost ties up working capital and there could be high administrative and insurance costs; storage space, quality because may deteriorate over time, become damaged or obsolete; and operational/organizational issues that may put undue pressure on the staff and so quality is compromised for throughput or databases need constant management. [Slack Alistair Johnston, 2013]

On the face of it, it may seem sensible to have a smooth and even flow of materials, customers and information through operational processes and networks and thus not have any accumulations.

We have inventories because it provide many advantages for both operations and their customers.

If a customer has to go to a competitor because a part is out of stock or because they have had to wait too long or because the company insists on collecting all their personal details each time they call, the value of inventories seems undisputable. The task of operations management is to allow inventory to accumulate only when its benefits outweigh its disadvantages.

The following are some of the benefits of inventory.[Slack, Johnston, 2013]

Physical inventory is an insurance against uncertainty; in fact, inventory can act as a buffer against unexpected fluctuations in supply and demand. For example, a retail operation can never forecast demand perfectly over the lead-time. It will order goods from its suppliers such that there is always a minimum level of inventory to cover against the possibility that demand will be greater than expected during the time taken to deliver the goods. This is buffer, or safety, inventory. It can also compensate for the uncertainties in the process of the supply of goods into the store.

Physical inventory can counteract a lack of flexibility, where a wide range of customer options is offered, unless the operation is perfectly flexible, stock will be needed to ensure supply when it is engaged on other activities. [Slack Alistair Johnston, 2013] This is sometimes called cycle inventory. Physical inventory can be used to anticipate future demands, medium-term capacity management may use inventory to cope with demand. Rather than trying to make a product only when it is needed, it is produced throughout the year ahead of demand and put into inventory until it is needed. This type of inventory is called anticipation inventory and is most commonly used when demand fluctuations are large but relatively predictable. [Slack Alistair Johnston, 2013] Physical inventory can reduce overall costs, in fact, holding relatively large inventories may bring savings that are greater than the cost of holding the inventory. This may be when bulk buying gets the lowest possible cost of inputs, or when large order quantities reduce both the number of orders placed and the associated costs of administration and material handling. This is the basis of the 'economic order quantity' (EOQ) approach. [Slack Alistair Johnston, 2013]

The objective of most operations managers who manage physical inventories is to reduce the overall level (and/or cost) of inventory whilst maintaining an acceptable level of customer service. . [Slack Alistair Johnston, 2013]

## 1.2 THE MAIN OBJECTIVES OF INVENTORY MANAGEMENT

According to Wild [1997] the first consideration is the overall objective of the work of stock control. Like all other activities in the company, inventory management has to contribute to the welfare of the whole organisation. The logistic operation must aim to “contribute to profit by servicing the marketing and financial needs of the company.” The aim is not to make all items available at all times, as this may well be detrimental to the finances of the company. The normal role for stock control is to “meet the required demand at a minimum cost.” The aim of long-term profitability has to be translated into operational and financial targets, which can be applied to daily operations. The purpose of the inventory control function in supporting business activities is to optimise three targets: [Wild 1997]

- Customer service
- Inventory costs
- Operating costs

The most profitable policy is not to optimise one of these at the expense of the others. The inventory controller has to make value judgements. If profit is lacking the company goes out of business in the short term. If customer service is poor, then the customers disappear and the company goes out of business in the longer term. Balancing the financial and marketing aspects is the answer: the stock controller has a very important and delicate role.[Wild 1997]

The first target, customer service, can be considered in several ways, depending on the type of demand. In a general environment, the service will normally be taken as 'availability ex stock', whereas in a supply to customer specification, the service expected would be delivery on time against customer requested date. The second target, inventory costs, requires a minimum of cash tied up in stock. This target has to be considered carefully, since there is often the feeling that having any stock in stores for a few months is bad practice. In reality, minimising the stock usually means attending to the major costs: very low value items are not considered a significant problem. Where the item is voluminous or the stores space restricted, the size of the items will also be a major consideration. The third target, avoiding operating costs, has become more important. The prime operating costs are the stores operations, stock control, purchasing and associated services. The development of logistics, linking distribution costs with inventory, has added a new set of transportation costs to the analysis. Optimising the balance between these three objectives is the focus of inventory management.[Wild, 1997]

## 1.3 CONTROL, TIMING AND VOLUME DECISION

Wherever inventory accumulates, operations managers need to manage the day-to-day tasks of managing inventory. Orders will be received from internal or external customers; these will be dispatched and demand will gradually deplete the inventory. [Slack Alistair Johnston, 2013] Orders will need to be placed for replenishment of the stocks; deliveries will arrive and require storing. In managing the system, operations managers are involved in three major types of decisions:

- *How much to order*. Every time a replenishment order is placed, how big should it be (sometimes called the volume decision)?
  In making this decision, we are balancing two sets of costs: the costs associated with going out to purchase the items and the costs associated with holding the stocks; the trade-off between costs and benefits. to make this decision, operations managers must try to identify the costs which will be affected by their decision.

- *When to order.* At what point in time, or at what level of stock, should the replenishment order be placed (sometimes called the timing decision)?
  Assuming that orders will arrive instantaneously and demand is steady and predictable, the decision on when to place a replenishment order will be self-evident. An order would be placed as soon as the stock level reaches zero. This would arrive instantaneously and prevent any stock-out occurring, but this rarely happens in real life. In fact, when replenishment orders do not arrive instantaneously, but have a lag between the order being placed and it arriving in the inventory. We can calculate the timing of a replacement order, so called 'lead time'. To avoid a stock out, we should not order the items when the stock level reaches zero, but we must always keep a 'safety stock'. The main consideration in setting safety stock is not so much the average level of stock when a replenishment order arrives but rather the probability that the stock will not have run out before the replenishment order arrives. The key statistic in calculating how much safety stock to allow, is the probability distribution, which shows the lead-time usage. The lead-time usage distribution is a combination of the distributions that describe its variation and the demand. If safety stock is set below the lower

limit of this distribution then there will be shortages every single replenishment cycle. [Slack Alistair Johnston, 2013]

- *How to control the system*. What procedures and routines should be installed to help make these decisions? Should different priorities be allocated to different stock items? How should stock information be stored?

  In order to control such complexity, operations managers have to do two things. First, they have to discriminate between different stocked items, so that they can apply a degree of control to each item, which is appropriate to its importance. Second, they need to invest in an information-processing system that can cope with their particular set of inventory control circumstances. [Slack Alistair Johnston, 2013]

## 1.4 POLICY OF INVENTORY MANAGEMENT

It is known that the inventory management is one of the hidden costs that is more difficult to analyse and contain. New techniques however, have allowed finding an appropriate solution for every situation. Frequently the use of JIT (Just In Time) techniques especially for more expensive items with more low index of rotation, in order to prevent these items from remaining unused in the warehouse company and incur the risk of obsolescence or damage to non-use. However, not all items JIT can be applied. For example, fast-moving items with low cost could be prove extremely critical for business management. Imagine a mechanical assembly company that has run out of screws because there was a sudden and unexpected consumption. [Tinarelli 1992] All productive activities stop only for the absence of that article. In that case, the costs of stock outs are higher than the savings that can be achieved with the application of JIT. Therefore, it is more convenient to manage these types of cases or issues using traditional techniques to spare with reorder point (the model of economic lottery is an appropriate solution). Nevertheless, how do we distinguish which items treated using a technique rather than another? ABC technique that is based on the theorem of Pareto, also called Law 80/20 (although in reality was enunciated by Juran) becomes helpful. According to this theorem, most of the effects depend on a limited number of cases (approaching, it appears that 80% of the effect depends on the 20% of cases).

This analysis allows defining what are the items on which we need to focus. The ABC analysis is extremely useful not only for defining the classes of articles based on their criticality, but also for articles at high rotation and furthermore, for defining the allocation zones within the warehouse. It is thus obtained a reduction of the required time to perform all the picking missions (picking). To realize the calculation, it is sufficient to use a personal productivity software, such as Excel. Proceed to listing of all the ordering items in descending order based on sales revenue. It calculates the cumulative sales per article. Having done the first brief analysis, we already noticed that there are some items whose influence on sales is higher than others items.

If a company trades a large number of items, we cannot even think to manage them individually and carefully; only the cost that should be supported to make accurate sales forecasts of each item would be too high. Therefore, what would be useful is a tool that can make it possible to identify, among many items, of those most important to monitor and control. This, in fact, allows dosing the intensity of management according to the economic interest of each item within the company. [Urgelletti Tinarelli 1992] Especially in large enterprises, the number of items in stock to handle is very high. In order to control this complexity, according to Slack, Chambers and Johnston [2010], the managers have two tasks:

Firstly, as we said, is ABC analysis; secondly is *information systems inventory*[1]. We need to invest in a system of information processing that monitor adequately stocks according to different circumstances and needs.

[1] Most inventories of any significant size are managed by computerized systems. The many relatively routine calculations involved in stock control lend themselves to computerized support. This is especially so since data capture has been made more convenient using bar-code readers and the point-of-sale recording of sales transactions. Many commercial systems of stock control are available, although they tend to share certain common functions. [Slack et al 2013]

## 1.5 ABC Analysis

ABC analysis is used to know the concentration of some phenomena, in particular, in the presence of a universe composed of several elements, allows detecting if a given character is concentrated on some of them or is uniformly distributed overall. As a general tool, we can apply to any aspect of the organization and not, as long as it is ordered. It can be used to study the composition of revenues, or profit, the economic importance of the customer, the turnover of the articles.

ABC analysis turns out to be useful especially to see how revenue is distributed on categories of stocks. That is, we will try to identify the elements that have a key role both costs and revenues, to control carefully. Instead, a less rigid control of other elements cannot produce any loss or gain. We speak of turnover because we think of commercial companies as Cavallone SRL. For the warehouses of manufacturing companies, such as the storage of raw materials or semi-finished, it comes to the cost or value of annual consumption per annum. However, this analysis is valid for all cases.

The main aim, using the criterion of turnover, is to understand what are the items that have a bigger both on costs and revenues, as well as to concentrate control over these, since less focus on other products should not lead negative consequences for the company [Tinarelli, 1981]. Discrimination in all three categories then allows we to define what are the articles on which the company needs to focus its attention, and, so that it can, as pointed Tinarelli [in 1992], "serve to achieve a differentiated management".

Vignati [2002] identifies three different elements that led to the success of the analysis ABC: simplicity, it is based on intuitive concepts and common use; the general validity that makes it applicable, in the same way, in many phenomena; the possibility to implement it, in short times, on a spreadsheet installed on a common personal computer. Although it is a method based on the principles born about a century ago, many traders, companies or production systems use this as a tool for inventory management [Grant, 1982]. Introduced for the first time in 1950 by Ford Dickie, uses a principle of selectivity which refers to the "fundamental principle of the Pareto Law", which states that "at any number of factors to be controlled, one can distinguish a small fraction, in terms of number, which can be traced back a great influence in terms of effects "[Donini, 1980]. The underlying principle of the ABC analysis is also known as "80-20 rule", according to which, in an approximate way, 80% of the effect is determined by the 20% of the cause that provokes it. a rule is very useful because it focuses the efforts to maximize results.

As part of the stocks this rule can be very convenient for the operator, because its areas of use can be multiple; for example: 80% of the references are almost always bought only 20% of suppliers, or 20% of references sold guarantees 80% of the total turnover and inventory turnover grows by 80%. Thus, finally, 80% of the space occupied in stock is dedicated to 20% of the references. [Savage 1997].

It is believed there is a number of factors responsible for a large share of the value of the shares, then an intermediate zone with elements responsible for a small proportion of the value, and, finally, a broadband, with the items that significantly effect on the total value of inventories [Marchetti, 2010].

Classes A, B and C represent classifications of decreasing importance. There is nothing sacred in the established classes, both in both the number and the distribution is subjective and depends on the type of material studied. On average, it will say that [Anderlini, Baracchino, 1986]:

- **A items**. Includes the elements of primary importance. Moreover the smaller, but is the class to which pay maximum attention. Are that 20% of items that account for about 80% of total revenue.
- **B items**. It includes elements of secondary importance. Usually the next 10% of products are those, which weigh often only 10% of the total value.
- **C items**. It includes residual elements with negligible impact on the phenomenon. Despite constituting 70% of the total stock, they are the ones who represent only 10% of total revenue.

From this it follows that by focusing on a few materials of classes A and B, which alone account for about 90% of the value of stocks, the effort management is concentrated, thus eliminating most of the inventory problems [Marchetti 2010] and to avoid the dispersion of forces on thousands of items [Anderlini, Baracchino, 1986].

The percentage of this allocation, set forth herein with cumulative values 80, 90, 100, however, are not absolute; They are indicative and mainly serve to illustrate that occurs a high concentration of value in a small number of items. In addition, these thresholds, which Tinarelli [1992] calls "the limits of cumulative percentages of turnover", and that simplifying call L1, L2, L3, must be decided case by case based on what it looks like the warehouse analysed. The possibilities are many; sometimes it can happen that the categories are not even three, but two or four.

Let us see how we should treat the items in the different categories. *Fig. 1* the articles of category A are those on which the company needs to invest more in terms of time and money. Ensuring a large share of turnover, and being particularly in demand, they are also the most expensive in terms of capital asset and require strict monitoring and constant. The management policies must be such as to predict an adequate supply in stock, at a level such as to avoid at the same time situations of stock outs, which would be particularly serious for the company being the core business, and situations with excessive inventory costs and avoidable waste.

We will also need to implement a system of close monitoring and permanent, with reorganization programs with frequent measurement of lots in accordance with detailed forecasts of demand. Here come into play mathematical methods based the Economic Order Quantity.

As for the items in Category B, being of limited quantity and value, we can use techniques of computerized management, software dedicated to control the level of inventories and forecasts about the best time to order [Wild, 1997]. Finally, the articles of category C, usually not a high proportion of its turnover. Therefore, we can monitor them making predictions summary, with controls diluted over time, creating a less scrupulous management. Being of low value, the weight of their stocks is overall little influence, and an excessive accumulation does not cause a big risk for the economy of the business. The most appropriate policy to manage the supply of items, based on a low frequency of orders, it may be that the so-called ***two-bin system*[2].**

We may need to classify references according to the choice of different criteria, depending on the feedback sought [Slack, Chambers, Johnston, 2010]:

[2] The simple two-bin system involves storing the re-order point quantity plus the safety inventory quantity in the second bin and using parts from the first bin. When the first bin empties, that is the signal to order the next re-order quantity. Sometimes the safety inventory is stored in a third bin (the three-bin system), so it is clear when demand is exceeding that which was expected. Different 'bins' are not always necessary to operate this type of system. [Slack at al 2013]

1. **Consequences of a stock-out.** High priority would be given to certain products or components that, if they were in the warehouse, would delay or seriously hinder the later stages or consumers.
2. **Uncertainty provider**. Some items, although of low value, could require more attention in the event of supply channels are uncertain or incorrect.
3. **High risk of obsolescence or deterioration.** Items that could see its value decrease due to obsolescence or deterioration needed more attention and monitoring.

| Characteristics | Policy | Methods |
|---|---|---|
| A Items<br>Few items<br>Most of turnover | Tight control<br>Personal supervision<br>Communication<br>JIT approach – balanced safety stock | Frequent monitoring<br>Accurate Records<br>Sophisticated forecasting<br>Service level policy |
| B Items<br>Important items<br>Significant turnover | Lean stock policy<br>Use classic stock control<br>Fast appraisal methods<br>Manage by exception | Rely on sophisticated system<br>Calculated safety stocks<br>Limit order value<br>Computerised<br>Management & exception reporting |
| C Items<br>Many items<br>Low turnover value (Few movements or low value items) | Minimum supervision<br>Supply to order where possible<br>'Large' orders<br>Zero or high safety stock policy | Simple system<br>Avoid stockouts and excess<br>Infrequent ordering<br>Automatic system |

Fig. 1 ABC inventory control [Wild 1997]

The strength of the analysis ABC, as we said, lies in its ease of application. It is useless to explain how operationally must be carried out an ABC analysis according to revenues. It is useless to explain how operationally must be carried out this kind of analysis. It is appropriate to proceed by defining the fundamental characteristics [Tinarelli, 1992]:

We call n the number of items that must be examined and νk (with k = 1, 2, ..., n) the turnover of Article k-th, obviously in reference to the period of interest.

The items are listed in descending order with respect to νk (with ≥ νk + 1). In this way, it builds a distribution of the type shown in *Fig.1.2*

It will calculate the total turnover denoted by V, from which $V(V = \sum_{l}^{n} vi)$

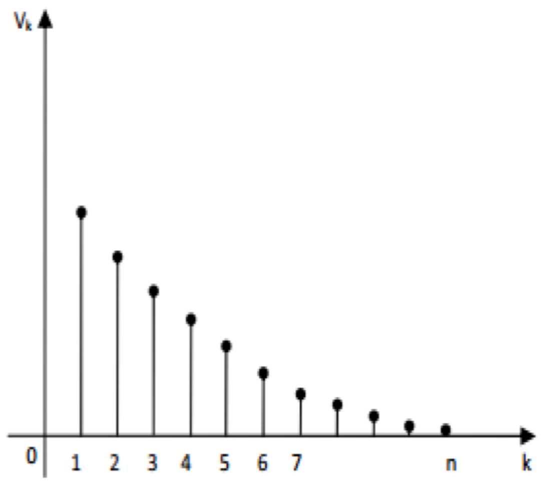


Fig. 1.2 [Tinarelli 1992]

After that, we should carry out the relationship between the revenue of each item and the total revenues ($v_i$ / V). We call $b_i$ the percent value of this ratio.

Now we calculate the cumulative sum of the values, that we call $\beta_i$. Whence:

$$\beta_i = \sum_{l}^{i} bs \qquad (i= 1,2,\ldots,n)$$

The $\beta_i$ have a distribution of the type shown in *Fig.1.3*

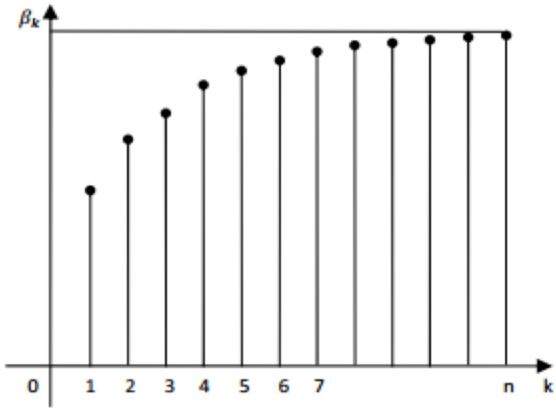


Fig.1.3 [Tinarelli 1992]

Once obtained the sum, we proceed to the division of the articles in the three classes. Comparing the values of βi with the "threshold values" ($L_1$, $L_2$, $L_3$) fixed on the ordinate axis that represents in this case the independent variable: in the class to be covered by the articles that $\beta i \leq L_1$; Class B will be the articles for which $L_1 < \beta i \leq L_2$ and $L_2$ in the class C $< \beta i \leq L_3$, or the rest.[Tinarelli 1992]

The data shown on the horizontal axis (the cumulative percentages of items) are a consequence (the dependent variable).

The limit of the model is the consideration only of the turnover as an index. Are neglected stocks, the result is often that the company is with elevated storage of noncritical items. Surely, ABC analysis of sales is of great help, but to overcome its limitations is frequently integrated with an approval for a cross analysis ABC inventory in order to highlight the critical management. For this purpose, it created a table, similar to the valuation of inventory at acquisition cost. As before, we classify the items according to the format suggested by the Law of Pareto, dividing them into classes A (articles that weigh on the value of the stocks up to 80%), B (80% to 90%) and C (from 90% to 100%). The next step is the intersection of the data in a table that allows highlighting critical situations.

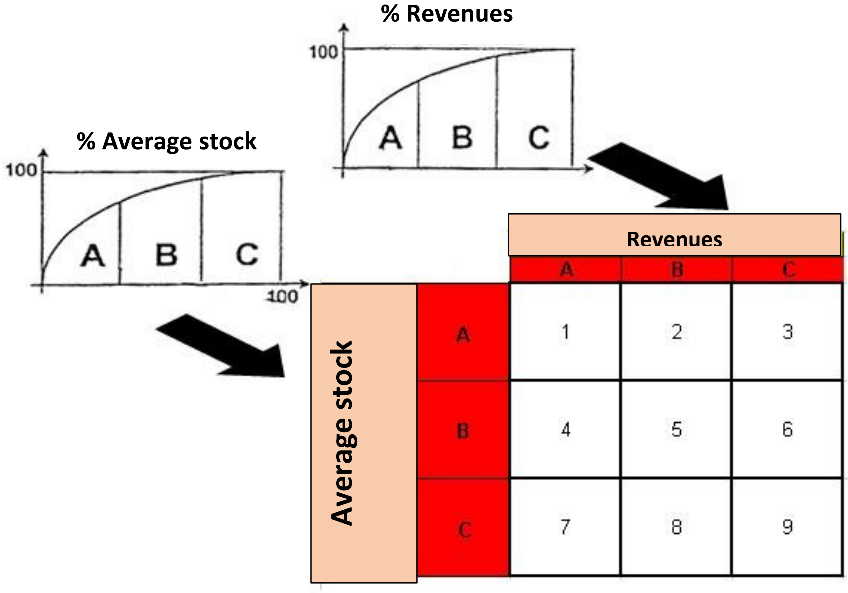


Fig. 1.4 ABC cross analysis (personal elaboration)

Combined analysis of the value of stocks and turnover are obtained, as can be seen in the picture, 9 areas, which are derived from the ABC classification of 2 tables above. (*Fig 1.4)*

We proceed now to the analysis of the results obtained. This reveals 9 different situations, highlighted by the number on the box. Each item is located in one of 9 situations proposals.

The diagonal (Boxes 1, 5 and 9) the situation is fair, in fact, they belong to the same class of revenues and stock . Stocks are adequate turnover of the product. However, box 1 (turnover A - stocks A) is considered the area to which special attention as it could present two extreme situations:

- Any stock outs produce drastic declines in sales
- At the same time, it is the area in which it can intervene to reduce inventory

Box 9 (C turnover - inventory C), however, lies in the complete turnaround. It is an area of inattention in which, most likely, there are items that are out of the market or in stock out (but whose value is so small as to be negligible).

The boxes 3 and 7 are, on the contrary, very critical areas. 3 (C turnover - stocks A) the high level of stocks is not justified by the sales and, therefore, the procedure for disposing of stocks (by blocking the supply or making sales promotions). The 7 (A turnover - inventory C) has a seemingly ideal situation. A low level corresponds to a high turnover of stocks. It should pay attention to this situation because it could hide dangers, such as higher risk of stock outs. Where a sudden demand for this article, the Company may not be able to meet that demand with subsequent erosion of a high revenue share.

Boxes 2,4,6 and 8 outline a less critical, even if the best solution is to restore the values to proper consistency between the various categories, acting on turnover or on stocks, as appropriate. The result obtained is an optimization of the warehouse.

The matrix ABC cross turnover of stock is an interesting and useful for dynamic analysis. It allows us to check the progress of the categories over time, preventing the risk of stock outs and at the same time to create a simple study of the product life. For example, a product that finds itself in section 9 (C turnover - inventory C) is most likely a product at the end of his life and the company can consider the opportunity to eliminate it from the range available.

