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Automation of purchase orders management to reduce components inventory in a company of the automotive industry.

Tutor

Prof. Luca Settineri

Candidate

Daniela Giraldo Gallego

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Introduction

The new challenges imposed by the economic and social development of some countries with more economic wealth, and the efforts made by others less wealthy, to achieve this desired development, have led to the emergence of new business philosophies aimed at achieving the gradual improvement of the functioning of the organizations. Improvement, as a renewing trend in the productive processes and in the rendering of services, constitutes a series of general programs of action and deployment of resources for the achievement of the expected objectives, which imply a process of continuous improvement.

In this sense, logistics as an area of key results within any organization, does not escape from this process of improvement, since logistics activities as vitally important elements are present in most business processes; transportation, storage, inventory management, material handling, contracting and negotiating with suppliers, requesting and purchasing products, are examples of some of these, which have been developed and perfected since the military sciences would group them and give it the name of Logistics, the same one that would reach its global plenitude as a science, with the economic growth experienced at the end of the Second World War (Ramirez Lambert & Muñoz Creagh, 2017).

Since the beginning of its history, humanity has used stocks of varied resources in order to support its development and survival, such as tools and food (Garcia, 2006). Currently, inventories account for more than 50%, on average, of companies' current assets (Christopher, 2002) are one of the main analysis factors in the decisions about logistics networks.

Among the costs of a logistics network, the inventory factor, that is, the ratio of goods available in stock, is one of the most important because it directly affects the two main indicators of the performance of a supply chain: the level of customer service in the perspective of product availability and the inventory turnover of the chain. While the former measures the good management of the logistics network relative to its main external focus (consumers), the second indicator represents how well is being managed one of the most important internal assets of the companies, since the stock has become the most representative in terms of capital employed and responsible for the greatest waste. Good inventory management reduces excess inventory, thereby improving the company's cash flow.

This thesis focuses on the creation of a system that facilitates logistical decision making, with the aim of reducing inventory levels through the automation of coverage calculations, and its implementation in a company in the automotive sector. The present study is organized in six chapters, which the reader will find information and support to understand the development, results and conclusions obtained. The first chapter provides a review on main inventory management topics, to offer a theoretical context of the subject. The second chapter presents a general company presentation to provide contextual elements of the business where the work was developed. The third chapter describe in more detail how the supply chain of the plant (Ivrea, Italy) works now. The fourth chapter describes the problem that currently occurs in the warehouses of the plant and their respective causes. The fifth chapter presents the development and application of a short-term solution proposed to the problem, with the creation of a system that automates the calculation of coverage to help decision-making regarding the provisioning of materials. Finally, conclusions and recommendations for the topic studied are provided in sixth chapter.

Chapter 1 Theoretical framework

1.1. Supply chain

1.1.1. Supply chain definition

The objective of supply chain management is obviously the supply chain, which is defined as an integrated process in which several organizations work together in the different processes and activities that produce value in the form of products and services for the final consumer, acquiring raw materials, converting raw materials into specified final products and delivering these final products to retailers or consumers (Beamon, 1998). These organizations may be firms producing parts, components and end products, logistic service providers and even the (ultimate) customer himself. So, the above definition of a supply chain also incorporates the target group – the ultimate customer.

At first glance, it could be thought that the supply chain is nothing more than a set of supply, transformation and transport activities, linked with similar activities by suppliers and customers. In other words, it would be a logistics beyond the limits of the company, covering the relationships, backwards and forwards, with supplier companies and client companies (Sethi, et al., 2005). If this were true, it would be nothing more than a comprehensive logistics and it would not be necessary to resort to a new concept. But this view is wrong or, at least, limited.

A supply chain includes the process of supply, manufacture and distribution and operates in an integrated manner with sales, marketing and development of new products, but also relates to other processes of the company such as pricing or payment policies to suppliers and collection.

A specialist in systemic thinking would describe a supply chain as a complex system with diffuse borders, in which it is not the components (organizations) separately that determine performance but the relationships between them. Within it each component performs a function that is related to other functions, achieving that the complete system has a specific behavior and performance (Chavez & Torres Rabello, 2012).

For there to be a supply chain, three or more entities are required. A relationship between two organizations, a customer and a supplier, would only describe one of the many relationships that a complex supply chain could contain.

In a narrow sense, the term supply chain is also applied to a large company with several sites often located in different countries. Coordinating material, information and financial flows for such a multinational company in an efficient manner is still a formidable task. Decision-making, however, should be easier, since these sites are part of one large organization with a single top management level.

A supply chain in the broad sense is also called an *inter-organizational* supply chain, while the term *intra-organizational* relates to a supply chain in the narrow sense. Irrespective of this distinction, a close cooperation between the different functional units like marketing, production, procurement, logistics and finance is mandatory – a prerequisite being no matter of course in today's firms (Stadtler & Kilger, 2005). Now will describe these two perspectives of supply chain proposed by (Ullrich, 2014).

- ***The inter-organizational perspective:***
  The inter-organizational perspective addresses a network of independent, meaning legally separated, companies that is referred to as a supply chain, which is the more common definition mentioned in the dissertation's outline. The word 'chain' suggests a linear sequence of companies. However, in practice, the structure of business relationships between companies is generally not linear but arborescent. Since companies often pursue a dual or multiple sourcing strategy, meaning they source required materials and components from several suppliers, 'supply network' would be the more accurate term to describe real-world business structures. Nevertheless, the term supply chain, often meaning a supply network, has become accepted in the literature. *Figure 1.1* depicts a classic inter-organizational supply chain structure.

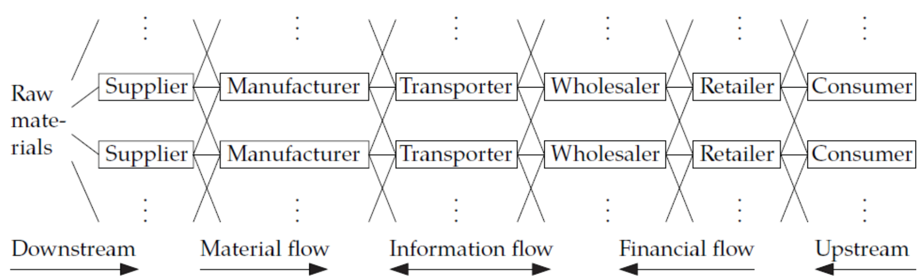

Figure 1.1 A classic inter-organizational supply chain structure

While the material flow generally proceeds down the supply chain, information flows in both directions. For example, orders are given up the supply chain, while the arrival times of the materials are communicated down. The financial flow generally proceeds up the supply chain.

In case of product recycling or reverse logistics of load carriers, for example, the material flows down as well as up the supply chain. The same holds for monetary payments. Contractual tardiness penalties can cause downstream financial flows, too. *Figure 1.1* only presents a classic structure that is relevant in many branches of industry.

- ***The intra-organizational perspective:***
  The intra-organizational perspective deals with the supply chain within a company, which can be explained by the *supply chain planning matrix* in *Figure 1.2*. The focus is on the activities carried out within a company.

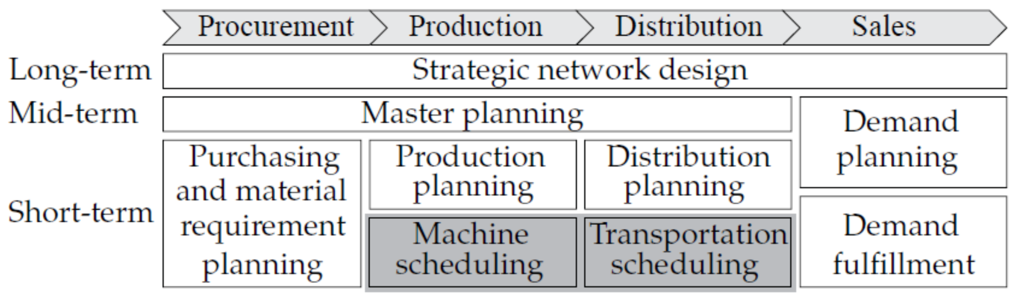

Figure 1.2 The supply chain planning matrix

Assumed to be linked by information flows in all directions, the rectangles represent typical planning issues arising in most industrial companies. The *y*-axis addresses the time horizon of these issues (Fleischmann, et al., 2008). The *x*-axis exhibits the material flow through the main activities *procurement*, *production*, *distribution*, and *sales*. For example, *strategic network design* requires making structural decisions with a long-time horizon. The challenge is to determine capacities, transportation modes, strategic business relationships, and locations of processing sites and warehouses. These decisions should be made simultaneously since they concern procurement, production, distribution, and sales more or less at the same time. A mid-term task is *master planning* which comprises the assignment of production quantities to processing sites, identification of bottlenecks, adjustment of capacities, and contracting with suppliers and third-party transporters. Covering the next sales cycles, master planning is based on demand forecasts provided by the department responsible for *demand planning*. Based on the results of master planning and a bill of materials explosion, the short-term material requirements can be planned and the materials purchased. *Production planning* and *machine scheduling* means determining lot sizes and production schedules for a given week, day, and/or hour. *Distribution planning* and *transportation scheduling* refer to assigning completed products to transportation batches and scheduling deliveries to customers.

Intra-organizational supply chain management focuses on the integration and coordination of the company-internal activities. Its aim is to improve the company's performance and competitiveness.

Compared with inter-organizational supply chains aligned by coordinating contracts, intra-organizational supply chains seem to have the advantage of a central head office that can issue instructions.

1.1.2. How supply chain works

According to (Hugos, 2003), there are five areas where companies can make decisions that will define their supply chain capabilities: production, inventory, location, transportation and information. These areas are performance drivers that can be managed to produce the capabilities needed for a supply chain.

A supply chain works by first understanding each driver and how it operates (each driver can directly affect the supply chain and enable certain capabilities). By second developing an assessment for the results that can be obtained by mixing different combinations of these drivers.

For the first step is necessary to describe each driver individually, like will be seen below.

- ***Production:***

Production alludes to the capacity of a supply chain to manufacture and lay up goods. The facilities of production are manufacturing plants and stockrooms. The most important decision that managers confront when making production decisions is how to solve the trade-off between responsiveness and efficiency. If manufacturing plants and stockrooms are built with a lot of extra capacity, they can be very supple and react rapidly to broad swings in product demand. Facilities where all or almost all capacity is being utilized are not capable of reacting easily to oscillations in demand. On the other hand, capacity costs money and extra capacity is inactive capacity, not exploited and not creating profits. So, the more extra capacity exists, the less efficient the process becomes.

- ***Inventory***

Inventory is expanding all over the supply chain and incorporates the whole things from raw material to work in process to finished goods that are held by the manufacturers, distributors, and retailers in a supply chain. Once more, managers have to make a decision regard where they want to place themselves in the trade-off between responsiveness and efficiency. Maintain large quantities of stock allows a company or a whole supply chain to be very reactive to changes in customer demand. Nevertheless, the creation and storage of inventory is a cost and to attain high levels of efficiency, the cost of inventory should be kept as low as possible.

- ***Location***

Location refers the decisions related to the geographical siting of supply chain facilities and to which activities should be performed in each of them. The responsiveness versus efficiency trade-off here is the choice between centralize activities in smaller quantity of places to obtain economies of scale and efficiency, or to decentralize activities in many places close to customers and suppliers to make operations more responsive.

When making location decisions, managers must consider a number of factors related to a particular location, including the cost of facilities, cost of labor, skills available in the workforce, infrastructure conditions, taxes and fees and proximity to suppliers and customers.

Location decisions have strong impacts on the cost and performance characteristics of a supply chain. Once the size, quantity, and position of facilities is decided, defines the possible paths through which products can flow on the way to the final customer.

- ***Transportation***

This refers to the movement of everything from raw material to finished goods between different facilities in a supply chain. In transportation the trade-off between responsiveness and efficiency is manifested in the choice of transport mode. Fast modes of transport, like airplanes, are very receptive but also more expensive. Slower modes like ship and railroad are very profitable but not so receptive. Decisions made here are very important because transportation costs can be as much as a third of the operating cost of a supply chain.

- ***Information***

Information is the basis upon which to make decisions concerning the previous four supply chain drivers. It is the connection between all the activities and operations in a supply chain. To the extent that this connection is strong (that is, the data is precise, timely and complete), companies in a supply chain can make good decisions for their own operations and tend to maximize their profitability.

Within an individual company the trade-off between responsiveness and efficiency includes weighing the benefits that good information can give against the cost of acquiring that information. Abundant, precise information can allow very efficient operational decisions and improved forecasts but the cost of building and introducing systems to deliver this data can be very elevated.

Within the supply chain as a whole, the trade-off between responsiveness and efficiency that companies make is to determine how much information to share with other companies and how much information should be kept private. The more information concerning items supply, customer demand, market forecasts, and production schedules that companies share with each other, the more receptive they all can be. However, by balancing this aperture, there are the concerns that each company has about revealing information that could be used by a competitor not in favor of them. The latent costs related with increased competition can influence the profitability of a company.

1.2. Inventory Management

The interval between receiving the purchased parts and transforming them into final products varies from industries to industries depending upon the cycle time of manufacture. It is, therefore, necessary to hold inventories of various kinds to act as a buffer between supply and demand for efficient operation of the system.

Inventory generally refers to the materials in stock and their main function is to reduce the interdependency between the various stages of the production and delivery system. That is because the impact of any disruptions in one of the subsystems of the whole process will be felt in the other ones. However, it is necessary to highlight that inventory only helps in diminishing the intensity of the impact of disrupted operations in one subsystem over other subsystems and does not eliminate it completely because the amount of inventories is limited (Vidal Holguín, 2005).

Inventory management include the widest spectrum of activities related to materials. Starting with the primary activities which include when and how much to make or purchase. In addition, timing of replenishments and decisions about storage are important decisions as well.

1.2.1. Reasons for keeping inventory

According Max Muller (Muller, 2011), some of the more important reasons for obtaining and holding inventory are:

- *Fluctuations in demand*: The demand for an item fluctuates because of the number of factors, *e.g.,* seasonality, production schedule, etc. You don't always know how much you are likely to need at any given time, but you still need to satisfy customer or production demand on time. The inventories (raw materials and components) should be made available to the production as per the demand failing which results in stock out and the production stoppage takes place for want of materials. Hence, the inventory is kept to take care of this fluctuation so that the production is smooth. If you could see how customers are acting in the supply chain, surprises in fluctuations in demand were held a minimum.

- *Quantity discounts:* Frequently the manufacturers offer discount for bulk buying and to earn this price advantage the materials are bought in bulk even if it is not necessary immediately. Thus, inventory is kept up to gain economy in purchasing.

- *Price protection:* The organizations must anticipate the changing market sentiments and they have to stock materials in anticipation of non-availability of materials or sudden increase in prices. Buying quantities of inventory at appropriate times helps avoid the impact of cost inflation. Note that contracting to assure a price does not require taking delivery at the time of purchase. Many suppliers prefer to deliver periodically rather than to ship an entire year's supply of a particular stock keeping unit (SKU) at one time.

- *To meet the demand during the replenishment period***:** During the materials procurement, the lead time of each supplier is variable, and it depends upon many factors like location of the source, demand supply condition, etc. So, inventory is maintained to meet the demand during the procurement (replenishment) period.

- *Unreliability of supply*: When an item is scarce, and a steady supply is difficult to ensure or, when you have unreliable suppliers, it is necessary to maintain inventory. Whenever possible, unreliable suppliers should be rehabilitated through negotiations or replaced. Rehabilitation can be accomplished through master purchase orders with timed product releases, price or term penalties for nonperformance, better verbal and electronic communications between the parties, and so on. This will lower your on-hand inventory needs.

- Sometimes the organizations have to stock materials due to other reasons like suppliers' minimum quantity condition, seasonal availability of materials or sudden increase in prices.

1.2.2. Types of inventory

According J. Viale and C. Carrigan (Viale & Carrigan, 1996), inventory is basically divided into raw materials, work-in-process, and finished goods.

- *Raw Material:* This includes all the purchased parts and direct materials that are used to produce partial products or completed goods. This type of inventory has value added to it as it flows together as subassemblies, assemblies and finally into the shippable product.

- *Work-in-Process*: Items are considered to be WIP during the time raw material is being converted into final products. Raw materials are released from inventory and moved to a work center. People (direct labor) and/or machines are used to add value by putting the parts together as subassemblies, assemblies and then into final products. These parts may be restocked temporarily until withdrawn for use later in the production process. While they are in this state, they may be referred to as semi-finished assemblies. WIP occurs because of such things as work delays, long movement times between operations, and queuing bottlenecks. WIP should be kept to a minimum.

- *Finished Goods:* These are shippable inventories ready to be delivered to distribution centers, retailers, wholesalers or directly to customers. It can also be used to buffer manufacturing from predictable or unpredictable market demand.

Other categories of inventory should be considered from a functional standpoint:

- *Consumables:* Light bulbs, hand towels, computer and photocopying paper, brochures, tape, envelopes, cleaning materials, lubricants, fertilizer, paint, dunnage (packing materials), and so on are used in many operations. These are often treated like raw materials.

- *Distribution Inventory:* This is inventory held at points as close to the customer as possible. Distribution points, such as warehouses or stores, may be owned and operated by the manufacturer or may be independently owned and operated.

- *Maintenance, Repair and Operating (MRO) Supplies:* These are after-market items used to "keep things going." As long as a machine or device of some type is being used (in the market) and will need service and repair in the future, it will never be obsolete. MRO items should not be treated like finished goods for purposes of forecasting the quantity level of your normal stock.

1.2.3. Components of inventories

Theoretically, there are two components of any inventory, *cycle stock* and *safety stock*, but sometimes companies need a third one, *seasonal stock* (Hugos, 2003).

- *Cycle stock*: is made up of the most "active" parts contained in the inventories (the high runners). This is the quantity of stock needed to satisfy demand for the product in the interval between purchases of the product.

- *Safety stock*: Inventory that remains as a buffer against uncertainty, also referred to as buffer stock, is used to protect against the fluctuations in demand or supply. It makes up inventory held to buffer against fluctuations in forecast, changes in a customer's order, or late shipments from a supplier. The impact of safety stock in a manufacturing environment is to release an order and bring inventory in before it is really needed. In the master schedule, safety stock is maintained to protect against forecast error.
  If demand forecasting could be made with perfect precision, then the only stock that would be necessary would be cycle inventory.

- *Seasonal stock*: This is inventory that is created in anticipation of predictable increases in demand that take place at certain period of the year. If a company has a fixed production rate that is costly to change, it will try to manufacture products at a constant rate throughout the year and accumulate inventory during periods of low demand to cover periods of high demand that will exceed its production rate. The alternative to accumulating seasonal inventories is to invest in adaptable manufacturing facilities that can rapidly change their rate of production of diverse products to react to increments in demand.

1.2.4. ***Inventory-Related Costs***

The focal point of inventory analysis lies in finding and measuring relevant costs. According S. Gupta and M. Starr (Gupta & Starr, 2014), six fundamental types of costs are examined and subsequently, in a seventh category, a few others are mentioned.

