POLITECNICO DI TORINO

Master of Science in Engineering and Management

Master's degree thesis

Application of Demand Driven Material Requirement Planning (DDMRP) methodology for components inventory management in a company of automotive industry

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Index

Index Figures

Index Tables

CHAPTER 1: INTRODUCTION

Actually, companies seek to continuous improve the management of their processes. Good manufacturing practices, improvement tools, and reliable information systems, among others, must support these processes in order to simplify tasks within the organization.

One of the most important processes that companies have is the production planning. Within the planning there is a determining factor, that is the correct inventories management of both raw material and final products. Companies increasingly seek to work under a Make to Order production system, based on a raw material inventory that allows them to satisfy the customer requirements, but at the same time allows them to manage and reduce their costs.

Most companies use MRP systems as the method for planning their production. However, in order to implement new methods that allow the company to work at the pace of demand and thus better manage inventory levels, it was proposed the methodology Demand Driven Material Requirement Planning (DDMRP), which is defined by the founders of the Demand Driven Institute as “formal multi-echelon planning and execution method to protect and promote the flow of relevant information and materials through the establishment and management of strategically placed decoupling point stock buffers”.

Dayco Europe works in the automotive sector, where is a company leader in the research, design, manufacturing and distribution of engine products, drive systems and services for automobiles, trucks, construction, agriculture and industry. This thesis was developed in the Ivrea production plant, where the main products that are produced are the tensioners, which are sold to markets such as Fist Plant and Aftermarket. The plant is made up of many areas, among which is the Supply Chain, department where this study was carried out. The specific processes that were the object of this work are the purchases and production scheduling.

At the Ivrea' plant, some failures were currently found in the production schedule. First, it was found that the suppliers Lead Times of some components are high and the variability inherent in these times is considerable, as well as the variability that can occur in the demand of products by customers. In addition, the company's current MRP does not take into account the capacity restrictions that the plant has, nor does it take into account the quantity of components available in the warehouse at its time of execution.

It is therefore, that the objective of this thesis is to apply the DDMRP methodology in order to propose an alternative management of component inventories. It should be noted that only the first four phases of the method were implemented, since making their proper adjustments requires a long window of time in order to collect the data necessary for the analysis.

After applying the methodology in the chosen components, a series of results was obtained which can be seen in chapter 6, where the detailed analysis of the component TL448AA was mainly carried out since the method to obtain these results is replicable.

Finally, the conclusions and recommendations for the implementation of the DDMRP methodology in the company Dayco Europe are presented.

CHAPTER 2: THEORETICAL FRAMEWORK

2.1. The supply chain

2.1.1. Definition

According to the Cambridge dictionary, *a company is an organization that sells goods or services in order to make money*. However, as cited by (Waters, 2003), these organizations do not work isolated, each one behaves as a customer when it buys materials from its own suppliers, and then it behaves as a supplier when it delivers materials to its own customers. Most products move through a series of organizations as they travel between original suppliers and final customers.

This is why the concept of Supply Chain becomes important. The supply chain can then be defined as all the processes that are involved directly or indirectly in satisfy all the requirements and needs of the customers. As cited by (Robert M. Monczka, 2009) the supply chain are composed of interrelated activities designed to achieve a specifics objectives that are internal and external to a firm, namely the supply chain requires the coordination of activities and flows that extend across boundaries.

On the other hand, The Institute for Supply Management defines supply management as the identification, acquisition, access, positioning, and management of resources and related capabilities and organization needs or potentially needs in the attainment of its strategic objectives.

Said the above, it can be defined the Supply Chain Management, as cited by (Weele, 2010) like the management of all activities, information, knowledge and financial resources associated with the flow and transformation of goods and services from the acquisition of raw materials and components in such a way that the expectation of the final customer of the company are met or surpassed.

The supply chain management involves the supply chain orientation and encompasses the proactively managing the two-way movement and coordination of goods, services, information and flows, from the raw material through end user, that is to say as is referenced by (PROJECT, 2011) the supply chain management encompasses the planning and administration of all activities that go from the sourcing and purchase until the all logistics activities.

It also includes the coordination and collaboration with channel partners, which can be suppliers, intermediaries, customers. Fundamentally, it can say that supply chain management integrates supply and demand management within and across companies. The following Figure shows how the supply chain system is on a large scale