We have seen, however, that from the theoretical point of view the analysis does not appear to pose any kind of problem; its practical application, however, can be problematic in the case of a high number of articles contained in each class. Vignati [2010] highlights the need to identify, within each class, the priorities defining an additional indicator of the relative importance of the articles; normally it uses Turnover (IR) to subdivide each of the classes ABC based on the movements of the articles. The further classification, so-called FMS [Dear, 1994], form subclasses: a fast rotation (F, fast), medium (M, medium) and slow (S, slow), based precisely on different values assumed by IR articles. Tinarelli [1992] defines this index "as the ratio between the outputs in a time period, and the average balance in the same period". Also according Tinarelli [1992] In addition, "it expresses the degree of mobility of stocks and therefore the capital invested in stock".

$$\boldsymbol{\frac{Expenditures\ in\ the\ period}{Average\ stock\ in\ the\ period} = I}$$

The period usually is 12 months, but some have chosen to taste. This index may be calculated for each individual item, or by category of items of the same type, or, still, for all items managed. It can be understood both as the ratio between amount, both as the ratio between values. If, of course, stocks are valued at cost, the outputs will have the same units. If not "the ratio would be influenced by the amplitude of the costs and the profit, as well as by any variations of these and those".[Tinarelli 1992]

$$\boldsymbol{I1 = \frac{Quantity\ of\ expenditure\ in\ the\ period}{Quantity\ of\ average\ stock\ in\ the\ period}}$$

$$\boldsymbol{I2 = \frac{Value\ of\ expenditures\ in\ the\ period}{Value\ of\ average\ stock\ in\ the\ period}}$$

Relating to a specific article, it indicates the number of times checking her makeover in stock, in order to allow the company to recover the funds invested in stocks. Therefore, it is a real tool to control inventory levels.

In practice, the more it is below the index of rotation, the greater will be the time of permanence and, accordingly it will have a cost for the company in terms of occupied space, maintenance, but especially for the immobilization of capital. In contrast, a high turnover rate means a short stay in warehouse inventories, implying increased handling activities, with entrances and exits very frequent.

## 1.6 THE INVENTORY MANAGEMENT COSTS

The stocks have a cost and this is an absolute truth that must be carefully considered when necessary to prevent significant exposure in financial terms and a heavier of ordinary operations [Marchetti, 2010]. However, it is not easy to identify, among the many business costs, those that influence directly or indirectly inventory management [Tinarelli, 1981]. As a general rule is said to manage inventory should include only the "relevant costs." They say they are important because they are needed because of his decision.

The cost of purchasing, ordering, storage, aging, shortage, etc. setup. Are examples of occurring costs for decisions relating to lot size and must therefore be considered. Costs, which instead would, also occurred regardless of the manager's decision, as the costs for heating or lighting, are not, and therefore are not considered as operating costs. They are called sunk costs [Fogarty and Hoffmann, 1983].

In addition to the relevance, another fundamental criterion to consider is the choice of the costs related to the actual management fees, that is actually disbursed amounts, or vice versa, the profit opportunity that we have to give [Magee, Boodmann, 1992]. Thus, we speak of "opportunity cost", i.e. a return of capital that would have been obtained with an alternative investment. This represents a loss of revenue due to the neglect of economic initiative in favour of another, due to limited resources. Even these costs, of course not appeared in the accounts, should be considered by the manager of the stocks [Fogarty, Hoffmann, 1983].

To derive the cost items and various data for their determination, the manager of the stocks will rely in the first instance records. The methods and the accounting procedures are manifold, but the only use of these is not exhaustive. It is very important that the accounting data is integrated with other data obtained with survey-book statistics. This makes it possible to arrive at a cost so-called "operational" substantially different from the accounting and administrative, in the amount that is in the purpose of use: the first is to create historical or financial reports, the second to provide elements for managerial decisions [Tinarelli, 1992]. Furthermore, while the costs derived from the accounting tend to be stable over time both in the principles that imputation, those that will provide the basis to control the production and inventory instead vary from period to period. Another difference concerns the meticulous calculation. The accounting systems are renowned for their accuracy and scrupulousness in the account even the most minimal amounts, on the contrary, the decisions on control of production and stocks are relatively insensitive to small changes in cost factors [Magee, Boodman , 1992].

In conclusion, the analysis proposed in sub-paragraphs following is useful to determine the nature of the basic operating costs and their relationship with the stock. Part of these costs will increase with them (storage costs, financial costs, costs for breakages \ damages, transportation costs, administrative and handling), instead of a downward trend (ordering costs, setup costs, costs for stock- out etc.) [Olivotto, 1992].

### 1.6.1 Purchase and production costs

“ The costs mainly related to the problem of the control of production and stocks are those that depend on the size of the order sent, whether it is sent to an external provider that connected to an inner loop manufacturing " [Magee, Boodman, 1992]. Properly on Tinarelli [1992] purchase costs states that it is "the amount that must be paid to those who supplied the goods." They should ideally represent the total sum paid to make the article available and ready to use. Since this is essentially costs associated with goods, it is natural to think that these are made primarily from stock type that we want. Thus, for example, for the first we will evaluate the purchase price plus any additional costs such as the costs of transport, for semi-finished and finished products is instead counts the amount spent for the materials used plus the costs for the process or processing materials (ex : labour, consumables, energy) [Bruno, 2005]. Their calculation is deceptively simple.

Since this is essentially costs associated with goods, it is natural to think that these are made primarily from stock type that we want. So for example, for the raw materials we will evaluate the purchase price plus any additional costs such as transportation costs. Instead, for semi-finished and finished products it counts the amount spent for the materials used plus the costs for the process or processing (labour, supplies, energy) [Bruno, 2005]. Their calculation is deceptively simple.

However, there is an exception. In fact, if the purchase price is constant, that is, does not vary depending on the quantity purchased or based on the time of purchase, then this is not considered as significant cost because as we said earlier, do not depend on any business decision [Tinarelli, 1992].

In all other cases, it will take into account, for example when there is a price advantage linked to the quantity purchased. That is, when we buy more than we need (thus cumulating stocks more) thanks to a favourable discount [Marchetti, 2010]. It is common, especially in the commercial, we can get discounts and / or benefits depending on the timing of payment and the quantity purchased [Bruno, 2005]. The discount consists of a modification of the unit cost, and varies depending on the quantity ordered.

### 1.6.2 Preparing and ordering costs

An important part of the acquisition and production costs consists a series of costs that occur each time a replenishment order is issued. We talk about preparation costs and ordering costs. Simply ordering costs if we run into secretarial expenses and preparing the documentation related to the issue of the order of delivery; whether it is communicated to the outside, both on its own production. To these must be added all other costs in related activities such as the transport of goods from the manufacturing plant and distribution canters. [Jacobs, 2011].

For the accuracy, it says that in the preparation costs should be also included labour costs related to administrative work necessary for the compilation of the order, for the preparation of technical specifications and the costs of registration and monitoring of procedures. We also consider the costs associated with the processes of reception of merchandise, control, billing and its in-stock position (so-called reception costs), the arrangement of payments, and fixed costs for its transportation, the latter to include only if constant and not already included in the purchase price [Tinarelli, 1992; Fogarty, Burnham, 1983].

Fogarty and Hoffmann [1983] propose three computational approaches based on the assumption of proportionality, that is, that the more orders issued, the greater the total order cost:

1) *Aggregate Approach*. Simply be the sum of the various expenses that affect and divide them by the number of orders, resulting in an average unit cost.

***Total order cost ($)*** = CPA[3] + $CPMS$[4] + $CSER$[5]+RC[6]

***Average cost per order (in $)*** = Total cost ÷ total Order Orders

The criticality of the method lies in its excessive stability since it is usually calculated on the average of the activities of the last three years, the time period in which, staff and personnel to the purchase often vary, there may be changes in the procedures and periods management systems in which idle in which no facts orders.

2) *Standard cost approach.* It is based on the sum of the accounting costs of type "standard" derivable from budget, then referring to a period of one year. They are items that do not change in the short period in contrast to what takes place for the real costs.
3) *Marginal Out-of-Pocket Cost Approach*. It refers to the marginal cost. If placing an additional order does not require additional spending per employee, then the order unit cost includes only small direct expenses such as stationery and communications.

Rely exclusively on theory and say, that the ordering costs are directly proportional to the amount of purchases made is not always true statement, especially if for a moment we think of the reality of the facts. For example Tinarelli [1981, 1992] points out that the cost of staff (which by the ordering costs are dominant) do not enjoy the principle of proportionality: if with two employees was able to issue 30 orders a week, and then, if we decide to also increase slightly this capability, it means that an employee will need to take in more.

### 1.6.3 Holding and storage costs

*Carrying Costs* fall in and are a natural consequence of the fact that an item is in stock. Within *Carrying Cost*, they include most types of spending, such as the cost of capital, deterioration, obsolescence, theft, insurance and taxes, storage costs, security, space and data retention activities. Each of these represents a real cost, then proportional, at least in

[3] Cost of Purchasing Agents, is the direct and indirect cost of personnel acquisition.
[4] Cost of Purchasing Management, Stenographers and Clerical Personnel, is the direct and indirect cost of the management staff and office.
[5] Cost of Services, is the cost of communications, stationery and miscellaneous supplies and services.
[6] Reception costs for goods.

theory, the size of the order [Fogarty, Burnham, 1983]. As has been done for the other categories, the starting point of this analysis will want to consider only the cost items related to extraordinary expenses or to miss profit opportunities.

Equally, to those ordering, determining the *maintenance cost* is quite problematic because we cannot always keep track of what was actually paid [Thierauf, Klekamp, 1975]. For this there is expressed in unit of goods, unit of time (ex: 100.00 per quintal per month) or as a percentage value on the time (ex: 10% per year) [Bruno, 2005].

The carrying cost consist of seemingly constant components, ie no variables to changes in the stock size [Tinarelli, 1992]. Items such as rent, heating and lighting are a clear example, since some warehouse space to be stored efficiently still needs ongoing expenses. So until the stocks do not exceed the deposit storage capacity it did not take into account because it is clear that it is not influenced by extraordinary expenses adopted policy, but of fixed costs that are part of ordinary management. What the opposite is the case if we pay for the rental of a warehouse, the place where the space available to the operator could be used for several different profitable [Magee, Boodman, 1992]. In this case the rent becomes decision variable and is a parameter that increases in proportion to the amount, the volume or value of the goods which is kept in stock and the shelf life [Tinarelli, 1992]. The same argument can be made for items such as insurance, safety, breakages and damage. Something different concerns interest expense on investment (taxes), which sometimes do not even appear among the cost components of inventories [Magee, Boodman, 1992].

- ***Explicit costs.*** The first category includes a series of "under-cost" generated by the following activities:
    - Insurance costs on materials kept in stock;
    - Expenses for maintenance and depreciation for warehouse equipment;
    - Cost of personnel engaged in the management of the warehouse;
    - Printed matter, chancellery, etc.;
    - Actual or imputed rent the premises for the maintenance of stocks;
    - Other warehouse utilities (electricity, fire, telephone, fax, PC, etc.);
    - Ageing or obsolescence costs;
    - Taxes.

The elements mentioned above are generally considered all proportional to the "instantaneous value of the stored goods, i.e. proportional to the average stock value [Tinarelli, 1992].

- ***Implicit costs.*** A particular focus is needed as it pertains the implicit component of the cost of maintenance, that is, relative to the assets in the cost of capital invested in stock.

Although inevitable, in the inventories represent the blocked capital, comparable to an investment that does not produce any cash revenue.

It is the result of three factors: the value of the capital absorbed by a unit in stock, as long as it remains "constrained" and the interest rate.

Regarding to the interest rate we need to make a discussion, because the doctrine has developed various approaches that come with the use of different cost configurations for its development [Mariani, 2007].

### 1.6.4 Depreciation and penury costs

Even if the stock should be a place where the goods are passing through, it often happens that for some reason most of the stations have here. The time factor inevitably results in a depreciation of stocks, or a loss of value to both changes in market prices is due to obsolescence [Bruno, 2005]. The natural aging or "artificial" that is, for some items becomes very relevant [Marchetti, 2010].

According to Magee and Boodman [1992] depreciation may take various forms.The first case involves a total deterioration of assets. Here, the cost of obsolescence occurs in full after a certain period from the production. Another hypothesis sees the risk that an article (or part thereof) will become technologically obsolete and therefore saleable only if it is applied a discount or we use it as a spare part [Magee, Boodman, 1992]. We cannot say this to happen because of errors in forecasting demand, rather for its deterioration. In fact, when considered today, the question is healthy and smooth and in line with expectations. However, there is always a considerable possibility that plunge into the future. Obvious examples of this are in the industries of products with a high rate of technological innovation, such as computers and pharmaceuticals [Song, Zipkin, 1994].

Technology is not the sole source of obsolescence. For goods subject to strong seasonality, the possibility of losing value at the end of the season only an estimated recoverable amount, it is highly probable hypothesis. Toys, no boxed food and clothing are among the categories, which run more risk of becoming unfashionable [Magee, Boodman, 1992]. Other sources of Outdated are caused by sudden changes in consumer preferences and market trends (ex: some books, discs, fragrances, food types). Regarding to industry, many products such as machinery and spare parts constantly face the so-called "event risks", ie the risk of competition from imports, the possibility of hazards to safety and a multitude of other factors [Song, Zipkin, 1994]In conclusion, the storage of obsolete goods in warehouses is a frequent problem. The cost component linked to it is the problem that management is not always willing to accept that. These products are classified as "slow-moving items" or with a very low turnover of stocks that some managers decide to consider them not as detractor just because they believe that eventually they will be sold. As said, the root cause of their formation is both in supplying and in demand forecasting: reduce uncertainty is like to reduce the exposure to obsolescence. Once accumulated, most companies find ways to make up for the loss by selling or eliminating obsolescence; but the basic point is the same anyway, namely, prevent this from happening. [Pay, 2010]

### 1.6.5 Stock-out costs

While the depreciation costs arise when supply exceeds demand, with Penalty Costs, the opposite occurs, and they are determined when the demand is greater than supply [Arrow, et al. 1958]. Not being able to meet customer requests for lack of goods, is configuring a situation of out of stock that has two possible developments [Fogarty, Burnham, 1983; Marchetti, 2010; Jacobs, 2011]:

- *Customers decide to wait (backorder situation).* If the manager operates in a monopoly situation, he probably will not have expenses other than those of the necessary documentation for ours records up to its availability. However, it is possible that he will be a having to resort to urgent and expensive re-orders at third parties or overtime hours; these charges can then be recharged to its original supplier, so the penalty becomes partial.
- *Customers are not waiting (no backorders situation).* They will lose sales and earnings, of course a bad publicity for the company and a decline in competitiveness. In these cases, the cost can equal the contribution margin of

product if the customer turns to other competitors. The penalty cost will be highest.

In both cases, calculating the costs of scarcity is very difficult. When a direct quantification of the results is not possible, the management opts for other instruments, by setting a desired level of reasonable customer service. These measures are frequently used as a surrogate for the calculation of the costs of scarcity. An example is the demand for a product satisfaction rate (ie the percentage of demand supplied directly from the warehouse on request). If the annual demand for an article is 1000 units and 900 are provided directly from the warehouse, 90% is fulfilled demand rate.

### 1.6.6 Cost of capital

A more common view recognizes two ways to address this issue. The first means the rate of interest, or the desired investment income such as interest due on a loan granted by a third party (ex.bank). While the second part from the fact that the company which invests money in stocks preclude the possibility to invest in other more productive activities, thus meaning the interest as an expense arising from missed opportunities for earning money [Garcia, 2004 - Magee, Boodman 1992 - Slack, Chambers, Johnston, 2010 - Mariani, 2007].

In the first case the question arises whether such funding is to be understood in "Long-term", so permanent, or "short term" and with low risk. As a rule, for transient nature of stocks, financial institutions evaluate the investment in stocks through a negotiable rate for short-term borrowings. In fact, this source would be the most suitable form to satisfy the current needs generated by natural stocks.

The quantification of the implicit cost should thus be obtained more correctly, using the WACC (weighted average cost of capital), resulting in general, cheaper than the short-term loan [Garcia, 2004 - Mariani, 2007].

The second vision, in contrast, considers the capital tied up in inventories as a missed opportunity by the company to realize additional income resulting from the use of those resources in alternative investments.

On the alternative hand, it aims in the long term, considering stocks as a continuum of investment, which assumes a permanent nature (Permanent Working Capital).

Sometimes entrepreneurs make the mistake of thinking that the cost of the money tied up in inventory is zero, especially if cash for inventory financing are obtained internally.

In the first case, the opportunity cost may be expressed by the interest rate of readily marketable securities - such as government bonds - essentially the risk-free rate; while in the second case, the "loss of income" may be quantified using the

ROI Company, since the company could use the financial resources "freed up" from the warehouse in core activities.

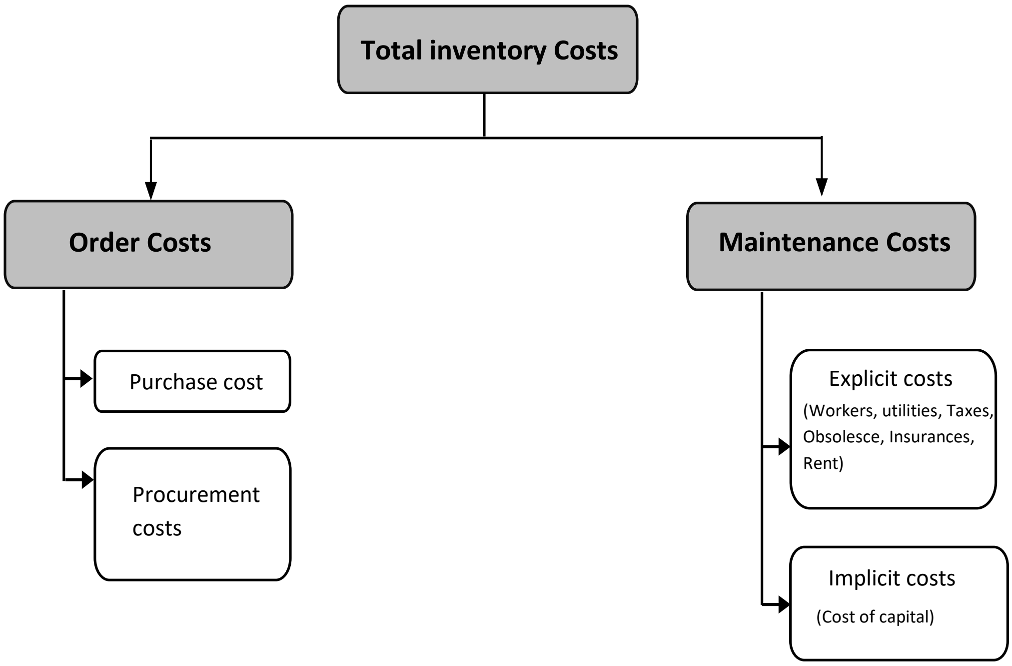


*Figure 1.5 Total inventory costs (personal elaboration)*

# 2 CHAPTER - MATHEMATICAL AND STATISTICAL MODELS FOR INVENTORY MANAGEMENT

The literature offers a wide range of quantitative mathematical-statistical models of inventory management in support of the delicate task of inventory manager. If these models are properly implemented, they suggest the main rules of rational behaviour in inventory management. [Tinarelli 1992]

As it was mentioned in the previous chapter, the chief decisions in inventory management are when and how much to order. It appears to be still useful for managers in the first try, using simpler models of inventory management, so that we can implement decisions based on intuition and perception. Later, depending on the features and peculiarities of its own stock and warehouse stocks, the manager will be able to implement more complex models and closer to the real situation of the company, an ad hoc model. A further advantage, often little considered, is that by implementing sophisticated management models to improve the efficiency of the warehouse door, of course, to collect the data necessary and this creates awareness of some fundamental values that should never be neglected. [Tinarelli Urgelletti 1992]

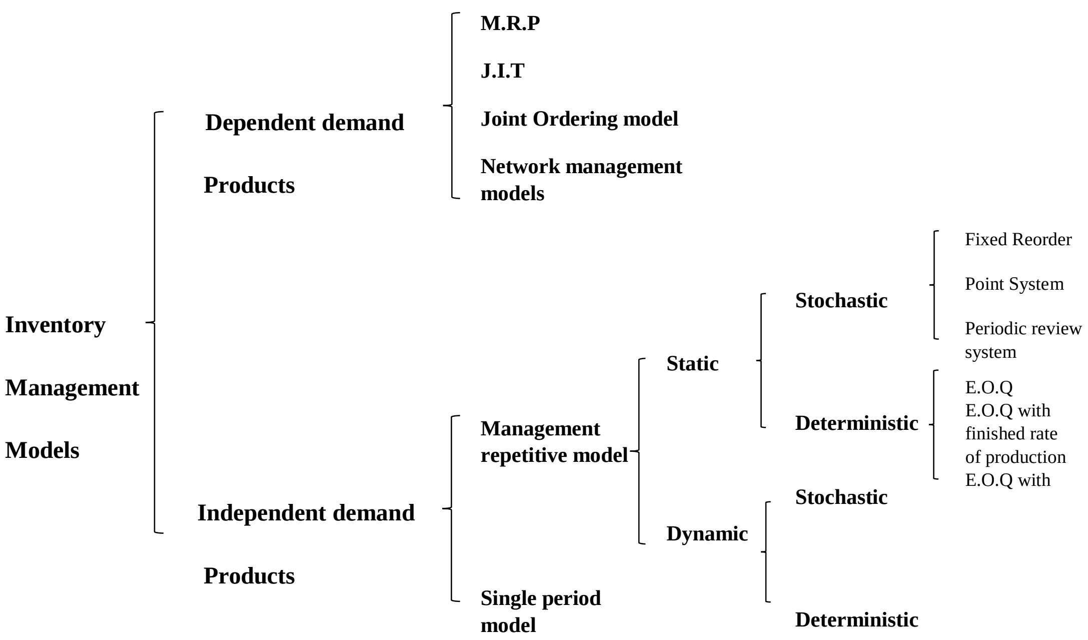


Fig. 2 Classification of inventory management models scheme [Tinarelli 1992]

Just as pointed out by Bruno [2003], the main variables to be taken into account depending on the complexity of the problem, the level of technology, the degree of computerization, the organizational situation, the required flexibility with respect to possible changes of data and characteristics of problem (ex. predictability of demand and / or prices, variability reorder time). In literature, several classification criteria led to determine numerous mathematical models. The latter fact can be distinguished: *continuous* or *discrete* models [Bruno, 2003] depending on whether the reference quantities for inventory management (demand, supply time) are described by continuous functions or discrete.

Models under *certainty* or *uncertainty* [Grando, 1995], or as defined by Hillier and Lieberman [2009] *deterministic* or s*tochastic*, with the first parameter values supposedly known (the application and the reorder time are known and constant), while in the latter they, or at least one of them, are uncertain, therefore described in statistical terms (ie. distribution function, mean, variance). Models at two levels, in which the user takes both decisions on when and how much to buy, and to a single level, in which the decision on the "when" is set to the user [Dear, 1994].