The six costs that will be described are:

- Costs of ordering
- Costs of setups and changeovers

- Costs of carrying inventory
- Costs of discounts
- Out-of-stock costs
- Costs of running the inventory system

- *Costs of Ordering:* The cost of ordering includes those cost objects that go into creating and placing an order, following up of the order and receiving the order. It consists of writing the purchase request form, making phone calls in correlation with details, and ordering, e-mailing, faxing, or mailing purchase orders to the supplier. All costs that increase as a function of the number of purchase orders qualify for inclusion.

- *Costs of Setups and Changeovers:* In a manufacturing situation, the ordering cost is replaced by the cost of setting up the equipment to do a production run. This requires cleaning up from the previous task, which also is called taking down. The procedure is known as changeover, and the costs can be considerable.

  A number of parts may have to be finished before the setup is complete. The cost of learning is involved, and defectives play a role. When acquiring equipment, changeover times and costs can be as significant to consider as production rates.

- *Costs of Carrying Inventory:* Inventory is a form of investment. Capital is tied up in materials and goods. The alternative uses of inventory include spending for R&D, new product and/or process development, advertising, promotion, and going global. Some firms even put the money into financial instruments, the stock market, or the savings bank.
  Expanded capacity and diversification are typical opportunities that, when ignored, incur the cost of not doing that much better with the investment funds. By holding inventory, the company foregoes investing its capital in these alternative ways. Such opportunity costs account for a large part of the costs of carrying inventory.

  These are the costs over which P/OM (Production and Operations Management) can exercise control using inventory policies. Thus, if a company can obtain discounts for purchases of quantities greater than its storage capacity, then to get this discount it must expand said capacity. It can buy or rent additional space.

There are options for ordering large quantities to obtain discounts without requiring expanded storage capacity. One of these is vendor releasing, whereby the supplier agrees to deliver small increments of the larger order over time.

Another method for reducing storage space requirements is the use of cooperative storage. Cooperative sharing reduces storage costs and increases the availability of expensive components that require large dollar expenditures.

Items carried in stock are subject to costs of pilferage, obsolescence, deterioration, and damage. These costs represent real losses in the value of inventory.

Obsolescence may be the most important component of carrying cost because it happens so often and so fast. Obsolescence occurs quite suddenly because a competitor introduces technological change. Out-of-season and out-of-style items can lose value and must be sold at a special reduced rate. The determination of how much inventory to carry will be affected by the nature of the inventories and the way in which units lose value over time. Delays in getting dated products to market will decrease revenues, productivity, and increase carrying costs.

An added component of carrying cost is both taxes and insurance. If insurance rates and taxes are determined on a per unit basis, then the amount of inventory that is stocked will determine directly the insurance and tax components of the carrying costs.

- *Costs of Discounts:* Accepting discounts by buying at least a certain quantity of items involves extra costs that may make taking the discount unprofitable. An appropriate inventory cost analysis must be used to conclude whether a discount that is offered should be taken. The extra costs for taking the discount are compared to the savings gotten from the discount. Extra expenses include extra carrying costs. A fraction of these carrying costs is caused for supplementary storage space.

- *Out-of-Stock Costs:* When the firm does not have stock to fill an order, there is a punishment to be paid. Maybe the client goes somewhere else but will return for the next buy. At that point the punishment is only the value of the order that is lost. In the event that the client is bothered by the out-of-stock circumstance and finds a new provider, the client may be lost forever. The loss of goodwill must be interpreted into a cost that is equivalent to the end of the income generation of that client. The particular cost is how much lower the lifetime value of that client becomes, or the income from that client may end entirely.

In case the buyer is willing to wait to have the order filled, the company creates a backorder. This calls for filling the order as before long as capacity is available, or materials arrive. Backorder costs incorporate the punishments of estranged clients. To maintain distance from this punishment, some mail-order companies prefer to fill customers' orders with a costlier substitute rather than making a backorder. The outage cost is related to diminish in benefit margin. In any case, the goodwill created by the motion is an intangible expansion to long-term benefit. Depending on the system that is utilized (i.e., backordering, substitutions, fill or kill, and so on), different costs of being out of stock will occur. The lost-goodwill cost is most troublesome to assess.

Organizations that are not near to their clients regularly disregard lost goodwill. This may happen since the firm does not know how to measure or recognize goodwill. Numerous bureaucracies are recognized as ignoring client satisfaction inadvertently by neglecting the work satisfaction of their workers who in turn bargain with the clients. Displeased employees distance clients which implies there are less happy clients.

- *Costs of Running the Inventory System:* Processing costs that are related with running the stock system are alluded to here as systemic costs. These costs are frequently related with data system costs called IT costs. This category of costs is usually a function of the size of the stock that is carried and the significance of knowing exact stock levels on-line instantly.

  An enormous portion of systemic cost is keeping up with incessant supplier cost changes, client demand modifications, carrying cost adjustments, labor costs for keeping records, and technology modification costs. Costs are related to the number of individuals working the inventory system. Operating costs also incorporate systems assistance, programming, and training costs. Training costs are high in well-run IT systems, particularly when labor turnover is significant and technology changes quicken. The amount of time that the system works (numerous times round-the-clock) and the number of areas that are networked into the centralized data system (round-the-world) have to be figured into this cost.

Systems including numerous stock-keeping units (SKUs) are dependent upon having an organized information system. There are diverse SKU part numbers for each model type, as well as for each size and color. Part numbers for SKUs distinguish particular suppliers and show where inventories are stored. When there are frequent online transactions with numerous SKUs, the amount of detail is great. Such systems are labor-intensive and costly to operate.

It makes sense to center on the SKUs for materials and items that are critical for production. Moreover, it makes sense to pay special attention to items that have high dollar volume since these items waste the larger part of the money apportioned if handled badly.

The status of work in process (WIP) can be observed by implies of bar codes, radio frequency identification (RFID), and optical readers. Regularly, these technologies are combined. Systemic costs proceed to be formidable.

- *Additional Inventory Policy Costs:* The six costs already talked about are generally the foremost important in deciding stock policy. However, other costs can play a part in particular cases. Each manufacturer recognizes his costs of delay when preparing orders with long setups are required. Service organizations are sensitive to the costs of delay.

  The costs of production interferences have already been related to the critical nature of stock items. Lost stock within the warehouse and mistakes in bookkeeping are causes of interferences. Lost baggage in airline travel is an illustration of a cost to both the traveler and the airline.

  Salvage costs can play vital roles, as can the costs be required for expediting orders. The costs of deterioration for food might be better handled as isolated costs rather than as a portion of the carrying cost related to obsolescence. The pro-and-con costs of central warehousing when compared to scattered warehousing can be significant. In different circumstances, one or more of these costs can dominate the inventory policy assessment. A solid systems study will see outside the ordinary boundaries of stock costs to spot those components that are affecting the cost/benefit system (Chase, et al., 2009).

1.2.5. Types of Inventory Management

Within the worlds of distribution, retailing, and replacement parts, an organization deals with finished products. Within the manufacturing world, an organization bargains with raw materials and subassemblies. Considerations of what to buy, when to buy it, in what amounts, and so on are drastically diverse in these two worlds.

In distribution, you are concerned with having the proper thing in the right amount. Issues relating to having the item at the proper time and place are regularly managed with by basically expanding safety stock on hand. That is not a great solution since it leads to wasted money and space. However, conventional formulae utilized to compute stock necessities in a distribution environment focus on item and amount instead of place and time. In manufacturing, you are concerned with having the proper thing, within the right amount, at the proper time, in the right place.

Demand for finished goods and spare parts for replacements are said to be "independent", while demand for items in the manufacturing world are said to be "dependent" (Kempf, et al., 2011). Understanding these distinctions will assist you in forecasting your procurement needs.

Independent demand is influenced by market conditions outside the control of your organization's operations. The demand for the widgets your organization sells will be independent of the demand for your gadgets, doodads, and whatchamacallits. Your products are independent of one another. In this environment, you must have the right item in the right quantity.

Dependent demand is related to another item. The demand for products built up or created from raw materials, parts, and assemblies is dependent on the demand for the final product. You would not need one item if you did not also require another, both of which would go into an assembly or finished product. In this environment, you must have the right items in the right quantities at the time to complete a finished product.

Dependent and independent demands demonstrate very different use and demand patterns.

Independent demand calls for a replenishment approach to inventory management. This approach assumes that market forces will exhibit a somewhat fixed pattern. Therefore, stock is replenished as it is used in order to have items on hand for customers.

Dependent demand calls for a requirements approach. When an assembly or finished item is needed, then the materials needed to create it are ordered. There is no fixed pattern because an assembly created in the past may never be produced again.

The nature of demand, therefore, leads to different concepts, formulas, and methods of inventory management (Hugos, 2003).

1.2.5.1. Independent Demand Inventory

Since items in an independent demand inventory system "stand alone," the appropriate reorder point for each item must be calculated using order-point formulae.

Order-Point Formula

Order-point formulae are used to determine how much of a given item needs to be ordered where there is independent demand. In these formulae, a reorder point (ROP) is set for each item. The ROP is the lowest amount of an item you will have on hand and on order before you reorder.

A Simple Min-Max Inventory System

Order-point formulae are based on some relatively simple concepts.

Imagine that all of a particular SKU are kept in a single bin. If no reorder point was set, then the entire batch would be used up without any order being placed. The organization would then be unable to sell or use that item during whatever timeframe—was required to order and bring the SKU in the lead time. It would therefore make sense to adopt a two-bin system, with Bin 1 containing working stock and Bin 2 containing working reserve. The amount of product in Bin 2 would be equal to your usage rate during that item's lead time.

In a two-bin system, if all goes as it should, then immediately on using the first item from Bin 2, you would reorder a quantity equal to both Bins 1 and 2. As you use the last item in Bin 2, the order arrives, and you refill both bins. This assumes that lead time is exact, there are no vendor stockouts or backorders, and that there are never any defects. That assumption is, of course, often false. Therefore, a true order-point system is a three-bin system, with Bin 3 containing safety stock.

Bin 3, safety stock, relates to Bin 2 since Bin 3 is to make up for uncertainties in lead time and defects. Mathematically safety stock is 50 percent of working reserve. (The average between having nothing in Bin 2 and having it at 100 percent full is 50 percent.) However, companies adjust safety stock levels to coincide with their actual experience.

Bins can be mathematically created or can reflect actual physical separation of items in the stockroom.

A simple formula for determining the ROP reflects the above concepts.

$$ROP = (Usage * Lead\,Time) + Safety\,Stock$$

The ROP is the "minimum" (min) in a "minimum-maximum" (min-max) inventory control system. In these systems there is a minimum below which you will not let your stock level fall, and there is a maximum above which you will not have items on hand or on order.

To compute the maximum in these systems, you must first determine how often you will place orders. This time period is called the review cycle.

The review cycle is the length of time between reviews of when you wish to order product. The formula to determine the review cycle is:

$$Review\ cycle = \frac{Total\ Purchases\ from\ Vendor\ for\ a\ Year}{Discount\ Quantity}$$

The unit of measure reflecting total purchases from a vendor can be dollars, pieces, pounds, units, or whatever your organization uses. The discount quantity is the minimum amount you have to order of that unit of measure in order to be granted a discount.

1.2.5.2. Economic Order Quantity

In 1915, F. W. Harris of General Electric developed the Economic Order Quantity (EOQ) formula to help stock keepers in determining how much product to buy (Saldarriaga Restrepo, 2013).

To calculate EOQ, assume:

A = Total Value of SKU Per Year

K= Carrying Cost (the K Factor)

R = Replenishment Cost (the R Factor)

P= Price Per Unit

Basic Formula

$$EOQ = \sqrt{\frac{2AR}{KP^2}}$$

This formula and its variations allow you to determine the following:

- Optimal quantity to order
- When it should be ordered
- Total cost
- Average inventory level
- How much should be ordered each time
- Maximum inventory level

The EOQ model is based on several assumptions:

- The demand rate is constant (no variations), recurring, and known.
- The carrying cost and ordering cost are independent of the quantity ordered (no discounts).
- The lead time is constant and known. Therefore, the ordering times given result in new orders arriving exactly when the inventory level reaches zero.
- The formula can handle only one type of item at a time.
- Orders arrive in a single batch (no vendor stockouts or backorders).

1.2.5.3. Dependent Demand Inventory

Materials Requirements Planning (MRP)

Controlling not only what item is purchased and in what quantities, but also the timing of its arrival through computerized systems is called materials requirements planning (MRP) (Gaither & Frazier, 2000). This concept of the right item, in the right quantity, and at the right time was first introduced by Joseph Orlicky in the early 1960s.

Independent demand inventory management is customer oriented. The objective of ROP rules and formulae is high customer service levels and low operating costs. Dependent demand systems, however, are manufacturing oriented. The objective of dependent demand inventory control is to support the master production schedule. Even if you have a low stock level of an item. it won't be ordered unless and until it is needed to produce something for the master schedule—a true requirements philosophy of inventory control. MRP-dependent demand inventory control is directed inward rather than outward like ROP inventory control.

MRP Elements. Key concepts in understanding MRP are the master production schedule and the bill of materials.

The master production schedule sets out what will be built, when, and in what quantities. It can either cover short or long-time horizons.

Short horizon—planning of initial requirements sets out:

- Final product requirements
- Schedule for production of components
- Purchase order priorities
- Short-term capacity requirements

Long horizon estimating long-term requirements sets out:

- Long-term production capacity required
- Long-term warehouse capacity required
- Long-term staffing required
- Long-term money required

The *bill of materials* (BOM) is the recipe of raw materials, parts, subassemblies, and so on required to build or make something.

MRP's chief advantage over the ROP approach is that it lets you customize your ordering strategy for raw materials, parts, and so on with different demand characteristics, such as lead times. The ROP approach answers the questions of what and how much. ROP does not answer the question of when.

MRP allows purchases to be made as and when needed to ensure that items will arrive when needed. It accomplishes this by setting up time phasing charts within the computer system (Heizer & Render, 2008).

The next step is a parts explosion, during which you review your on-hand inventory levels to initially determine if any POs must be prepared and released.

You then engage in detailed capacity planning to decide if you can proceed or if the master schedule, capacity, or the planned release of POs must be changed.

Ultimately, all parts, equipment, and so on come together and the stool is built.

MRP works well because it is a forward-looking system. The predictability of events allows for careful planning and a reduction in unnecessary inventory.

A major drawback of MRP and JIT systems is that they are highly data dependent. Not only do you have to have all the data easily available on an ongoing basis, but, in addition, the information must be accurate and timely. Organizations lacking a strong software/hardware infrastructure will have difficulty in fully implementing an MRP system.

Just-in-Time (JIT) Inventory Systems

JIT was first developed within Toyota's manufacturing operations by Taiichi Ohno in the 1970s as a means of meeting customer demands with minimum delay. In its original form, it referred to the production of goods, assemblies, and subassemblies to meet exactly the customer's demand in terms of time, quality, and quantity. With a JIT system, the "buyer" can be the actual end user or another process along the production line (Farahani, et al., 2011).

JIT goes further than MRP, because you control not only the right item, in the right quantity, at the right time, but you also bring that SKU to the right place. Under this time-based concept, an item appears exactly when it is needed—not before, not after.

The American Production and Inventory Control Society (APICS) has the following definition of JIT:

... a philosophy of manufacturing based on planned elimination of all waste and continuous improvement of productivity. It encompasses the successful execution of all manufacturing activities required to produce a final product, from design engineering to delivery and including all stages of conversion from raw material onward. The primary elements include having only the required inventory when needed; to improve quality to zero defects; to reduce lead time by reducing setup times, queue lengths and lot sizes; to incrementally revise the operations themselves, and to accomplish these things at minimum cost (Funk, 1989).

The many benefits of a JIT system include:

- Reduction of stockouts
- Reduction of inventory levels
- Reduction of need for material handling equipment
- Reduction of timeframes between delivery and production
- Significant quality improvement
- Employee inclusion in continuous quality improvement

JIT is a management philosophy rather than a technique.

The terms/acronyms MRP III, Computer-Integrated Manufacturing, Lean Manufacturing, Short-Cycle Manufacturing. Just-in-Time, JIT, Enterprise Resource Planning, ERP, and so on all relate to the fundamental notions that:

- Manufacturing activities should be integrated.
- The actions and decisions of each department should complement all other departments.
- Information should flow both internally throughout the organization and externally to/from suppliers/customers electronically rather than through:

  - The movement of hard paper copies, or
  - Individual software (accounting) modules whose data do not flow into one another both automatically and in real time.
- Suppliers are reliable and raw materials are without defect.
- All employees follow the philosophy of continuous quality improvement in all aspects of the operation.

Let's concentrate on how these concepts—by whatever name—relate to inventory. They all regard inventory as waste.

Today JIT has come to mean producing with a minimum of waste. "Waste" is used in the broadest sense and includes any non-value-adding activities. For example, storing, inspecting, and counting materials doesn't change the items; therefore, those actions add no value. There are seven types of waste JIT systems strive to eliminate:

1. Overproduction producing more than needed. Wasted money, effort, space, etc.

2. Waiting time—decreases productivity and efficiency.

3. Transportation-double and even triple handling of an item from one storage position to another.

4. Processing—what are the interfaces between parties, departments, you, and your suppliers? The fewer and faster the better.

5. Inventory—stock simply sitting around does no one any good.

6. Motion-reduce motions such as those involved in looking for materials.

7. Defects—defective goods not only cost money directly, but they also cause stops and delays.

1.2.6. Inventory Management Tools and Techniques

In this part, various tools and techniques will be reviewed for determining the appropriate levels of inventory to buffer against fluctuations in demand and supply.

1.2.6.1. Forecasting and determining inventory levels

Forecasting is critical to estimating future demand. This estimate may be developed by using mathematical formulas, data from informal sources or a combination of both. Forecasting is key to all aspects of a successful business planning system. As customers place more demands and require faster deliveries, the ability to forecast as accurately as possible is essential (Vidal Holguín, et al., 2004).

For forecasts to be usable, they must be based on timely data gathered in a consistent manner. A good forecasting process must include:

- The use of forecasting tools e.g., using historical results to predict future sales
- The creation and collection of information
- The management of this information
- The making of well-informed decisions about what you need to produce

Forecasting is meaningful only if it helps to:

- Improve customer service
- Reduce inventory
- Increase productivity
- Improve the deliveries from suppliers

Every good forecast includes an estimate of the forecast error. The forecast error is the difference between what you thought you were going to ship and what you actually shipped. In order to improve sales forecasts, you will first need to calculate the forecast error (actual sales minus forecasted sales equals forecast error). The larger the forecast error, the higher the level of inventory needed to satisfy customers.

The more accurate your individual product sales forecasting is, the smaller your forecast error, and the less inventory you'll have to carry to maintain a specified level of customer service. By carrying less inventory, you can more effectively use the capacity of machines required to build the products. Inventory is not being built before needed, thus committing capacity of machines too early. By carrying less inventory, less space is used, and it is not used too early (Viale & Carrigan, 1996).