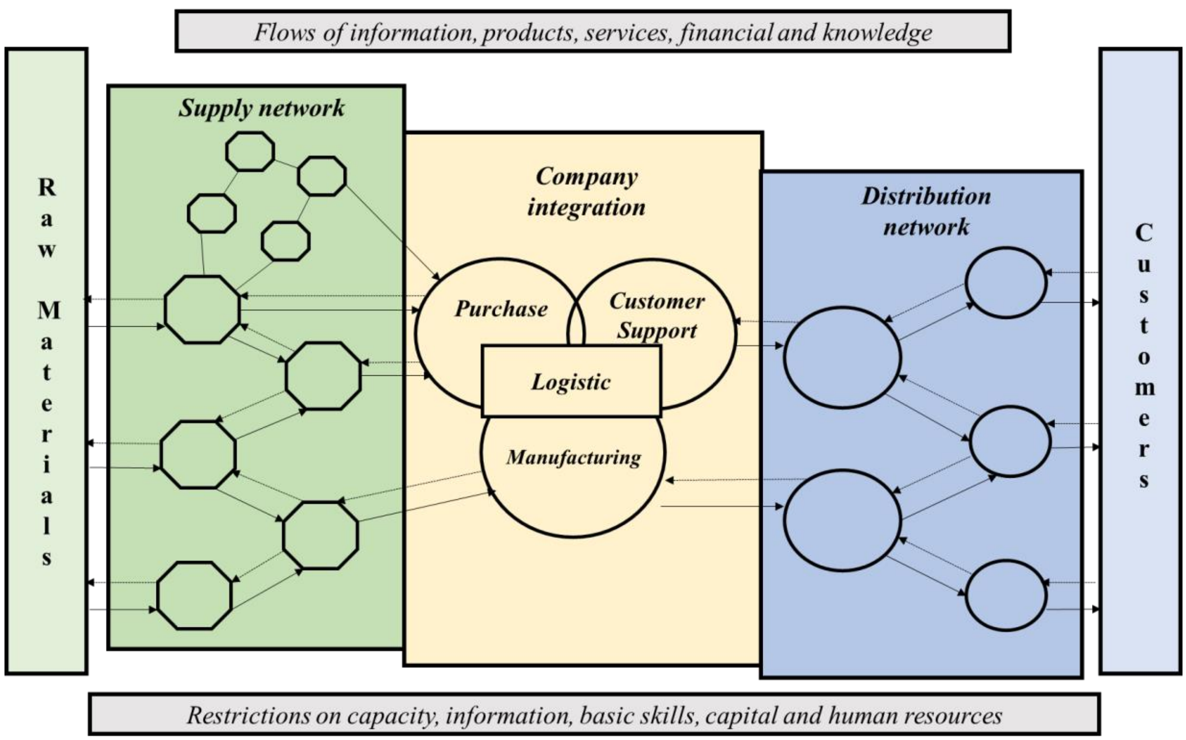


Figure 1. Supply chain system.

Taken from (Donal J. Bowersox, 2007)

2.1.2. Origin supply chain

As the history shows, the goods that people needed could not be produced where they were required or simply were not accessible at the time they wanted to consume them. This limited system frequently obliged people to live close to production sources and consume a limited range of products. The food and the useful goods were widely dispersed and were only found in abundance at some times of the year. The ancients consumed the products immediately or decided to move them to another place, storing them for later use. However, as transport and well-developed storage systems did not yet exist, the transport of goods was limited to what an individual could personally transfer, and the storage of delicate goods was only achievable for a short period.

From there begins to give importance to what is known today as supply chains.

As cited by (Ballou, 2004) "*before companies showed interest in coordinating supply chain processes, the military was well organized to carry out logistics activities. More than a decade before the period of development of logistics in business, the military carried out what was called the most complex and best planned logistics operation of that time: the invasion of Europe during the Second World War. Although the problems of the military, with their extraordinarily high customer service requirements, were not identical to those of the businesses, the similarities were large enough to provide a base of valuable experience during the years of logistics development. For example, the military industry itself maintained inventories valued at almost a third of those maintained by US manufacturers. In addition to the administrative experience provided by such large-scale operations, the military industry sponsored, and continues to sponsor, research in the area of logistics through organizations such as the RAND Corporation and the Office of Naval Research. With this basic information, the field of business logistics began to grow. Even the logistic term seems to have had its origins in the military.*"

2.1.3. Importance of the Supply Chain.

The supply chain management has developed into one of the key business drivers, since according to (Ballou, 2004) the supply chain always revolves around creating value for the stakeholders, both customers, suppliers and shareholders of the company. The value in the supply chain is expressed mainly in terms of time and position. The products and services have no value unless the client can receive them at the right time and place (i.e. at the specific time required). A good logistic management visualizes each activity in the supply chain as a contribution to the process of adding value. However, value is added when customers prefer to pay more for a product or service than it costs to deliver them.

It can be said that some of the most important factors that become the supply chain in one of the most important business drivers for the company are:

- *Costs:* Over time, different studies have been carried out to establish the supply chain costs for the economy in general, particularly for companies. According to the International Monetary Fund (IMF), the average of logistics costs is around 12% of the world's gross national product. For a particular company, the costs of the supply chain have been extended from 4% to more than 30% of its volume of sales. This is how the value is added, by minimizing these costs and passing the benefits to the consumers and to the shareholders of the company.

- *Customer service:* The internet, on-time operation methods and the continuous replenishment of stocks, have contributed to customers expecting high velocity in the processing of their requirements and in the delivery of their orders, as well as a high level of availability of the products. In addition, the continuous improvement of information systems and flexible manufacturing processes have led the market towards "mass personal fabrication".

- *Supply and distribution lines*: Currently, companies are looking for or have developed global strategies, designing their products for a global market and producing them where raw materials, components and labor can be found at low cost, or simply, companies produce at locally level and sold internationally. The supply and distribution lines have been expanded, thus creating greater complexity in their management.

  The globalization of industries everywhere will depend largely on the performance and costs of the supply chain, as companies reach a more global vision of their operations. While material and workforce costs can be reduced, supply chain costs are more likely to increase due to increased transport and stock costs. The contracting of third parties for certain internal activities of the company adds value, but requires a careful management of the logistics costs and the flow times of the product in the supply channel.

- *The company's strategy*: Companies spend a lot of time looking for a way to make different their products from those of their competitors. When management recognizes that the supply chain affects a significant part of a company's costs and that the result of the decisions it makes in relation to the processes of the supply chain results in different levels of customer service, it is in position to use this effectively to penetrate new markets, to increase market share and to increase profits. That is, a good direction of the supply chain can not only reduce costs, but also generate sales.

2.1.4. How to work the Supply Chain.

According to (Robert M. Monczka, 2009), a great set of activities in addition purchasing is part of supply chain management. Each of these activities has one important characteristic in common: it is part of a network that will describe how efficiently and effectively goods and information flow across a supply chain. Although the need to manage supply chain has been present for many years, the organization's willingness to align, coordinate, integrate, and synchronize these activities and flows that is relatively new.