Finally, models *dependent demand* or *independent demand* [Tinarelli, 1992]. A final distinction is based on demand regarding the product to manage [Tinarelli, 1981, 1992; Fogarty, Hoffmann, 1983], and considering the purpose of this paper, it is the one that will be taken into account.

It is based on the principle of Orlicky [1975] that is based on the concept of splitting all goods used in company products between "dependent demand" products and "independent demand" As shown in (Fig. 2.) The first category are generally associated with all those articles that enter directly in the manufacturing process, where all raw materials, components, semi-finished and packaging materials, whose demand depends on the amount (i.e. demand) of the finished products made from company. The demand for such items is therefore highly dependent on the general level of production (MPS) for assessing medical needs of each finished product. Management systems designed to manage the stocks of these items are mainly: MRP (Material Requirements Planning) and the latest JIT (Just In Time).

By contrast, the goods in question are independently identified finished products or parts for which demand is evident from the market outside the company, and whose needs cannot be related directly to the production plan. Examples of this include all sectors distribution, from the food to the apparel. The techniques of inventory management in this category are based on the model of Wilson (EOQ), with political order point, and the model to periodic reorganization. According to this subdivision, it may be observed that the requirement for dependent demand products is calculated in a deterministic manner, as well as this has been set demand for finished products in a certain period. The demand for these products must be independent instead, identified by means of a statistical prediction of future needs; for estimating the demand for these products, it is therefore necessary to use calculation methods based on the analysis and extrapolation of time series.

## 2.1 INDEPENDENT DEMAND MODELS

Regarding Independent demands, it can be known only by extrapolating the trend of demand in previous periods for a future prediction. One typical case would be commercial environments, where the multitude of customers determines the trend of demand with an independent behaviour but quite repetitive. From the mathematical point of view, the demand can be represented by a random variable "A random variable (rv) is considered note when they know values and their probabilities or, if it continues, the density function or distribution" [Tinarelli , 1992].

The demand is assigned to a variable with a certain probability distribution. The other variable that influences the management is the time to reorder. This factor can be represented by a random variable. To address the case of independent demand management, aleatory [Tinarelli, 1992], we start from the so-called Wilson (EOQ) model, which solves the problem of optimizing the management, however, referring to a very simplified case. A further specification can be done within the multi-period models, separating systems to periodic review (Periodic Review System) and constantly monitoring the level of the product in regular intervals by reordering systems to fixed point (Fixed Reorder Point System), which clears up only when it reaches a certain level of inventories.

### 2.1.1 Wilson's Model

The most common approach to deciding how much of any particular item to order when stock needs replenishing is called the economic order quantity (EOQ) approach. This approach attempts to find the best balance between the advantages and disadvantages of holding stock. [Slack, Johnston 2013] It manages the products to independent demand and is the most important and popular among business enterprises as it helps manage stocks in the clarification of the economic lottery of purchase, a phenomenon that is the stimulus to the accumulation of goods at the warehouses or production lines [Olivotto, 1992].

The Wilson's model, which is one of the oldest models of inventory management, is developed based on the following assumptions [Tinarelli, 1981, 1992]:

Regarding revenue:

- The price-cost of purchasing goods is known. It does not vary over time (constant) and is not dependent on the number of items purchased.
- The order is processed entirely at once.
- It is possible to purchase any quantity, even non-integer
- The reorder time (lead-time) is known and constant.

Regarding outputs:

- The article has a known demand with constant intensity over time. Its sale price does not vary but remains the same.
- The aim is to meet any demand without waiting or losing customers. It is therefore considered that the costs of penury in this model are very high.

Regarding the nature of the article:

- The item is not perishable.
- The conservation cost of goods involves expenses that are considered proportional only to the value and the storage time.

From these assumptions, it can be derived that, being the demand constant over time, the amount purchased will be constant over time, we will call it lot and we will denote it by Q. In the same way, the range between two successive arrivals, or between two emissions of orders, it will also be constant. We will call it recycling time and indicate it by T. *Figure 2.2* shows the level of stocks and the relationship between quantity and time. The profile that emerges is commonly called "saw tooth", a name that recalls its classic form:

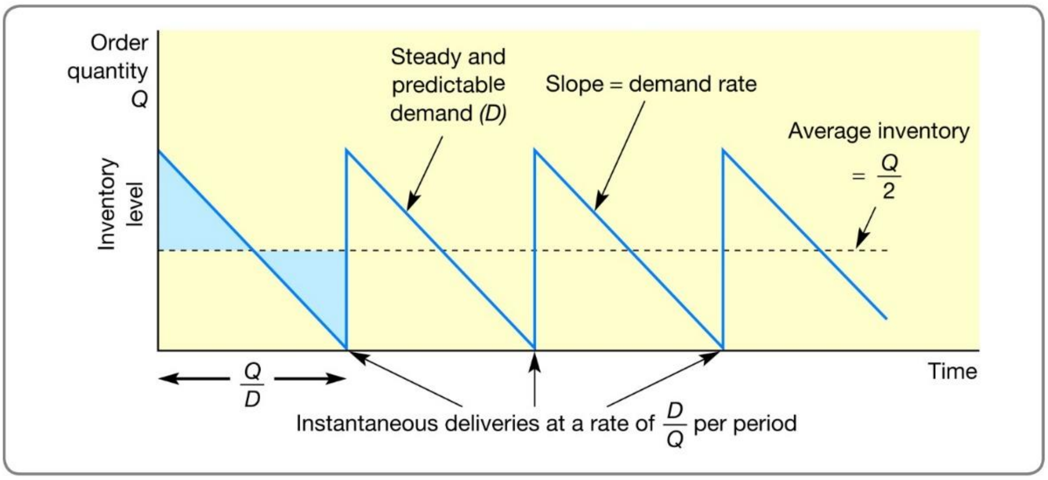


*Fig. 2.2 Revision from Slack, Jonhston 2013*

Every time an order is issued, there was supplied a certain amount of product Q. The supply comes as assumptions instantly and in one solution. The application of the article is also stable and perfectly predictable, and this makes sure that the consumer requires a certain amount of D units periodically, such as monthly. When the demand runs out entirely the stocks of an article, another order arrives immediately, and so on [Slack, et al. 2010].

Under these circumstances, we have that [Tinarelli, 1992]:

- The average level of the stock is $\frac{Q}{2}$ because being fully known, should not ever have stock when another order arrives at the warehouse, while minimizing the costs of conservation

- The interval time, between successive deliveries (T), corresponds to T = $\frac{Q}{D}$

- The frequency of deliveries in the period is equal to the reciprocal of T, that is $\frac{1}{T} = \frac{D}{Q}$

This model is also based on some simplifying assumptions [Vignati, 2010 - Bruno, 2003 - Tinarelli, 1992]:

1. Q: annual demand of the product (quantity of goods per unit of time) is known[7] and not seasonal;

2. $C_o$: Cost of ordering the order is constant;

3. P: purchase price or variable cost of production is known, and regardless of the amount;

4. $C_h$: holding costs are proportional to the stock level and the time of presence in the store;

5. Lead-time supply is known and constant (delivery / immediate production of the goods);

6. There is no limit on the size of the lot purchased;

7. The amount that we buy in each order is delivered in a single solution.

The assumptions underlying the model are, in fact, quite restrictive, and deviate from the real operating conditions, but they are necessary for its initial theoretical formulation. Dropping gradually we can still approach the situations that govern business processes. Define a policy of inventory management means, therefore, to identify the optimal size of the lot Q called EOQ which derive from the procurement cycle T = Q / D [Bruno, 2003]. To determine the optimal size of the batch of purchase is necessary to identify the expression that represents the total costs associated with the creation of the stock and determine the amount Q as to minimize them. Pointing with CA total cost of purchase, CO with the total cost of ordering and CM with the total cost of maintenance to supply, the total cost for the stock will be:

[7] Having assumed the demand known in advance, the model does not allow to have periods without the presence of stocks (no stock out)

$$C_{tot} = C_{\mathrm{a}} + C_{\mathrm{o}} + C_{\mathrm{h}}$$

Where:

Ca = Product price * annual demand = $P * D$

Ch = Ordering cost per unit * number of orders for the period = $c_o * \frac{D}{Q}$

Ch = Holding cost per unit * average stock = $c_h * \frac{Q}{2}$

Substituting we obtain:

$$C_{tot} = P * D + C_h \frac{Q}{2} + C_o \frac{D}{Q}$$

The optimal quantity, as can be observed from the graph, is located at the minimum point of the curve of total costs. (*Figure 2.3)*

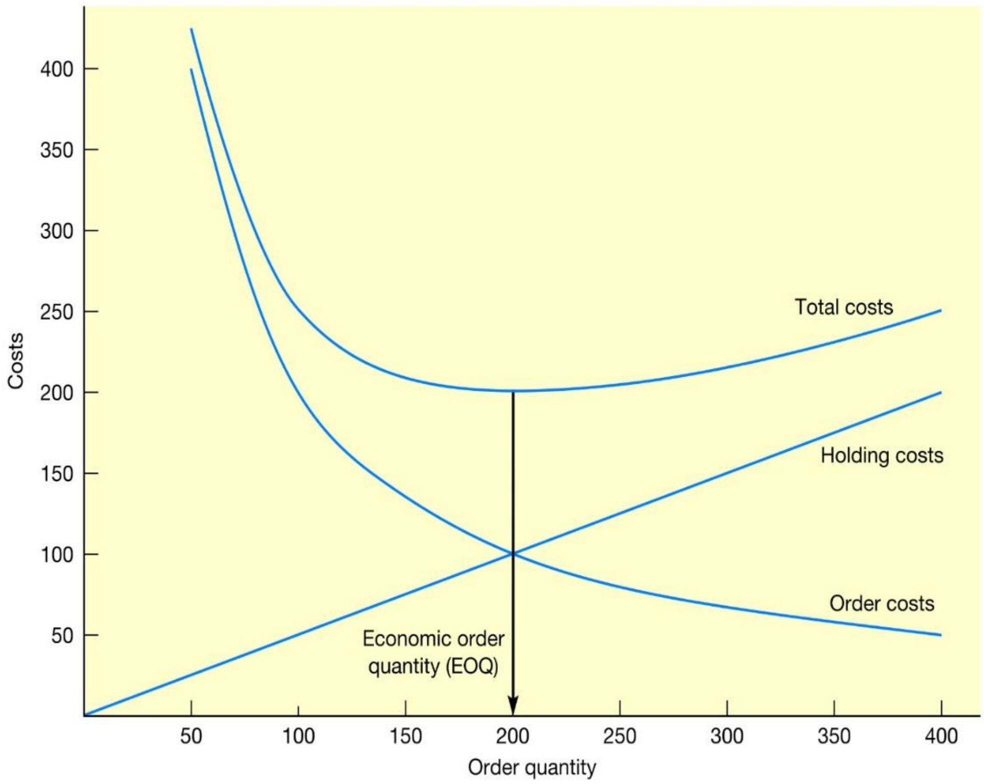


*Fig. 2.3 Graphical representation of the economic order quantity [Slack el at 2013]*

When we are using the E.O.Q. the time that elapses between the orders is equal to $\frac{EOQ}{D}$ while the frequency in period it is to mutual, i.e. $\frac{D}{EOQ}$

Now that the "how much" has been established, we have to decide "when" order. In accordance with the assumptions of the model, the warehouse should be replenished exactly when stocks are exhausted. Since some time is needed for the operation, it is necessary to make the order in advance. The stock level at which the order should be issued is called "reorder point" (S). It is exactly the same for consumption in the reorder time said *lead time*[8] (τ) [Tinarelli, 1992]:

$$S = D \times \tau$$

As we said, the model of Wilson is very simple to use, but very often, to use it in real cases is necessary to make changes. Successively removing some of the basic assumptions, we get different other models suitable cases of great interest and that frequently occur in practice [Tinarelli, 1992]:

1. Model with variable prices depending on the quantity purchased in each order;
2. Model for buying and selling whole quantity or multiple lots predetermined;
3. Model with transport costs piecewise constant;
4. Model management of stocks and currency devaluation;
5. Model with reordering costs negligible.

In relation to the business case that we analyse in the next chapter, be given special attention to Model with variable prices depending on the quantity purchased in each order: “Quantity discount model”.

[8] So-called procurement time, is the time that elapses between the forward of the purchase order and the time that goods have arrived.

## *2.1.2 Variations to Wilson's model*

The model of Wilson is the foundation of all mathematical models of inventory management. Its simplified implementation, allowing it to adapt to most concrete cases, which may arise in the company. However, the same assumptions, so simplified does not always make it a model capable of giving a reliable result [Dear, 1994]. From this model, we start to study the real cases that are obtained by adding or eliminating some of the basic assumptions. Therefore, for example, we can give up the assumption that the purchase price is constant, admitting however that the seller allows discounts for purchases over dates given amounts: then we have "models with quantity discounts." Another case is supposed to buy and sell only whole quantity of goods or multiple quantities belonging to predetermined batches offered by the provider: in this case, the model is called "EOQ with discrete batches". [Tinarelli 1992].

By abandoning the deterministic hypothesis, it is assumed that the parameters and values related to reorder time and demand, or both, are no longer so regular and known a priori as before. The use of random variables means adopting random variables (R.V.)[9], notes, if assigned to distributions of value with its chances or if assigned to a continuous density function or distribution. From this hypothesis are born "*fixed reorder point system*" (reordering of a constant amount each time the stock reaches the point of order) and "*periodic review system*" (reordering at fixed intervals of variable amounts generally) [Tinarelli, 1989, 1992].

## 2.1.3 Fixed reorder point and Periodic review system

The minimum point of the function of total cost - expressed graphically in *Figure 2.3* - is obtained deriving the total cost with respect to Q (is the unknown factor to be determined) and putting the result equal to zero, we get the following expression for Q*:

$$Q* = EOQ = \sqrt{\frac{2DCo}{Ch}}$$

Where $Q^*$ is the optimal batch of purchase.

[9]A random variable (RV) is considered note when they know values and their probabilities or, if it continues, the density function or distribution [Tinarelli, 1992].

In practice, as pointed out Grando [1995], the difficulties of calculating economic batch will refer mainly to the precise determination for each article of the terms included in the expression. From the formula of economic batch can be obtained also optimal lead-time $T^*$ and the number of orders $n^*$:

$$T^* = \frac{Q}{D} = \sqrt{\frac{2Co}{Ch\ D}}$$

$$N^* = \frac{1}{T*} = \frac{D}{Q*} = \sqrt{\frac{Ch\ D}{2\ Co}}$$

At this point, after having determined how much to order, it is necessary to answer the second question, when to order. Normally we answer this question is not seeking a moment in time, but determining a limit level of stock, said ordering point. As defined by Tinarelli [1992], the ordering point (also called reorder level) is therefore the stock level reaches that we must start the reordering operations. Considering the above mentioned assumptions, D with constant and uniform consumption over time, then the development of stocks can be depicted through the saw tooth, in which evidence the link between the temporal profile of stocks, reorder level and the lead-time procurement.

The reorder level coincides with the stock sufficient to meet consumption (or sale) during the lead-time procurement (hypothetically known and constant). In view of the simplifying assumptions introduced, the reorder level is exactly equal to the consumption during the time of replenishment, namely [Vignati, 2010]:

$$R\mathrm{L} = D * LT_a$$

Where:

$R$L = reorder level (units);

$D$ = average consumption rate per unit time (unit/days.);

$LTa$ = lead - time procurement (days.).

This configuration, as seen, appears optimal when both the demand and the lead-time of the order is completely predictable. Anticipating the issuance of the order, by a time equal to LTa, allows the arrival of the goods at the time in which it manifests the needs, that is, when the stock reaches the value equal to zero. The reorder level, in fact, is equal to the number of items that are supposed to sell during the time of supply.

However, in most real cases it is not always so. If the rate of demand and / or reorder time result variables, we must place an order for replenishment a little earlier than we would in a situation purely deterministic [Slack, Chambers, Johnston, 2007]. The most common way to avoid the risk of incurring in a stock-out, is to increase the level of stocks defining an appropriate safety stock. The level of this particular stock is proportionate to stable demand, as well as the reliability of the supply system and the level of service desired [Grando, 1995]. The concept of reordering will also be applied in this case with a modified formula compared to the previous [Vignati, 2010]

$$\mathrm{RL} = D * LTa + SS$$

Where SS are Safety Sock.

The level of safety stock can be determined in scientific statistical methods, but this is not considered useful for the purposes of our research.

### 2.1.4 “Quantity discount” model

In the model of Wilson, as we already mentioned, we assume, for simplicity, that the price-cost of a unit of goods did not vary with the size of the order. This basic assumption has allowed us to overlook the cost of purchase in the objective function: indeed, it would not be a function of Q, but steady. [Tinarelli 1992] In the real business cases, it often happens, especially in the commercial field, that suppliers offer discounts on the price of the items to entice buyers to buy larger lots, creating the possibility to benefit from economies of scale, transport and process costs [Benton Park, 1996]. Now, let us see how the Wilson’s model changes in these cases, of course, without claiming to represent all possible situations, but only to indicate the "methodology" to be followed in similar cases. It is known that the recent buying strategies focus increasingly on the conquest of flexible resources and ensuring supplies of components and products of high quality. Getting hold of such advantage, enables the company to be competitive in the market. Applying these strategies in models with quantity discount as Benton Park [1996] says "will help make better purchase decisions" and it’s due to the beliefs of two authors in one of the critical components to win in the market consists precisely in adopting a policy of lower prices than competitors. Consequently, it is normal to believe that control of the acquisition cost is the variable on which many managers are looking to leverage in order to obtain similar benefits [Anderlini, Baracchino, 1986; Aguiari, Marini, 1999].

Usually the literature used to distinguish between the determinations of the economic batch by the buyer and by supplier, dealing with the two issues in separate ways. In fact, it is observed that, by dividing the points of view, it is supposed that the two agents do not cooperate. In a way, the maximization of profit of one does not coincide with the objectives of the other, which is true in many cases. The fact remains, however, that there are models that solve the problem through a joint profit maximization, combining the times and the needs of both with a collective benefit [Benton Park, 1996].

Given the vast literature on this topic, it is preferable to focus on the analysed case in which, we anticipate that there is no possibility of collaboration between supplier and buyer. We thought that it would be appropriate to analyse therefore only models in the so-called "buyer's perspective" in the presence of an overall discount to be applied to all units (all-quantity) excluding cases with incremental discount. Because, in fact, this is not the case. Within the buyer's perspective, the method that assumes a constant in the evolution of demand (Non-Time-Phased demand) will be considered. This method is in contrast to the Time-Phased-Demand method.

“All-quantity Discounts in static assumptions are models where the variable demand is assumed to be continuous and deterministic. As it is known, the total cost associated with stock is the sum of the acquisition costs, ordering costs and holding costs. From the moment in which the cost function is convex, if there are no quantity discounts, the batch size is obtained by deriving the optimal function with respect to the amount and by requiring that the result is equal to zero. The solution depends on the amount we get the traditional EOQ Economic Order Quantity. Under the condition of aggregate discount instead, which is valid for total quantity, the stocks prices decreases when the total order increases, as determined by the offered discounts scales and based on the agreements reached with the supplier. A modified price $Pi$ is applied to all references of an order if they fall in a certain amount of quantities defined by [ $_{i+1}$ -1]. In this situation, the objective function is discontinuous at the boundaries of such domains, and the absolute minimum should be sought between these points of price breaks and valid points of minimum, therefore EOQ, calculated for each cost function, will remain the domain membership [Tinarelli, 1992]. From this often used theory, different authors have proposed modifications or clarifications.

## 2.2 Depended Demand Models

Within the business process, play great importance not only finished products but also those relating to all components (raw materials, semi-finished products, packaging etc.) that will train them. In this case, the question is then dependent on that "external" of the finished product (random). The goal is to constantly keep a suitable value of storage in stock for each level of the production process and in the case where they reduce, restore it immediately.

The models below are united by the concept of "lean synchronization". This philosophy aims to achieve a flow of products and services that always have exactly what customers want, in the required quantities, when they need it, where they need it and at the lowest possible cost [Slack, Chambers, Johnston, 2010]. The objective is therefore to produce only when needed and nothing more, without waste.

### 2.2.1 Just In Time (JIT)

It develops for the first time in Japan, put into practice in the '70s by the establishments "Toyota" with the aim of finding a system that would allow the company to respond as quickly as possible to market demands. The objective of the JIT is perhaps even more ambitious than the MRP, as it aims to ensure that each component arrives at the assembly line in the necessary amount and the time when it should be assembled. Having the right amount at the right time, neither before nor after.

As defined by Tinarelli [1992], the JIT is a management methodology of production that consist to produce exactly the quantities of each items required in the short term and not even those that were estimated it can sell in the future. Monden [2011] also emphasizes that if we apply the JIT across the enterprise; it eliminate all stocks of superfluous material in the factory and make it useless warehouses and stores. The inventory costs are thus decreased while is increased the turnover of capital. For this reason, it is also identified as a philosophy to zero stocks because the basic principle is to eliminate all waste in order to have an overall improvement in productivity.

It differs also from MRP (programmed system and central), for the use of so-called "kanban"[10], which allow the implementation of a system for the regulation of stocks managed directly by the departments and whose replenishment flows from a production centre to another self-adjust to the progress of production, without any higher-level, centralized. [Slack, Chambers, Johnston, 2010].

### 2.2.2 Material Requirements Planning – MRP

MRP is an approach introduced in 1975 by Joseph Orlicky, useful to calculate how many and which components or materials of different types are needed and in what timescales are needed. With the MRP technique arises then the goal of identifying [Vignati, 2010]:

- What components are needed to meet the production plan;
- The amount to be purchased and / or produce;
- The instants of time in which such quantities must be available.

Under optimal conditions, the MRP system should ensure the cancellation of stocks by submitting components only when they are needed. Specifically, the operation of the system is based on a substantial volume of information concerning the process. The schedule is developed based on [Grando, 1995]:

1. Master production schedule of codes, finished products and assemblies, schedule object. It constitutes the most important input for the MRP and guide all activities of production and supply which eventually combine to give life to the final products;

2. Bill of Materials, such as defined by Tinarelli [1992], represents the document that defines the structure of the product as precise of which and how many parts it is composed of a finished product. It describes, formally with tree structure or table, the explosion of a product in its entirety, according to a scheme of

[10] Japanese word for card or signal. It is often called "the invisible mover" because it controls the transfer of components between the different phases of operations. In its simplest form is a card used by a stage downstream to ask the upstream phase to send other pieces. Receiving a kanban triggers the movement, production or supply of a unit or a standard container units [Slack, Chambers, Johnston, 2010].

progressive detail, with the aim of determining the last requirement of each material or component [Grando, 1995];

3. Inventory Record File, which keeps track of inventory levels available for each component and material;

4. Lead time external and internal, at all levels and for all distinct codes.

This series of input allow to MRP to calculate thus the requirements of the components and of the materials at each level of assembly or manufacture, starting from the program of finished products to be assembled until reaching the maximum level of decomposition. Thereby, operating for periods and levels, allowing a strict control of timing of each order (thanks to the pre-calculated lead time) and the amount in storage, ringing, or be ordered.