Since all forecasts have a forecast error, the next question is how to calculate the amount of inventory needed to buffer this forecast error and meet the company's objective of on-time shipment (i.e., customer service level).

- *Customer Service (Customer Service Ratio):* is a performance measure that is shown as a percentage of on-time versus promised delivery dates. It is stated both in dollars and units. Some companies call this the fill rate or order fill rate.
  Another measure that is used in customer service is called the stockout rate or percentage. A stockout is the number of times each year that you run the risk of not having inventory when needed. The percentage of stockouts shows total stockout to total orders.
  Customer service can also be looked at from the standpoint of "exposures" to stockouts. The number of stockouts can be calculated by dividing the annual usage by the lot size.

$$Stockout = \frac{Annual\ usage}{Lot\ size}$$

One of the most important tools used in determining the required inventory is the Standard Deviation of the Forecast Error calculation. The purpose of this calculation is to calculate an amount of inventory that will allow for the forecast error and establish a certain probability of still shipping on time.

- *Standard Deviation* is a statistical calculation that deals with difference. In the context of this book, it is the difference between forecasted shipments and actual shipments. This difference is called a forecast error.
- *Mean Absolute Deviation (MAD)* is a shorter version of the standard deviation calculation. To calculate MAD, simply total the forecast error, disregarding the fact that the forecast error is negative or positive. The sum of this total is then divided by the number of time periods being reviewed.
- *The Bias* shows a pattern of forecast errors (deviation) from the mean, either consistently too high or consistently too low. A good forecasting model should contain little or no bias.
- *Tracking Signal* is used to measure the "health" of your forecasting model. This measure is calculated by dividing the sum of the period forecast error by the mean absolute deviation.

1.2.6.2. *The 80/20 rule (ABC analysis)*

This law was discovered by Pareto, an Italian economist, approximately 100 years ago. He discovered that a small percentage of a population always has the greatest effect (Castro Zuluaga, et al., 2011). Pareto's law was further expanded to the ABC classification and is summarized below in *Figure 1.3*.

20% of customers, products, or parts =	80% of the company's revenue and inventory investment	These are called "A" customers "A" products "A" parts
30% of customers, products, or parts =	15% of the company's revenue and inventory investment	These are called "B"* customers "B" products "B" parts
50% of customers, products, or parts =	5% of the company's revenue and inventory investment	These are called "C"* customers "C" products "C" parts

Figure 1.3 ABC classification summary

Note that the A customers still want the same level of shipments of your B and C products as they receive from the A products.

The fluctuation in demand for the B and C products causes most of the product mix problems, the changes on the shop floor (capacity) and the changes in the supplier due dates.

1.2.6.3. *Lot size and safety stock*

Once the levels of inventory are determined, the next step is to calculate in what quantities the inventory will be replaced. This is called lot sizing. The lot size is the amount of material to be ordered from a supplier or produced internally to meet demand.

There are nine major types of lot-size methods, which fit into the following two categories:

- ***Demand-based methods (static):*** Order quantities are kept constant.
  - *Fixed Order Quantity:* Fixed order quantity method will always suggest planned orders be released for a predetermined fixed

quantity. The predetermined quantity can be established based on experience and/or the use of the economic order quantity technique.

- *Economic Order Quantity*: previously described.

- ***Discrete method (dynamic):*** Order quantities vary.

  - *Period order quantity:* Period order quantity is a lot-sizing technique in which the lot size is equal to the requirements for a given number of periods into the future.

$$POQ = \frac{EOQ}{Average\ Period\ Usage}$$

  The period order quantity is similar to the period of supply, except the order cycle is based on the EOQ calculation. The order frequency as well as the order quantities are scheduled using this method.

  - *Lot-for-lot:* This is an MRP lot-sizing technique commonly used in Just-in-Time (JIT) situations, in conjunction with safety stock. In this method, the planned orders are generated equal to the net requirements in each period. The safety stock level is determined by the standard deviation discussed earlier or is based on experience or trial and error.
  The lot-size quantity matches the amount required to meet the demand and cover the safety stock quantities.

  - *Periods of supply:* This method simply establishes – primarily through experience – an order quantity that will cover a predetermined period of time. The only difference between this method and period order quantity is that method uses experience rather than the EOQ formula.

  - *Least unit cost:* The least unit cost method adds ordering cost and inventory-carrying cost for each trial lot size and divides by the number of units in the lot size. The lot size with the lowest unit cost is chosen.

- *Least total cost:* The least total cost lot-sizing technique calculates the order quantity by comparing the set (or ordering) costs and the carrying costs for various lot sizes and selects the lot size where these costs are most nearly equal.

- *Part-period balancing:* This technique is similar to the least total cost method. However, this method employs a routine called look ahead/look back. When the look ahead/look back feature is used, a lot quantity is calculated, and before it is firmed up, the next or previous period is reviewed to determine whether it would be economical to include either in the current lot.

- *Wagner-Whitin algorithm:* The final method is the Wagner-Whitin algorithm. This is a very complex method that evaluates all possible ways to cover the requirements in each period of the planning horizon.

Selecting the appropriate mix of lot-sizing methods will help to reduce ordering, setup and carrying costs, as well as reduce the overall levels of work-in-process inventory.

Chapter 2 DAYCO presentation

2.1. Who is Dayco

Dayco is a global leader in the research, design, manufacturing and distribution of essential engine products, drive systems and services for automobiles, trucks, construction, agriculture and industry.

Dayco's contributions are integral to how people get from place to place, goods are transported, food is harvested, and infrastructure is built. The company operates according to long-held values — keeping promises, delivering on time all the time, and an intense commitment to service no matter what the obstacles. For more than a century, Dayco has overcome challenges, emerging stronger and smarter at every turn.

Dayco improves how the world moves by creating products, systems and relationships that endure.

Dayco's annual revenue is around 1,6 billions of dollars.

2.2. History

Nothing is more critical to human progress than movement. Today, they're all part of a global movement economy — a dynamic flow of people, products, systems and relationships.

With ever-greater power, this movement economy rushes along with unstoppable force. It is driven by technology, consumer needs and government rules. It shapes and re-shapes the strategies of manufacturers, distributors, and retailers worldwide.

But in the seeming chaos of economic disruption and change, there are certain constants. Like the value of keeping promises — the ability to deliver on time, all the time — and the commitment to service no matter what the obstacles. These are the basis for building personal and professional relationships that last — partnerships that endure.

There is no company that understands the power of endurance better than Dayco. Dayco itself has endured, despite tough odds — always coming out stronger, smarter, and more resilient. On the strength of more than 110 years of experience, Dayco has continuously improved how the world moves by creating products, systems and relationships that endure.

Figure 2.1 shows a deep history underpinned by commitment to innovation.

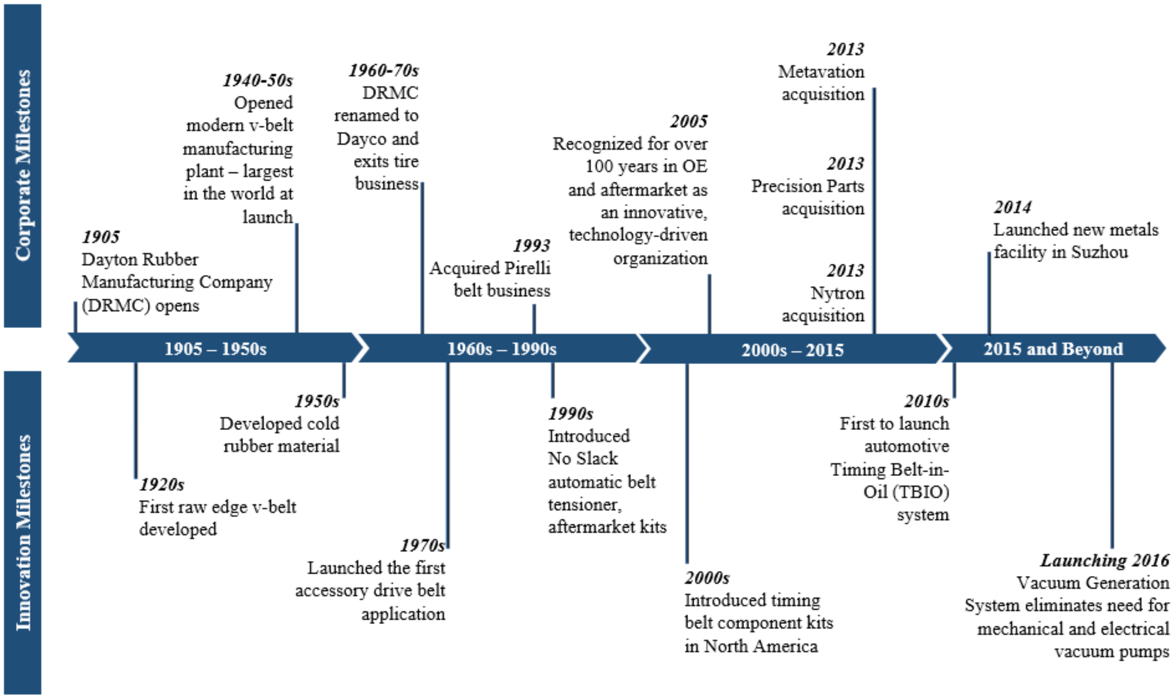

Figure 2.1 Dayco evolution time line

2.3. Values

- **Responsiveness**

They are quick to listen and to act.

They respond directly to the need at hand. Their ability to be reachable, to be open, to be nimble, and to adapt helps them maintain and deepen the relationships they thrive on - with their customers, and among their selves.

- **Ingenuity**

They excel at finding new ways of getting the job done.

They relish challenges and strive to meet them head-on. They are clever, original and inventive in how they develop solutions. Over the years, they have pioneered many firsts - and will pioneer many more in the years to come.

- **Integrity**

They practice integrity as the three-part discipline it is.

The soundness of their products, which must perform without fail. Being honest and open with everyone they work with. The wholeness of their company, as one enterprise.

- **Foresight**

They anticipate what's around the corner and prepare to take advantage of new opportunities.

They've always been good at looking ahead. They haven't endured for more than 100 years by waiting around for change to come to them; rather, they've learned that standing still is not an option, and they push their selves to always look and think ahead.

- **Collaboration**

They depend on each other to succeed.

They share best practices, no matter where they live and work. Collaboration is the only way to learn and grow as one organization. It is also the only way to learn what matters most to their customers and to grow by deepening their relationships with them.

2.4. Core capacities or strengths

For more than 100 years, Dayco has cultivated fundamental strengths which explain how their company creates value and are the pillars of their identity.

- **A Drive to Innovate**

Dayco has a history of industry leading firsts that have improved the effectiveness, efficiency and impact of products in ways that are continuously benefiting customers and consumers alike.

- **An Instinct for Pushing the Boundaries of Endurance**

Dayco understands the power of ‘building things to last,’ which shows up in their products, their customer relationships and within the very DNA of their company.

- **A Bias Toward System Dynamics**

Dayco provides solutions that are based on how components operate together, positively affecting their performance and perceived value.

- **An Urge to Serve**

Dayco is — and has always been — driven to help their customers succeed and to improve how end-users live and work, every day.

2.5. Products

Dayco has invested to keep their manufacturing facilities among the best in the world, and their extensive knowledge of drive systems allows them to develop the innovative products and solutions that are vital to peak engine performance.

Dayco continues to take the steps necessary to globalize their operations in order to provide a seamless service experience, from manufacturing to delivery to technical support. With an instinct for pushing the boundaries of endurance and on the strength of more than 110 years of experience, their essential engine products and drive system solutions improve how the world moves, delivering engine economy, efficiency and exceptional performance while minimizing noise, vibration and harshness.

Dayco produces essentially belts and mechanical products such as pulleys, tensioners, idlers, dampers, decouplers and vacuum generation systems whose characteristics will be described below:

2.5.1. Accessory drive belts

- First-to-market with accessory drive belts in 1970s.
- Flexible design and manufacturing strategy matches materials to specific application needs.
- Coverage across all market segments no matter the application, environment or performance requirements.
- Latest advanced engineering technologies, such as molded belts, elastic belts, EPDM compounds and aramid reinforcement, all of which result in a cooler running belt with less slippage and reduced NVH.

Figure 2.2 Accessory drive belts

2.5.2. Automotive and industrial V-Belts

- Optimal resistance to repeated flexions.
- Bottom cog, top cog and raw-edge designs.
- Unique constructions for a wide range of automotive and industrial applications.
- High resistance to heat.
- High friction coefficient.
- Resistant to oil, grease, chemical agents, ozone.

Figure 2.3 Automotive and industrial V-Belts

2.5.3. Accessory drive tensioners

- Durable and highly efficient tensioners matched to the required application performance requirements.
- Work in concert at the system level to reduce vibration and friction losses ensuring optimal efficiency is achieved.
- Design flexibility offering flat or round wire springs ensuring optimization to the application needs.
- Enables operation with lower belt tension relative to a fixed tension system and subsequently increases the life of the belt significantly, reduces the risk of premature accessory bearing failure and lessens the risk of belt slip noise.

Figure 2.4 Accessory drive tensioners

2.5.4. Pulleys and Idlers

- As a complement to its accessory drive belts and tensioners, Dayco designs a wide range of pulleys and idlers in stamped and formed steel, plastic and powdered metal.
- Multiple bearing configurations available to optimize design for a wide range of belt loading.
- Premium, lubricated bearings and high temperature seals assure peak performance and durability.

Figure 2.5 Pulleys and Idlers

2.5.5. Timing belts

- As one of the largest timing belt manufacturers in the world, Dayco offers a variety of belt constructions suitable for any application using the latest materials and a highly engineered, patented timing belt tooth composition.
- Specialized cog design that runs quieter and is more economical than a typical timing chain.
- Premium, high modulus glass fiber cord delivers precise length stability to keep the engine running smoothly over the life of the belt.

Figure 2.6 Timing belts

2.5.6. Timing belt tensioners

- Dayco offers a complete line of single-and double-eccentric mechanical timing belt tensioners.
- Optimized for each application considering specific driving behavior to ensure a lifetime of smooth operation.

Figure 2.7 Timing belt tensioners

2.5.7. Timing belt-in-oil system

- In 2007, Dayco introduced the first timing belt-in-oil system for automotive applications.
- Technological breakthrough that lowers emissions, increases fuel efficiency and improves NVH.
- Weighs less, has lower stretch, reduces friction and is quieter than traditional chain-driven components.
- Higher engine performance, lower emissions and improved fuel economy.
- Reduces engine packaging, resulting in less individual components and lower weight.

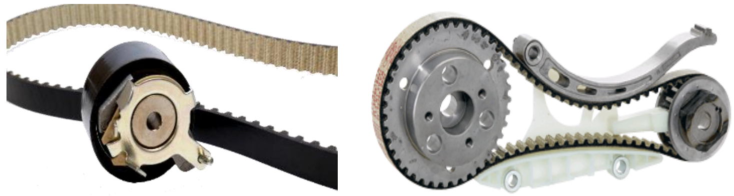

Figure 2.8 Timing belt-in-oil system

2.5.8. Crankshaft dampers

- Dayco has a long history of designing and manufacturing vibration dampers for automotive and drivetrain applications.
- Designed to reduce NVH and ensure longevity of the engine crankshaft.
- The Dual Action Tuned Absorber (DATA) and the Radially Asymmetric Dual Arc Profile (RADA) are a few of Dayco's industry-leading technologies being implemented in new applications.

Figure 2.9 Crankshaft dampers

2.5.9. Driveline dampers

- Multiple designs depending upon the mode of vibration they attenuate (linear, torsional, or mixed).
- Innovation and creativity coupled with analytical and empirical validation tools are the key factors that distinguish Dayco as the technical leader in this field.
- The Recessed Belt Damper (RBD), Radial Internal Tube Damper (Radial ITD) and the Low Frequency Grommet Damper (LFGD) are all examples of thinking outside the box.
- Capacity to design multi-mode dampers utilizing a single mass-spring system.

Figure 2.10 Driveline dampers

2.5.10. Crankshaft decouplers

- Improves accessory drive system stability and durability; particularly important as fuel saving engine technology trends lead to harsher NVH.
- Reduces NVH at engine start.
- Integrated into design of new higher performance engines.
- Reduces belt noise and tension subsequently lowering friction losses and improving fuel economy.
- New product pipeline technology recognized by customers as superior in performance to competition.

Figure 2.11 Crankshaft decouplers

2.5.11. Electric power steering belts

- Manufactured with a special grade HNBR polymer to prevent environmental contamination and allow the belt to operate under extreme temperature fluctuations without failure.
- Unique belt characteristics lead to long-lasting performance in terms of high load capacity, resistance to tooth jump, extreme temperature variations, high resistance during severe environment conditions and reduced span vibration, all with a quiet-running belt.

Figure 2.12 Electric power steering belts

2.5.12. Vacuum generation system

- Engineered for systems requiring vacuum such as vacuum brake assist, fuel vapor purge and crankcase ventilation.
- Higher vacuum capability and supports higher performance brake systems.
- Eliminates need for costly, heavy and fuel-consuming vacuum pumps (both mechanical and electrical).
- Lower system costs, better fuel economy and higher performance
- Strong and broad intellectual property.

Figure 2.13 Vacuum generation system

2.5.13. Aftermarket kits

- Originally introduced aftermarket kits in 1994 in Europe – selling in multiple regions today after further expansion in the 2000s.
- Provides a holistic solution – bundles multiple engine components that work together with the timing and/or accessory drive belt and have similar lifecycles so that all parts can be replaced concurrently.
- Creates service efficiencies and convenience for the end customer.
- End-user trusts that Dayco includes the right products in the kit.
- Aligns with Dayco's focus on providing system solutions.

Figure 2.14 Aftermarket kits

2.5.14. Aftermarket CVT Belts

- Innovative, breakthrough designs.
- Faster, more consistent throttle responses at high speeds.
- Deep top cogs, bottom rounded cogs.
- Reduction in slippage during the highest levels of torque.
- Resistant to compression and heat, designed to reduce side wear.
- Snowmobile, ATV and scooter applications.
- Cooler-running temperature.
- Tested and proven reliability.

Figure 2.15 Aftermarket CVT Belts

2.5.15. Aftermarket general industrial belts

- Designed for the general industrial, agriculture, fleet, lawn and garden, mining, construction and oil field industries.
- Manufactured to resist stretch, heat, oil, chemicals, ozone and aggressive weather conditions without jeopardizing machinery power and performance.
- Ranging from low horsepower machinery to high-output agriculture equipment.
- Extreme flexibility enabling belts to run of smaller pulleys when needed.
- Polyester cord eliminates belt whip and turnover allowing the drive to tolerate peak shock loads more effectively.
- Longer belt life without jeopardizing increased horsepower capacity and/or higher speed drives.