The supply chain is composed by activities such as (Robert M. Monczka, 2009):

2.1.4.1. ***Purchasing***

The organizations include purchasing as an important supply chain activity and it is recognized link with upstream activities, because according to (Waters, 2003) the purchasing should be finds appropriate suppliers, negotiates terms and conditions, organizes delivery, arranges insurance and payment, and does everything needed to get materials into the organization.

2.1.4.2. ***Inbound Transportation***

Organizations usually have a particular traffic and transportation function to manage the physical and informational links between the supplier and the buyer. For some organizations, transportation is the single main category of single costs, especially for highly diversified organizations.

2.1.4.3. ***Quality Control***

Organizations recognize the importance of supplier quality and the need to prevent, rather than simply detect, quality problems. The emphasis has moved from detecting defects at the time of receipt or use to prevention early in the materials sourcing process. Progressive companies work directly with suppliers to develop proper quality control procedures and processes. This includes forecasts of anticipated demand, inventory adjustments, orders taken but not filled, and spare-part and aftermarket requirements.

2.1.4.4. ***Receiving, Materials Handling, and Storage***

All material that arrives into the organization must be received as it moves from a supplier to a purchaser. In a non-just-in-time environment, material must also be stored or staged. Receiving, materials handling, and storage are usually part of the materials management function because of the need to control the physical processing and handling of inventory.

2.1.4.5. ***Materials or Inventory Control***

The materials control group is responsible for determining the suitable quantity to order based on estimated demand and then managing materials releases to suppliers. This includes generating the materials release, contacting a supplier directly concerning changes, and monitoring the status of inbound delivery. On the other hand, the inventory control group is responsible for determining the inventory level of finished goods required to support customer requirements, which emphasizes the physical distribution side of the supply chain.

2.1.4.6. ***Order Processing***

Order processing helps ensure that customers receive material when and where they require it. The most common problems with order processing have involved accepting orders before determining if adequate production capacity is available, not coordinating order processing with order scheduling, and using internal production dates rather than the customer's preferred date to schedule the order. Order processing is an important part of supply chain management because it represents a link between the company and the external customer.

2.1.4.7. ***Production Planning, Scheduling, and Control***

These activities involve determining a time-phased schedule of production, developing short-term production schedules, and controlling work-in-process production. The production plan often depend on forecasts from marketing to estimate the volume of materials that are required in the short term.

2.1.4.8. ***Warehousing/Distribution***

Before a product directs to the customer, it may be stored for a time in a warehouse or distribution center. This is for companies that produce according to a forecast in anticipation of future sales. More and more, as companies attempt to make a product only after receiving a customer order; this part of the supply chain may become less important.

2.1.4.9. ***Shipping***

This activity involves physically getting a product ready for distribution to the customer, which requires packing to prevent damage, completing special labeling requirements, completing the required delivery documents, and/or arranging transportation with an appropriate carrier.

2.1.4.10. ***Outbound Transportation***

Less organizations “own” the transportation link to their customers, compared with just a few years ago. Increasingly, full-service transportation providers are designing and managing entire distribution networks for their clients.

2.1.4.11. ***Customer Service***

Customer service includes an extensive set of activities that attempt to keep a customer satisfied with a product or service. The three primary elements of customer service are pre transaction, transaction, and post-transaction activities.

2.1.5. Supply Chain Integration

As cited by (Robert M. Monczka, 2009), integration is define as "*the process of incorporating or bringing together different groups, functions, or organizations, either formally or informally, physically or by information technology, to work jointly and often concurrently on a common business-related assignment or purpose.*"

This author mention that integration can occur in many forms. It can occur through functions, such as in sourcing or new-product development teams. It can also take place through cross-location teams, where people from different business units are brought together. Finally, the most difficult and challenging form is cross-organizational teams, which includes working with suppliers, customers, or even both concurrently. There are two kind of integration according to (Robert M. Monczka, 2009):

2.1.5.1. Internal Integration

To make possible integration with other internal functions, a number of critical communication linkages or interfaces have evolved between supply management and other departments. Many organizations have actively moved toward an outsourced environment, and in some cases are sourcing all products through low-cost-country sourcing environments or contract manufacturers. The supply management must play a critical role in establishing the agreements and identifying global requirements for success. Supply management must often work to become part of the global negotiations teams and become involved in supplier qualification, contract management, and logistics, working with multiple internal parties in the firm including finance, legal, logistics, marketing, and operations.

The following Figure shows the linkages between supply management and other key groups:

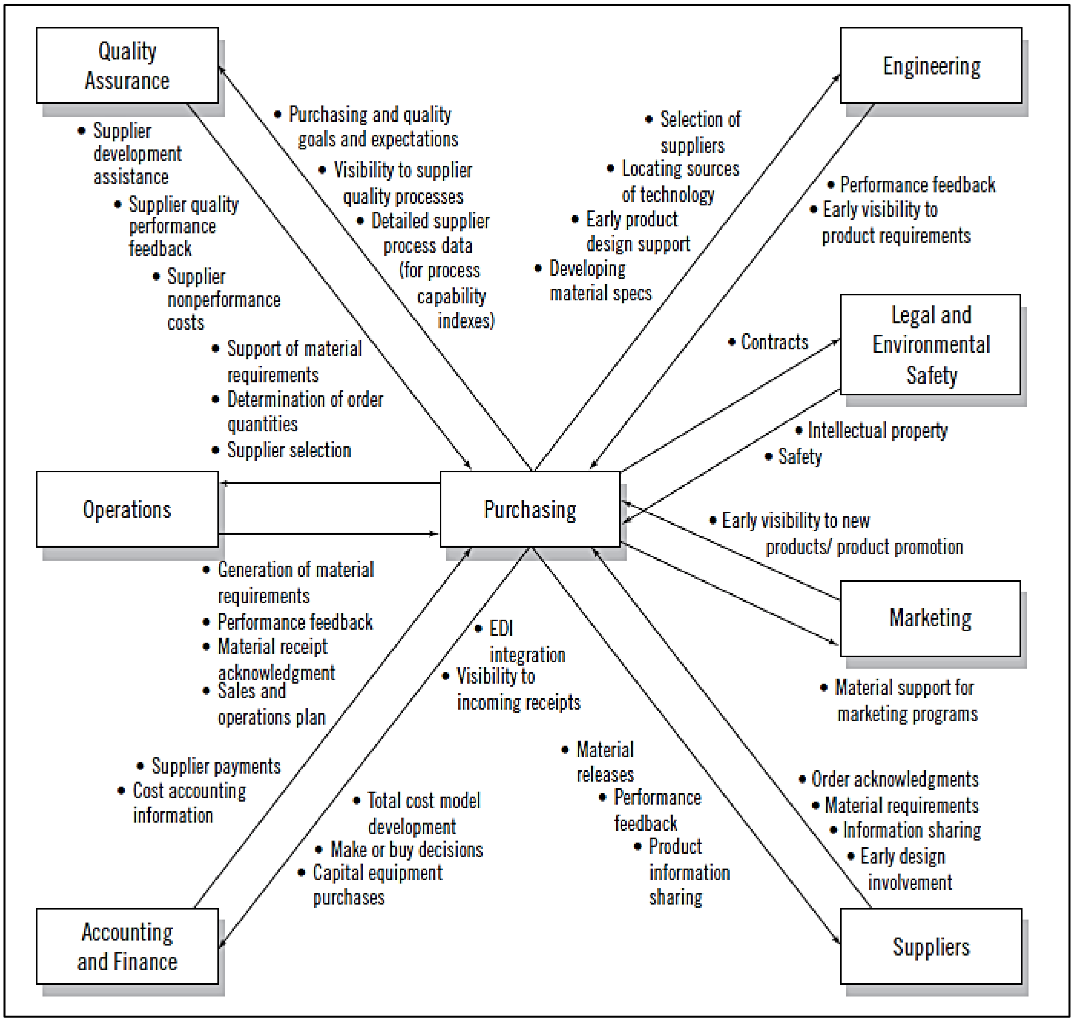


Figure 2. Supply Management Communications Flows and Linkages.

Taken from (Robert M. Monczka, 2009)

2.1.5.2. ***External Integration***

Supply management represents the external face of the organization and serves as the primary vehicle by which to integrate external suppliers and other entities into the organization. This is done by creating and maintaining linkages with groups external to the firm.

Supply management acts as a connection with external parties on multiple fronts, including materials, new technology, information, and services. These parties include suppliers, government, and local communities.

- **Suppliers:** Supply management's primary external linkages are with its suppliers. Supply management's primary responsibility is to maintain open communications with suppliers and select the suppliers with which to do business. Supply management has the responsibility to select suppliers and to remain the primary commercial linkage with the buying firm, including any matter involving the conditions of the purchase agreement or other issues of importance.

- **Government:** Supply management sometimes maintains communication linkages with governments at different levels and locations. For example, supply management has an active role in international countertrade and often negotiates directly with foreign governments when establishing countertrade agreements. Supply management may also need to consult with federal government agencies on various matters.

- **Local Communities:** Supply management may have contact with local communities and leaders. Because supply management controls a large budget, it has the potential to affect certain social goals. These goals include sourcing from local suppliers, awarding a certain percentage of business to qualified minority suppliers, and establishing ethical business practices in all dealings.

2.2. The Purchasing Process

2.2.1. Concept

The purchasing can be defined like the entity of an organization, responsible for realize in an efficiently and effectively way, the procuring of all the products that are necessary for the correct performance of the firm, which includes goods related to the production as direct materials (raw material, semi-finished products and components, finished products), and indirect materials (that are all these materials that do not become part of the company´s value proposition) and general services. By that, the purchasing can also is defined as a functional- operational activity of a company.

The purchasing department must perform their activities to guarantee the delivers can give the maximum value to the company. For that reason, the responsible of this department needs to have an excellent knowledge of the product or service that the company require, with the purpose to achieve a correct choice of the suppliers. All this process as was cited by Robert M. Monczka, (2009) includes a "supplier identification and selection, buying, negotiation and contracting, supply market research, supplier measurement and improvement, purchasing systems development". All the purchasing process also includes the identify customer requirements, the evaluations of this requests successfully; follow up to ensure proper the delivers and payments and always drive a continuous improvement of this activities.

Actually in the manufacturing sector, "the percentage of the purchases to sales is around 55% on average, means that for each euro of revenue collected on goods or services sales, more than half of this money goes back to the suppliers" (Robert M. Monczka, 2009), which indicates that purchasing process is one of the most important area for cost saving. The company can get that savings through approaches like: hard price reductions and build relationship with the suppliers.

Therefore, it can be said that this department must work around "the five rights: the right quality, in the right quantity, at the right time, for the right price, from the right source" (Robert M. Monczka, 2009).

In the Figure 3, it can be seen a general purchasing process model.