# 3 Chapter - Cavallone S.r.l Business case

The first three chapters were instrumental in introducing the most relevant aspects of stocks, analysing costs, functions and management methods. In particular, management models aimed at improving the performance of the stock exposed. This chapter contains probably the important part of the job, where we proceed to the application of these models to a business case. After introducing the company and explained how the variables are defined, we can see if these theories are able to put the assumed benefits in practice.

In this chapter we will focalised on the Cavallone srl company on the base of his inventory management; type of business; the organizational structure ; operating systems; the style of leadership and , more generally , the organizational culture. Focusing on the company and its requirements, it will be analysed the inventory through an ABC analysis. The assumption that a stock control model is able to manage simultaneously all inventory is not always true. Rather, empirical rules explain how to focus on a critical product is more simple and useful for the purpose of such research.
From this, it will then pass to the analysis of sales of selected product; the obtained results will be the basis to building the management model.

## 3.1 Company presentation

The Cavallone Srl was born with the name of ELCA in 1956 in the field of repair of static and dynamic electrical machines. They are the years of the Economic boom that will mark the Italian economy. Concomitantly with economic development, in 1960, the company made a qualitative leap and started to be interested in industrial electrical systems. After many years, the ELCA has grown and has become one of the vanguard companies in the sector. The years spent focusing on installation, maintenance and repair of groups purchased and then resold, human capital and knowledge that has accumulated over time, led this company to become a leader company in its field in Puglia.

In 1969, the company changed the name and became Cavallone srl, with a new type of internal organization and business, to keep up with a new environment.

## 3.2 PRODUCTS, ORGANIZATION STRUCTURE AND ROLES

***Products***

The Cavallone srl is based on distribution of Electrical equipment, and inside it, there are four different business area:

- The first one is based on distribution of “Electrical material”, which is the area in the centre of our research. Cavallone srl has matured sixty years of experience in the distribution sector of electrical equipment. They are specialized in products and solutions for the market in its various sectors: civil, industrial, medium voltage, lighting, instrumentation, automation. Furthermore, they rely too highly qualified personnel, able also to realize electrical panels. That company is part of the group CODIME (Consortium Distributors Electrical Material) Elettroteca[11], which allows it to be highly competitive in the territory.

- “Security sector”, that offers specific solutions for each safety-related Requirements at home, in the workplace, in the public places, in banks, in industry and in commercial establishments, offering the most comprehensive range of anti-theft systems, fire prevention and CCTV.

- “Keluce” is the lighting division of Cavallone srl. It is a showroom where we can admire the design of the most popular brand and market trend. It offers targeted solutions for every requirement of design, both interior and exterior, and home automation systems for residential and tertiary. The synergy that links the company to the most important industries in the sector enables a continuous update on the development of artificial light, in particular on energy-saving products and innovative LED technology and optics.

- The “switchboards” sector is structured to offer the customer a finished and certified product ready for installation.

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[11] In 2007 was founded Elettroteca by some distributors of electrical equipment that detect and share a platform with the aim to pursue the sale "on line" of electrical equipment in large industrial companies. Then, it becomes consortium: the founding partners include that in order to make the most of the synergies should think in a logical group buying as well as selling group.
Elettroteca is now a national group that operates on much of the Italian territory, open to new collaborations that share our project and our values and label products to be developed, because one of the first purpose of Elettroteca is to be direct protagonist of sale.

The experts of Cavallone srl - based on drawings, specifications and bills of quantities supplied by the customer - derive the dimensioning of low-voltage electrical panel and draw up the front-end design, the list of materials and the calculation of the labour required for assembly and wiring.

After approval of the budget, the framework is prepared and delivered to the client, complete with certificate of conformity and updated wiring diagrams. The division is also involved in the management of medium voltage panels and resin power transformers and oil, always present in stock and ready for delivery to the customer.

**Organization structure**

An organizational structure defines how activities such as task allocation, coordination and supervision are directed toward the achievement of organizational aims. Depending on its objectives, it can be structured in many different ways. The structure of an organization will determine the modes in which it operates and performs, and allows the expressed allocation of responsibilities for different functions and processes to different entities. [Lawrence B. Mohr, Explaining Organizational Behavior. The Limits and Possibilities of Theory and Research., Jossey-Bass Publishers, 1982.]

Exists different type of corporate governance:

- Functional structure is one of the most common organizational structures. Under this structure, the organization groups employees according to a specialized or similar set of roles or tasks. While functional structures operate well in stable environments, where business strategies are less inclined to changes or dynamism, the level of bureaucracy makes it difficult for organizations to respond to changes in the market quickly. [Julie Davoren, studio]
- Divisional structure, its divisions according to the specific demand of products, markets or customers, its focus on a higher degree of specialization within a specific division, so that each division is given the resources and the autonomy to fast react to change in their specific business environment. Moreover, this structure has a subset of specialized and different specialized SBU’s that satisfying the demand of different markets, products and costumers. The different between functional organization and divisional organization is that the first one is oriented to satisfy all shareholders of the company (customers, markets and

products), on the contrary, Divisional organization is oriented to satisfy a specific group that is inside the company.

- Matrix structure is a mix between functional and divisional model, and it can have different levels of integration.

Cavallone srl is organised following the divisional model, in this way they are able to a fast response of specific group of customers, markets and products, and because that division are more specialized in a certain field. Follow the company's organizational chart to understand the roles and the responsibility.

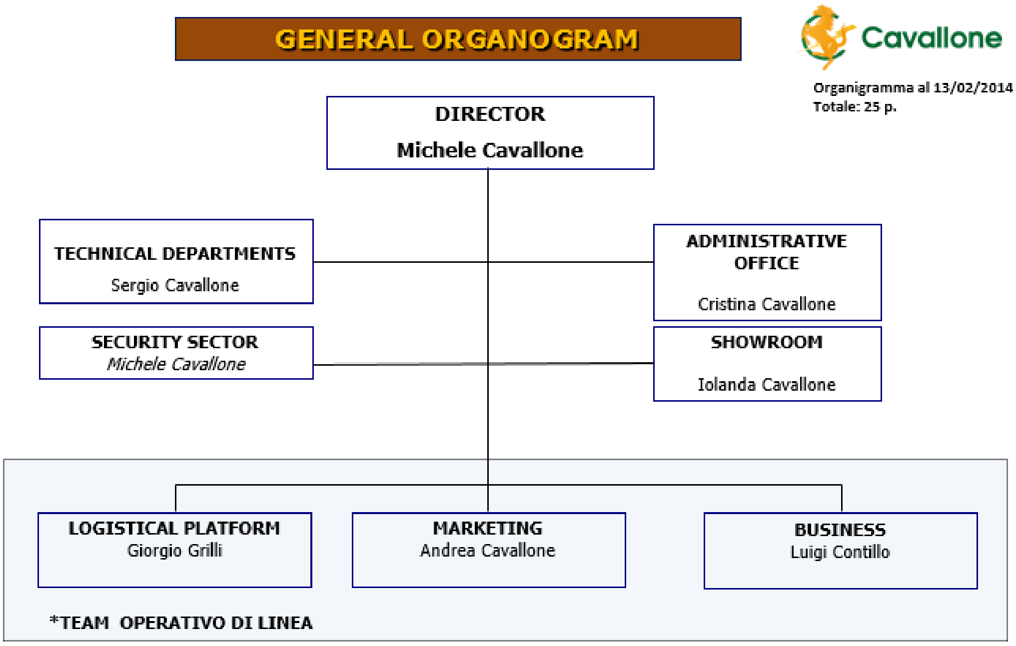



*Fig. 3.1 - Cavallone srl General organogram*

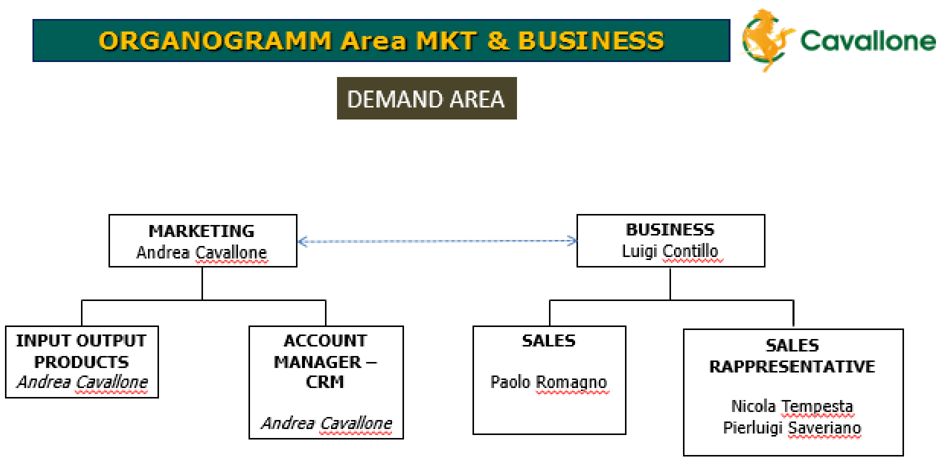


*Fig. 3.2 – Organogram area marketing and business*

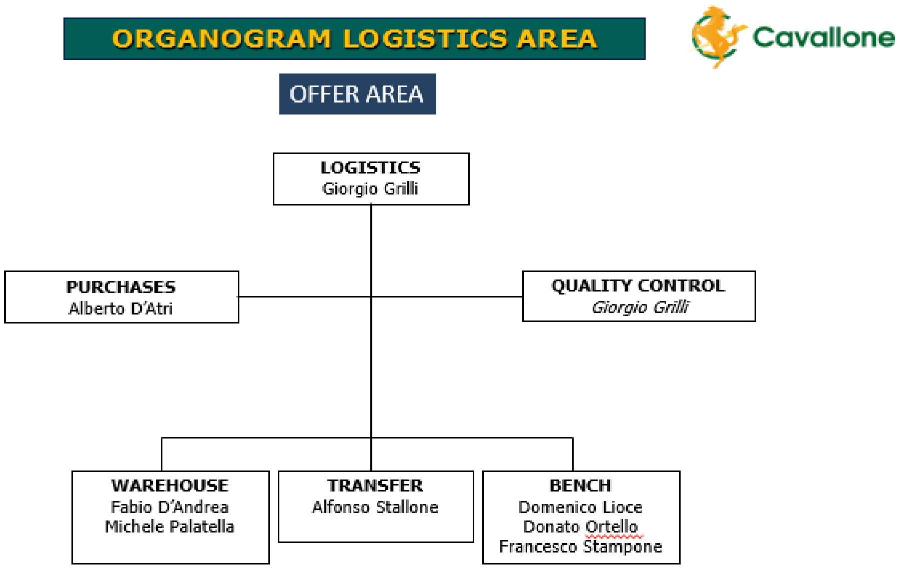



*Fig. 3.3 – Organogram logistics area*

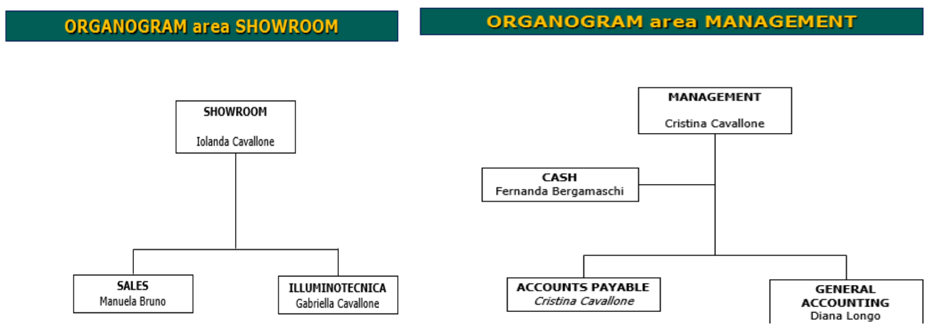



*Fig. 3.4 – Organogram area showroom and management*

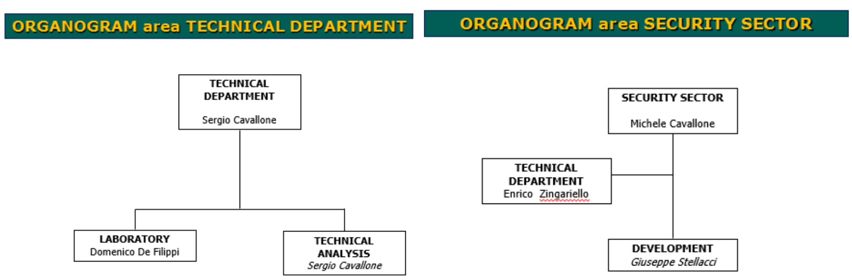



*Fig. 3.5 – Organogram area technical department and security sector*

**Roles and responsibilities**

*General Director* of Cavallone srl is Michele Cavallone, he has the main responsibility inside the company. His most important task are to define Business strategies first, without that, the company does not know what strategy has to follow. Maintains a consistent organizational culture that determine the modes in which the company operates and performs, and allows the expressed allocation of responsibilities for different functions and processes to different entities. Create team spirit and delegation and, in the same time, distributes financial and human resources. Defines and monitors the achievement of business objectives to understand if the followed strategy is correct or not. All these activities are completely customer-oriented.

*Logistics coordinator* is the administrator of logistics area. He has some tasks, first to analyse and optimize logistics costs, such as, purchase costs, maintenance costs "buffer Stock", transportation costs. Furthermore, he has to maintenance and improvement of the service level; Personnel Management; and, in the end, the organization of cyclical inventories.

That entire task has as an input the demand area, and as output customers.

*The Marketing coordinator* has skills and task that include all of marketing area:

- Process analysis of the market, competitors and products;
- Research new products and proposes the exclusion of non-competitive products (phase-in / phase-out);
- Locate new commercial channels;
- Assists the commercial coordinator in drawing up price lists, pricing and forecasting budget;
- Organize the promotion and advertising of the products and the company logo;
- Introduces new computerized systems to streamline the relationship with the customer (see CRM systems[12])
- Identify potential suppliers (purchasing marketing);

[12] Customer relationship management (CRM) is a term that refers to practices, strategies and technologies that companies use to manage and analyze customer interactions and data throughout the customer lifecycle, with the goal of improving business relationships with customers, assisting in customer retention and driving sales growth. CRM systems are designed to compile information on customers across different channels - or points of contact between the customer and the company - which could include the company's website, telephone, live chat, direct mail, marketing materials and social media. [techtarget.com]

- Organize, with suppliers, courses and updates on a monthly basis.

All of those activities are pushed by the market and pulled by commercial sector and costumers.

*Purchasing agent (Buyer),* which is in the area of logistics. He has a direct boss of course, the logistics coordinator, who must report all its activities.

- Care of the administrative and operational aspects involving the purchase planning (stock levels, etc.)
- Preparation of any inquiries and analysis of vendor offerings
- Comparison of offers
- Negotiation management with suppliers to purchase inventory
- Preparation of orders and framework agreements
- Maintaining relationships with suppliers
- Coordination with the business side for negotiations with suppliers for purchases on order
- Optimization of solicitous and order confirmations

All of those activities have as input the demand area, and as an output the warehouse.

*Manager online sales* and *Counter Sales*, which is involved in logistics area. He has to report to the marketing coordinator, that is his direct manager. The major tasks that is should be perform are to management and withdrawal of goods for orders that come from online channels and, When not engaged, it performs the functions of counter Sales. His input is demand area, and the output is customer focus.

*Warehouse manager*, is included in logistics area, and he has to report directly to the sole administrator. Main tasks and activity that he has to perform are:

- Upon arrival of the goods, immediately executes the partial entry in order to place all employees aware of the goods arrived and not yet stored on the shelf
- Quality control and quantity of the goods received from suppliers
- Registration with management software, goods inbound from the warehouse in the shortest possible time, and finally put the product immediately in a position to be sold

- Check the conformity of the transport document with the order, communicating any difference to the supplier and, for information, to the purchasing department and accounting
- Management of the orders coming from the sellers, by representatives and from the bench for delivery on building sites
- Care and disposal of products and goods on the shelves of the store and of the bench in accordance with the mapping;
- Transport of personnel management and warehouse
- Deliveries programming
- Maintenance and improvement of the service level
- Optimization of transportations costs

For that position and role, the direct input is the supplier, whereas the output are bench and transports.

*Carrier*, that is involved in the area of transport logistics, and has to report all of his activities to the warehouse manager.

Main tasks are:

- Make the delivery of products to customers according to delivery schedule under the supervision of warehouse
- When not engaged, it performs the functions of warehouseman

The input for that position is the coordinator of logistics, and the output is the customer.

*Warehouseman*, which is involved in the logistics area of the company, and has to report to the warehouse manager.

Main activities:

- Takes care of the disposal of products and goods on the store shelves, the bench and the exhibition by placing the new arrivals behind or underneath the existing ones
- Takes care of the order and cleanliness of the shelves, warehouses and the forecourt
- Receives orders for supplies and cutting cables
- Prepare orders to customers for deliveries scheduled
- Takes the orders by bench customers for the construction site or other locations, and then, to handed them to the warehouse manager

For *warehouseman*, the input is the supplier, and the output are bench sales and transports.

*Counter Sales*, involved in the logistics area, has to report to the commercial coordinator. Main activities and tasks:

a. Compilation of the picking list in its entirety, starting from the customer's request
b. Management of the relationship with the customer
c. Check the availability of the goods to the pick locations for the enslavement to the sales desk
d. Prevent and report stock-outs
e. Preparation of the bench and exhibition spaces
f. Recurring communication with the marketing coordinator about obsolete products, slowly rotating, most requested products and customer behavior, by supplier groups
g. Preparation and delivery of products to the customer in a timeframe consistent with customer satisfaction
h. Carrying out the requests for quotation at the counter and follow them up to the positive or negative conclusion
i. Take orders from customers at the counter for deliveries on site building or other locations and, after, delivered it to the warehouse manager
j. Weekly reporting
k. (The person in charge of returns) makes the return of the goods and does sign up a credit note for counterproof by another counter sales
l. He makes the bill vision and sign up for counterproof by another counter sales
m. Returns the material sold for cash only AFTER the presentation of the invoice / receipt
n. He makes sure that customers signing in legible way the documents

The direct input are the warehousemen and the output are the clients.

*Business coordinator*, he is involved in the commercial area, and has to report to the sole administrator.

His main activities are:

a. Managing agents, sellers and sales assistants

b. Preparation and management of a sales plan and sales budget
c. Maintenance and improvement of customer contacts
d. Report to the marketing department about the behaviour of costumers/ competitors and about the products to be excluded or introduce
e. Management of negotiations with suppliers for purchases on commission
f. Introduces new computerized systems to streamline the relationship with the customer (see CRM systems)

His work input are bench sales, customer, and marketing department, and the output are the costumers.

*Sales representative*, is involved in commercial area, and has to report directly to the commercial coordinator.

a. Draw up the preform sales orders on paper-based or on computer-based
b. It informs continuously on the market situation in which it operates and communicates it to the commercial coordinator
c. Visit and maintains constructive contacts with customers
d. Implements the sales plan
e. Work using the CRM program

His input is the commercial coordinator, whereas the output are the customers.

In the end, there is the *Administration coordinator* that works in administration department. He has to reports directly to the sole administrator.

The main activities are:

- Update tax registers
- Check budget constraints
- It implements maintenance policies of the accounting warehouse.

The input are various business functions, and the output is the sole administrator.

## 3.3 CURRENT INVENTORY MANAGEMENT

Is important to highlight that Cavallone srl has an excellent procedure for inventory management. Indeed, it bought one of the best software for the management and forecasting of inventory. His name is E3TRIM, it consider the customer service level as a key reference point, identifying it, on a metaphorical level, as the 'Steering "System for" Driving "stocks towards the desired benefits. This is desirable if we manage a company of Intermediate Distribution or Retail. In fact, these are commonly service companies that need to keep in stock thousands of items to meet the demands of their clients. It is results efficient manage the average service level through the classes, and usually try to have a high level of service for strategic products, which cannot be missing, while keeping a low level of service for products not important. The most common method is the analysis and breakdown of items for Classes A, B and C. The Class A items, typically high-rotating have the highest level of service, while those belonging to B and C generally have a lower service level. Although this method is an excellent starting point, we can step forward and establish service levels also based on the profit of the article and on the geographical region in which they are marketed.

The software provides the necessary data to identify the levels of service, which match best with the directives and the Company's interests. The result will be to improve the cost-benefit ratio for each article that we want to keep in the set.

It should also be noted that a proper Service Level Management also serves to enhance or maintain the image of his company in the market in which it operates. Once established the Service Level for every Classes / Items and Geographical Area where it is marketed, the system optimizes the management of stocks and orders to suppliers taking into account all the financial variables such as Cost of Capital immobilized in stocks, maintenance cost of inventory, cost of sending the order and others. Another important thing is the management of items / location (SKU); it means that the same article kept in stock for more Branches / deposits is run according to demand of each subsidiary / deposit.

The philosophy used for inventory optimization is to break down the procurement process into seven steps (Step), each of which uses the most advanced techniques, tested in more than 21 years, and then contribute to the expected results mentioned above.

Seven "Steps" are used in the purchase process:

*1. Demand Forecasting*

*2. Prediction of Delivery Terms (lead-time)*

*3. Cycle Analysis of Order to the Supplier*

*4. Analysis of the Customer Service Level*

*5. Supply*

*6. Analysis Special orders*

*7. Validation of the Order to the Supplier*

***Demand Forecast***

An issue of fundamental importance in every supply system uses the advanced statistical techniques developed especially for forecasting demand for Low-rotating. The system automatically selects the "routine" calculation without any operator intervention. Of the seven steps of the purchasing process, this phase should have more attention. Although many buyers are now supported by historical data of 2 or 3 months, a historic of 2 or 3 years would be the most appropriate period to allow proper analysis of information. Distinguishing the demand from sales, it calculates lost sales, a key factor for the correct supply.

Seasonal items. For this class the system indicates whether an article is seasonal and automatically creates a seasonal pattern according to the deposit/ Subsidiary in which is located.

***Forecast of Delivery Terms***

There are still few companies that invest time and resources in the area of forecasting of delivery time (Lead Time), as important as the demand forecast. In fact it is difficult to Buyer (purveyors) to keep the goals on the service level with the minimum level of stocks no useful statistics on suppliers.

The system automatically calculates the different times of delivery by keeping them constantly updated. Also it indicates immediately when the Suppliers' Delivery Times are worse than those agreed upon in advance.

### *Cycle Analysis of Order to the Supplier*

With a sophisticated economic simulation, the system automatically identifies the optimal frequency for each supplier to submit orders that maximizes profit for the client company. In an everyday practice, due to lack of time and efficient tools to support the purchasing office, we find in many companies used to order a “fixed cycle”. The order at a fixed cycle, in the case where it is not a constraint by the supplier, should be avoided because source of “Overstock". The new philosophy is therefore to be ordered when there is a need and not according to the day of the week.

### *Analysis of Customer Service Level*

Currently few companies carry out a careful study on the best goal of service level to be assigned to each item in the warehouse function / Subsidiary in which it is located. This study is extremely important because this also depends on the level of stock needed. Inventory Management shall offer its cooperation to determine the best values of the Services level until we reach the detail Item / Location. The system will then to maintain these values by calculating properly automatically the security stock for each item in the geographical area in which it is marketed.