Figure 2.16 Aftermarket general industrial belts

2.5.16. Aftermarket cooling systems

- Components designed to maintain ideal engine temperature
- Fluid transfer hoses: Heater hose; molded radiator and bypass hose; branched radiator hose; coolant hose; hose clamps; and connectors
- Radiator coolant tanks: Coolant expansion and overflow tanks
- Thermostats and thermostat gaskets
- Heater tap control valves
- Fan clutches

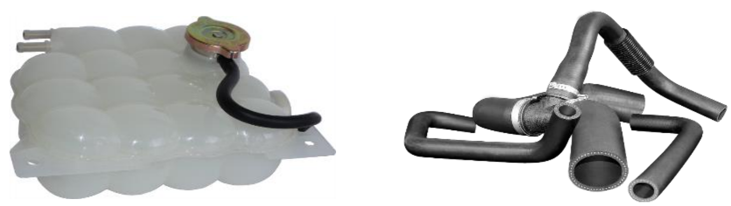

Figure 2.17 Aftermarket cooling systems

2.6. Infrastructures

As *Figure 2.18* shows, Dayco is present in 20 countries: Canada, United States, Mexico, Brazil, Argentina, Spain, Italy, Poland, United Kingdom, France, Germany, Sweden, Russian Federation, Turkey, United Arab Emirates, Portugal, Serbia, Australia, India, China and Japan; with around 338.953 m² of facilities total area and more than 50 locations that are distributed between manufacturing, technical, distribution and sales centers supporting the diverse needs of their global customer base.

In addition, *Table 2.1* shows how each manufacturing plant is responsible to produce a determinate kind of product depending on its nature: belts or mechanical products.

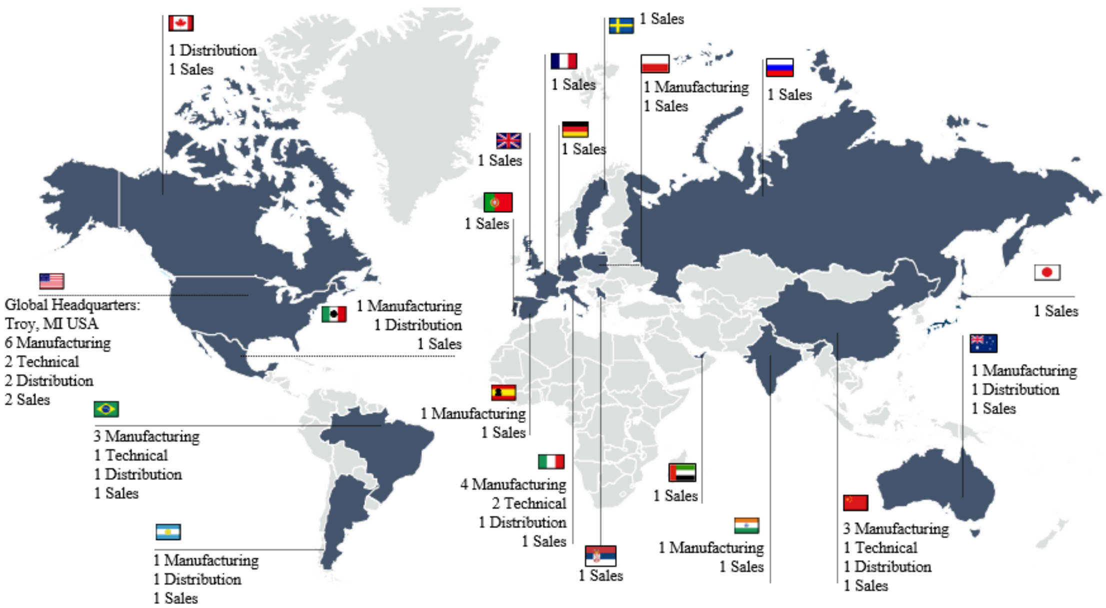

Figure 2.18 Dayco's locations around the world

	Plant location	Products
Belt Product	Chieti, Italy	Accessory belts
	Colonnella, Italy	Timing Belts
		CVT Belts
	Manoppello, Italy	Timing Belts
	Walterboro, South Carolina, United States	Raw-Edge V-Belts
		Accessory Belts
		CVT Belts
	Walterboro, South Carolina, United States	Accessory Belts
		Timing Belts
		V-Belts
	Córdoba, Argentina	Accessory Belts

	Plant location	Products
Mechanical Product	Ivrea, Italy	Dampers
		Idlers
		Tensioners
	Manresa, Spain	Dampers
		Pulleys
		Pressed Parts
	Tychy, Poland	Dampers
		Decouplers
	Hillsdale, Michigan, United States	Rubber Strips
	Mt. Pleasant, Michigan, United States	Torsional Vibration Dampers
	Mt. Pleasant, Michigan, United States	Driveline Dampers

		Timing Belts
	Guiyang, China	Accessory Belts
		V-Belts
	Suzhou, China	Accessory Belts
		Timing Belts
	Roseville, Michigan, United States	Springs – Roundwire, Flatwire
	San Luis Potosi, Mexico	Dampers
	Springdale, Arkansas, United States	Tensioners
		Idlers
		Vacuum Generation System
	Wagga Wagga, Australia	Dampers
		Pulleys
	Contagem, Brazil	Dampers
		Idlers
		Tensioners
	Itapira, Brazil	Idlers
		Tensioners
	Manesar, India	Dampers
		Tensioners
		Idlers
	Suzhou, China	Dampers
		Tensioners
		Idlers

Table 2.1 Type of product manufactured in each plant

2.7. Employees

Dayco's staff is one of its main strengths in developing its business model and achieving its goals. More than 4.500 professionals regularly collaborate with the company, consisting of 3.740 employees in the manufacturing and technical plants and 814 in the distribution centers. *Figure 2.19* shows the distribution of the employees around the world, evidencing that the area in which there are more resources is Europe/ Middle East / Africa with a 38%.

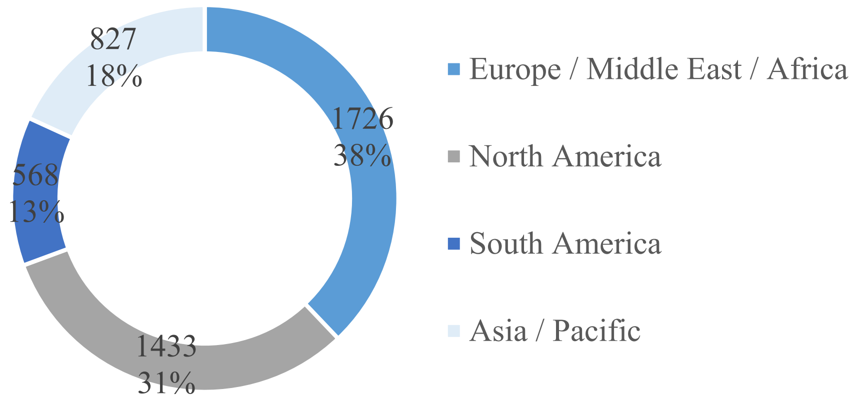

Figure 2.19 Distribution of Dayco employees in the world

The company promotes the employment and motivation of teams, establishing long-term occupation and promoting a work atmosphere that includes high levels of motivation and satisfaction. There are agreements with different universities with the aim of providing students with the opportunity to apply and extend their knowledge, to identify and select new professionals for the group.

2.8. Customers

Being a global leader in the manufacturing of essential engine products, drive systems and services for automobiles, trucks, construction, agriculture and industry, the main customers of Dayco are automotive and heavy load cars manufacturers companies. Some customers of the company are in the *Figure 2.20*, but the most important ones, that is, the clients that demand more volumes and therefore contribute more to the annual income are: Ford, FIAT, Volkswagen and Peugeot by the automotive side; and FPT industrial, MAN, Volvo/Renault Track, Scania and Deutz by the industrial side.

Further, Dayco produces also for an "aftermarket" customer, selling products that are not marked with the logo of a specific client. This kind of products are sold by Dayco to a car parts' distributors that work as outsourcers between Dayco and the end customer.

Figure 2.20 Some Dayco customers

Chapter 3 Ivrea plant supply chain

This work was developed in the Ivrea, Italy's plant, where dampers, tensioners and idlers are produced.

The group of tensioners is subdivided into 2 types of different tensioners: timing belt tensioners and accessory drive tensioners. While as an idler, a customized product called Friction Wheel Prince is produced for a specific customer. This is engineered to transfer the power from the crankshaft pulley to the water pump pulley through a unique and patented system.

In addition to these, the plant sells other products that are not assembled there, they only go through a packing change line (from supplier's packaging to Dayco packaging) to be resold.

This plant has 17.870 m^2 and its employees represent 33% of Europe resources percentage with 570 professionals.

The intra-organizational supply chain of Ivrea's plant is made by logistic and purchasing departments. These areas and its functioning will be described in this chapter.

3.1. Logistics department

3.1.1. Introduction to logistic

The Council of Supply Chain Management Professionals (CSCMP) has defined logistics as "…that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements" (Vitasek, 2013).

Besides, logistics management activities include inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfillment, logistics network design, inventory management, supply/demand planning, and management of third party logistics services providers. To varying degrees, the logistics function also includes sourcing and procurement, production planning and scheduling, packaging and assembly, and customer service. It is involved in all levels of planning and execution, strategic, operational and tactical.

Logistics management is an integrating function, which coordinates and optimizes all logistics activities, as well as integrates logistics activities with other functions including marketing, sales manufacturing, finance, and information technology.

3.1.2. Why logistics is so important to supply chains

Implementing seamless logistics is a key element in keeping pace with customer demands and outperforming competitors.

Whatever the size of a business, will want to grow and expand. That probably means expanding on a regional, international or global level. Whatever the business location or industry, logistics can help cut on the costs and time you spend to move products from one point to another.

Supply chains are complex and sensitive as they depend on always-changing customer demands. A supply chain cannot ensure high value if it is without effectively organized transport (A&A, n.d.). For this reason and others that are detailed below, logistics is one of the most important factors in the quality of any supply chain.

- *Helping businesses create value:* Providing value to customers does not only refer to quality or quantity. It also refers to availability. As better logistics makes your products more available to an increasing group of people, wise business leaders consider it a very important tool in creating value for customers.
  Logistics creates and increases the value businesses offer by improving merchandise and ensuring the availability of products. In order to provide more value, businesses either work on improving their own logistic activities or rely on professionals.

- *Helping in reducing costs and improves efficiency:* Businesses can reduce their costs by establishing partnerships with other businesses which offer transportation and warehousing, improving their overall business efficiency, sometimes dramatically. If they let these partners take charge of shipping their goods to end customers, this results in a better reputation and a stronger brand. This leads to an improved customer experience and higher working efficiency in general.

- *Helping to deliver your product at the right place timely:* With professionally organized logistics, businesses are able to answer short-time requirements. By choosing an experienced team of professionals, business entrepreneurs can ensure quick and safe shipping, warehousing and delivery of their products to customers. They can incorporate these services in a way that adds value to their offers, and ensure their products get to the right place on time.

- *Keeping your customers satisfied:* Satisfied customers are the most precious asset for any business, they are the main drive for the supply chains in each of the three phases: manufacturing, marketing and logistics. For this reason, it is a priority for each business owner to clearly understand customer needs, preferences and demands, and then work relentlessly to meet them.
  When successful business leaders acknowledge the needs and requirements of their existing and potential customers, they develop a strategy. Whether the business is small, middle-sized or large, strategies rely on effective logistics.

3.1.3. Logistic process in Dayco Europe s.r.l. – Ivrea

After understanding logistic in a general way, will continue describing the procedure specifically performed by the logistic department in Dayco Europe s.r.l., conformed by 10 resources.

Like showing in *Figure 3.1*, this department develops the follow main functions: customer services, production scheduling, materials/components reception and shipping; that integrated can achieve the logistics goals.

The process begins with the reception of the customer's order, when clients put data in the system specifying the quantity and the delivery date for each product requested. When customer services assistants receive the notification, proceed to process the order, which means checking that the customer's order is feasible both in quantity and delivery time.

If the order is not feasible, customer services assistant interacts with the customer through any communication channel (e.g. telephone, internet) in order to negotiate with the client regarding the specifications of the order. Once they agree, customer proceeds to correct the order in the system.

On the other hand, if the order is feasible, the production planner blocks the orders in system at the moment and processes the MRP system, which takes out the materials' requirements to create and send to suppliers their respective delivery schedule.

After having processed the MRP, there are two activities to develop in parallel, (a) doing the production scheduling for the next week: they do the scheduling every Friday and schedule the production that should be done next week to comply with the customer's orders timely; (b) awaiting the arrival of the materials that had been schedule for the supplier in earlier times. When materials arrive, the inventory operators register the material' income in the system and proceed to stock it.

With the union of these last two activities (a) and (b), the production can be done. Production is not an activity that concerns to logistic department, then won't be described here.

Once the production has been finished, inventory operator can bring end-products to warehouse and finally, the customer's orders are prepared and delivered doing its respective notification in the system.

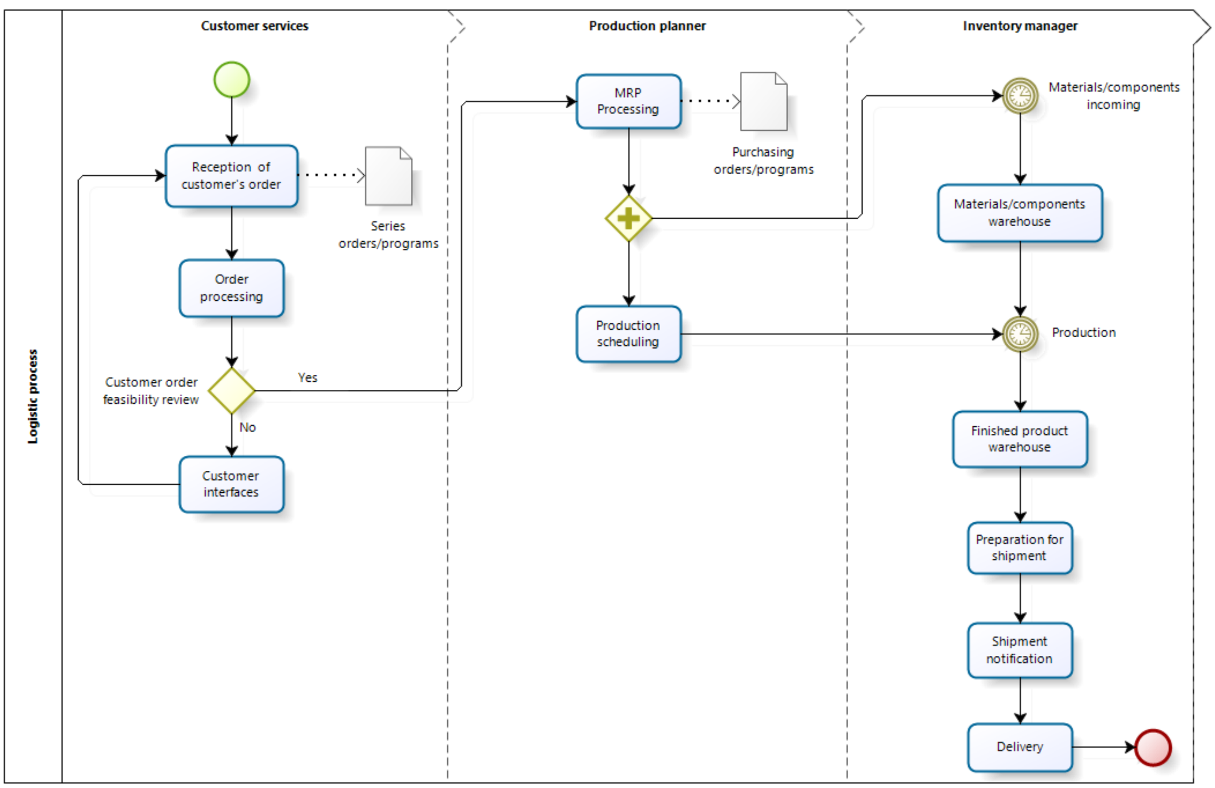

Figure 3.1 Flow chart of logistics process

That is roughly the way as all different activities are interrelated. This work will be focused on the materials/components warehousing, then that activity will be described in depth in chapter 5.

3.2. Purchasing department

3.2.1. Introduction to purchasing

Purchasing is a functional activity as well as a department. The first one refers to the action of buying goods and services while the second one is a formal entity on an organizational chart conformed by the necessary quantity of resources who have the aim to develop “the management of the company’s external resources in such a way that the supply of all goods, services, capabilities and knowledge which are necessary for running, maintaining and managing the company’s primary and support activities is secured at the most favorable conditions” (Weele, 2010). This is possible by doing some activities as mentioned below:

- Determining the purchasing specifications of the goods and services that need to be bought.
- Selecting the best possible supplier and developing procedures and routines to be able to do so.
- Preparing and conducting negotiations with the selected supplier to establish an agreement and to write up the legal contract.
- Placing an efficient purchase order.
- Monitoring KPI (Key Performance Indicator)

3.2.2. Importance of purchasing to business

The analysis of the cost structure of manufacturing companies shows the importance of purchasing into organization indicating that the average purchasing value in relation to cost of goods sold is approximately 50% (Weele, 2010). In addition, considering that Dayco Europe s.r.l is an assembler company, it could be said that this percentage is higher because there isn’t a large value-added respect the cost of the components, just the assembly function. That means that for every dollar of revenue collected on goods and services sales, more than half goes back to suppliers. So, it is not difficult to see why purchasing is clearly a major area for cost savings and why the suppliers’ capabilities can help differentiate the end-product.

Purchasing contributes to improve the company's savings negotiating hard for price reductions and building relations with suppliers to jointly pull costs out of the product (Monczka, et al., 2009), as described below:

- *Reduction of all direct materials costs*: Many measures may lead to lower direct materials costs such as reduction of the number of suppliers, improved product standardization, applying competitive tendering and looking for substitute materials.
- *Reduction of the net working capital employed by the company*: getting longer payment terms, reduction on inventories of base materials through just-in-time agreements with suppliers, supplier quality improvement and leasing instead of buying equipment.
- *Improving the company's revenue generating potential*: mobilizing the suppliers' expertise and involving supplier technical experts early in the new product development process.

In addition, purchasing also has a major impact on product and service quality because in many cases, companies are seeking to increase the proportion of parts, components, and services they outsource in order to concentrate on their own areas of specialization and competence. This further increases the importance of the relationships between purchasing, external suppliers, and quality (Monczka, et al., 2009).

Finally, acting as the liaison between suppliers and engineers, purchasing can also help improve product and process designs in order to begin to add new value and contribute to increasing their competitiveness, developing teams that involve suppliers early in the design process with the scope to receive more improvement suggestions from them (Kumar & Suresh, 2008).

3.2.3. Purchasing concepts

It is essential to define various terms used in purchasing before proceeding with the purpose of having a contextualization to continue with the description of the purchasing process in the company and make it easier to understand.

- *Supply:* includes at least purchasing, materials management, incoming inspection and receiving. Supply is used when relating to buying based upon total cost of ownership in a manufacturing environment.