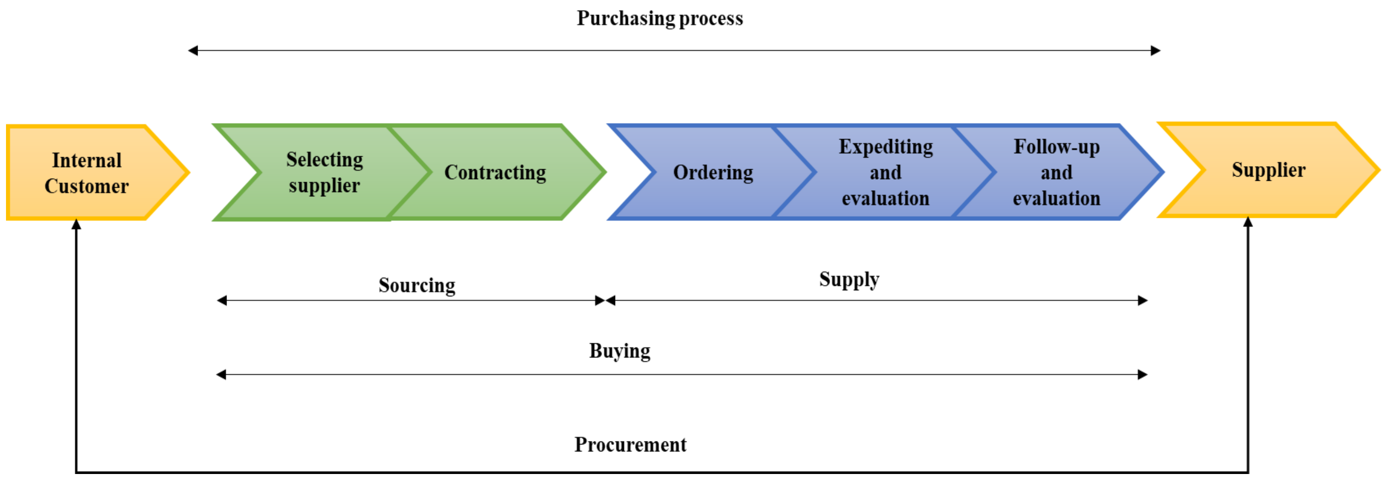


Figure 3. The Purchasing Process

Taken from (Weele, 2010)

2.2.2. Why purchasing is Important

Currently, companies are working to increase the value for their customers, improving their performance considerably, but at the same time, the organizations are giving greater importance to purchasing and supply management.

According to (Robert M. Monczka, 2009), it can say that many features that have the final products originate with suppliers. This is why the purchasing department must analyze them correctly, because supplier capabilities can help differentiate a producer's final good or service. Another important factor that should be highlighted is that purchasing has an essential impact on the product and service quality, this further has that increases the importance of the relationship between purchasing, suppliers and quality. In this way, an effective purchasing become an important way for improve the key businesses and gain a competitive advantage for company.

As cited by (Robert M. Monczka, 2009), "the purchasing acting as the liaison between suppliers and engineers, can also help improve product and process designs. Involving suppliers early in the design process is a way purchasing can begin to add new value and contribute to increasing their competitiveness".

2.2.3. Purchasing Glossary

- Request for Quotation (RFQ): Is a document that the firm sends to the potential suppliers for, obtain the bids for goods and services that it need according of technical design of the product.
- Cost Breakdown (CBD): According with Cambridge dictionary is the process of dividing the cost of something into the different parts that make up the total amount, according to who is doing the work, what materials are needed. As cited by (Thibodeaux, s.f.) The Cost Breakdown is the systematic process of identifying the individual elements that encompass the total cost of a good or service. With this, the responsible assigns a specific euro value to each element.
- Bill of materials (BOM): Is a list that contains the quantity of components, ingredients and materials necessaries for elaborate a product and the technical design
- Production Part Approval Process (PPAP): The PPAP defines the approval process for new or revised parts, or parts produced from new or significantly revised production methods. The resulting PPAP submission provides the evidence that the supplier has met or exceeded the customer's requirements and the process is capable of consistently reproducing quality parts. (Quality One, s.f.).
- Supply: According to (Weele, 2010) the supply is an operation that 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
- Sourcing: Finding, selecting, contracting and managing the best possible source of supply on a worldwide basis (Weele, 2010)
- Procurement: As cited by (Weele, 2010) the procurement relates to the function of purchasing inputs using in the company´s value chain.
- Quality: The quality refers to the total features of a product or service that bear on its ability to satisfy a given need. Quality is meeting a customer´s requirement that have been formally agreed between a customer and a supplier. (Weele, 2010)

- Indirect Materials: Are the purchased materials and services that do not become part of the company's value proposition. May be classified into MRO-supplies, investment goods (also referred to as Capital expenditure or CAPEX) and services (Weele, 2010)
- Direct Materials: All purchased materials and services that become part of the company's value proposition. These include raw materials, manufactured goods or half fabricate components and modules- identical to BOM- (Weele, 2010)
- Raw material: Are the materials, which have undergone no transformation or a minimal transformation, and they serve as the basis materials for a production process (Weele, 2010).
- Capital Expenditure (Capex): The Capex are funds (money) used by a firm to acquire, upgrade, and maintain physical assets such as property, industrial buildings, or equipment. (Investopedia , s.f.)
- Budget: According to (Weele, 2010) a budget is a vehicle for delegating activities and responsibilities to lower management's levels in the organization.
- Payment Terms: This term is relate to what, how and when the buyer will pay for the products and services delivered by the supplier (Weele, 2010)
- Macroeconomics Indicators: Are those Indicators that provide insight into the economic performance of a particular country or region (Alpari, s.f.)