### *Procurement*

After ending the previous four steps, the calculation of the quantity to be ordered for each article and deposit / Subsidiary, we get accurately and automatically by the software. Important feature is that the Order Balance required relieving urgent orders unplanned. The system using processing during the night, examines all the suppliers, everyday, repairing the order proposals to be submitted to the Buyer (purveyors) at the beginning of their daily activities.

### *Analysis Special Orders*

Besides the normal amount to be ordered to maintain the desired Services level according to the "normal" business, it is appropriate that the Buyer obtains the greatest economic advantage of any special offers from suppliers such as, discounts, price increases and extended payment terms.

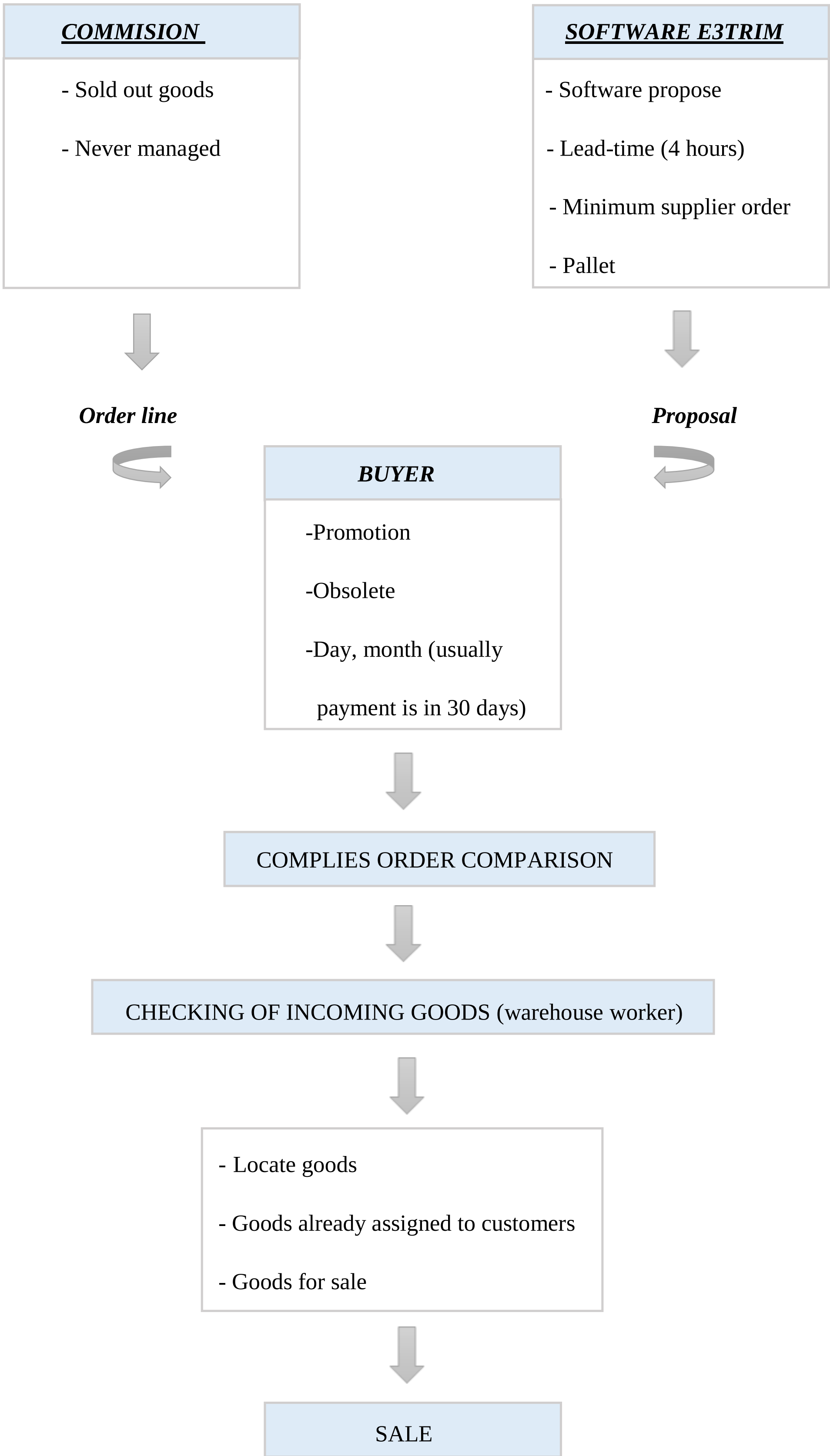
This technique, which is called "Forward Buy" (Speculative Buying), calculates the quantity to be ordered, in the face of each offer, which makes up the Profit for Distribution Company. This is achieved by managing the company's financial parameters as well as an excellent anticipation of even apply for low rotating. The company that create a software, to improve the profit, recommends the technique of Speculative Buying.

### *Validation of the Order to the Supplier*

Now that the order has been created taking into account the special orders, before formulating an order proposal to Buyer, the system performs a self-check to ensure that it meet the constraints of the suppliers such as minimum and multiple in number of pieces, minimal in terms of the Order value, Minimums by weight or volume, etc. If the order does not respect these constraints will recalculates the order to meet all the imposed constraints, of course in an automatic and balanced manner. This, sometimes, deprives the Buyer by one of his toughest tasks as manual adjustment of the order in order to respect the constraints of Suppliers, because it can sometimes require a lot of time.

The Cavallone srl does not just rely on software; it combines robot's calculations and technology to man's capabilities (Buyer). Furthermore, for Cavallone srl is very important not to run into a stock out risk.

This is the purchasing process of Cavallone srl :



After analysing the purchasing process, we want to focus our attention on the problems that the inventory may encounters. First of all there is a common problem which “lost sales”, this happened when we do not have a product available in my company, and we need to order it but the client cannot wait. Another problem is the “erroneous sales”, that problem can also lead to loss of sales, because we may have mistakenly given the product to another customer. Furthermore, we have also an “obsolescence” problem of goods, which can be natural or technological.

In the end, we have a “over stock” problem, that occur when the supplier forces me to buy a minimum lot of pieces. On the contrary, we can have also “stock out”, when we run out of stocks of a certain item in the store or warehouse. This situation, in addition to causing damage to the image of the brand and dealer, may have the effect of directing the demand towards other brands, resulting in a loss of customers and therefore a decrease in revenue.

It is precisely to avoid this detrimental situation that many businesses, especially those operating in the industrial goods sector, keep in stock a security escort (buffer stock) and rely on a shortlist of suppliers; thus, in fact, they can cope with unpredictable changes in demand or any delays in deliveries and so avoid breakage of stock.

## 3.4 ABC ANALYSIS AND CHOICE OF PRODUCT TO FOCUS

An operating method for efficiently managing an inventory comprising a large number of articles is the ABC analysis. The goal, as already discussed in the previous chapter, is to subdivide the articles by grouping them into classes "for concentration of value" [Marchetti, 2010].

The ABC analysis in this context will mainly be used to see how the revenue is distributed on categories of inventories. It takes into account the turnover because it is a commercial company and not production. Using the Pareto Law is expected that at least 80% of sales is concentrated in 20% of the inventory list.

To begin the analysis were extrapolated data of the supplier of the year 2013 from business software and have been exported to Excel; then it proceeded as follows [Tinarelli, 1992]:

a. Said *n* the total number of items to be examined and $vi$ (i = 1,2, .., n) the turnover i-th article are arranged in descending order of the values in Euro for the calculation of the percentage on revenue;
b. Identify the percentage impact on revenue $v_i$ / $V$ with $V = \Sigma n 1\ vi$
c. Said, it add another column in which the cumulative sums of $bi$ values will be calculated;
d. Based on the value of the cumulative percentages of the turnover part numbers have been divided into four classes, using the following formula: = IF (% cumulative <= 80%; "A"; SE (% cumulative <= 90%; "B"; SE (% cumulative <= 100%; "C";)). Then it is

2. *Class A*: items which account for 80% of sales revenue;
3. *Class B*: items which account for 10% of sales revenue;
4. *Class C*: items representing 10% of the sales revenue .

We carried out an ABC analysis on 1500 products treated by the company, for a more accurately analysis. From conversations that took place between myself, the sales manager and the buyer, and the results from the ABC analysis, it seemed logical to focus our attention on products that represent the core of the company, bringing nearly 30% of sales, the “coils of electric cables”.

In the following tables, we reported only revenue and the second one by average stock conduct the data related to the product of our interest, the first ABC analysis.

| Code | Description | Revenues | %Revenues on tot | % cumulated | Class Revenues | Class Average stock |
|---|---|---|---|---|---|---|
| | | | | | | |
| FG71X240 | FG7 1X240 SU BOBINA | € 91.945,27 | 4% | 20% | A | A |
| FG7R4G16B10 | FG7 4G16 SU BOBINA | € 86.088,67 | 3% | 29% | A | A |
| N07VK1X4BLM1 | N07VK4 BLU 5015 | € 84.210,15 | 3% | 31% | A | A |
| N07VK70NEB | N07VK70 NER SU BOBINA | € 85.716,39 | 2% | 33% | A | A |
| N07VK1X2,5MA | N07VK2.5 MAR | € 86.355,02 | 2% | 36% | A | A |
| FG75G4 | FG7 5G4 SU BOBINA | € 85.388,19 | 2% | 38% | A | A |
| N07VK1X1,5GRN | N07VK1.5 GRI | € 32.391,99 | 2% | 40% | A | A |
| FG7R3G2,5M1 | FG7 3G2.5 MATASSA | € 14.446,36 | 2% | 45% | A | A |
| FA-12BAM100 | CAVO ANTIF.4X0.22+2X0.50 300V | € 12.336,13 | 2% | 47% | A | A |
| N07VK1X2,5GRN | N07VK2.5 GRI | € 12.200,40 | 1% | 50% | A | A |
| RG7H1M11X95 | CAVO MEDIA TENS.1X95/20KV 32GR | € 12.930,00 | 1% | 52% | A | A |
| N07VK1X6BLM1 | N07VK6 BLU 5015 | € 10.548,91 | 1% | 53% | A | A |
| RG7H1M11X50 | CAVO MEDIA TENS.1X50/20KV 32GR | € 10.313,10 | 1% | 54% | A | A |
| N07VK10GRM | N07VK10 GRI MATASSA | € 5.222,56 | 0% | 65% | A | A |
| FROR5G1 | FROR 5G1 SU BOBINA | € 4.786,64 | 0% | 68% | A | B |
| FG74X1.5 | FG7 4X1.5 SU BOBINA | € 4.005,76 | 0% | 71% | A | B |
| N07VK1X1,5RSM | N07VK1.5 ROSA | € 3.945,77 | 0% | 76% | A | C |
| DX15020 | TUBO CORRUGATO D20 NERO | € 3.943,21 | 0% | 76% | A | A |
| N07VK10BLM | N07VK10 BLU MATASSE | € 2.990,02 | 0% | 78% | A | A |
| FROR5G1M | FROR 5G1 MATASSA | € 2.827,77 | 0% | 79% | A | A |
| G9K1X2,5BLM1 | N07G9K 2.5 BLU AFUMEX | € 2.647,54 | 0% | 80% | A | B |
| N07VK16BLM | N07VK16 BLU MAT | € 1.291,07 | 0% | 81% | B | B |
| G9K1G2,5GVM1 | N07G9K 2.5 GIALLO/VERDE AFUMEX | € 2.271,41 | 0% | 81% | B | A |
| 753143 F AL | DADO PIATTO 41/41 M8 | € 1.749,00 | 0% | 84% | B | C |
| DX15032 | TUBO CORRUGATO D32 NERO | € 1.672,57 | 0% | 84% | B | B |
| N07G9K4GV | N07G9K 4 GV AFUMEX | € 1.435,42 | 0% | 85% | B | A |
| | | | | | | |
| TOTAL | | € 663.659,33 | | | | |

*Fig. 3.6 – ABC analysis about revenues*

The same procedure was followed to gather the items according to the value of the stock. For the year 2014, the ABC of the warehouse value is:

| Code | Description | Purchasing cost | Avarage cost | Class |
|---|---|---|---|---|
| | | | | |
| FG71X240 | FG7 1X240 SU BOBINA | € 11.990,48 | € 35.971,44 | A |
| FG7R4X16B10 | FG7 4X16 SU BOBINA | € 4.453,01 | € 35.624,09 | A |
| N07VK1X4BLM1 | N07VK4 BLU 5015 | € 203,21 | € 8.331,57 | A |
| N07VK70NEB | N07VK70 NER SU BOBINA | € 3.551,45 | € 31.963,04 | A |
| N07VK1X2,5MAM1 | N07VK2.5 MAR | € 129,56 | € 8.810,22 | A |
| FG75G4 | FG7 5G4 SU BOBINA | € 1.337,93 | € 73.586,04 | A |
| N07VK1X1,5GRM1 | N07VK1.5 GRI | € 81,21 | € 4.466,28 | A |
| FG7R3G2,5M1 | FG7 3G2.5 MATASSA | € 662,96 | € 15.247,99 | A |
| FA-12BAM100 | CAVO ANTIF.4X0.22+2X0.50 | € 245,12 | € 1.470,71 | A |
| N07VK1X2,5GRM1 | N07VK2.5 GRI | € 129,56 | € 7.385,03 | A |
| RG7H1M11X95 | CAVO MEDIA TENS.1X95/20I | € 9.100,00 | € 18.200,00 | C |
| N07VK1X6BLM1 | N07VK6 BLU 5015 | € 298,59 | € 12.839,33 | A |
| RG7H1M11X50 | CAVO MEDIA TENS.1X50/20I | € 5.598,00 | € 22.392,00 | A |
| N07VK10GRM | N07VK10 GRI MATASSA | € 622,92 | € 21.179,31 | A |
| FROR5G1.5 | FROR 5G1.5 SU BOBINA | € 596,24 | € 16.694,61 | B |
| FG74X1.5 | FG7 4X1.5 SU BOBINA | € 580,27 | € 17.988,28 | C |
| N07VK1X1,5RSM1 | N07VK1.5 ROSA | € 83,14 | € 6.318,56 | C |
| DX15020 | TUBO CORRUGATO D20 NER( | € 7,28 | € 1.157,52 | B |
| N07VK10BLM | N07VK10 BLU MATASSE | € 622,92 | € 7.475,05 | A |
| FROR5G1M | FROR 5G1 MATASSA | € 471,29 | € 11.311,06 | B |
| G9K1X2,5BLM1 | N07G9K 2.5 BLU AFUMEX | € 240,69 | € 18.292,06 | B |
| N07VK16BLM | N07VK16 BLU MAT | € 954,61 | € 15.273,82 | B |
| G9K1G2,5GVM1 | N07G9K 2.5 GIALLO/VERDE A | € 229,44 | € 10.783,45 | B |
| 753143 F AL | DADO PIATTO 41/41 M8 | € 37,00 | € 8.510,00 | C |
| DX15032 | TUBO CORRUGATO D32 NER( | € 23,46 | € 2.533,46 | C |
| N07G9K4GV | N07G9K 4 GV AFUMEX | € 326,23 | € 15.006,72 | A |

*Fig. 3.7 – ABC analysis about average stock*

Mixing these two tables above (*Fig. 3.6 and Fig 3.7*), the revenue and the average stock, we will get a cross-analysis ABC. (*Fig. 3.8*)

| Code | Class Revenues | Class Average stock | Cross analysis |
|---|---|---|---|
| | | | |
| FG71X240 | A | A | AA |
| FG7R4G16B10 | A | A | AA |
| N07VK1X4BLM1 | A | A | AA |
| N07VK70NEB | A | A | AA |
| N07VK1X2,5MAM1 | A | A | AA |
| FG75G4 | A | A | AA |
| N07VK1X1,5GRM1 | A | A | AA |
| FG7R3G2,5M1 | A | A | AA |
| FA-12BAM100 | A | A | AA |
| N07VK1X2,5GRM1 | A | A | AA |
| RG7H1M11X95 | A | A | AA |
| N07VK1X6BLM1 | A | A | AA |
| RG7H1M11X50 | A | A | AA |
| N07VK10GRM | A | A | AA |
| FROR5G1 | A | B | AB |
| FG74X1.5 | A | B | AB |
| N07VK1X1,5RSM1 | A | C | AC |
| DX15020 | A | A | AA |
| N07VK10BLM | A | A | AA |
| FROR5G1M | A | A | AA |
| G9K1X2,5BLM1 | A | B | AB |
| N07VK16BLM | B | B | BB |
| G9K1G2,5GVM1 | B | A | BA |
| 753143 F AL | B | C | BC |
| DX15032 | B | B | BB |
| N07G9K4GV | B | A | BA |

*Fig. 3.8 – ABC Cross-analysis*

Hereinafter, there are charts that summarize the ABC analysis conducted on 1500 total products:

| Class | Average stock | % Revenues on tot. | % Cumulated | N. articles | % N. Articles on tot. |
|---|---|---|---|---|---|
| A | € 530.621 | 80% | 80% | 113 | 7,53% |
| B | € 61.488 | 10% | 90% | 86 | 5,73% |
| C | € 61.498 | 10% | 100% | 1301 | 86,73% |
| | | | | | |
| | | | | | |
| TOTALE | € 653,607 | 100% | 100% | 1500 | 100% |

*Fig. 3.9 – ABC average stock all products*

| Class | Revenues | % Revenue | % Cumula | N. articol | % N. Articles on tot. |
|---|---|---|---|---|---|
| A | € 1.332.147 | 80% | 80% | 90 | 6,00% |
| B | € 167.081 | 10% | 90% | 115 | 7,67% |
| C | € 166.684 | 10% | 100% | 1.295 | 86,33% |
| | | | | | |
| | | | | | |
| TOTALE | € 1.665.913 | 100% | 100% | 1.500 | 100% |

*Fig. 3.9.1 – ABC revenue all products*

| | Average stock | | | | |
|---|---|---|---|---|---|
| Revenues | | A | B | C | TOT |
| | A | 48 | 18 | 25 | 91 |
| | B | 18 | 21 | 76 | 115 |
| | C | 46 | 48 | 1200 | 1294 |
| | | | | | |
| | | | | | 1500 |

*Fig. 3.9.2 – Chart cross average stock/revenues*

| Fatturato/ Giacenze | | |
|---|---|---|
| Classe | N. Articoli | % sul totale |
| AA | 48 | 3% |
| AB | 18 | 1% |
| AC | 25 | 2% |
| BA | 18 | 1% |
| BB | 21 | 1% |
| BC | 76 | 5% |
| CA | 46 | 3% |
| CB | 48 | 3% |
| CC | 1.200 | 80% |
| | | |
| TOT. | 1.500 | 100% |

*Fig. 3.9.3 – Summary diagram*

Following a careful analyses of all products in the company's warehouse, and after a long discussion with the buyer and the sales manager of Cavallone srl, we decided to put our attention on coils of electric cables. That category represent the 30% of total revenues for the company, is a sort of core business for Cavallone srl. Furthermore, in order to validate our choice, and to understand how important is this category of products for the company, we can say that it was purchased a facilities used as a warehouse for sole use of the coils of the electric cables.

We have analysed above all the entire warehouse taking into account 1500 products, after this analysis, we focused our attention on a category of products that represent the core business for the company. Finally, we focused on a single product, on a single type of cable that is placed in AA box inside ABC cross-analysis (Fig.3.8). The chosen item is electrical cable with code: FG75G4 on coils. It is a product highly demanded by customers for its technical prescriptions and reliability. For a more comprehensive study, we need to understand, through a brief description, the item subject of our analysis. Cables for control and signalling, this category of cables is used for the connection of the control equipment, measuring, signalling, and in all those cases where it is necessary to transmit the signals, which are not affected by electromagnetic interference in the environment. Is possible to roll 800 meters of this cable around the coil.

How we said in the first chapter, the item that is in AA box (revenues A - stocks A) should have more attention instead of the other area (AB, BA, AC, CA, BB, CC, etc). In fact, it is considered the area to have special attention because it could happened two extreme situations:

- Any stock-outs produce drastic declines in sales
- It is the area in which we can intervene to reduce inventory amount

How is possible to see by the ABC analysis; Cavallone Srl Company has a good inventory management since 2010, year in which they bought a management software.

Nevertheless, we can help the company, in accordance with the sales manager and buyers, to better manage the product FG75G4 having a lower cost function, and therefore, a reduction of inventory amount.

*Fig. 3.9.4 Picture of electrical cable's coils*

# 4 CHAPTER - DEMAND AND COSTS ANALYSIS

In this chapter, we proceeded to estimate the demand and the stock costs. The demand estimation was conducted using statistical tools (ARIMA, SARIMA, Gretl) and studying the historical series. After demand's analysis, becomes logical to get all the elements necessary for final construction of the mathematical model.

To this end, we try to reconstruct the company operation's chain, in order to understand whom, and with what effort, has been involved in the preservation and ordination of the product; and if there were other factors that influenced the decisions of the buyer.

By observation and the use of data and estimates, we were able to calculate the ordering and holding costs, they are variables necessary to develop management models.

## 4.1 DEMAND ANALYSIS

Often occurs, in order to estimate future demand, to refer to historical sales of the product. It might think that the historical sales data are not a reliable because over the months and years has been encountered a stock-out, then, the sales does not coincide perfectly with the actual demand. In our case, this is not to be taken into account because the company has never gone into stock-outs, being more the scarcity costs than those to have an over-stock for it. Resulting benefit that the historical of sales exactly matches with demand.

| Months | Months | Year 2012 | FG75G4 coils sales 2012 | Year 2013 | FG75G4 coils sales 2013 | Year 2014 | FG75G4 coils sales 2014 |
|---|---|---|---|---|---|---|---|
| Gen | 1 | | 3 | | 3 | | 3 |
| Feb | 2 | | 3 | | 3 | | 4 |
| Mar | 3 | | 4 | | 4 | | 4 |
| Apr | 4 | | 4 | | 4 | | 4 |
| May | 5 | | 4 | | 4 | | 4 |
| June | 6 | *2012* | 4 | *2013* | 5 | *2014* | 5 |
| July | 7 | | 5 | | 5 | | 5 |
| Ago | 8 | | 4 | | 4 | | 4 |
| Sep | 9 | | 4 | | 4 | | 4 |
| Oct | 10 | | 4 | | 4 | | 4 |
| Nov | 11 | | 4 | | 3 | | 3 |
| Dec | 12 | | 3 | | 3 | | 3 |
| TOT | | | 46 | | 46 | | 47 |

Personal elaboration about historical demand of product FG75G4

In *Figure 4.1* we show the demand series collected at the Cavallone s.r.l. over the last three years. As we can see, the demand is almost stationary, and have to take into account the same trend all over the 3 years.