- *Total Cost of Ownership (TCO):* Relates to the total costs that the company will incur over the lifetime of the product that is purchased.
- *Direct materials:* All purchased materials and services that become part of the company's value proposition. These include raw materials, semi manufactured goods or half fabricates, components and modules.
- *Indirect materials:* All purchased materials and services that do not become part of the company's value proposition. May be classified into MRO-supplies (maintenance, repair and operations), investment goods (also called CAPEX-Capital Expenditure) and services.
- *Request for Information (RFI):* Suppliers are invited to submit general information that may help the buyer to qualify them for a potential tender.
- *Request for Quotation (RFQ):* Suppliers are invited to submit a detailed estimate, including the cost breakdown, which meets the requirements of the request for quotation with the lowest price possible.
- *Payment terms:* payment terms relate to what, how and when the buyer will pay for the products and services delivered by the supplier.
- *Bill of Materials (BOM):* is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture an end-product.
- *Production Part Approval Process (PPAP)*: ask the supplier for the first quote that will go into quality control to show that they developed their design and production process to meet the client's requirements, minimizing the risk of failure.
- *Budget*: an estimate of income and expenditure for a set period of time.

3.2.4. Purchasing process in Dayco Europe s.r.l-Ivrea

After having seen the purchasing process in a general way, proceed to describe the procedure specifically performed by the purchase department in Dayco Europe s.r.l., conformed by 5 resources.

There are two global functions to develop throughout the year to secure the provide of the necessary materials in the best possible way: give support for program management and a trend control yearly routine.

3.2.4.1. Support for program management

It is the function that is directly related to the purchase task, responsible for providing the necessary components for the daily activity of the company. There are two procedures to develop depending on the type of request received: if it is an open order or a close order.

- *When receive an open order*:

    An open order is an order that regulate the serial production, that is an order that the company does every certain time and usually refers to a direct materials requirement.

    Figure 3.2 shows graphicly the process, which begins with the arrival of the E.C.R or N.P.A and the technical design. E.C.R and N.P.A are internal documents in which the technical department communicates to the company that a specific component (a component that is the result of the modification of an existing one or a new component respectively) has generated a bill of materials and a registries data.

    Later, the purchasing strategies of the project are established, that is, decide factors such as: the most appropriate technology for the product development, the suppliers that have available this technology and those that at the same time can offer the best price/quality ratio on the market; to finally get a list of possible suppliers.

    When the possible suppliers are defined, proceed to do the Request for Quotation (RFQ) according to the technical design of the product. Once all the offers have been received, advance putting together all the data to analyze them through a Business Case (BC), that is a document where comparing the prices, the quality and the technologies used by each supplier concerning their process, machinery and materials, to finally choose one (or more if necessary).

    Subsequently, the data of the selected supplier is used to make a project's financial analysis and to elaborate the cost pack (document where there are financial indices such as: EBITDA, EBIT, Net Income, percentage that represents the value of the raw material in the total cost of the product). At the same time must be established commercial agreements with the suppliers, whose objective is to define the final details and update the cost pack if it is necessary.

At this point, the cost pack must be sent to the responsible party for its approval: in the case it is positive, a phase of development of the agreements and the product is begun, by means of which an improvement of costs or technologies of the product is looked for to make the client a more attractive offer; in the other case, a technical, production and supplier review must be done and the financial analysis must be updated.

If the costs of the new offer resulting after the development phase are equal to or less than the costs presented in the cost pack before it, the order must be sent to the supplier and because of that, the system creates an order's number for the equipment request (Tooling kick off- TKO) and the PPAP request (Project kick off- PKO); else, a technical, production and supplier review must be done and the cost pack must be updated until the new offer equal to or less than the previous one.

Then, to finalize the agreements, the company and the supplier sign the contract, paper where all the supply's clauses are indicated: general rules of supply, validity of the contract, technical rules, cooperation with Dayco, rules of behavior after the start of the contract, volumes, investments, security stock, line equipment, prices, delivery conditions, competitiveness clauses, guarantees, line's stops and intellectual property.

At this stage, the process continues doing the PPAP order and waiting for the pieces' quality control. At the same time, if is also necessary to do an equipment investment for the supplier, an RDA (purchasing request, by its initials in Italian) must be done, that is putting on the company system a close-order request.

If the pieces' quality is rejected, the defects must be reported to the supplier asking them to apply the changes and send the parts back (this process must be repeated until the quality is accepted). If instead it is approved, the process ends doing the prices list and the percentage assignment when there are more suppliers.

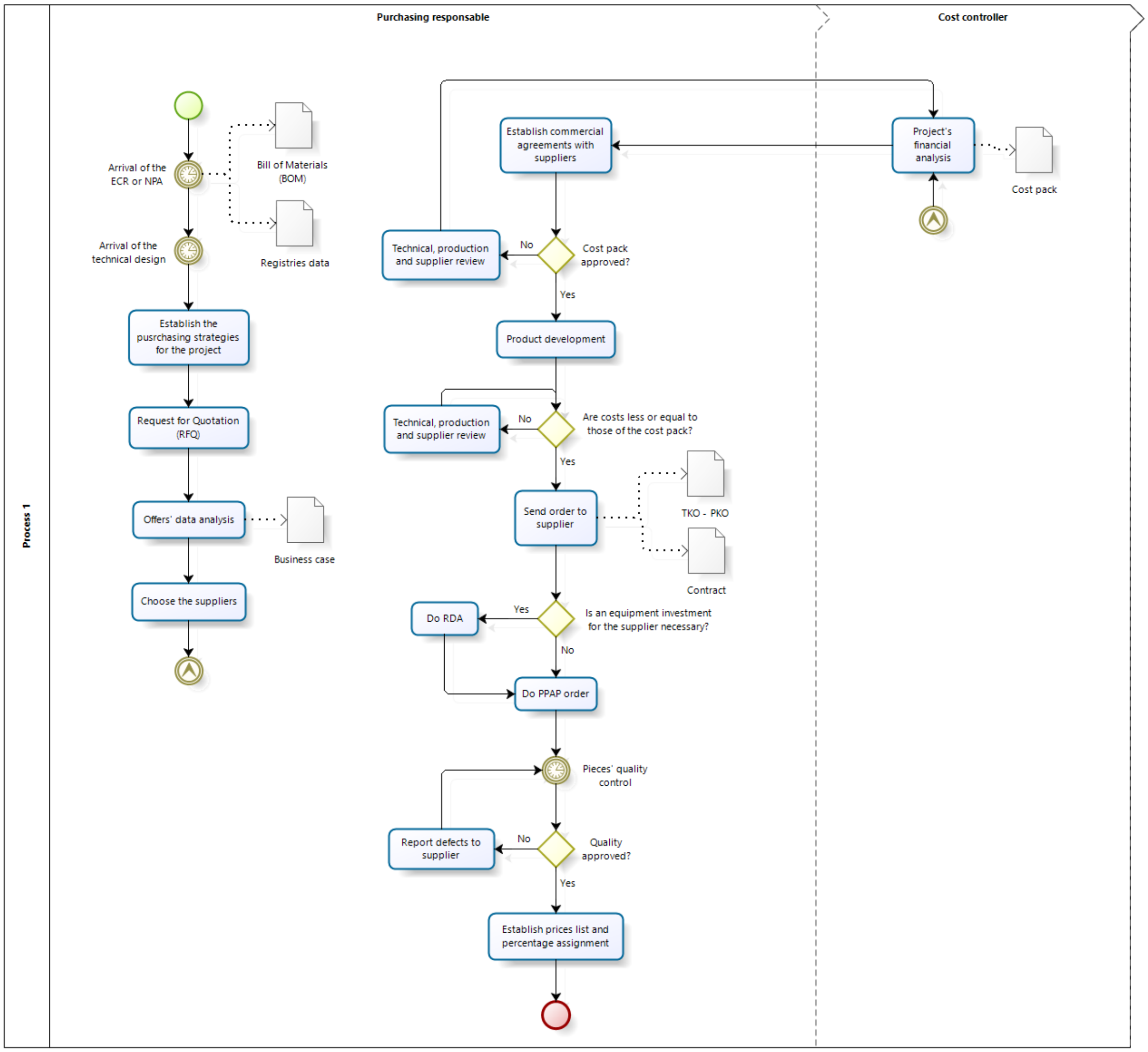

Figure 3.2 Flow chart of the process of an open order request

- *When receive a close order*:

  A close order is an order limited to a single activity, it means an order that the company does just once and usually refers to an indirect material requirement. It could also be a direct-material requirement only for urgent matters.

  Figure 3.3 shows like the process begins with the arrival of a company necessity that could be a service or an indirect material. If there are no costs to the outside of the company, proceed with the operation and the process ends. If instead there are costs, continue doing the RFQ, project's data analysis and selection of the supplier as described in the open-order case, through a business case. If the business case shows that the project couldn't bring more benefit to the company, the process finishes, but when it shows more benefit, must be done the financial analysis (cost pack) and wait its approval, to finally do the RDA.

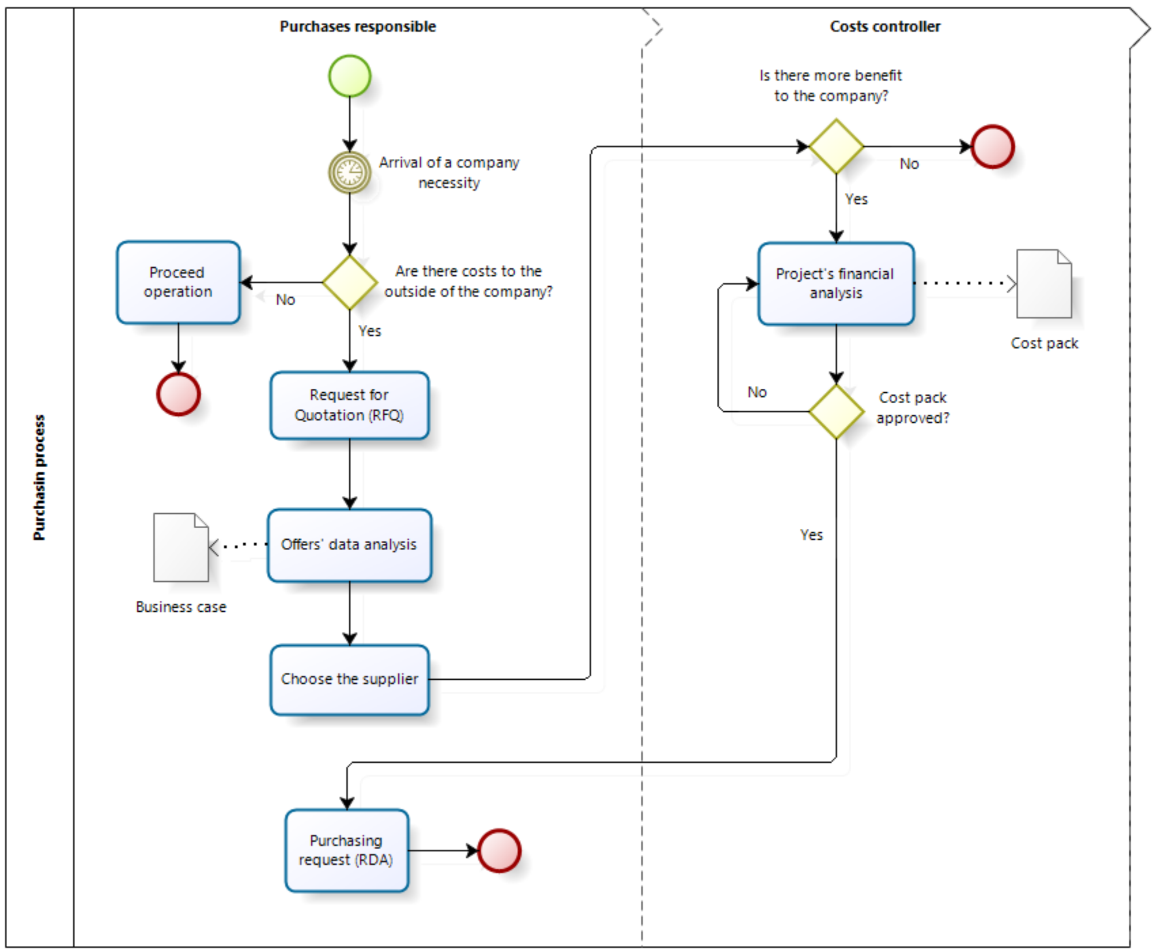

Figure 3.3 Flow chart of the process of a close order request

3.2.4.2. Trend control yearly routine

It is the function that refers to the performance management of activities that are carried out in the department. This management is done through the analysis of the budget inflation (called PPV-Purchase Price Variance) and the review of the supplier relationship.

- *Budget Inflation:* Indicates the difference in the value of the components I buy compared to the previous year or at an average price. It is calculated by the difference between the budget calculated with the volumes and prices for the next year, and the budget calculated with the same volumes and prices for the current year. The components' prices for next year depend on two macroeconomic variables, the change in the raw-material cost and the variation of the exchange rate, which the company cannot control, and which are obtained through a monitoring and negotiation that is done throughout the year with suppliers.

The budget inflation is positive when the prices increase and negative when the prices decrease regard the previous year prices. The company has to seek that this inflation was the lowest possible and to achieve it, it's necessary a re-negotiation with the suppliers regard the macroeconomic variables already mentioned or making new possibilities intervene such as:

- *Long term agreements (LTA):* purely commercial contracts with which discounts are granted by virtue of strengthening the link and lengthening the collaboration. For example an agreement in which you guarantee the supplier the buy of the component throughout the years but he has to guarantee you a price discount each year.
- *Indexation:* it means putting a protective mechanism on the raw material, that is, the price of the raw material on the purchase price is bound to the fluctuations of the market. So if the raw material goes up, consequently with the indexation, the price goes up, if the raw material comes down, the price drops. To do this one must define a shared indicator of control of the raw material that is checked quarterly between the company and the supplier and every three months the raw material value is calculated.
- *Other agreements:* any type of agreement different from the previous ones that seeks the reduction of the purchase prices of the components.

Another thing that is not within the PPV, but serves to reduce the budget inflation impact, is the *COP (Cost Out Program):* these are actions that are implemented to save or reduce the costs of the components. The most frequent one is to look for a new supplier that offers a better price. Another may be the exchange of percentage allocations among current suppliers.

- *Supplier relationship:* It is a day-to-day activity that consists of keeping under control the relationship with the suppliers so that they can continue to provide their products. This is based on the following aspects:
    - *Commercial:* you must always be sure that the suppliers are selling you at the best price. In case it does not, you have to find a small adjustment to get it right.
    - *Technical:* you always need to know what the suppliers are selling you compared to what you're asking.
    - *Quality:* you need to know if the suppliers are sending pieces well done in accordance to your defined quality standards.
    - *Supply level:* you need to know if the suppliers are sending the pieces in the agreed time.

Chapter 4 Diagnosis of the current situation

4.1. Warehouses description

Dayco Ivrea's plant has 25 warehouses distributed in approximately 5 groups: Raw materials/components, materials in production, finished products, non-ownership inventory and others. In *Table 4.1* can be seen the name/number of the warehouse with its respective description.

In the raw materials group there are 4 warehouses, containing transmissions (229), prince (231), tensioners (232) and dampers (233) components.

In materials in production, there are 4 warehouses (203, 204, 209, 236) containing the components ready to go into production. These warehouses are replenished according to the production requirements. Production operators knowing week production schedule, can also know the quantity of materials required to manufacture. When preparing production lines, they make a kind of order to warehouse operators, specifying the amount of material that should be placed in the respective production warehouses. These are located in such a way to be more accessible to the production operators, putting the materials on the lowest levels of the storage shelves.

In finished products group there are also 4 warehouses (235, 239, 249 and 269) corresponding to each type of product that is manufactured in the plant.

Non-ownership inventory group has 5 components (200, 205, 243, 291 and CDE). These warehouses contain materials which are not property of the company, even being physically there. They can be materials of passage belonging to another headquarters of the company, or material in consignment belonging to the suppliers, which once used by the company, becomes their property and is paid to the supplier.

The last group is composed by 6 warehouses, these ones that do not have a direct relationship with the production cycle, but nevertheless are necessary. Here we find the materials that are pending to go through a quality control (241), materials that are waste from production, quality or clients returns (206, 207, 242 and 237), slow ride materials (220) and consumption materials (299).

Slow ride components are low rotation materials than have not been used for a long time, therefore its amount does not increase or decrease.

Warehouse	Description
200	Subcontracted suppliers stock
203	Tensioners’ production
204	Prince’ production
205	Warehouse in transit from Poland
206	Scrapping from production
207	Production waste material
209	Transmissions’ production
220	Slow ride components
229	Timing belt tensioners’ components
231	Prince’s components
232	Accessory drive tensioners’ components
233	Damper’s components
235	Finished products - Damper
236	Damper’s production
237	Customer waste
239	Finished products - Prince
241	Quality/Samples
242	Quality waste
243	Consignment stock
244	Safety stock
249	Finished products - Tensioners
269	Finished products - Transmission
291	Material to be returned to suppliers
299	Oils and solvents
CDE	Consignment stock - Chieti

Table 4.1 Warehouses description list

4.1.1. Warehouses’ current state

In the plant are stored a total of 31'950.159 items in the set of all warehouses, for a total of 16'710.035,18 euros stored between raw materials, finished products, components in production and other materials already described above. From these data an average cost per article of 0,52 euros is calculated. However, it is known that the cost of the articles is variable, and that the final products have an added value regarding the components not yet assembled.

Making an analysis of the current state of the warehouses of the company, it is found that in most cases there is no match between the warehouse with the largest amount stored, and the warehouse with the highest value stored.

Taking as a reference the data of August 4, 2018, *Table 4.2* shows the warehouses ordered from highest to lowest by quantity and value. From there it can be seen that the only ones that coincide in both characteristics are 232, 229 and 220. The first two are those with the greatest amount and stored value, while the 220 is the one with the smallest specifications.

The change of position of the other warehouses depends on a relation between the costs of the articles that are there. There are some in which even having a lot of pieces stored, has a lower value compared to another with less or equal amounts because the value of the items is much lower. And vice versa, there are others in which there is not so much quantity of pieces, but they have a higher value regarding another with smaller or equal amounts, because the value of their articles is greater.

From the same table, it can be seen that 3/4 of the components' warehouses (232, 229 and 231) are part of the first 5 warehouses in the list ordered by quantities, while 4/4 are part of the first 5 in the list sorted by value. Which means that the components' warehouses are those that contain more stored inventory, both in value and in quantities.

It also continues verifying that warehouses 232 and 229 are the most representative for the company, storing 52.06% of value among them.