2.3. The Production Process

In most cases, the origin or raison of any good or service arises from the needs of man. To produce these goods or provide services, capital investment is required to acquire the inputs, machinery, technology and the most important part the human talent. In this way companies are formed, within the community society, to satisfy the needs (Carro Paz & Gonzales Gomes, 2011).

The concept of production consists in the fact of transforming, which is the sequence of operations that transform the materials, causing them to change from one form to another. Production is also understood as the addition of value to a good or service, by the effects of a transformation. Produce is to extract, modify the goods in order to make them fit to meet the needs (Carro Paz & Gonzales Gomes, 2011).

Production is the main activity in a production system (Gaither & Frazier, 1994) define it as the process by which workers, materials and machines are used to convert inputs like raw materials, technology, cash and information into products, which can be goods or services.

Gaither and Frazier (2002) define two main approaches in production systems: the process-focused and the product-focused. The first aimed at the process or function, characterized by high use of equipment, the second, is developed depending on the type of product produced and the needs that this requires.

2.3.1. Production Management

Some years ago, production was considered within the purely manufacturing context and the managerial scope of production was left aside. That is why the term "operations" was taken as an expression that covers both the actions in the field and the service (Sipper D. , 1998). Therefore, the term production began to transform and is now called administration or direction of operations in which inclusion is generated to all types of organizations, regardless of their core business or size (Groover, 2007).

That is why today there is not much talk about production but management of operations or production management, which is the art of combining the resources of an organization to produce products or provide services. Considering the concept widely, the administration of operations is related to the production of goods and services. On a daily basis, we have contact with a range of goods and services, which are produced under the supervision of operations managers (Carro Paz & Gonzales Gomes, 2011).

At a superficial level it seems that the services operations have little to do with manufacturing, however, a characteristic of these operations is that both can be considered as processes of transformation. In manufacturing, inputs of: raw materials, energy, labor and capital are transformed into finished products. In service operations, the same inputs are transformed into service products (Chase, Jacobs, &

Aquilano, 2009). Managing transformation processes efficiently and effectively is the ultimate goal of managing operations.

The above because production cannot only be seen as the action of transforming an input into an output. In other words, the real concept of production management is based on management, transformation, production, manufacturing, and the generation of value, which must be framed within the context of the systems (Ballou, 2004).

A system is a whole that is made up of many parts, in which each part contributes to the purpose of the system, but in which no part alone can achieve that purpose, although each of the parties has its own purpose interdependent form. Therefore, to study and analyze the management of production we must understand how each part fits into the system, but we cannot understand the system by identifying each part; that is, we can understand how the system works, but we cannot know the system without looking at it from the outside to see why it exists (Chase, Jacobs, & Aquilano, 2009). To understand a system we must understand its purpose, its interactions and its interdependencies. Analyzing the production process from a systemic perspective, we can represent it in the following Figure:

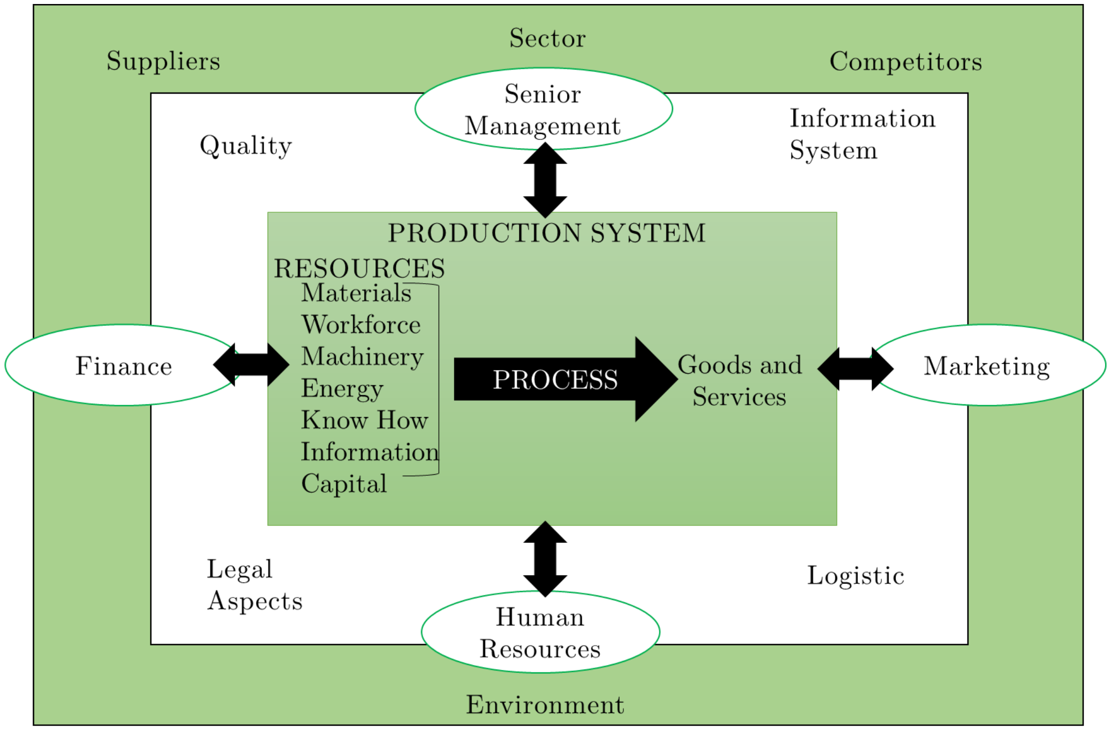


Figure 4. The Production Process.