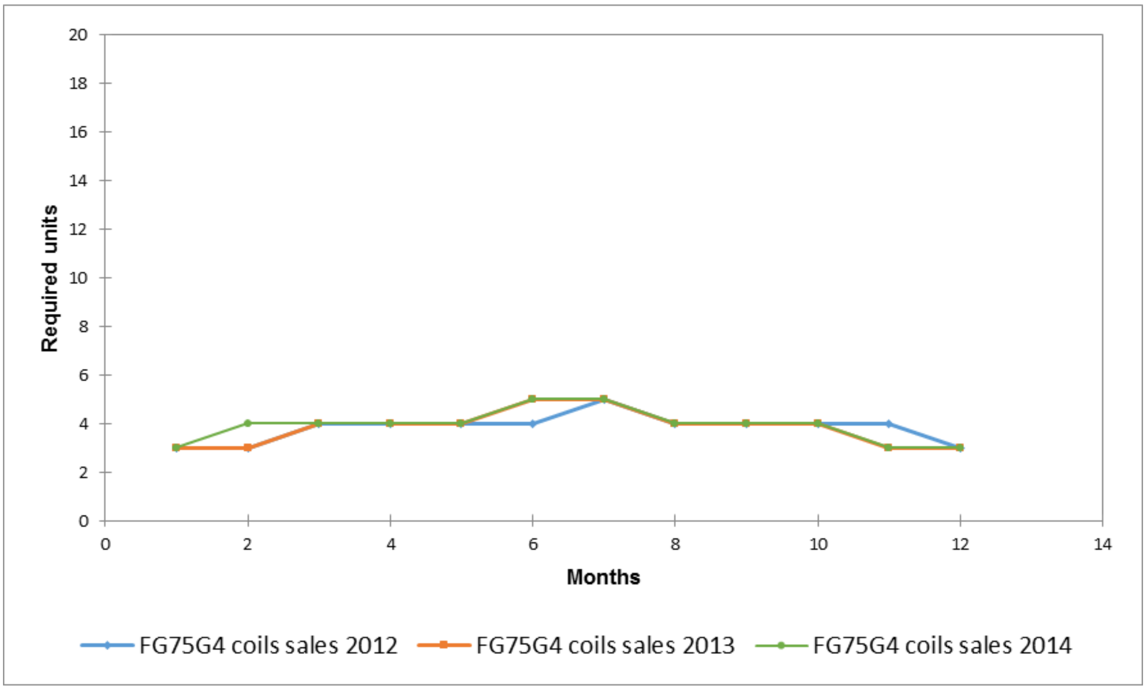



*Figure 4.1 Demand SKU FG75G4 years 2012 blue, 2013 green and 2014 red one. (Personal elaboration)*

Given the variable Y measured over time (t), indicated by $Y_t$, its values are then naturally ordered with respect to time.

To select an appropriate forecasting method is necessary to consider the different type of data patterns of a time series. The data generating process is written as $Yt = f(t) + \varepsilon t$ and the focus is primarily on the deterministic part f (t), i.e. the trend components, cycle and seasonality. Relegating the stochastic component $\varepsilon t$ to a residual role.

- *Stationary*: It is a fluctuation around a constant level or mean.
- *Trend:* It is a growth or decline over several periods. It represents the long-term component of the phenomenon. Is a component that varies slowly over time and determines the level of the series, i.e. $lt$. [Di Fonzo, Lisi, 2005]
- *Seasonal*: A seasonal variation may reflect weather conditions, school schedules, holiday's causes. It is typical for series whose frequency lays below the year (days, months, and quarters). This component could be disregarded for long-term analysis but must be taken in account for short-medium term analysis.
- *Cyclical:* It is a rises and falls not of a fixed period. The cyclical component is the wavelike fluctuation around the trend that is usually affected by general economic conditions (business cycle). If this component exist completes the cycle over several years. [Wei, 2006]

The purpose of the statistical analysis of a time series consists in modelling the dependence and in trying to explain the random mechanism that generated it. In the related literature, many theoretical models that combine many of the mentioned components. In practice, only a few of them are suitable to be adapted or rather to express the time series effectively. The choice of a model must inevitably follow the benchmarks. A good procedure of choice is what we consider a good compromise between goodness of fit (the "model's ability to explain" the observed data) and complexity (number of model parameters). I.e. a model that is "adequate" and "caring" at the same time.

The best strategy is to estimate all possible models compatible with the characteristics of the series and then order them. Two famous criteria designated for this purpose are the *Akaike Information Criterion (AIC)* and the *Bayesian Information Criterion (BIC).* [Wei, 2006]

We used the Box and Jenkins procedure to study our demand. In fact, this process shapes time series so that we can take advantage in order to study it and make plausible forecasts. This allows construction of a SARIMA model that adequately represents the generating process of the data and that is based on steps that can be repeated several times in an interactive way, the model identification, estimation of it and the control phase. The identification phase consists in the model specification by identifying the parameters (p, d, q) and possibly (P, D, Q), trying to recognize in the global and partial autocorrelation functions, from an empirical standpoint, and the theoretical autocorrelation functions. To make it difficult to identify the model can contribute disturbing elements such as non-stationary and seasonality.

These elements can however be attenuated by applying the appropriate mathematical transformations. The most commonly used models for the analysis of time series are the SARIMA models (p, d, q) (P, D, Q)s and ARIMA model. They are mixed models of autoregressive moving average component and they shall take into account the possible non-stationary or seasonality or other variables. These models seek to explain the trend based on history, describing the phenomenon through the adaptation of both the seasonal and non-seasonal part, because it proves that, it is necessary that the studied series is characterized by a strong serial correlation to seasonal delays, in addition to the usual short-term autocorrelation. [Box, Jenkins 1976].

We ran the analysis, which led us to the comparison of two models with plausible parameters. Later, following a careful analysis of the parameters as explained above, and with the help of residues and AIC and BIC, we have chosen the model that we will call SARIMA (1,2,0) (1,0,0).

We used GRETL statistical program to conduct our analysis.

From the graph (*Figure 4.1*)of the time series, we may notice a slightly growing trend, so let us see the graph of the number one *Figure 4.2* with a differentiation.


*Figure 4.2 Time series with differentiation*

This graph shows a stationary. Let us try anyway to see the correlogram of the latter (*Figure 4.2*)

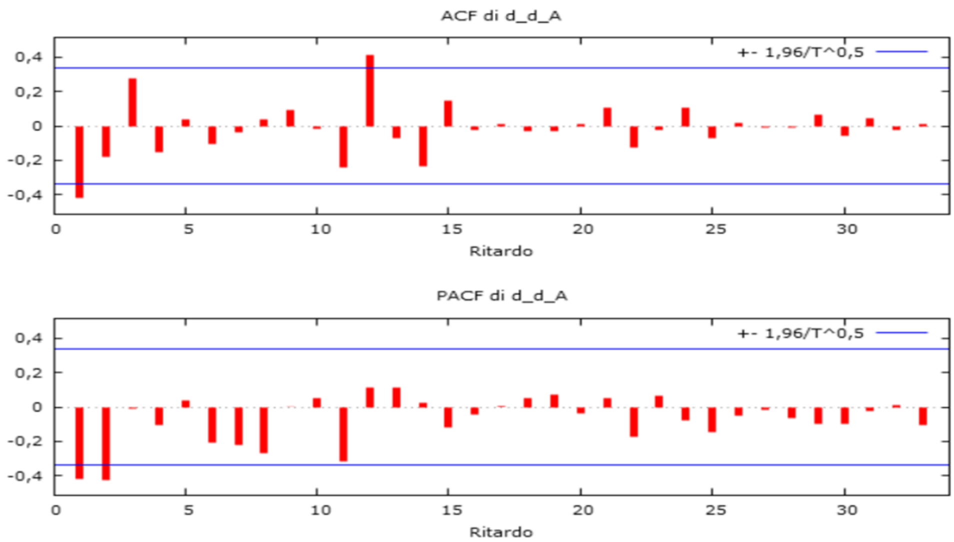



*Figure 4.3 Correlogram of the latter (personal elaboration)*

There seems to be an autoregressive component, probably seasonal.

Therefore, we try to estimate two SARIMA following models, and after choose which one is the best:

SARIMA (1,2,0) (1,0,0): (Fig 4.4)

```
Valutazioni della funzione: 16
Valutazioni del gradiente: 8

Modello 34: ARIMA, usando le osservazioni 2012:03-2014:12 (T = 34)
Stimato usando il filtro di Kalman (MV esatta)
Variabile dipendente: (1-L)^2 A
Errori standard basati sull'Hessiana

             coefficiente   errore std.      z      p-value
  ----------------------------------------------------------
  const       -0,0882106     0,599440     -0,1472   0,8830
  phi_1       -0,513475      0,156369     -3,284    0,0010   ***
  Phi_1        0,586595      0,133198      4,404    1,06e-05 ***

Media var. dipendente -0,205882   SQM var. dipendente    4,395448
Media innovazioni     -0,086502   SQM innovazioni        3,065103
Log-verosimiglianza   -89,01032   Criterio di Akaike     186,0206
Criterio di Schwarz    192,1261   Hannan-Quinn           188,1028
Note: SQM = scarto quadratico medio; E.S. = errore standard

                      Reale   Immaginario   Modulo  Frequenza
  -----------------------------------------------------------
  AR
  Radice  1          -1,9475     0,0000     1,9475    0,5000
  AR (stagionale)
  Radice  1           1,7048     0,0000     1,7048    0,0000
  -----------------------------------------------------------
```

*Figure 4.4 Model SARIMA (personal elaboration)*

SARIMA(1,0,0)(1,1,0): (Fig 4.5)

```
Valutazioni della funzione: 29
Valutazioni del gradiente: 13

Modello 35: ARIMA, usando le osservazioni 2013:01-2014:12 (T = 24)
Stimato usando il filtro di Kalman (MV esatta)
Variabile dipendente: (1-Ls) A
Errori standard basati sull'Hessiana

             coefficiente   errore std.      z      p-value
  ----------------------------------------------------------
  const        0,420521      0,514076      0,8180   0,4133
  phi_1        0,451649      0,186717      2,419    0,0156   **
  Phi_1       -0,656139      0,171854     -3,818    0,0001   ***

Media var. dipendente  0,375000   SQM var. dipendente    3,004526
Media innovazioni     -0,052702   SQM innovazioni        1,867266
Log-verosimiglianza   -52,53412   Criterio di Akaike     113,0682
Criterio di Schwarz    117,7805   Hannan-Quinn           114,3184
Note: SQM = scarto quadratico medio; E.S. = errore standard

                      Reale   Immaginario   Modulo  Frequenza
  -----------------------------------------------------------
  AR
  Radice  1           2,2141     0,0000     2,2141    0,0000
  AR (stagionale)
  Radice  1          -1,5241     0,0000     1,5241    0,5000
  -----------------------------------------------------------
```

*Figure 4.5 Model SARIMA (personal elaboration)*

Both are the best models in terms of AIC and BIC when compared with the respective models without an AR [13]component (seasonal and otherwise). Either models are good in

[13] Autoregressive model

terms of parameter estimation; we can think off the intercept in both. Then, try to see the normality and the correlogram of the residuals.

In both models, the residuals are uncorrelated, in the first model, however, the normal condition seems more respected that in the second. (*Figure 4.6) (Figure 4.7*)

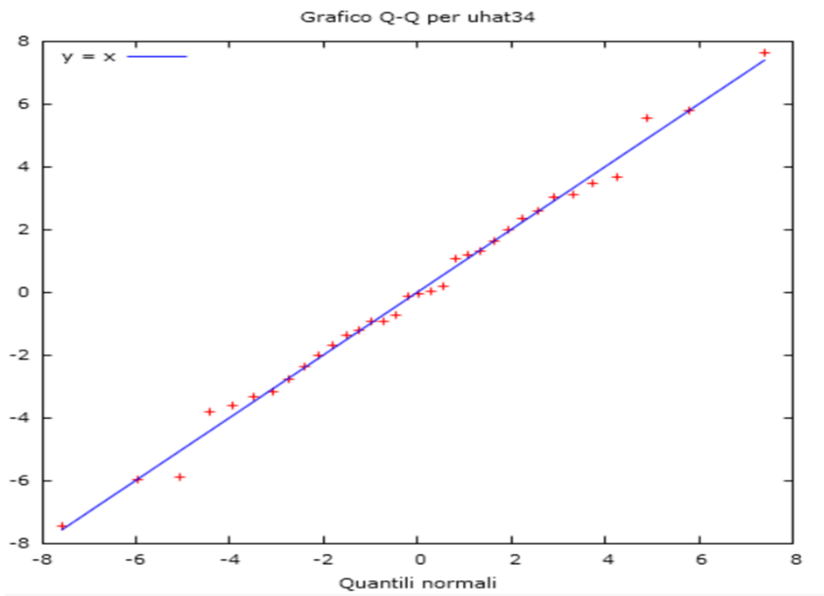



*Figure 4.6 Graph Q-Q Residual SARIMA (1,2,0) (1,0,0) (personal elaboration)*

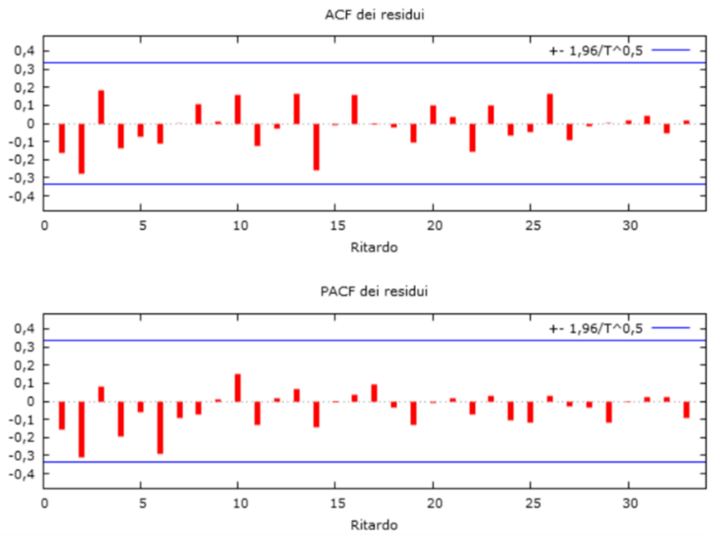



*Figure 4.7 Graph Residual SARIMA (1,2,0) (1,0,0) (personal elaboration)*

The conclusion is that the SARIMA model (1,2,0) (1,0,0) is the best model.

After a careful analysis, we can say that it is a model with AR seasonally. The demand has a slightly positive trend. We cannot say that the demand is completely static.

However, we should also made a study taking into account a lot of variable that occurs in a real life and implement a model that match with the characteristic of Cavallone Srl. Demand has a slightly trend, that it can be also considered equal to almost zero in the next 2 years. That means that we should find a model that focuses on known demand, and take into account another type of characteristic of the product.

## 4.2 COSTS AND BUSINESS PROCESSES ANALYSIS

This part of the work focuses on the calculation of the costs attributed to the products storage. After demand's analysis, becomes logical to get all the elements necessary for final construction of the mathematical model. To this end, we try to reconstruct the chain of business processes, in order to understand who, and with what effort, has been involved in the preservation and ordination of the product; and if there were other factors that influenced the decisions of the Buyer.

Understanding and describing the business processes is without any doubt an activity that must be made in advance to understand which costs depending on buyer's decision. It recalls that, according to the operational researcher, only those items of expenditure which are influenced by the decisions we make regarding stocks are worthy to be calculated, as they generally are those that "increase if we keep large amounts of stock and decrease if it keeps walking, and vice versa. Other costs, in fact, since it does not affect the selection can be neglected "[Tinarelli, 1981, 1992].

Another important premise that we have to make is that the analysis and the subsequent cost calculation is not the more difficult part, nevertheless it is the more sensitive part, since we need to estimate correctly how much each product unit costs to the company. We also need to consider each cost item.  Once highlighted, the items are "reclassified "or rather modified so as to be properly attributed to the individual product or category to which it belongs. In some cases, we have recourse to approximations in order to estimate a cost for the stock that is as accurate as possible or in any case very close to the cost actually paid out, therefore, likely. In fact, for each percentage or approximation, especially in the case of calculating the hourly costs it has recourse to a valuation based on logical- mathematical considerations and, if this is not possible, very importantly, the opinion of the manager and the experience in the field of stakeholders involved in the stock process.

A crucial step is to understand how the chain of business processes is made and how it has changed or evolved over time. In fact, not always the company given equal "weight" to the product. For an accurate estimation, it should be taken into account that the expenditure should be calculated considering not a single moment, but an entire three-year period (2012-2014), as in this case. During this time the staff has been subject to rotation, processes can be streamlined or innovative were resulting in a reduction or increase in expenditure.

It is logical to proceed before any calculation, to the reconstruction of history of the product, to understand how the company had administered the stock over the years analysed. In this paragraph, we will simply describe in general the administration and operations of the stock management, without using any calculations.

In the company, at the operational level management of the commercial products is left up to the purchasing office. Inside the office, there is a buyer to take care of the provider, using the computerized system of business management, statistics and his own experience, the buyer is able to estimate the amount to restock.

Once the buyer is confronted with top management and after consultation with marketing manager and sales manager, he fills out the order that will be sent directly to the provider. Confirmation received, the goods are prepared and sent to the warehouse within the agreed dates, with shipping costs charged to the supplier. To determine the optimal amount and then to issue the order, it is necessary that the buyers consider a number of variables such as quantity discounts, lead-time, payment terms, trends dictated by fashion. The goods arrived at their destination, and the warehouse staff who receives transports and stores the goods at the place of storage.

The pallet is broken down and it checks the correspondence of the goods with the order, then, each item is placed on the shelf or in their own spaces of the warehouse used only for coils of electrical cables. It occurs that there is not defective or broken goods.

The job of warehouse worker staff ends with various practices, first, they have to load into the business software, goods received. The private and external couriers will provide within a week to make all physical movements of the product, delivering it due to contact. Once the goods arrived at the destination, if the order is fully processed, the invoice is ready to be paid.

Therefore, it is delivered to the executive department, where the office staff is responsible before a further verification of coincidence between what is in the goods return note and the one shown on the invoice, the bureaucratic practices and then the payment of real effects through web. Finally, it updates the company's website, where they now appear the restored amount of available goods.

To run a more detailed analysis possible, we began from the analysis of the aggregate category coils of electrical cable, and knowing the demand and characteristics of SKU (Stock Keeping Unit), we arrived at the estimate of the costs attributed to it. It represents 8.3%[14] of the entire category.

$$\frac{42{,}576€\ (Average\ Total\ value\ of\ aggregate\ coils/year)}{5{,}123€\ (Average\ value\ single\ SKU/year)} = 8.3\%$$

[14] This percentage has been calculated through the ABC analysis of the entire category and through the budgets of the company. The entire category of electric cables accounted for 30% of total sales, while the single SKU is the 8.3% of the aggregate. ((42,576€ Average Total value of aggregate coils/year) / (5,123€ Average value single SKU/year = 8.3%))

## 4.3 CALCULATION OF PURCHASE COST

The purchase cost is the amount that must be paid by the company to the supplier for purchased good. As already mentioned it is a cost that should be entered only if its nature is variable that is not constant in relation to the quantity ordered [Magee, Boodman, 1992].

In our case, the company has the right to the discounts based on quantities purchased, or more precisely, based on the total it spends on one order. In the *Figure 4.9,* we can see how the discount varies depending on the amount purchased. Obviously, the buyer, after following management software's advices and of course taking into account the trade-off: the benefit discount for large quantities purchased and storage costs can carry out the order to the supplier.

The purchase price of FG74G4 product remained unchanged over the past years; it is equal to € 1,337.93 for 800 meters of cable that represent one full coil. It is wound around a coil for easy transportation and storage, like almost all the electrical cables.

The commercial term applied then depends on the total amount of coils reached in an order, in the sense that it considers not only the single SKU purchase, but also all the other items purchased from the same supplier. The *figure 4.8* shows the values of commercial conditions.

| ***Total amount of coils for one order*** | ***All quantity discount*** |
| --- | --- |
| | |
| x ≤ 10 | 0% |
| 10 ≤ x < 20 | 5% |
| 20 ≤ x < 30 | 7% |
| 30 ≤ x < 40 | 8% |
| 40 ≤ x < 50 | 10% |
| 50 ≥ x | 13% |

*Figure 4.8 Discount on total amount for one order (Personal elaboration)*

The table shows that greater will be the total price indicated on the invoice, greater will be the discount applied by the supplier for that order. We can say that, if the total order amount of coils is less than 10 coils, no discount will be applied. If the total amount is between 10 and 20 coils, they will receive a discount of 5%. If it is between 20 and 30 of number of coils, the discount will be 7%, and so on.

We can say (*Figure 4.9*) that the cost of a single SKU and the total order are inversely proportional. With the increase of the order amount, the unit cost goes down and vice-versa. We can also say that the percentage of discount is convenient, but it should be related to inventory cost, it means to do a trade-off between convenience comes from discount to purchase in big quantity and cost to have stock.

Order in large quantities usually allows us to decrease the unit price. The use of the discount allows on one hand to improve the service to the consumer, on the other aggravating costs, increasing maintenance costs. The buyers, in order to make a rational decision, he must consider the trade-off between the benefits gained from large quantities ordered and disadvantages related to the higher costs. We can anticipate that the choice of my model will fall on one of the Wilson EOQ model variant with all quantity discount.

| ***Total amount for one order*** | ***All quantity discount*** | ***Purchase unit cost*** | ***Discount*** | ***Unit cost with discount*** |
|---|---|---|---|---|
| | | | | |
| x ≤ 10 | 0% | € 1.337,93 | € - | € 1.337,93 |
| 10 ≤ x < 20 | 5% | € 1.337,93 | € 66,90 | € 1.271,03 |
| 20 ≤ x < 30 | 7% | € 1.337,93 | € 93,66 | € 1.244,27 |
| 30 ≤ x < 40 | 8% | € 1.337,93 | € 107,03 | € 1.230,90 |
| 40 ≤ x < 50 | 10% | € 1.337,93 | € 133,79 | € 1.204,14 |
| 50 ≥ x | 13% | € 1.337,93 | € 173,93 | € 1.164,00 |

*Figure 4.9 Discount about unit cost SKU (Personal elaboration)*

## 4.4 CALCULATION OF THE ORDERING COST

The ordering cost is a source of expense for the company created by the existence of a standard business practices, administrative and bureaucratic that allow us to close the procurement process. Not just about fill the order and arrangement of the effects to suppliers but also the physical movement (for example from the production site to the warehouse and from the warehouse to the shelf) and the control of the goods to be stored [Jessop, Morrison, 1995; Weiller, 1995]. According to Fogarty, Hoffmann and Burnham [1983].

There are three different approaches to the calculation of the ordering costs: the *Aggregate*, the *Standard* and, in the end, *Marginal Out-of-Pocket Cost* Approach. Taking into account the company's situation, we thought it appropriate to use the first of these.

*Aggregate Approach.*

Simply be the sum of the various expenses that affect and divide them by the number of orders, resulting in an average unit cost.

***Total order cost (€)*** = $\mathrm{CP}A^{15} + CPMS^{16} + CSER^{17} + \mathrm{RC}^{18}$

***Average cost per order (in €)*** = Total Order cost ÷ total Order

The criticality of the method lies in its excessive stability since it is usually calculated on the average of the activities of the last three years, the time period in which, staff and personnel to the purchase often vary, there may be changes in the procedures and periods management systems in which idle in which no done orders.

The Cavallone srl gives great importance to the relationship with the supplier. The order is carried out with a certain frequency and seriousness in delivery and quality of products contributes to justify and to prefer the choice of this calculation approach than the other two.