Warehouse	Sum of quantities
232	11.119.526
229	7.428.592
209	3.202.241
203	2.906.795
231	2.876.939
204	1.907.724
200	715.530
233	670.473
236	306.675
249	206.034
269	198.378
206	119.371
291	116.795

Warehouse	Sum of value
232	5.180.476,51
229	3.519.532,87
231	1.214.328,77
269	1.064.964,62
233	975.130,51
209	971.885,93
249	805.871,59
203	767.805,42
200	754.872,35
236	288.260,24
239	263.392,60
204	151.721,00
243	141.874,21

207	91.791
239	21.413
242	14.660
CDE	13.586
235	11.332
243	10.585
205	4.362
241	3.679
237	2.253
299	1.025
220	400
Total	31.950.159

291	122.740,75
235	112.788,34
CDE	104.839,27
242	66.348,94
207	57.417,22
205	48.625,76
206	45.132,35
237	29.374,73
299	13.889,43
241	8.249,90
220	511,87
Total	16.710.035,18

Table 4.2 Quantity and total value stored in each warehouse in descending order

Figure 4.1 shows how the quantities of stored inventory perfectly fulfill the Pareto principle, with 18.52% of the warehouses that contain 86.57% of the material in the company. This time the data are based on the average quantities of the last year (from August 2017 to July 2018) and not on an exact date, which can be concluded with greater certainty that the warehouses that contain more material are those of raw material, with 67.42% of the total inventory stored in said 4 warehouses.

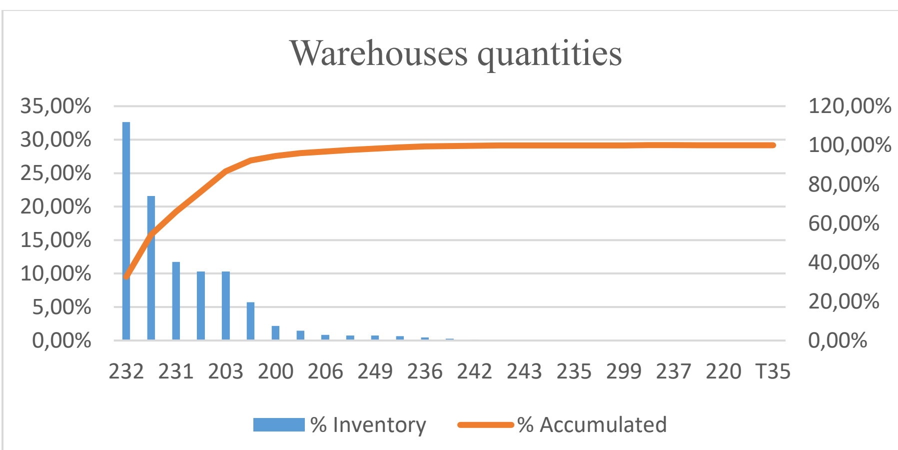

Figure 4.1 Pareto chart of amount stored in each warehouse

4.2. Inventory supply

The warehouse replenishment function is developed mainly by two groups of operators. Production planners who are in charge of generating the orders to the suppliers, and the warehouse operators who are in charge of receiving the materials and arranging them in their respective places.

As can be seen in *Figure 4.2*, the process of warehouses' supplying begins with the extraction of the material explosion data from the system, where the quantity and date in which each component from each supplier must arrive is recorded, in order to have enough material ready for production and not incur the expenses caused by having production lines stopped due to lack of raw materials.

The MRP system of the company presents some errors, for which planners must manually verify the accuracy of the data thrown by it. Since the company seeks to have a JIT system in order to minimize its inventory value, planners schedule the weekly arrival of materials according to customer's orders. However, the MRP does not prepare the orders taking into account that it is looking for the arrival of material just to produce, but it orders the materials required for the production of all the customer's orders in the system, regardless of whether the demand horizon is a week or more. This generates that the system creates orders of more components than necessary for the weekly production and the rest must be stored, which goes against the objectives.

Therefore, the verification of the accuracy of the data is the next step.

Once the errors in the orders to suppliers generated by the system have been identified, they are corrected, that is, the arrival of material is scheduled according to the weekly demand of the customers. The quantities to be asked for each supplier for each component are then corrected, to finally generate the orders and send them.

There ends the part of the process developed by the production planner. Then, proceed to wait the arrival of the material and here is when the work of the inventory operators begins.

As soon as the material arrives, workers make a visual verification comparing what is written on the shipping document with what is observed to have arrived. If the material that has arrived matches the information in the shipping document, it is received, it is accommodated in the corresponding warehouse and the entry in the system is made.

On the other hand, if the information in the input document does not match with the material that has arrived, there are two types of procedures that can be developed depending on the type of error that the provider has made.

- If the error is only in the record of the quantity sent, that is, if the registered components arrived but in different quantities, the correction is simply made in the delivery note, the supplier is notified, and operators proceed with the reception and storage of the material.
- If the error is not in quantities but in the type of item sent, that is, if the item that arrived does not match with the item registered in the delivery note, the supplier is notified, and the material is returned.

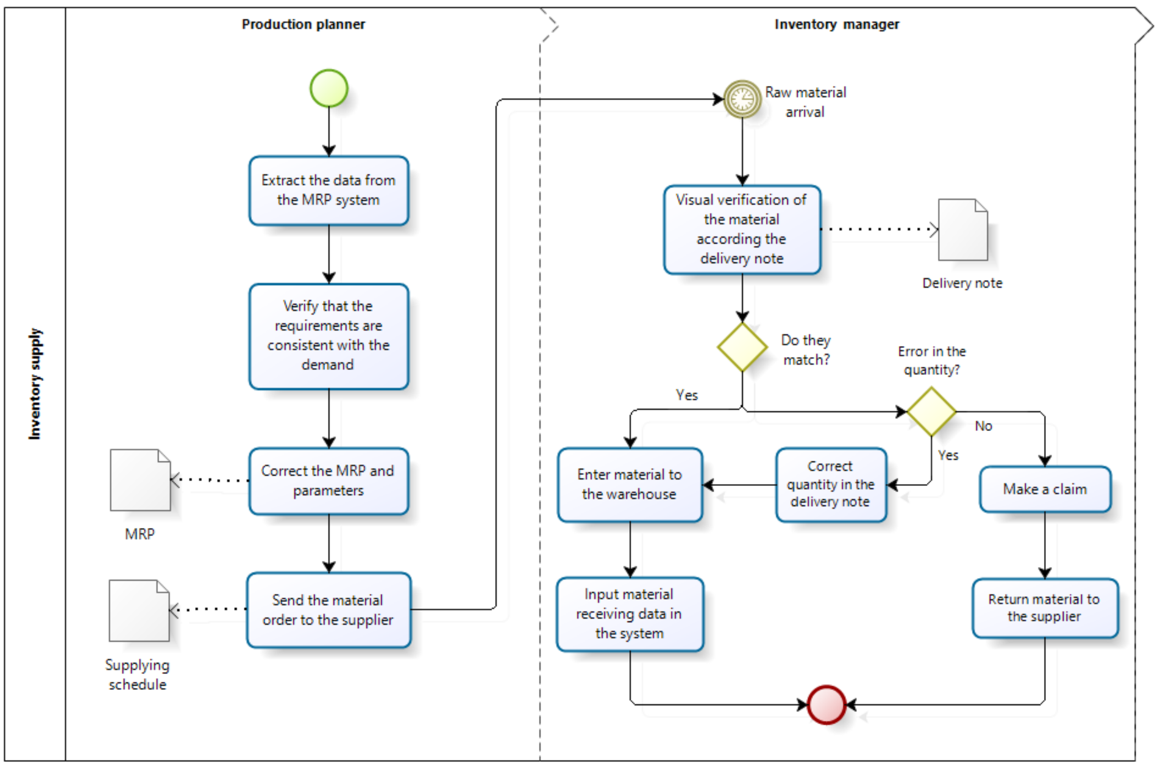

Figure 4.2 Flow chart of the inventory replenishment process

4.3. Information technology

The company has a business management system called AS400, in which all the information considered necessary for a better functioning of the company is entered.

For inventory management, this system is used to record the data of all material movements: material entry, movement of material from one warehouse to another, and delivery of final products.

When the material that arrives from the suppliers is received, the following data is recorded in the system, contained in the delivery note:

- Article code
- Customer code
- Quantity
- Arrival date

By entering this data into the system, it automatically fills in the rest of the data to create a more complete record:

- Product line to which the material belongs
- Article’s name
- Supplier's name
- Article’s unit cost
- Total value of the amount of material entered

Then, when placing materials in their respective warehouse, system continues receiving information in order to have a consistent data base. Now, the following information about the materials’ location begins to be part of the data base:

- Warehouse
- Storage shelves’ level

With all that information, at the end of every month, a data controller downloads a file to keep historical data about inventory’s state, since system does not save old information, it only makes the most recent data available.

Once logistics manager receives the monthly data base from data controller, proceeds to update a file where he makes an inventory analysis, evaluating the following points:

- How much value there is in each warehouse?
- What trend has warehouse had in recent months? Is it increasing? Is it decreasing? Why?
- Does any particular warehouse need special attention?
- Elaboration of Pareto diagrams to know the balance within each warehouse.

Finally, based on the results of his analyzes, logistics manager begins decision making that considers necessary for the correct management of the inventory.

4.4. Problem statement

At the Dayco Ivrea's plant there are 22 assembly lines, dedicated to the production of transmissions, prince, tensioners and dampers. These lines are divided into 3 groups each responsible for producing a type of product.

- *Auxiliaries:* This group consists of the 2, 3, 4, 5, 6, 7, 21, 23, 31 and 33 lines, responsible for producing accessory drive tensioners.
- *Distribution:* This group consists of the 8, 10, 11, 19, 26, 27, 32, Bio Linx and STS lines, responsible for producing timing belt tensioners.
- *Prince:* This group consists of the 15-20 lines, responsible for producing the friction wheels.

In addition to these lines, there is line 36 where dampers are produced.

Each line has a different capacity, shown in *Table 4.3*. For line 36 there is no production data recorded, so it does not appear in the table.

There can be seen the theoretical capacity of production, which is that capacity that the machine could have if it worked 100% of the time, without considering the stoppages that they must do to enlist production for a product change. The capacity of the line after considering these times is also observed.

The total annual capacity of the lines was estimated by the following formulation:

$$Annual\ capacity\ (line) = (Dw * Hw + Ds * Hs) * Hp * E$$

Dw: Total number of working days in a year (No Saturdays)

Hw: Hours worked on a week day

Ds: Total Saturdays in a year

Hs: Hours worked on a Saturday

Hp: Hourly production of the line

E: Production efficiency (considered by the production department)

Obtaining a total of 19.506.080 pieces of total theoretical capacity.

The capacity considering set-up times is obtained from the product of the total annual capacity calculated and the set-up time percentage considered for each line (varying between 0% and 15%), obtaining a capacity of 17.348.755pieces.

These data were calculated considering that they work from Monday to Saturday; however, when more production capacity is needed, Sundays are also worked. Capacity calculations are not made considering Sundays because it is not known exactly how many Sundays in a year it will be necessary to work, in order to comply with all customer orders on time.

This last capacity, considering the set-up times, in a way remains a theoretical capacity, since the set-up is not the only cause of downtime that a production line could present.

Department	Line	Capacity without set up times	Capacity with set up times
Auxiliaries	2	756.752	643.239
	3	814.964	692.719
	4	814.964	692.719
	5	1.397.081	1.327.227
	6	1.513.504	1.286.479
	7	1.280.657	1.088.559
	21	756.752	643.239
	23	814.964	692.719
	31	814.964	692.719
	33	931.387	922.073
	37	1.397.081	1.369.139
Distribution	8	814.964	692.719
	10	1.571.716	1.335.959
	11	1.455.293	1.236.999
	19	698.540	663.613
	26	1.280.657	1.088.559
	27	698.540	698.540
	32	698.540	593.759
	Bio Linx	349.270	349.270
	STS	69.854	62.869
Prince	15-20	575.636	575.636
Total		19.506.080	17.348.755

Table 4.3 Lines capacity with and without set up times

The production management of the company keeps a record of the causes of unemployment of the lines, which records the reason why the line was stopped and the respective amount of lost time. The reasons for line stoppage identified by them are described below:

- *Maintenance:* It is the time the line was stopped due to maintenance interventions.
- *Production inefficiency:* It is the time the line was stopped due to different types of causes that make production less efficient. Within these causes are considered the times of: staff training, assemblies and medical visits, head round interventions, micro-breaks, set up, quality tests, extra cycle processing and reworks.
- *Lack of components:* It is the time the line was stopped because there were not enough components available for production.
- *Personal lack:* It is the time the line was stopped because there were not enough personnel to cover the production.
- *Machine inactivity/ No line programming:* It is the time the line was stopped because it was not programmed to produce.

With the recorded data of time lost from November 2017 to January 2018, an estimate was made of the time lost in a year due to the causes previously described.

Additionally, the calculation of the total of pieces not produced in the year is made by the difference between the total capacity of the lines without considering the set-up time and the number of pieces produced in a year, finding a total of 8’024.918.

Figure 4.3 shows the percentage of time lost for each cause, taking a total of 58.825 hours that the lines were stopped, that is, an average of 2.674 production hours lost in each line.

According to what can be observed in the graph, the cause that represents less loss of time in the lines is the lack of components, and the one that keeps the lines stopped for more than 50% of the time is the non-programming. However, this shows a great error that occurs in the data collection, and that at the same time becomes a point to improve, since there is no record of the causes why the lines have not been programmed to produce.

On some occasions the production programmers do not program the lines because there are not enough components available to send them to produce, but by not informing that to the production responsible, they do the registration as a non-programming of the line and not as a lack of components. That is, part of the time that the machine is stopped with non-programming record, it may actually be time that it was stopped due to lack of components.

The above could also occur with the cause "lack of personnel", which makes the record of 59.38% of time lost per inactive machine is not totally accurate.

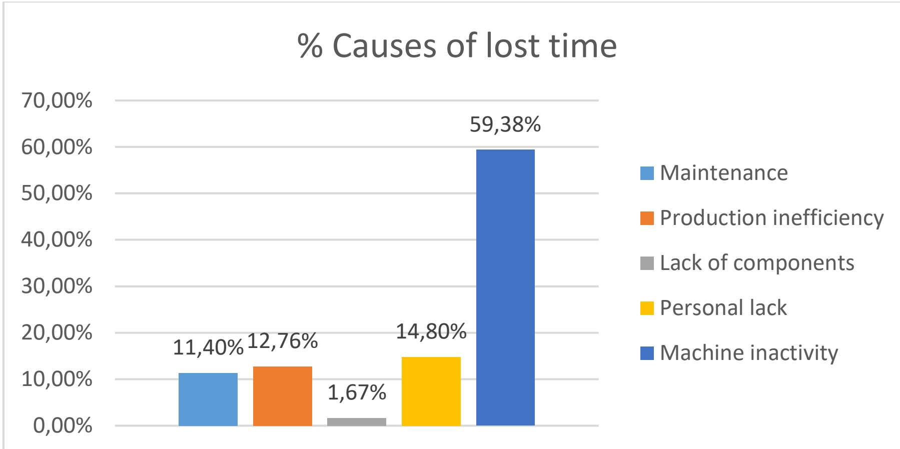

Figure 4.3 Causes of lost time

In total 40.15% of the time that could be used working from Monday to Saturday is lost.

Every time the production is delayed, regardless of the cause, the units that were not produced generate a gap between demand and sales, creating a quantity of delayed orders. At the end it could represent losses for the company, either because it runs the risk of losing the client, or because the fact of not delivering the goods to the customer on time, can generate a production stoppage to him, which leads to a loss of his sales, that normally in the supply contracts, these costs must be borne by the supplier company. That is, every time the production stoppages generate a delay in deliveries to customers, the company runs the risk of incurring very high costs.

The logistics and production department, planned to recover the lost production and untangle in the pending orders, for which they continued making the order of components to their suppliers according to their demand, assuming that the production would have the ability to comply with all orders, both expired and current ones. However, as the months go by, they realize that recovering the time necessary to assemble such a large amount of products is not so easy, which is why both the delay in delivery to customers and the inventory of components dammed in the warehouses were increasing.

Figure 4.4 shows the total purchases made by the company, from June 2017 to May 2018. There can be observed how the purchases of components continued with a tendency to remain close to the average although there is a slight growth in the last months, since as mentioned above, orders were continued to be made to suppliers according to current demand, without considering that the capacity of the lines was not sufficient to recover the pending orders and perform the current ones. If this had been considered, purchases would probably have remained below the average or the increase would not have been so high in such a short time.

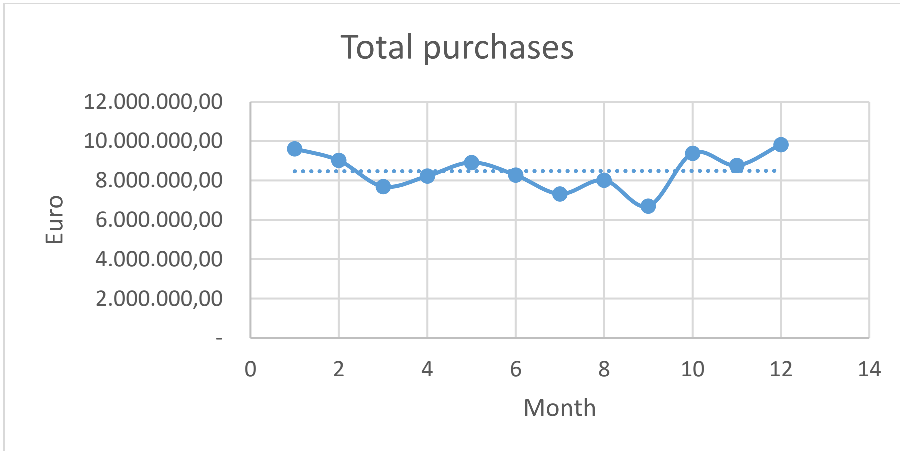

Figure 4.4 Total purchases made from June 2017 to May 2018

On the other hand, *Figure 4.5, Figure 4.6, Figure 4.7* and *Figure 4.8* shows the quantity of pieces stored in each raw material warehouse, 232, 229, 231 and 233, which store the necessary components for the production of each type of product sold by the company, accessory drive tensioners, timing belt tensioners, fiction wheel prince and dampers respectively. They are shown in descending order, starting with the warehouse that contains the most pieces and ending with the one that stores the least quantity. These graphs contain storage data from August 2017 to July 2018.

These reflect the consequence of the combination of the two facts already described, the loss of production time and the constant flow of orders to suppliers without considering the lines' capacity, evidencing an increase in the value of the material stored in the warehouses.

Although these graphs represent the quantity of pieces, it is also possible to affirm that the stored value would not change the position of their order, since as seen in *Table 4.2* (table of quantities and value stored in each warehouse) the position of one with respect to another does not change when passing from pieces to value.