Taken from: (Andino, 2015)

In production systems, you usually think about the portion that you can see, which the transformation process is. However, most production systems are like icebergs, the visible part is only a small fragment of the system. To study production systems it is necessary to consider many of their components that include products, customers, raw material, transformation process, direct and indirect workers and the formal and informal systems that organize and control the entire process. These components lead to actions and decisions that must be taken into account in order for a production system to operate properly. The analysis of the production systems will be structured around four different components: production flow, construction of system blocks, technology and size.

However, although it is necessary to see the management of production at the system level for understanding it, it is very important to focus on the clearly productive process. The soul of any production system is the manufacturing process, a flow process with several important components but among those that stand out two: materials and information. The physical flow of materials can be seen, but the flow of information is intangible and more difficult to trace. Both types of flow have always existed, but in the past, little importance was given to the flow of information (Gaither & Frazier, 1994).

The flow occurs in a context called process, which consists of any activity or group of activities through which one or several inputs are transformed and acquire added value, thus obtaining a product for a customer. The types of inputs used vary from one industry to another. If the operation is manufacturing, the capital and energy inputs for the machines, installations and tools will be necessary. Labor will also be needed to operate and maintain the equipment as well as the necessary material inputs that will form the basis of the process of converting raw material to finished product (Carro Paz & Gonzales Gomes, 2011).

Each transformation action that leads to changes in inputs is called an operation and the sequence of operations required to complete a given transformation cycle is called a process. That is why we speak of the transformation process. The Figure 5 represents a sequence of activities or a whole process.

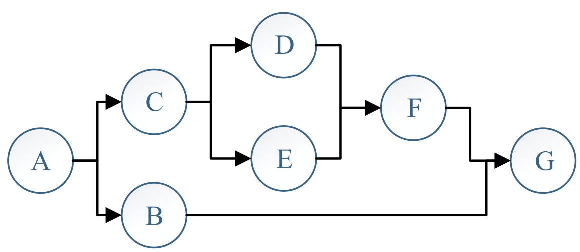


Figure 5. The Process' Activities.

Own construction

As mentioned, the new information technology has given another form to production systems, in such a way that the flow of information is critical (Gaither & Frazier, 1994). In the Figure 6 a generic model of the physical flow in a production system is shown. The material flows from the supplier to the production system to become raw material inventory, and then moves to the plant where the material conversion takes place. The material moves through different transformation processes in the workstations but does not necessarily go through the same route each time. The material in the plant is known as work in process inventory (WIP). When it leaving the plant, the material moves to a place where it becomes an inventory of finished products. From there it flows towards the final client (Groover, 2007).

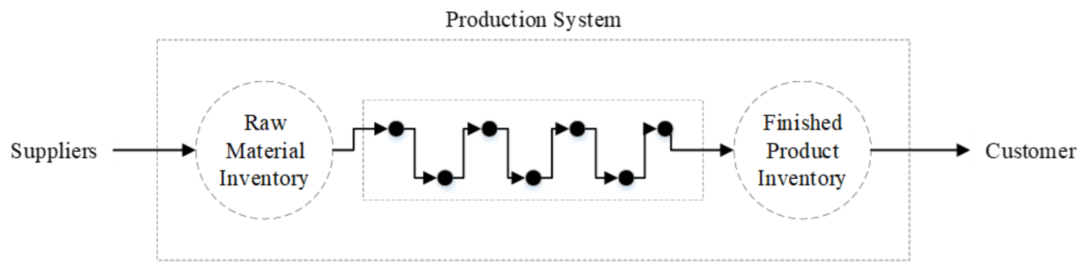


Figure 6. Physical Flow in a Production System

Own construction

The previous figure applies not only to a complete company but also to the work of its different departments, because each of these receives inputs and uses various processes to supply products - often services that can be information - to its own customers. Both the manufacturing and service organizations have clients: final clients -external-, and intermediate clients -internal- in the next office, workshop or department that depends on the inputs that the company produces.

The client approach is basic in operations management (Groover, 2007), regardless of whether the final product consists of services or manufacturing. In operations, the transformation system is in constant interaction with its environment. There are two types of environments that should be considered (Carro Paz & Gonzales Gomes, 2011). First, the other business functions and top management, which are found within the company and outside of operations; and the second, the external environment or environment outside the company that could change in terms of legal, political, social or economic conditions, thus causing the corresponding change in inputs, products or system of transformation of operations.

The production systems in modern society are outstanding. These systems form the basis for building and improving the economic strength and vitality of a country. The task of developing and operating production systems grows in complexity.

Important changes in products, processes, management technologies, concepts and culture, result in increasingly greater challenges and needs. These changes require that the processes are becoming more robust and then they need more articulated information systems in order to feed the system coherently (Carro Paz & Gonzales Gomes, 2011).

In conclusion, the production management is decisive for each type of organization because it can only achieve its goals through the right direction of people, capital, information and materials (Chase, Jacobs, & Aquilano, 2009). At the beginning, it was mainly referring to manufacturing production; however, the growing economic importance of a wide range of non-manufacturing commercial activities expanded the scope of the Operations Directorate as a function and today is part of the direction and control of the processes by which inputs are transformed into goods and services.

2.3.2. Classification of production system

The production process has general concepts applicable to any type of organization, regardless of the production model and the good or service provided. Production systems can be classified according to the type of product, availability of the product, type of flow or circulation of the product within the production system.