---

[15] Cost of Purchasing Agents, is the direct and indirect cost of personnel involved to the purchase.
[16] Cost of Purchasing Management, Stenographers and Clerical Personnel, is the direct and indirect cost of the management staff and office, and warehouse staff
[17] Cost of Services, is the cost of communications, stationery and miscellaneous supplies and services
[18] Reception cost for goods.

In the calculation of the order cost for the *Aggregate Approach* are considered the following items:

1) *Cost of Purchasing Agents*

They Are expenses related to the choice of supplier, issue and possible solicitous of the order [Tinarelli, 1992]. Company in this expense is attributed entirely to the figure of the buyer. Through a continuous exchange of information between the central warehouse and office purchases, the buyer always knows when the total stock is approaching exhaustion. Considering the lead-time and a corporate schedule, he proceeds to prepare the order with the right timing, thereby avoiding falling into stock-outs. His work follows a process: first, the valuation of inventories, then contacts the suppliers via email, then require the offer and finally decides the replenishment quantities. The order is then processed and sent.

| ***Buyer activity*** | ***% Average monthly time dedicated to all orders*** | ***% Average monthly time dedicated to SKU*** |
|---|---|---|
| *Monitoring of stocks and continuously updated with warehouse* | 60%[19] | 3%[20] |
| *Issuance of purchase orders* | 20% | 1% |
| *Market monitoring* | 10% | 1% |
| *Preparation of company financial documents and reports* | 10% | 1% |

We can consider a period of 1 year, 2014. As evidenced by the financial statements, the gross annual salary of the buyer is 39,000 € (it is inclusive of social and tax charges), that divided by 12 months is equal to is 3,250 €. He works 8h per day for 20 days in one month. We have as result 8h*20d= 160h/month. We have 8*h**5 days = 40h. He spends almost 7h in one month to issue SKU order. From an estimate of the time that buyers

[19] Value calculated as a result of an estimate of the hours spent by the buyer when making orders
[20] Value calculated as a result of an estimate of time spent by buyer to issue SKU order

spend on the order process, we can say that he spends about 6% of the time available in a month for the order concerning the SKU.

We can say that:

$$\boldsymbol{CPA} = \frac{39{,}000€ * 2h\ for\ one\ order}{48\ weeks * 40h} = 40.63€\ \textit{total order}$$

To learn about the individual product's incidence has applied a percentage. The ratio of the average annual expenditure in the individual product stocks and the total value invested in aggregate products (coils of electrical cable) is an incidence rate of SKU in terms of spending per order.

$$\frac{42{,}576€\ (Average\ Total\ value\ of\ aggregate\ coils/year)}{5{,}123€\ (Average\ value\ single\ SKU/year)} = 8.31\%$$

$$CPA = 40.63\ € * 8.31\ \% = 3.37\ €\ \textit{monthly unit cost order SKU/tot}$$

*2) Reception cost for goods*

These are costs of handling and physically locate the stock in the specific shelf inside warehouse [Tinarelli, 1992]. This task is responsibility of the warehouse staff. The goods, shipped and stacked on pallets, arrives at its destination via courier. Here enter the figure of manager, that proceed to the loading and unloading of products, to verify the correspondence with order note, the preservation of the goods in the appropriate warehouse space. Finally proceed to the IT load through the business management software. Time is also spent to verify the integrity of the goods and any defects or damages, for which there is a procedure of non-compliance with rendered. To deal with the receipt of the goods there are 3 warehousemen. Since the estimate of the time devoted to the activity of reception depends on the amount of the order coming up, it is very difficult to calculate how long time the employees dedicated to this specific activities for SKU due to the high variability of this data. Therefore, estimate an average cost per order would be difficult. However, we can estimate the average time that the storekeepers spend daily for the reception activities , which is around 4hours/daily, which are multiplied by the staff, 3 people. We can also assume that the 10% of those activities comes from the single product FG75G4. We can see from the financial statements the annual salary of the warehouse amounted to € 2,100, which multiplied by the number of people involved in the activities of merchandise receipt is equal to € 75,600. The number of working days in one year is equal to 235, the weeks in one year are 48 and, in the end, the working hours in one week are equal to 40h. For computational simplicity, rounding defect in all the results.

$$\boldsymbol{RC} = \frac{75{,}600€ * 253\ working \frac{days}{year} * 4h}{48 weeks * 40h * 3\ peolpe} = 12{,}337€\ \ tot\ order$$

$$RC = 12{,}337\ € * 10\ \% * 8{,}31\ \% = 102{,}5\ €\ for\ SKU/tot$$

We do not consider transportation costs, because they are always charged to the supplier and then Freeport.

3) *Cost of Purchasing Management, Stenographers and Clerical Personnel*

Administrative expenses are necessary to conclude the storage process. The Administrative Office shall conduct an additional check on the correspondence with the order and then the invoice is paid. Standard costs for the office staff cover the direct and indirect costs attributable to those people, whereas each one takes about 2 hours on average for this activity of aggregate coils, regardless of the amount of the order. The CPMS (Standard Cost Stenographic and Clerical) are derived as follows [Fogarty and Hoffmann, 1983]:

$$\boldsymbol{CPMS} = \frac{50{,}400€ * 2h/day}{48 weeks * 40h * 2\ people} = 26.25\ €\ tot\ order$$

$$\mathbf{CPMS} = 26.25\ € * 8.31\% = 2.18\ €\ \mathit{SKU/Tot}$$

4) *Cost of Services, is the cost of communications, stationery and miscellaneous supplies and services*

They include stationery, printers, telephone, fax, etc. It assumes a flat rate charge of € 7 per order, which compared to single SKU result to be about

$$\boldsymbol{CSER} = 0.70 \text{ cents}$$

Following the Aggregate approach, we should sum up all costs as (*Figure 4.10)*:

| | |
|---|---|
| **CPA** | 3.37€ |
| **CR** | 102.50€ |
| **CPMS** | 2.18€ |
| **CSER** | 0.70€ |
| = | = |
| **Tot. average cost per order** | 108.75€ |
| **x Average number order in a month** | x 3.92 |
| = | |
| **Aggregate Cost per month** | 426.3€ |
| **Aggregate cost per year** | 5,115.6€ |

*Figure 4.10 Aggregate approach chart (personal elaboration)*

Is immediately visible the level of costs of order from a glance at the table below (*Figure 4.11):*

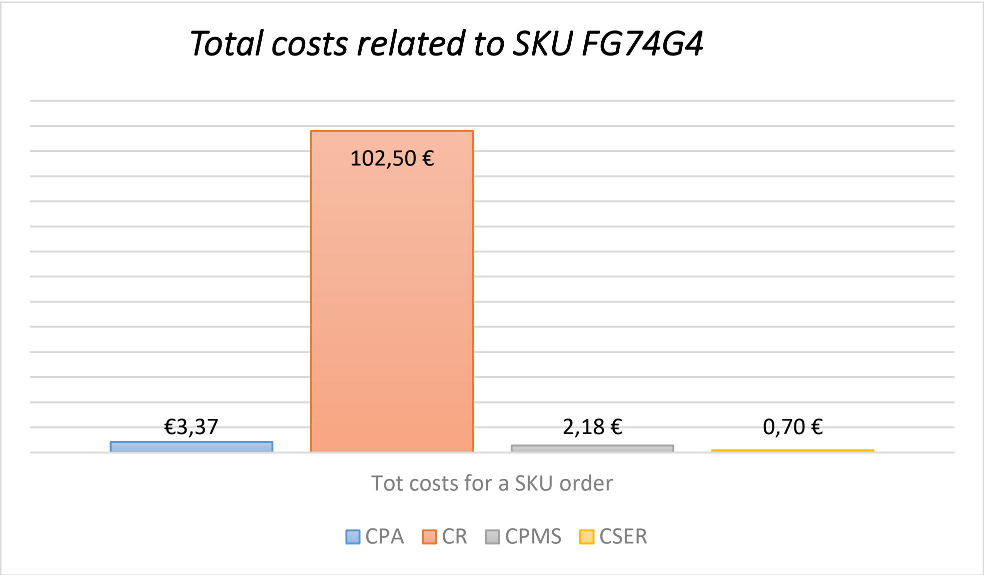



*Figure 4.11 Total ordering costs for SKU (personal elaboration)*

## 4.5 CALCULATION OF THE HOLDING AND STORAGE COST

The costs of preservation or storage are "the expenses necessary to preserve the goods in the warehouse. They stem from the fact that the goods take up space, require maintenance and sometimes appropriate treatments to maintain over time its material properties "[Tinarelli, 1992]. These are generally conspicuous expenditure on all stocks, so it is reasonable to think of the possibility of encountering difficulties in their allocation to individual unit or category. The related literature [Marchetti, 2010; Greene, 1997; Tinarelli, 1992; Fogarty Hoffmann, 1983] agree in suggesting opting for a realistic computation. Starting from the main balance sheet items affecting the stocks, the decision applies a certain percentage (thus subjective) that is expected to express the incidence of goods kept in stock per unit time.

For the purposes of this analysis, we should consider the following costs:

- Storage costs: this cost refers to the amortization of the building dedicated to storage, for the exclusive use of the category of electric cables, as it turns out to be owned by the company Cavallone SrL.

Furthermore it includes the maintenance fee to the building itself in order to respect the rule of law and the tax IMU on the same building. As we have already said in the previous chapter, the Cavallone srl has a warehouse it owns in which they stocking the entire electrical cables category, because, this category appears to be a slice of crucial importance within the company.

- *Amortization costs*

- *IMU*

- *Insurance costs*

- *Utilities*

- *Monitoring costs by the warehousemen*

- *Obsolescence costs*

- *Stock-out cost*

The storage costs shall be expressed as a percentage of the amount or volume of a stock commodity in the period under consideration, or a percentage of the value of the goods stored within the relevant time.

- *Amortization costs of warehouse*

Within the calculation of preserving good costs covered the warehouse amortization because this last results to be owned by the company. The financial statements show that the entire building amortization amounted to € 119,057.

By dividing the annual amortization cost for the number of months in one year, we will have

$$\frac{€\ 119{,}057}{12\ monhts} = 9{,}921.42\ €$$ [21]

From the company's layout, it can be traced to the total area covered by the building at the site amounted to 2.956 $m^2$. The annual cost per square meter is therefore equal to

$$\frac{€\ 119{,}057}{2.956\ m2} = 40.27\ €$$ [22]

From a visit to the warehouse and a discussion with warehouse workers, it is likely to say that the space in the warehouse used for FG75G4 product is equal to 5% of the total space, because they position the coils of electrical cables with FG75G4 code in a particular corner of the warehouse and in certain shelves of it.

Accordingly, we can calculate the space in $m^2$ in this way:

$$2.956\ m^2 * 5\% = 147.8\ m^2$$ [23]

The annual amortization attributable to the product under consideration is therefore equal to

$$40\ €/m^2 * 147.8\ m2 = €\ 5{,}888$$

[21] It is monthly cost of amortization.
[22] Rounded down it is equal to 40 €
[23] It is the number of square meters dedicated to the product object of our analysis, the space it occupies in warehouse

- *IMU*

As stated in Article 13 of Law 214/2011, the ownership of real estate is subject to those charges and is part of the cost of storage of goods. In FY 2014, it amounted to € 24,953.590. Considering the total area of the building it is

$$\frac{€\ 24{,}953.590}{2.956\ m2} = 8.44\ €/m^2$$

The cost of those charges attributable to the building dedicated to the storing of FG75G4 is equal to

8.44 €/m2 * 147.8 m2 = 1,247.4 €

- *Insurance costs*

Cavallone S.R.L has signed a bill of fire and theft insurance. The insurance covers property damage resulting from the events described in the contract that the entire building, the equipment needed for the movement of goods and those used in offices, the furniture and goods, preserved is within the warehouse both in offices, they may suffer. The insurance cost is one of the storage costs of the goods and will be expressed in proportion to the duration of the stay of goods in stock, the value or volume of the Buffer Stock. Dividend the amount of the policy between the different areas that the policy covers the same could not be due to a lack of data relating to the value of goods, office equipment, equipment used for handling, machinery, of 'durably decor employees in the company. Financial statements show that the annual insurance cost of the warehouse for the category "electrical cable" amounted to 1,121 €. If we divide the amount of insurance for square meters of warehouse space, we get the cost per m$^2$

$$\frac{1{,}121\ €.}{2.956\ m2} = \ 0.38\ €$$

At this point, we can multiply this data for the percentage of stock only dedicated to our product:

0.38 € * 147.8 m2 = 56.16 €

- *Utilities*

The utilities are all those expenses that relate to the electricity, gas, heating, and internet. In the case of Cavallone's warehouse, there will be only the expenditure for the light because the products do not need heat. Therefore, we can say that this expense flat rate amounts to about € 2,100 per year

$$\frac{€\ 2{,}100}{2.956\ m2} = 0.71\ €$$

After, to find the cost attributable only to the product of ours analysis we can:

$$0.71\ € * 147.8\ \text{m2} = 105\ €$$

- *Monitoring costs by warehousemen*

In the same way to the purchasing department, the warehouse manager also uses a daily part of his time to control the situation of the stock and to update the quantity available on the company website. That calculated below is the expense for the hourly rate of web manager where on average 30 minutes per day are devoted described in monitoring. From the financial statements, it is clear that the gross annual salary of the director of the warehouse is € 25.200. Therefore, to calculate the cost of monitoring from he spent for the SKU we can:

$$\frac{€\ 25.200 * 0.30\ h}{48\ weeks * 40h} = 3.94\ €$$

$$3.94 * 8.31\%\ ^{24} = 0.33\ €$$

[24] 42,576€ (Average Total value of aggregate coils/year) / 5,123€ (Average value single SKU/year)

- *Obsolescence costs*

With regard to obsolescence costs, they appear to be superfluous in the analysis of our case. The category of electrical cables coils, and, hence, also our product FG75G4 , they are not perishable goods, because the materials of which the electrical cables are made are copper, aluminium, iron; all these materials are resistant to climate changes and to their nature and their widespread use, are ad hoc created materials to last over the long-term.

- *Stock-out costs*

They are the costs resulting from missed opportunity to close the deal due to the exhaustion of the stock. This cost-penalty is ruled out, because there had never been no stock shortage. The stock-out cost in this case is not calculated because the company has never gone out in stock. This cost for the company is quite high, and it is more convenient to have an over stock.

## 4.6 COST OF CAPITAL

Within the category of maintenance costs exists a submerged part called implicit, defined as to distinguish it from the rest of the just seen these explicit costs. Such implicit part is identified substantially in the costs associated with the capital invested in stocks.

Is to be considered among these cost entries also the cost of capital invested in stock (or rather "cost for invested capital" [Buttignon, 2014]). The calculation of this cost is not simple; in fact, it should be consistent with the risk profile of the business and with its own duration of the investment. We must then calculate the Weighted Average Cost of Capital (WACC):

$$WACC = \frac{E}{V} K_e + \frac{D}{V} K_d$$

It is determined by three components: Cost of Equity ($K_e$) Cost of Debt ($K_d$) and the financial structure of the analysed company.

The most common methods used for calculating $K_e$ are the *Fama-French three-factor model*, *CAPM* and *APT* [Koller, Goedhart Wessels, 2010]. In this case, we used the *CAPM* method, because it represents the most commonly used method to estimate the expected rate of return in unlisted companies. The Capital Asset Pricing Model (CAPM) states that the expected return is given by how sensitive it is true performance to the market portfolio.

This sensitivity is measured using a term known as *beta* (β). The other two components of the cost of equity according to CAPM are *Risk-free rate* ($R_f$) and the *Market risk premium* (MRP).

$$K_e = R_f + beta * MRP$$

Where:

- $K_e$ = cost of equity;

- $R_f$ = yield on zero-risk securities, so-called risk-free rate;

- β = coefficient of systematic enterprise risk;

- $r_m$ - $r_f$ = market risk premium.

The CAPM provides an expected return or discount rate appropriate to the characteristics of the asset (financial or real) being valued. Leaving aside a discussion of other factors, what matters most purposes the elaborate is the estimate of the beta coefficient of systematic risk. It is the most difficult element to estimate and it depends on the type of enterprise. For the listed companies the beta indicates the way in which, on average, the returns of a title vary with the market returns. In this specific case, however, where it is considered a non-listed company, it is difficult to think about an approach to explain the business risk, not being able to refer to any kind of shares [Koller et al., 2010]. For non-listed company is used an average of sector beta, it understood as a set of comparable listed companies. This method allows even non-listed companies to be equipped with its own systematic risk coefficient.

The *Risk free rate* is the yield that is obtained with a risk, measured as beta with the market equal to zero. Despite even the government bond have a beta (risk rates are less), it is still considered the rate of such Italian bonds, taking those in the longer term to ensure that the beta is minimized.

$Rf$ = $BTP$ 10 years = 3%[25]

Because Cavallone Srl is an unlisted company, we used instead of the specific beta unlevered firm (which cannot be calculated), the Business Risk Index (BIS) of the company belonging to the field *Electrical Equipment*

BRI = 1.03[26]

This indicator should be used to calculate the levered beta of the individual enterprise unlisted re-levered with the rate Debt / Equity own the company (1.5). The formula for the Re-leverage of not listed company is

$$\beta_l = BRI * [1 + (1 - t) * \frac{D}{E}]$$

[25] Source: http://www.dt.tesoro.it 31/08/2016

[26] Source: http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datacurrent.html. Domodaran

$$Beta = 2.62$$ [27]

For the estimation of *market risk premium* (MRP) we have chosen to use a rate of 5.6%[28] reported in perceived risk on the Italian financial market in 2016.

The proper use of these components according to the CAPM, therefore, determine the annual rate of the cost of capital for the company

$$K_e = 3\% + 2.62 * 5.6\% = 17,6\%$$

Obtained $K_e$ (Cost of Equity), it is time to estimate the $K_d$ (Cost of Debt).

$$K_d = Risk\ free\ rate + credit\ spread^{29} = 3\% + 5.50\% = 8.50\%$$

Knowing that $\frac{E}{V} = 40\%$ and $\frac{D}{V} = 60\%$, I obtain:

$$WACC = \frac{E}{V}K_e + \frac{D}{V}K_d \quad = 12,14\%$$

Which converted to monthly rate becomes equal to 1.1%. It, multiplied by the average monthly value of the stock in the timeslot of analysis, allows us to calculate the monthly cost of capital immobilized 794.73 € monthly[30].

The annual cost of immobilized capital for the product object of analysis is 8,933.35 €[31] annual. (*Figure 4.12)*

[27] Beta = 1.03 * [1 + (1 – 0,3) * 1,5] ; T= 30%
[28] Pablo Fernandez, Alberto Ortiz and Isabel F. Acín ;Market Risk Premium used in 2016

[29] Spread calculated based on the rating simulation model Prof. A. Damodaran (parameter EBIT / OF = 2.6 = B = 5.50%)-http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datacurrent.html. The financial charge is considered net of the tax shield (IRES)
[30] It Is equal to 73,586.04 € * 1.1%
[31] It Is equal to 73,586.04 € * 12.14 % (average costs of stocks in one year)

| | |
|---|---|
| Amortization costs | 5,888 € |
| IMU | 1,247.4 € |
| Insurance costs | 56.16 € |
| Utilities | 105 € |
| Monitoring costs by the warehousemen | 0.33 € |
| Cost of capital | 8,933.35 € |
| = | = |
| Total holding costs | 15,229.65 € |

*Figure 4.12 Total holding costs (personal elaboration)*

# 5 CHAPTER – MODEL CHOICE AND IMPLEMENTATION

After collecting all necessary data and framing exhaustively the business situation, we will proceed to the selection and application of the mathematical model able to manage efficienlty the economic lot. Not always, the literature provides the solution to every business case; sometimes we need to use the basic tools to fit the characteristics of the studied company to the model. In fact, the literature does not provide a model that matches perfectly with the characteristics of the Cavallone Srl., to conduct a valid study we decided to focus on the possibility to adopt quantity discounts on larger lots, assuming a stable demand. In this last chapter will be presented management methods that assume the presence of multiple discounts offered by the supplier All-units discount.

## 5.1 MODEL SELECTION

Order in large quantities usually allows we to decrease the unit price. The use of the discount allows on one hand to improve the service to the consumer, on the other aggravating costs, increasing maintenance costs. The buyers, in order to make a rational decision, he must consider the trade-off between the benefits gained from large quantities ordered and disadvantages related to the higher costs.

The basic assumptions are the same as Wilson's model in which, as we know, the point of good in terms of quantity and costs can only be calculated if it does occur crucial hypothesis: the demand should be relatively steady, then present a situation different from the current, for which it is recalled, this is a relatively growing trend. Assuming the truthfulness of results seen with the estimated demand with Gretl, which of course we acknowledge, it is also right to make subjective evaluations of a descriptive nature. In fact, it observes, beyond the result, that the positive trend in demand is not excessively pronounced. It means that the dynamism of the series is not accentuated and we cannot confidently assert that in the following period the dynamism of the demand will occur again, it could be absent. From the study carried out on the demand, appeared that the demand has a positive trend, but with a very low growing rate, close to zero. As a demonstration of what has been said we can assume that the sales about one month (October 2014), would decrease from 4 to 2 units, the same simulation in Gretl would change drastically, indicating a steady demand. At the light of what is said, it can be appropriate to study a model that would fit the situation in which demand is relatively stable, and focus our attention on models that take into account another variable(All discount quantity).

The Economic Order Quantity (EOQ) of Wilson, is the simplest and fundamental model of all inventory management models. It describes the strategic trade-off between order costs and holding costs, and it is the basis for the analysis of more complex models. [Di steven Nahamias, lennon Olsen 7th Edition] [Wild ,97'].

The purpose EOQ model is to determine how much to purchase (order quantity) and when to place the order (the reorder point). The common thread across these models is the assumption that demand occurs continuously at a constant and known rate. We start with the simple model in which all demand is satisfied on time.