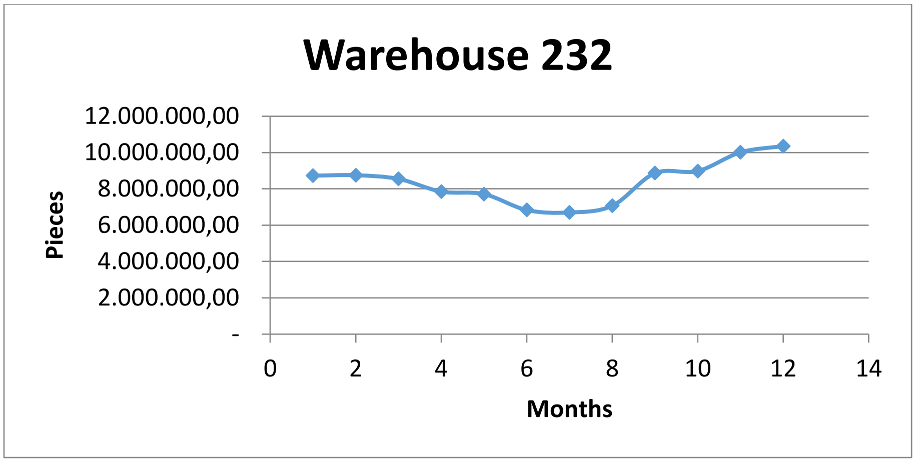

Figure 4.5 Quantity of pieces stored in warehouse 232

Figure 4.6 Quantity of pieces stored in warehouse 229

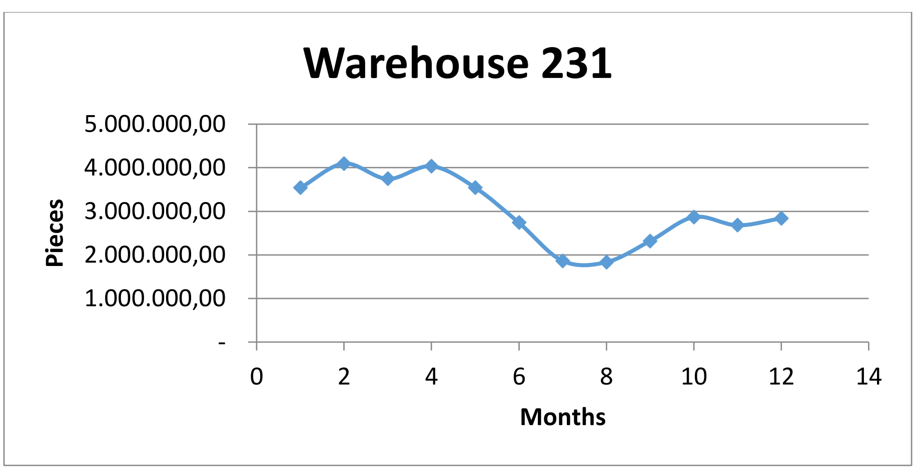

Figure 4.7 Quantity of pieces stored in warehouse 231

Figure 4.8 Quantity of pieces stored in warehouse 233

Due to the great increase in value that is occurring in these stores, the need to make a more exhaustive check is created, in which control is maintained between the quantities stored, the quantities ordered and by ordering to suppliers and, the demand considering lines' capacity; in order to find that stored value decreases, since the excess of inventory generates high costs for the company, and the fact of continuing with the orders to the suppliers of components that are currently in excess will generate that the damming of material and consequently of costs continues to increase.

Chapter 5 Results analysis and interpretation

The company is currently seeking to establish a DDMRP system (Demand Driven Materials Requirement Planning) in order to have more control over the components in inventory and orders to suppliers. In addition to this, another of the objectives of setting up this system is the reduction of costs in human resources, since currently these tasks are developed manually by 3 workers, and by achieving that everything is done in a more automated way, it could be investing their work time in other activities, or even not needing so many resources dedicated only to those tasks.

However, because the implementation of a DDMRP system involves a lot of work and therefore a lot of time, this project seeks a short-term solution for the control of inventories and orders to suppliers.

In order to reduce inventories, having greater control over orders to suppliers, a program was created with Visual Basic Excel that is able to determine automatically and according to certain characteristics of the material, if it should continue with its regular supply or if due to excess inventory, orders must be blocked to suppliers.

Because the company currently has 1399 components stored in raw materials warehouses (229,231,232 and 233), and that collecting from the system some of the necessary information is done manually, it becomes necessary to segment products to test the program created. Once the system has been implemented for the selected components, the company can decide if it continues with the extension of the program for the rest of the components.

5.1. Warehouse selection

Initially, starting with an analysis of the quantity of pieces stored in each warehouse, since for privacy reasons, it was not possible to analyze the value in euros of these warehouses.

The program receives the inventory data stored at the end of each month, updating the information for the last year and yields a warehouse analysis in which the following information can be found:

- *Average stock:* Average monthly inventory of the last year stored in the warehouse.
- *% Inventory:* Percentage that represents the inventory quantity of each warehouse with respect to the total of pieces stored in all warehouses.
- *% Accumulated:* Accumulated percentage of the inventory quantity per warehouse.

- *% Total variation:* Total percentual variation obtained in each warehouse in the last year.

From this first analysis it was found that 67.42% of the total of products stored throughout the company, is represented by the components in the 4 raw material stores (229, 231, 232 and 233). In addition, as shown in *Figure 5.1*, 48.42% of the total of components stored in these 4 warehouses, is composed of only the components of the warehouse 232 (accessory drive tensioners).

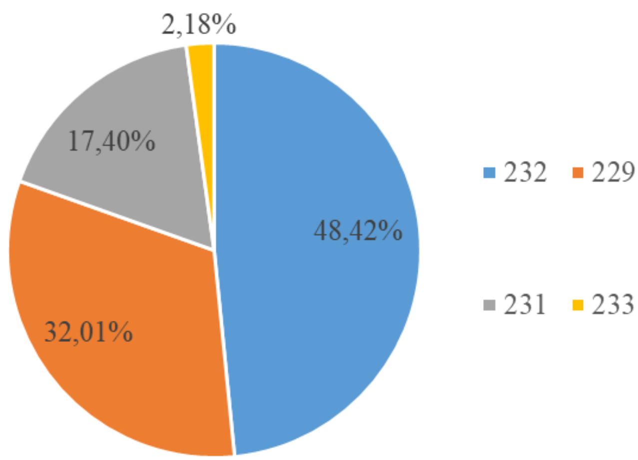

Figure 5.1 Percentage of inventory stored in each components warehouse

Calculating an average price per component of 0.47, 0.42, 0.47 and 1.45 for warehouses 229, 231, 232 and 233 respectively (with the storage data of August 4, 2018 presented in chapter 5), it can be concluded that even if the average value of a component of warehouse 233 has more than triple the average value of the other components, this is still the store with the lowest stored value, since it represents only 2.18% of the stored quantities.

This is why the warehouse 232 is selected for the development of this work, since having the same average value per component of the warehouse 229, it is the one that has greater quantities of stored pieces, and therefore more dammed costs.

5.2. ABC classification of components on selected warehouse

Once selected the warehouse with which the analysis will continue, proceed with an analysis of the components that are stored there.

When selecting the warehouse in the program and ask it to analyze the components, it looks for each component that belong to the warehouse in the historical data of purchases, and then it shows a data table with the following results:

- The value of purchases made of that component for each of the months of the last year.
- The total value of purchases of the component made in the last year.
- The percentage represented by the purchases of the component with respect to the total of purchases made for all the components stored in the warehouse.
- The cumulative percentage of the value of purchases made.
- The ABC classification of the components in the warehouse under the following criteria:

  - ✓ *Zone A:* 80% of the value of purchases represented by approximately 20% of the components.
  - ✓ *Zone B:* 15% of the value of purchases represented by approximately 20% of the components.
  - ✓ *Zone C:* 5% of the value of purchases represented by approximately 60% of the components.

As a result, for warehouse 232, it is found that there are 864 items that have been stored there in the last year, in which has been invested in purchases a total value of 46,405,498.09 euros.

In *Figure 5.2* can be observed how the purchases of the last year (from June 2017 to May 2018) were showing a decrease, but from March 2018 it stars to increase again. This is because the demand of customers is growing, but at the same time it evidences the problems that led to the excessive increase of inventory, since as described above, the inventory is being supplied according to demand, without taking into consideration that the lines do not have the capacity to assemble both delayed and new orders.

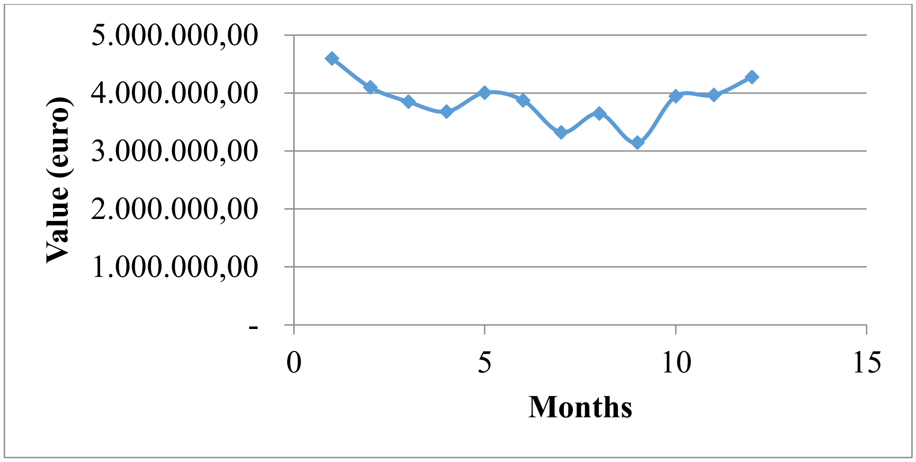

Figure 5.2 Total of components purchases for warehouse 232

Generally, the ABC classification is made with historical demand data, however, in this case it was done with purchases, assuming that the demand for the component was the purchases made of it, since the company does not keep historical demand, only purchases and sales. This assumption is considered valid because the company orders its components according to its demand, since it means being able to comply with all the orders. Therefore it can be affirmed that the purchases made of each component correspond to its past demand, even if this demand could not be fulfilled (in this case, the components are stored in the warehouse).

The *Figure 5.3* shows the results obtained from the ABC classification of the components of warehouse 232. In this it is obtained that a total of 166 components belong to zone A, being 19.21% of the items that represent 79.99% of the value of annual purchases; 167 components that belong to zone B, that is, 19.33% of the items that represent 15% of annual purchases; and finally 531 components that belong to zone C, where 61.46% of the items stored in warehouse 232 represent only 5.01% of annual purchases.

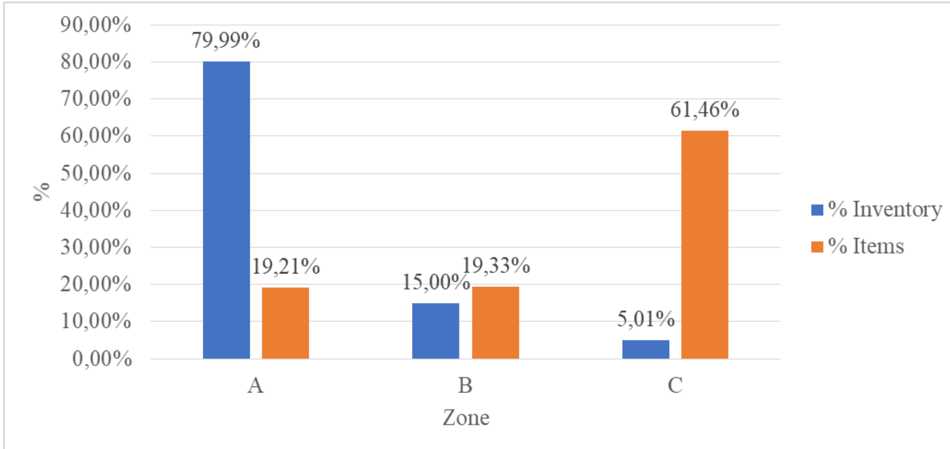

Figure 5.3 ABC classification of components in warehouse 232

Because the business system used in the company currently does not allow the creation of any document from which the data of the BOM of a product can easily be extracted, the consultation of the use of each one of the components must be done manually, looking for component by component in the system and writing one by one the products in which it is used.

Therefore, the components selected to continue with the analysis will not be the 166 items belonging to zone A, but the first 76 products, which, although being 8.8% of the components, account for 60.1% of the purchases annuals that are made to supply the warehouse.

5.3. Demand analysis

Since the objective of this work is the automation of the data analysis of the components, which allow a decision making more agile regarding the programming of the orders to the suppliers, in order to have under control the value stored in the warehouses; once selected the components that will be used, which correspond to the 76 most representative items stored in warehouse 232, we proceed with an analysis of the demand of each one.

In this analysis of the demand, a comparison is made between 3 possible types of demand that each one of the components has:

- *Average Use - Last Year (Units/Month):* The monthly average of units sold in the last year.

- *Material Demand - Next Month (Units/Month):* The demand for the next month sent by the client. Corresponds to the next 4 weeks from the first Monday after the day the document of future demands is downloaded from the system.
- *Budget Quantity FY 19 (Units/Month):* The monthly amount planned by the company for the current year budget.

For the example, they were used respectively:

- Sales from June 2017 to July 2018.
- Demand for the next 4 weeks from September 3, 2018.
- Planned demand in the fiscal year 2019 budget (March 2017 to February 2018).

Appendix 1 shows the results of the analysis of demand data for each of the 76 items.

Figure 5.4 and *Figure 5.5* show the variation percentage of the demand proposed by the client for next month with respect to the average monthly demand of the last year and to the amount of monthly utilization proposed by the company for the budget of the current year respectively.

In *Figure 5.4*, it can be observed that 61.8% (47 items) of the components had an increase in demand compared to that of the previous year, while 38.2% (29 items), on the other hand, had a decrease.

Although most variations do not exceed 50%, there are 7 components that exceed this value, 4 with little difference and 3 with an atypical difference.

The first point that exceed 100% variation corresponds to the component TB113B with an increase of 122%, going from a demand of 6.879 to 15.272. This is because two of the final products of which this component is part, had an increase in their demand of 118% and 538% respectively.

The second one corresponds to the component TM004C with an increase of 126,4%, going from a demand of 9.502 to 21.512. This is because eight of the final products of which this component is part, had an increase in their demand by over 100%.

Finally, the third one corresponds to the component TL178CB with an increase of 215,8%, going from a demand of 2.116 to 6.683. This is because three of the final products of which this component is part, had an increase in their demand by over 100%, among them one that had an increase of 552%.

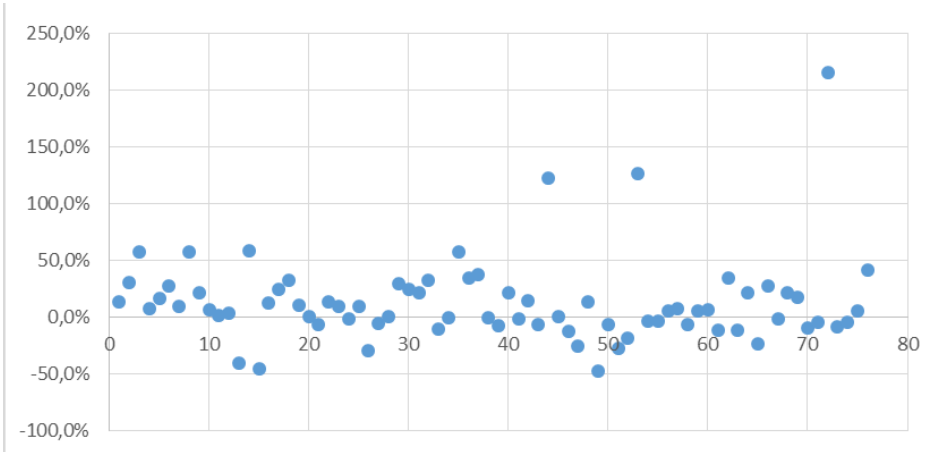

Figure 5.4 Variation in demand compared to last year

On the other hand, in *Figure 5.5* can be observed that 59,2% (45 items) of the components had an increase in demand compared to that of the previous year, while 35,5% (27 items), had a decrease. The remaining 5.3% (4 items) does not have information on the amount planned in the budget, therefore they are not considered.

In this case, most of the variations are also within the 50% range, however there are 6 components that exceed this limit, of which 2 are above 100%.

The first point corresponds to the TM015CA component, with an increase of 323% with respect to the amount planned in the budget, going from 87.202 planned units to 369.227 real demand units. This is because 21 of the final products of which this component is part, had an increase in their demand by over 100%.

The second one corresponds to the TM160AB component, with an increase of 141,4% with respect to the amount planned in the budget, going from 23.509 planned units to 56.754 real demand units. This is because 12 of the final products of which this component is part, had an increase in their demand by over 100%.

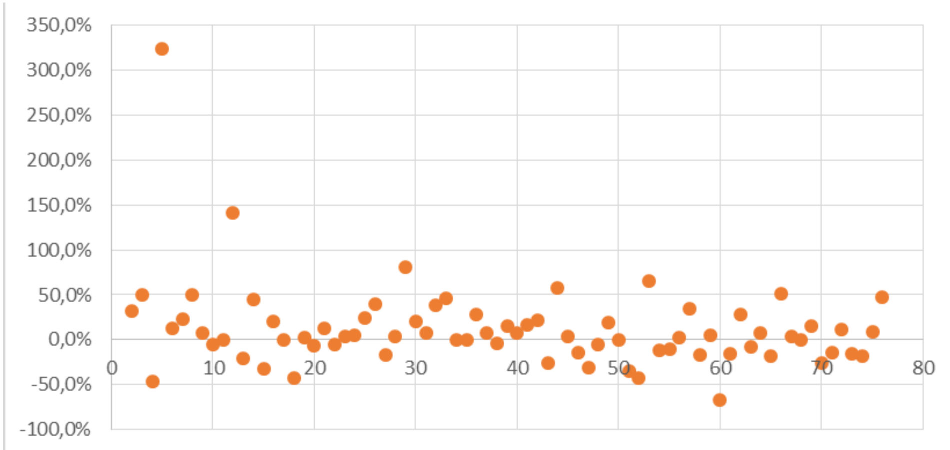

Figure 5.5 Variation in demand compared to the budget

5.4. Coverage analysis

This last analysis aims to give an immediate indication regarding the scheduling of orders to suppliers. Here is the demand coverage that is currently available and a decision is made according to the replenishment lead time of each component.

For decision making, the following parameters were considered:

- *Material Demand - Next Month (Units/Month):* The demand for the next month sent by the client. Corresponds to the next 4 weeks from the first Monday after the day the document of future demands is downloaded from the system
- *Actual stock:* The amount of inventory of the component currently available in the warehouse.
- *Supplier order:* The number of units already ordered to the provider that are pending to arrive.
- *Stock at next month (Units):* The units that will be available once the demand of the next month is satisfied. This parameter is calculated with the following formulation:

$$Stock\ at\ next\ month = Actual\ stock - Material\ demand + Supplier\ order$$

- *Reorder Lead Time (Months):* The replenishment time component established by the provider.
- *Coverage at next month (Months):* The months of coverage that are held as of the following month, if the demand behaves according to the sales of the component of the last year. This parameter is calculated with the following formulation:

$$Coverage\ at\ next\ month = \frac{Stock\ at\ next\ month}{Average\ Use\ -\ Last\ Year}$$

- *Decision:* Determines the procedure to be followed regarding to suppliers' orders. This can be "Block orders" or "Continue ordering" depending on the following characteristics:
  - *Block orders:* This decision is made when the lead time is less than the coverage time of the component under the current characteristics of stock, demand and pending orders to arrive. With this, the excess inventory is evident.
  - *Continue ordering:* This decision is made when the lead time is greater than the coverage time of the component. Indicates when the characteristics of current stock, demand and pending orders are not enough to cover the next month's demand.

Figure 5.6 shows the number of components for which it is advisable to block orders or continue with them. This shows that 61.8% of the orders must be blocked, because there is enough inventory to cover the demand during the lead time, while 38.2% of the orders can continue according to the plan.

The table with the complete analysis for the 76 components is shown in Appendix 2. There it is observed that 23 (79.31%) components of the 29 that must continue with the orders, are those whose stock at the end of the next month is left with a negative balance, that is, components were missing even to cover the demand of said month.

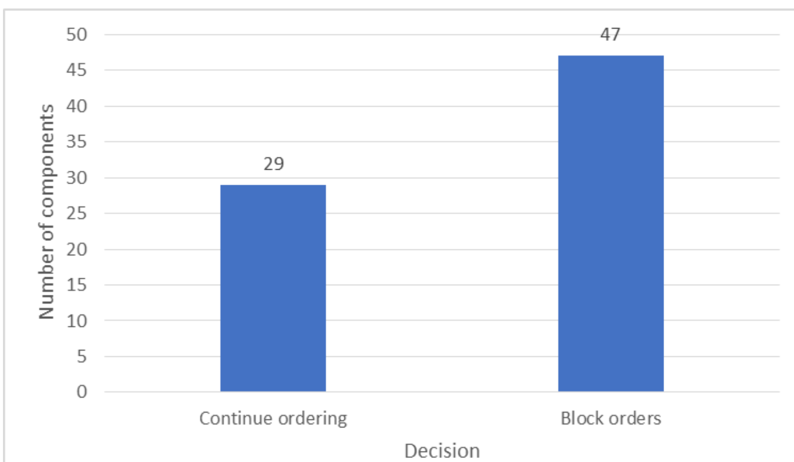

Figure 5.6 Replenishment decision

Chapter 6 Conclusions and recommendations

The purpose of this chapter is to present in a clear and synthetic way the general conclusions on results, the recommendations and the next steps for the topic developed.

- Beginning with chapter 4, after having a clear overview of how the inventory replenishment system currently works, it can be concluded that the process they are using is not very efficient, since doing it manually and not using a computer tool that streamline the process, employees must spend a lot of time working on planning and executing orders to suppliers. In addition, this also implies that the probability of human error is greater and there is a risk of receiving greater or lesser quantities of material in the warehouse than is necessary.
  Therefore, it is recommended to streamline the creation and implementation of a computer system that makes the MRP more accurate and reliable than the current one, since the time spent by workers in this action is represented in costs for the company, which could be minor with the decrease of resources necessary to carry out the operation.

- On the other hand, regarding the causes that led to the large increase in inventory, it can be concluded that the data collection is a weak point of the company and that it is an operation that could be significantly improved by a rethinking of the causes of lost time of production. This in order to have a more clearly defined weight for each cause, representing the reality, to know exactly what points should be attacked to reduce the times of non-production.
  The first cause that is recommended to rethink is the time lost by not programming the machine, since most of this time is actually represented by the lack of components, which is currently not evident because programmers knowing in advance the lack of material to produce, do not program the machine. Therefore, the way in which they collect data nowadays causes them to be inconsistent with what they actually suffer.
  Therefore, the way in which they collect data currently causes them to present inconsistencies with what they actually suffer, which at the same time generates poor decision-making, since the quality of these are proportional to the quality of the data.

- One of the benefits of this study for the components warehouse of Ivrea, Italy plant can be the identification of process flows and AS-IS situation of the replenishment processes performed by the warehouses and the understanding of the criticalities found for them.

- Although the tool created does not calculate the MRP to have maximum control of the orders to the clients, it provides a solution in the short and medium term, reducing the time currently used to perform calculations that allow decision-making in order to reduce the inventory. Meanwhile, is recommended to the company as a long-term solution the implementation of a new enterprise system, which although it requires a large initial outlay, minimizes over time the necessary human resources costs and facilitates and streamlines operations and decision making.

Bibliography

A&A, n.d. *A&A.* [Online] Available at: https://www.aacb.com/why-logistics-is-so-important-to-supply-chains/
[Accessed September 2018].

Beamon, B. M., 1998. Supply Chain Design and Analysis: Models and Methods. *International Journal of Production Economics,* pp. 281-294.

Castro Zuluaga, C. A., Vélez Gallego, M. C. & Castro Urrego, J. A., 2011. Clasificación ABC Multicriterio: Tipos de Criterios y Efectos en la Asignación de Pesos. *ITECKNE,* Volumen 8, pp. 163-170.

Chase, R. B., Jacobs, F. R. & Aquilano, N. J., 2009. *Administración de operaciones. Producción y cadena de suministros.* 12th ed. s.l.:McGRAW-HILL / INTERAMERICANA EDITORES, S.A..

Chavez, J. H. & Torres Rabello, R., 2012. *Supply Chain Management (Gestión de la cadena de suministro).* Santiago de Chile: Ril editores.

Christopher, M., 2002. *Logística e Gerenciamento da Cadeia de Suprimentos - Estratégias para a redução de custos e melhoria dos serviços..* São Paulo: Ed. Pioneira.

Farahani, R. Z., Rezapour, S. & Kardar, L., 2011. *Logistics Operations and Management: Concepts and Models.* 1st ed. s.l.:Elsevier Inc..

Fleischmann, B., Meyr, H. & Wagner, M., 2008. *Supply Chain Management and Advanced Planning – Concepts, Models, Software and Case Studies..* New York: Springer.

Funk, J. L., 1989. A comparison of inventory cost reduction strategies in a JIT manufacturing system. *International Journal of Production Research,* p. 17.

Gaither, N. & Frazier, G., 2000. *Administración de producción y operaciones.* 8th ed. s.l.:Ediciones Paraninfo.

Garcia, E. S. e. a., 2006. Gestão de estoques: otimizando a logística e a cadeia de suprimentos.. *E-papers Servicos Editoriais Ltda..*

Gupta, S. & Starr, M., 2014. *Production and Operations Management Systems.* s.l.:Taylor & Francis Group.

Heizer, J. & Render, B., 2008. *Dirección de la producción y de operaciones: Decisiones tácticas.* 8th ed. Madrid: PEARSON EDUCACIÓN, S.A..

Hugos, M., 2003. *Essentials of supply chain management.* Hoboken, New Jersey: John Wiley & Sons, Inc..

Kempf, K. G., Keskinocak, P. & Uzsoy, R., 2011. *Planning Production and Inventories in the Extended Enterprise.* London: Springer Science+Business Media.

Kumar, S. A. & Suresh, N., 2008. *Production and operations management.* 2nd ed. s.l.:New Age International (P) Ltd., Publishers.

Monczka, R. M., Handfield, R. B., Giunipero, L. C. & Patterson, J. L., 2009. *Purchasing and Supply Chain Management.* s.l.:Cengage Learning.

Muller, M., 2011. *Essentials of Inventory Management.* 2nd ed. s.l.:AMACOM.

Ramirez Lambert, M. A. & Muñoz Creagh, O., 2017. Propuesta de un procedimiento para perfeccionar la gestión de aprovisionamiento de la empresa de bebidas y refrescos Santiago de Cuba (EMBER)..

Saldarriaga Restrepo, D. L., 2013. Modelos de gestión de inventarios para demandas aleatorias. En: *Gerencia, planeación y control de inventarios.* s.l.:s.n.

Sethi, S. P., Yan, H. & Zhang, H., 2005. *Inventory and supply chain management with forecast updates.* s.l.:Springer Science+Business Media, Inc..

Stadtler, H. & Kilger, C., 2005. *Supply chain management and advanced planning.* 3rd ed. Berlin: Springer.

Ullrich, C. A., 2014. *Issues in Supply Chain Scheduling and Contracting.* s.l.:Springer.

Viale, J. D. & Carrigan, C., 1996. *Basics of Inventory Management : From Warehouse to Distribution Center.* s.l.:Course Technology Crisp.

Vidal Holguín, C. J., 2005. *Fundamentos de gestión de inventarios.* 2nd ed. Santiago de Cali, Colombia: s.n.

Vidal Holguín, C. J., Londoño Ortega, J. C. & Contreras Rengifo, F., 2004. *Aplicación de Modelos de Inventarios en una Cadena de Abastecimiento de Productos de Consumo Masivo con una Bodega y N Puntos de Venta,* s.l.: s.n.

Vitasek, K., 2013. *CSCMP Council of Supply Chain Management Professionals.* [Online] Available at: https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx?hkey=60879588-f65f-4ab5-8c4b-6878815ef921
[Accessed September 2018].

Weele, D. A. J. v., 2010. *Purchasing & Supply Chain Management: Analysis, Strategy, Planning and Practice.* s.l.:Cengage learning.

Appendixes

Appendix 1: Demand analysis for selected components

Item	Average Use - Last Year (Units/Month)	Material Demand - Next Month (Units/Month)	Budget Quantity FY 19 (Units/Month)
TM143BA	76.785	86.982	-
TD029CA	121.750	159.084	120.023
TB470AA	85.784	134.738	89.890
TM175AB	47.609	51.011	94.726
TM015CA	316.739	369.227	87.202
TD004DA	54.295	69.013	61.200
TL907AA	25.810	28.211	22.983
TF151CA	85.784	134.738	89.890
TB331BB	47.323	57.419	53.167
TM020A	24.167	25.747	27.022
TM019A	49.832	50.420	50.620
TM160AB	54.637	56.754	23.509
TB230AA	43.732	25.900	32.888
TG122BA	82.397	130.418	89.890
TF129BA	40.655	22.195	32.888
TL082C	33.575	37.733	31.279
TW068AA	16.570	20.589	20.549
TD036DA	8.392	11.085	19.294
TM075AA	15.648	17.243	16.942
TL577BB	15.637	15.638	16.702
TW152BA	23.439	21.941	19.434
TF160EB	48.306	54.911	58.333
TB198AA	12.793	13.973	13.450
TL285BA	11.073	10.840	10.336
TB121EB	11.922	13.089	10.582
TL372CB	25.890	18.109	12.979
TB299BA	12.547	11.894	14.285
TB075EB	25.798	25.889	24.875
TL363CB	3.820	4.928	2.733
TB042KA	14.888	18.495	15.433
TD098AE	47.323	57.419	53.167
TM023A	12.223	16.210	11.664
TL198B	21.919	19.540	13.352

TD003D	31.380	31.337	31.243
TL557CA	85.784	134.738	-
TE125AA	85.184	114.578	89.890
TF010DB	25.988	35.776	33.239
TD024DA	26.728	26.590	27.606
TD020DA	20.008	18.562	16.166
TF177BA	47.323	57.419	53.167
TL089EA	11.833	11.693	10.027
TD043CA	9.700	11.134	9.106
TB310DB	46.467	43.219	58.333
TB113B	6.879	15.272	9.656
TF056B	25.798	25.889	24.875
TD035DA	23.892	20.775	24.335
TB106GA	16.786	12.483	18.045
TG140BA	48.306	54.911	58.333
TM155AA	7.975	4.146	3.486
TD085CA	46.467	43.219	-
TBL100AB	39.040	28.080	43.333
TC021BB	100.939	82.290	142.978
TM004C	9.502	21.512	13.034
TD027C	21.243	20.463	23.201
TJ024GB	28.843	27.849	31.289
TF152BB	17.033	17.895	17.438
TB165DA	7.135	7.659	5.681
TF067HA	25.147	23.451	28.076
TG056A	28.309	29.835	28.570
TD067BA	2.489	2.656	8.042
TG052EA	28.545	25.100	29.801
TK097AA	85.184	114.578	89.890
TD008D	19.219	17.070	18.661
TK110AB	47.323	57.419	53.167
TB142E	14.351	10.921	13.284
TW059CA	30.836	39.325	26.093
TK063BB	42.853	42.130	40.804
TL903AA	47.323	57.419	-
TP168AA	63.320	74.103	64.587
TJ007E	49.527	44.696	60.777
TJ074BA	13.401	12.768	14.938
TL178CB	2.116	6.683	5.981
TF032FA	14.733	13.437	15.853
TG131CA	12.851	12.245	14.938

TD002B	10.522	11.130	10.219
TB140CA	9.941	14.107	9.561

Appendix 2: Coverage analysis for selected components

Item	Material Demand - Next Month (Units/Month)	Actual Stock	Supplier order	Stock at next month (Units)	Reorder Lead Time (Months)	Coverage at Next Month (Months)	Decision
TM143BA	86.982	-	71.400	-15.582	2,00	-	Continue ordering
TD029CA	159.084	283.807	123.950	248.673	1,25	2	Block orders
TB470AA	134.738	-	120.000	-14.738	2,00	-	Continue ordering
TM175AB	51.011	-	120.320	69.309	2,00	1	Block orders
TM015CA	369.227	111	77.127	-291.989	2,00	-	Continue ordering
TD004DA	69.013	141.210	54.000	126.197	1,25	2	Block orders
TL907AA	28.211	17.496	30.000	19.285	1,50	1	Block orders
TF151CA	134.738	-	87.360	-47.378	2,00	-	Continue ordering
TB331BB	57.419	54.864	46.448	43.893	1,50	1	Block orders
TM020A	25.747	20	32.000	6.273	2,00	0	Continue ordering
TM019A	50.420	10.080	10.080	-30.260	2,00	-	Continue ordering
TM160AB	56.754	3.000	15.000	-38.754	2,00	-	Continue ordering
TB230AA	25.900	900	-	-25.000	2,00	-	Continue ordering
TG122BA	130.418	128.000	117.600	115.182	1,25	1	Block orders
TF129BA	22.195	-	-	-22.195	2,00	-	Continue ordering
TL082C	37.733	73.170	15.000	50.437	1,25	2	Block orders
TW068AA	20.589	-	9.540	-11.049	2,00	-	Continue ordering
TD036DA	11.085	4.737	25.200	18.852	1,25	2	Block orders
TM075AA	17.243	139	14.000	-3.104	2,00	-	Continue ordering
TL577BB	15.638	36.608	20.000	40.970	1,25	3	Block orders
TW152BA	21.941	112.928	-	90.987	2,00	4	Block orders
TF160EB	54.911	122.545	44.355	111.989	1,00	2	Block orders
TB198AA	13.973	14.040	11.700	11.767	2,25	1	Continue ordering

TL285BA	10.840	15.229	9.744	14.133	1,50	1	Block orders
TB121EB	13.089	165	-	-12.924	2,00	-	Continue ordering
TL372CB	18.109	21.060	12.000	14.951	0,50	1	Block orders
TB299BA	11.894	35.424	18.816	42.346	1,00	3	Block orders
TB075EB	25.889	28.741	21.848	24.700	1,25	1	Block orders
TL363CB	4.928	3.875	5.722	4.669	2,00	1	Block orders
TB042KA	18.495	-	15.000	-3.495	2,00	-	Continue ordering
TD098AE	57.419	46.810	58.000	47.391	1,25	1	Block orders
TM023A	16.210	-	4.400	-11.810	2,00	-	Continue ordering
TL198B	19.540	38.700	16.000	35.160	1,25	2	Block orders
TD003D	31.337	93.272	23.500	85.435	1,25	3	Block orders
TL557CA	134.738	-	132.608	-2.130	1,50	-	Continue ordering
TE125AA	114.578	73.980	129.600	89.002	1,50	1	Block orders
TF010DB	35.776	-	35.600	-176	2,00	-	Continue ordering
TD024DA	26.590	79.280	17.500	70.190	1,25	3	Block orders
TD020DA	18.562	20.465	20.000	21.903	1,25	1	Block orders
TF177BA	57.419	85.610	29.655	57.846	1,00	1	Block orders
TL089EA	11.693	-	8.880	-2.813	0,50	-	Block orders
TD043CA	11.134	15.280	11.400	15.546	1,25	2	Block orders
TB310DB	43.219	36.369	-	-6.850	1,00	-	Continue ordering
TB113B	15.272	16.650	13.728	15.106	2,25	2	Block orders
TF056B	25.889	3.620	-	-22.269	2,00	-	Continue ordering
TD035DA	20.775	86.007	22.000	87.232	1,25	4	Block orders
TB106GA	12.483	50.031	-	37.548	1,00	2	Block orders
TG140BA	54.911	67.600	53.200	65.889	2,00	1	Block orders
TM155AA	4.146	6.000	-	1.854	2,00	0	Continue ordering
TD085CA	43.219	-	-	-43.219	1,25	-	Continue ordering
TBL100AB	28.080	-	35.028	6.948	2,25	0	Continue ordering

TC021BB	82.290	324.000	108.000	349.710	1,50	3	Block orders
TM004C	21.512	8.640	-	-12.872	2,00	-	Continue ordering
TD027C	20.463	77.464	17.200	74.201	1,25	3	Block orders
TJ024GB	27.849	59.800	32.000	63.951	1,50	2	Block orders
TF152BB	17.895	30.173	29.527	41.805	1,00	2	Block orders
TB165DA	7.659	8.640	9.104	10.085	1,50	1	Block orders
TF067HA	23.451	470	-	-22.981	2,00	-	Continue ordering
TG056A	29.835	53.200	28.000	51.365	2,00	2	Block orders
TD067BA	2.656	11.669	7.200	16.213	1,25	7	Block orders
TG052EA	25.100	118.714	-	93.614	1,50	3	Block orders
TK097AA	114.578	140.091	120.000	145.513	2,00	2	Block orders
TD008D	17.070	34.741	14.800	32.471	1,25	2	Block orders
TK110AB	57.419	55.513	63.000	61.094	2,00	1	Block orders
TB142E	10.921	-	-	-10.921	2,00	-	Continue ordering
TW059CA	39.325	210	41.200	2.085	2,00	0	Continue ordering
TK063BB	42.130	97.500	37.500	92.870	2,25	2	Block orders
TL903AA	57.419	6.210	64.512	13.303	1,50	0	Continue ordering
TP168AA	74.103	49.400	64.000	39.297	2,00	1	Continue ordering
TJ007E	44.696	134.400	57.600	147.304	1,50	3	Block orders
TJ074BA	12.768	3.600	18.000	8.832	1,50	1	Block orders
TL178CB	6.683	5.562	7.700	6.579	0,50	3	Block orders
TF032FA	13.437	26.498	13.632	26.693	1,00	2	Block orders
TG131CA	12.245	23.597	16.089	27.441	1,50	2	Block orders
TD002B	11.130	43.265	9.000	41.135	1,25	4	Block orders
TB140CA	14.107	7.182	1.905	-5.020	1,50	-	Continue ordering