The basic assumption are:

1- The demand rate is known and is relatively constant λ units per unit time. The unit of time can be days, weeks, months, etc. In my analysis, I assume that the default unit of time is a year.
2- Storage costs are not permitted.
3- There is no lead time (this assumption will be relaxed)
4- The costs are:
    a. Setup cost at *K* per order
    b. Proportional order cost at *c* per unit ordered
    c. Holding costs at *h* per unit held per year

In the basic EOQ is assumed that the cost *c* of each unit is independent of the size of the order. Often happened that the suppliers is willing to charge less per unit for larger lots. Although many different type of quantity discount exist, we will discuss about two types of quantity discount contracts: all units' discounts and incremental quantity discounts there are two that are the most reliable. They are the most reliable models. In each case there are one or more breakpoints defining changes in the units' costs. In *All-units*, the discount is applied to all units in an order; instead, in *incremental discounts*, it is applied only to additional units beyond the breakpoint. . [Di steven Nahamias, lennon Olsen 7th Edition]

The *incremental quantity discount* case differs from the all units discount case. In this situation, as the quantity per order increases, the unit purchasing cost declines incrementally on additional units purchased as opposed to on all the units purchased. Let $q_1 = 0, q_2, ..., qj, qj+1, ..., q_m$ be the order quantities at which the unit purchasing cost changes. The number of discount levels is m. In the example, we assumed that the units are discrete; for analysis, we will assume that the units are infinitely divisible and the purchasing quantity can assume any real value. The unit purchasing cost is the same for all values of Q in $[q_j, q_j+1)$, and we denote this cost by $C_j$. By definition, $C_1 > C_2 > \cdots > C_j > C_j+1 > \cdots > C_m$. The incremental quantity discount case differs from the all units discount case. In incremental, as the quantity per order increases, the unit purchasing cost declines incrementally on additional units purchased as opposed to on all the units purchased. We choose the All-unit discounts because we want to apply the discount to all the units in an order. [Muckstadt, John A., Sapra, Amar, 2010]

## 5.2 ALL-UNITS DISCOUNT MODEL

The assumptions are the same of EOQ model: [Di steven Nahamias, lennon Olsen 7th Edition]

1. Demand arrives continuously at a constant and known rate of ($\lambda$) units per year. Arrival of demand at a continuous rate implies that the optimal order quantity may be non-integer. The fractional nature of the optimal order quantity is not a significant problem so long as the order quantity is not very small; in practice, one simply rounds off the order quantity. Similarly, the assumption that demand arrives at a constant and known rate is rarely satisfied in practice. However, the model produces good results where demand is relatively stable over time.
2. Whenever an order is placed, a fixed cost ($K$) is incurred. There are also the holding costs ($I$), to holding stock in inventory. Therefore, if a unit's purchasing cost is C, it will cost $I * C$ to stock one unit of that item for a year.
3. The order arrives $\tau$ years after the placement of the order. We assume that $\tau$ is deterministic and known. (days)
4. All the model parameters are unchanging over time.
5. The length of the planning horizon is infinite.
6. All the demand is satisfied on time. No stock out.

In the following *Figure 5.1* we can see the graphics distribution of total purchasing cost for all units discount.

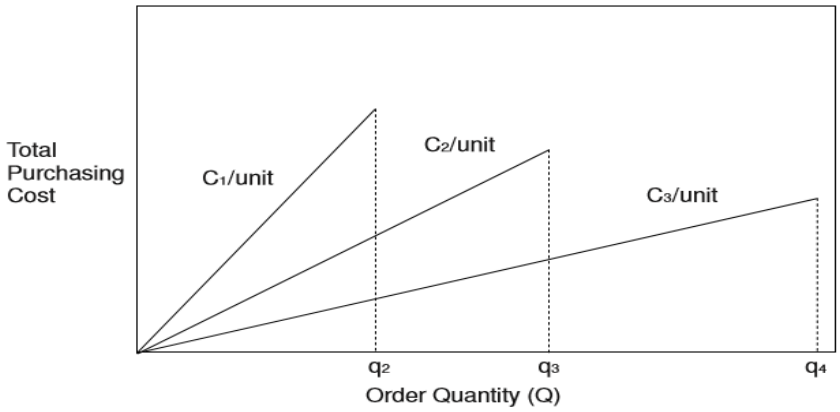



*Fig. 5.1 Total purchasing costs for all units discount [Muckstadt, John A., Sapra, Amar, 2010]*

Similarly, to the EOQ model, we assume that backordering[32] is not allowed. Let *m* be the number of discount possibilities. There are three discount levels, so *m* = 3. Let $q_1 = 0, q2, q3, \ldots, qj, qj+1, \ldots, q_m$ be the order quantities at which the purchasing cost changes. Even though we gave an example in which units were discrete, for simplicity in our analysis, we will assume from now on that units are infinitely divisible. The unit purchasing cost is the same for all Q in [qj,qj+1); let the corresponding unit purchasing cost be denoted by Cj. Thus, the *j*th lowest unit purchasing cost is denoted by Cj; C*m* is the lowest possible purchasing cost with $C_1$ being the highest unit purchasing cost.

The expression for the average annual cost is given by

$$Z_j(Q) = C_j\lambda + K\frac{\lambda}{Q} + \frac{IC_jQ}{2}, \quad q_j \leq Q < q_{j+1}.$$

The optimal EOQ is given by

$$Q_j^* = \sqrt{\frac{2K\lambda}{IC_j}}.$$

In the *Figure 5.2* we can see the graphic distribution of the total cost for all units discount.

[32] The term Backorder is a compound word from back (behind) and order to indicate an order from a customer that cannot be processed at the time and for which it require a wait time.
The grounds on which the order cannot be fulfilled are varied, and the backorder is usually placed in a queue that can be called backorder inventory.

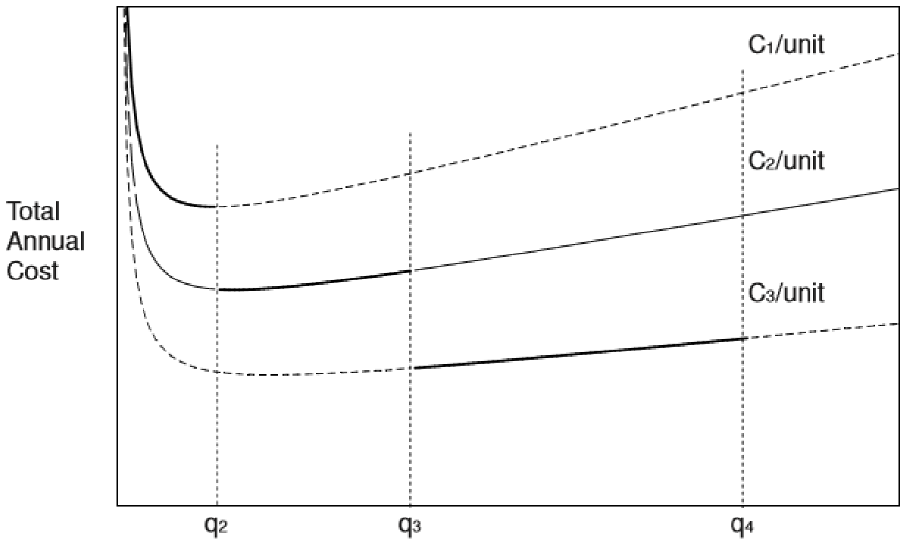



*Fig. 5.2 Total cost for all units discount [Muckstadt, John A., Sapra, Amar, 2010]*

Step 1: Set j = m. Compute the optimal EOQ for the *m*th cost curve, which we denote by $Q^*_m$:

$$Q^*_m = \sqrt{\frac{2K\lambda}{IC_m}}.$$

Step 2: Is $Q^*_m \geq q_m$ ? If yes, $Q^*_m$ is the optimal order quantity and we are done. If not, the minimum cost occurs at Q = q*m* owing to the convexity of the cost function. Since the minimum point $Q^*_m < q_m$, the cost function for the *m*th discount level is increasing on the right of q*m*.

Consequently, among all the feasible order quantities, that is, for order quantities greater than or equal to qm, the minimum cost occurs at Q = q*m*.

Compute the cost corresponding to Q = q*m*. Let this cost be denoted by Z*min* and Q*min* = q*m* and go to Step 3.

Step 3: Set j = j−1. Compute the optimal EOQ for the jth cost curve:

$$Q^*_j = \sqrt{\frac{2K\lambda}{IC_j}}.$$

Step 4: Is $Q_j^*$ in $[q_j, q_{j+1})$? If yes, compute $Z(Q_j^*)$ and compare with Zmin. If $Z(Q_j^*) <$ Zmin, $Q_j^*$ is the optimal order quantity. Otherwise, Qmin is the optimal order quantity. In either case, we are done.

Otherwise, if $Q_j^*$ is not in $[q_j, q_{j+1})$, then the minimum cost for the jth curve occurs at $Q = q_j$ owing to the convexity of the cost function. Compute this cost $Z(q_j)$. If $Z(q_j) <$ Zmin, then set Qmin = $q_j$ and Zmin = $Z(q_j)$. If $j \geq 2$, go to Step 3; otherwise, stop. [Muckstadt, John A., Sapra, Amar, 2010]

## 5.3 MODEL IMPLEMENTATION: ALL-UNITS DISCOUNT

After an accurate analysis of the costs and process about Cavallone Srl company, we can say that the order cost (K) is equal to 5,115.60 €, the holding costs (I) are based on 20% annual interest rate and the annual demand rate for year 2014 ($\lambda$) is equal to 47 units. We apply the algorithm to compute the optimal order quantity. There are five discount categories, so m = 5.

And qj is equal to $q_0 = 0$, $q_1 = 10$, and $q_2 = 20$, $q_3 = 30$, $q_4 = 40$ and $q_5 = 50$

From a glance at the table below (Fig. 5.1), it would seem trivially $C_4$ the ideal solution because the amount of coils falls exactly in the range which includes our demand $\lambda = 47$. Now, let us implement the algorithm of the model and see what will be the result that we will obtain.

The function of $C_j$ is

| $C_j$ | *Total amount of coils for one order* | *All quantity discount* | *Unit cost with discount* |
|---|---|---|---|
| | | | |
| $C_0$ | x < 10 | 0% | € 1.337,93 |
| $C_1$ | 10 ≤ x < 20 | 5% | € 1.271,03 |
| $C_2$ | 20 ≤ x < 30 | 7% | € 1.244,27 |
| $C_3$ | 30 ≤ x < 40 | 8% | € 1.230,90 |
| $C_4$ | 40 ≤ x < 50 | 10% | € 1.204,14 |
| $C_5$ | x ≥ 50 | 13% | € 1.164,00 |

*Table 5.1 Cost function (personal elaboration)*

**Iteration 1**:

Initialize j = 5

*Step 1:* We compute $Q_5^* = \sqrt{\frac{2K\lambda}{ICj}} = \sqrt{\frac{(2)*(5,115.6)*(47)}{(0,2)*(1,164.00)}} = 45,5$

*Step 2:* Since $Q_5^*$ is lower than $q_5 = 50$, the minimum cost occurs at Q = 50. This cost is equal to

$$Zmin = Cj\lambda + K\frac{\lambda}{Q} + \frac{ICjQ}{2} =$$

$$= (1{,}164)\,(47) + \frac{(5{,}115.6)*(47)}{50} + \frac{(0.2)*(1{,}164)*(50)}{2} = \ 65.336{,}62\ €$$

Now we proceed to Iteration 2.

**Iteration 2**

*Step 1*: Now, we set j = 4. We compute $Q_4^* = \sqrt{\frac{(2)*(5{,}115.6)*(47)}{(0{,}2)*(1{,}204.14\ )}} = \ 44.8$

*Step 2*: Since $Q_4^*$ is feasible since it lies in the interval [40,50), the minimum cost occurs at Q* = 44.8. This cost is equal to

$$Z(q_4) = (1{,}204.14)\,(47) + \frac{(5{,}115.6)*(47)}{44.8} + \frac{(0.2)*(1{,}204.14)*(44.8)}{2} =$$

$= $ 67.355,79 €

Which is higher than Z*min* and so the value of Z*min* remains unchanged. Now we proceed to iteration 3.

**Iteration 3**

*Step 1*: Now, we set j = 3. We compute $Q_3^* = \sqrt{\frac{(2)*(5{,}115.6)*(47)}{(0{,}2)*(\ 1{,}230.90\ )}} = \ 44.2$

Once again, $Q_3^*$is not feasible since it does not lie in the interval [30,40).

*Step 2*: Now, we set j = 2. We compute $Q_2^* = \sqrt{\frac{(2)*(5{,}115.6)*(47)}{(0{,}2)*(\ 1{,}244.27\ \ )}} = \ 44.0$

Once again, $Q_2^*$is not feasible since it does not lie in the interval [20,30).

*Step 3*: Now, we set j = 1. We compute $Q_1^* = \sqrt{\frac{(2)*(5{,}115.6)*(47)}{(0{,}2)*(1{,}271.03)}} = \ 43.4$

Once again, $Q_1^*$is not feasible since it does not lie in the interval [10,20).

*Step 4:* $Q^*_0$ is also not feasible because does not lie in the interval [0,10).

In this table that follows, we summed up and calculated the $Q_j^*$ and $Z_j(Q)$

| Cj | Total amount of coils for one order | C discounted | EOQ (Q*j) | Feasible Q | Total cost function Zj(Q) |
|---|---|---|---|---|---|
| | | | | | |
| $C_0$ | 0 ≤ x < 10 | € 1.337,93 | ~~42,4~~ | ~~10~~ | - € |
| $C_1$ | 10 ≤ x < 20 | € 1.271,03 | ~~43,4~~ | ~~20~~ | - € |
| $C_2$ | 20 ≤ x < 30 | € 1.244,27 | ~~44,0~~ | ~~30~~ | - € |
| $C_3$ | 30 ≤ x < 40 | € 1.230,90 | ~~44,2~~ | ~~40~~ | - € |
| $C_4$ | 40 ≤ x < 50 | € 1.204,14 | 44,8 | 44,8 | 67.355,79 € |
| $C_5$ | 50 ≤ x | € 1.164,00 | 45,5 | 50 | 65.336,62 € |

*Table 5.2 – Implementation all-units discount model (personal elaboration)*

| | |
|---|---|
| λ | 47 |
| K | 5.115,60 € |
| I | 20% |

*Table 5.3 Data of: order costs (K), Demand (λ) and holding costs (I). (Personal elaboration)*

At the light of values resulting from the model, we can say that the optimal solution is to order 50 units, corresponding an average annual cost of purchasing and managing inventory equal to 65.336,62 € , while, before, it was equal to € 73,586.04.

Therefore, we are talking about an economic benefit about € 8,249.42. From the table 5.2 and the iteration 3, we can see that $Q^*_0$, $Q^*_1$, $Q^*_2$ and $Q^*_3$ are not feasible because it does not is in the interval, this means that are not possible options. In that way we will have less costs, but we are not following this type of policy, because it does not satisfy our demand.

In the beginning, from a first glance, it appeared that the best solution was $C_4$ , with $40 \leq x \leq 50$, because our demand is equal to $\lambda = 47$.

Against all expectations, after the implementation and the results of the model, it is much more convenient the choice of $C_5$. This is because, the cost function (as we can see in step 2 iteration 1) it is *Zmin* compared with other *Zj*. This means that by ordering a higher quantity of coils or equal to 50, we will have a discount of 13%, which will allow us to pay a $C_5$ = 1.164,00 €, and, above all, to satisfy all my demand. Order an x ≥ 50 coils is the optimal point of trade-off: order/maintenance costs and purchase discounted costs/demand to be met.

Observe that the algorithm stops as soon as we do find a discount for which $Q_j^*$ is feasible. This does not mean that the optimal solution is equal to $Q_j^*$; the optimal solution can still correspond to the (j +1)st or higher-indexed discount. That is, the optimal solution cannot be less than $Q^*$.

In that manner we are able to satisfy all demand, regardless of the risk of running into a situation of stock-outs, which, as we said in chapter 4, is a risk too high that we cannot run. In addition, it turns out to be the best trade-off between cost and benefit.

From the *Figure 5.4* we can see our costs function $C_0$,$C_1$, $C_2$, $C_3$, $C_4$, and $C_5$.

From this figure we can immediately note that the $Q^*_5$ is the minimum point and the optimal $Q^*$, which falls at the point of 50 units. $C_5$ cost function is the lowest, but it is not necessarily always like this. Indeed, it depends on the convexity of the parables. The more convex the parables are, the higher the cost function with lower discounts will be. How we can find in the book of Di steven Nahamias, lennon Olsen 7th Edition, a clear example of how it is possible, thanks to the convexity of the functions, the high cost function is the one with a smaller discount.

In our case, is possible to find a Z*min* with a lower discount by varying greatly the holding costs percentage. Indeed, through a sensitivity analysis, we found that the more the holding costs are high, the more convenient will be to order a smaller amount.

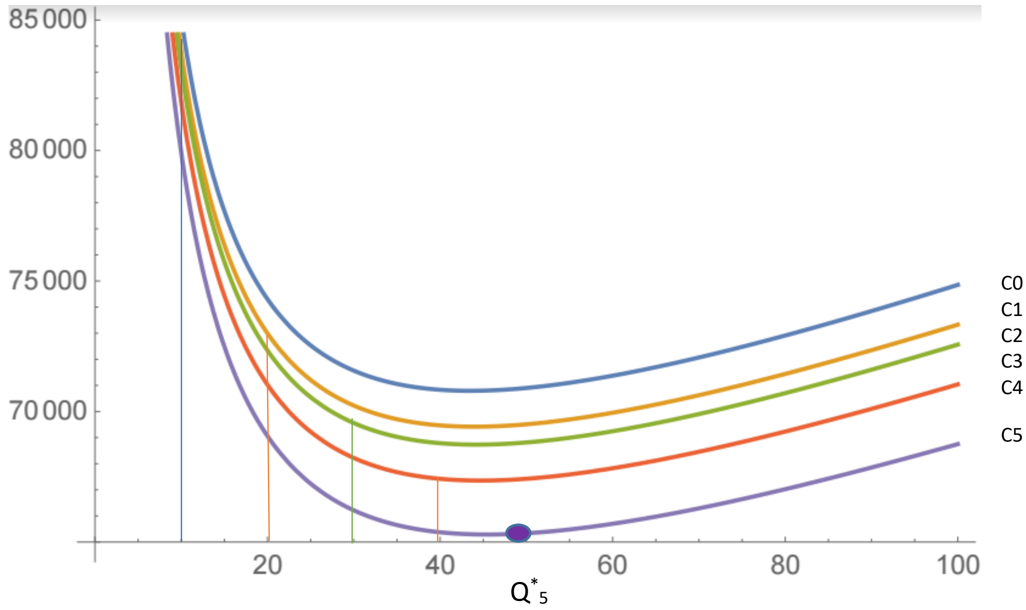



*Figure 5.4 Costs function graph (personal elaboration)*

In the table below, we can see pros and cons of All-units discount model applied to our case.

| **All-units Quantity Discount** | |
|---|---|
| **PROS** | **CONS** |
| ➢ Easy application<br>➢ The EOQ searching for extensive periods of analysis<br>➢ Identifies the price/cost most beneficial at which the buyer would have to buy<br>➢ it considers the presence of multiple discounts<br>➢ Total freedom of buyers when placing orders | ➢ Does not consider the lead time<br>➢ Standard Assumptions of the Wilson model |

# CONCLUSIONS

This work tackles the inventory management for the activities of Cavallone Srl, a company dealing with electrical materials. The aim of our analysis was to concentrate in a particular product of the firm and determine whether it were possible to reduce the holding costs without incurring into stock out.

An essential aspect, which is worth dwelling, is the methodology by which this study has been carried out. The problem has been solved gradually, following step by step the company's requirements. With the objective of obtaining competitive advantages, such as cost leadership, we devoted our research to new methods of replenishment for the Stock Keeping Unit (SKU), which we deemed crucial in terms of revenue maximization.

Starting from the sales and stocks data related to the three years 2012-2014, an analysis about 1500 products inside the company has been carried out, using cross-ABC technique. It emerged that one category of products representing the core business of the company; it is "coils of electrical cable". In fact, this class of products represents 30% of the Cavallone Srl total sales. Within this category, we have detected a SKU, codified article "FG75G4", which requires more conspicuous investment in stock (about 20% of stock value on the total value of the category), and, at the same time, it has a relevant weight in terms of revenue (€ 85,388.19). This product is located in the box A-A of our ABC cross analysis, and we know that this box needed more attention, because both, revenues and stock costs, are high. The analysis is performed for a unique item nevertheless, an analogous way of reasoning can be done for other items.

Once the object of study was clarified, it was decided to determine the rest of the variables needed to solve the problem. First we estimate the demand in order to understand how to manage inventory and, especially, stocks. The statistical tools of ARIMA and SARIMA (mixed models of autoregressive moving average) and the program "Gretl", detected a demand with an upward trend close to zero.

Subsequently, we determined the stock costs. In this step, the greatest problems were found in the estimation of the cost of capital, which in turn implies the calculation of the "beta" index (the coefficient of systematic enterprise risk). The costs that we calculated are the order costs and the holding costs (Amortization costs, IMU, Insurance costs, Utilities, Monitoring costs by the warehouseman). We found out that our article

"FG75G4” has a Weighted Average Cost of Capital (WACC) about 12.14% in respect to the entire category.

Regarding the estimation of the purchase cost, we have observed that it is not fixed, but rather variable. In fact, it depends on the total quantity ordered from the supplier. Unquestionably, multi discount factor was the variable that caught our attention the most. The quantity discounts characteristic is a very interesting variable to be analysed, because it allows us to have a relevant discount based on quantity purchased. Cavallone Srl retains utmost important not to run into stock-out risk, because it would lead to high penalty costs, in terms not only of gain but also even of firm image.

Hence, after a careful analysis carried out with the commercial director, it seemed appropriate to focus our attention on the problem of how much to order based on quantity discounts. In that work, we considered also the research of the optimum point, for the buyers, in the trade-off between quantity discounts and holding costs.

After analysing the problem and the related theoretical literature, we selected a group of models that were applicable in this case and we concentrated in the models which take into consideration the quantity discounts. The choice fell over the so-called “Quantity Discount Model” which assumes, unlike the standard models, that the unit cost of stock is not constant but it varies according to some thresholds. The model that best reflects this problem is the “All-units discount model”. For the application of this model, the demand should be known and relatively stable.

We then implemented the all units discount model to calculate the convenience of buying a big amount of products in the presence of multiple discounts. The algorithm stops as soon as we do find a discount for which the optimal quantity ($Q^*_j$) is feasible. This does not mean that the optimal solution is equal to the feasible optimal quantity. Therefore, the optimal solution cannot be less than the optimal quantity to order. In this manner, we are able to satisfy all demands. In addition, this solution turns out to be the best trade-off between cost and benefit.

The foundations of the method are that, every time that a certain discount threshold is reached, the buyer has to buy larger amounts than those optimal, thus moving away from the minimization of the cost function.

In the beginning, from a first glance, it appeared that the best solution was to have a purchase costs about 1.204,14 € ($C_4$) because it falls in the interval $40 \leq x < 50$ units and our demand is equal to 47 units.

Despite all expectations, after the implementation and the results of the model, it is much more convenient the choice a purchase costs equal to 1.164,00 € ($C_5$) with 13% of discount. This is because the cost function of $C_5$ is lower than that of $C_4$.

In the light of values resulting from the model, we can conclude that the optimal solution is to order 50 units, corresponding an average annual cost of purchasing and managing inventory equal to 65.336,62 € , while, before, it was equal to € 73,586.04 ordering 55 units of products. Therefore, we are talking about an economic benefit about € 8,249.42. The latter may seem like an insignificant value, but it is not, considering the fact that the company handles thousands of products. Order fifty coils is the optimal point of trade-off between order/maintenance costs and purchase discounted costs/demand to be met. The optimal economic quantity for Cavallone srl before our analysis was about 55 units of products, because the company had underestimated the holding costs, assessing them at around 14% instead of 20%. Based on the incorporated algorithm and the correspondent findings, we carried out sensitivity analysis by varying some costs. This was to see if the estimation costs made would lead us to a noticeable change in the results, although we verified that it did not happen.

Considering all above, with optimal order quantity equal to 50 units, we are ordering 6.4% more in respect to the demand (3/47 units), for not running into stock out risk. To sum up, we can assert that the finding of this experimental analysis is valid and significant and of course beneficial for the company in order to improve their inventory management.

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