2.3.2.1. ***Type of product***

In this case, production systems are divided between those that produce goods or provide services, which is:

- Those that produce tangible goods or Manufacturing.
- Those that produce intangible goods or Services

These differences between service management and manufacturing can be summarized in the following criteria:

Criteria	Product	Service
Inventory	If they want, they can have inventories of products.	There are no inventories of finished product
Capacity needs	According to the demand	According to the service level
Quality control	The product is delivered to the consumer after an exhaustive control	The client will be the inspector. There are controls but the last word has the client
sequence	Optimization sequence	Almost always FIFO sequence
Localization process	Not necessary near of the client	Near of the client
Management model	Organizational model by processes or functions	
Inversions	High capital	Low capital
Workforce	Not necessarily high	High

Table 1. Product vs Service criteria

Own construction

2.3.2.2. ***Product availability***

According to their availability and the rapidity of the customer's demand, the production systems can be classified into MTO, MTS, ATO, and ETO according their specifications and customizations.

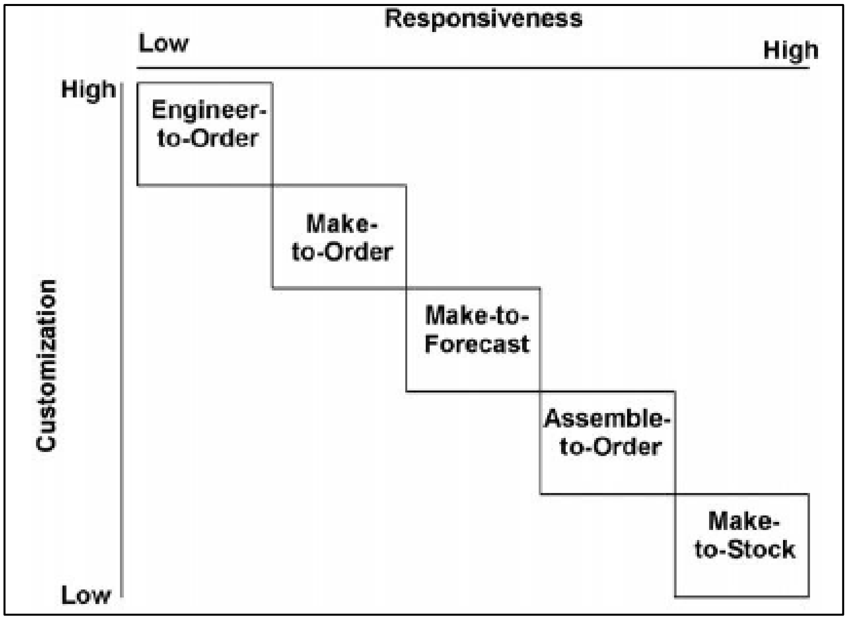


Figure 7. Production Strategies.

Taken from: (Meredith & Akinc, 2007)

2.3.2.2.1. MTO or Make to Stock

In this type of production, the production plans are based on historical information of the demand, together with the sales forecasts. The MTS strategy is appropriate for the manufacture of large volumes of products where demand is seasonal or easily predictable, or both (Chase, Jacobs, & Aquilano, 2009).

There are many examples of production systems that maintain a stock of products to serve their customers such as retail stores, where the product is available on shelves, refineries. So, another characteristic of this type of production is the standardization of the product or, from another point of view, little variety, so that the productive operations are repeated very frequently, that is, they are systems of high efficiency in the use of the resources.

An operations management approach that refers to this type of system is push production. In the planning pushes production the sizes of production orders are based on medium or long-term forecasts, so they are generally large and variable, and generate high inventories, whose cost is compensated by economies of scale of the product. The representation is on the Figure 8

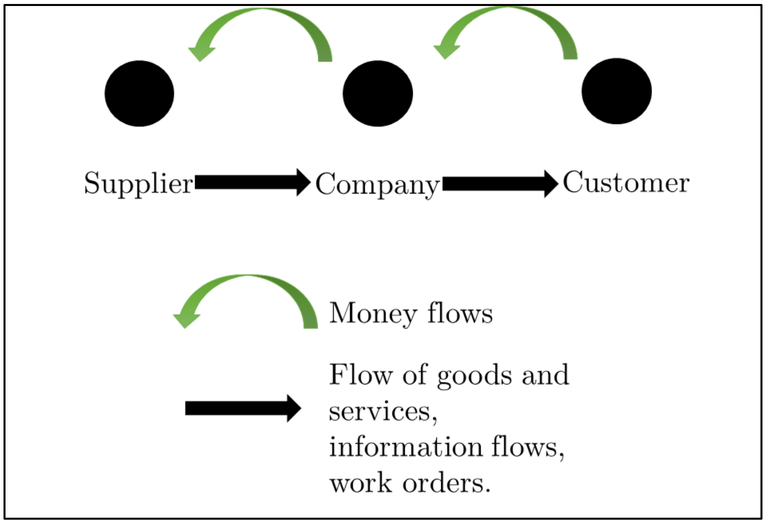


Figure 8. Push System

Own construction.

This approach is convenient when the manufacturing of the product faces significant economies of scale and, in particular, when the demand is seasonal the strategy of maintaining inventories for the peak season is applied, thus avoiding investment in very high production capacities (Muñoz, 2009).

The risk faced by the push approach lies in the occurrence of radical changes in demand patterns, which make the product obsolete in inventory, so this approach only works in case of poorly differentiated goods or when there are supply contracts that ensure the sale of the product (Muñoz, 2009).

Producing in this way requires:

- Forecast the future trend of the market. The product has to be finished before the demand occurs.
- Reduce the unit cost of the product as much as possible. Stock costs must be low.

It should be noted that any forecast is always subject to errors, so one of the problems faced by these systems, on a permanent basis, is the determination of the stock levels suitable for, or shortage the demand, or exceed the costs of the inventories.

Given the above, the main objective of this type of companies that adopt this way of producing is:

- Reduce the cycle of permanence of the product in the process, from its entry into the process, whatever the degree of finishing until its exit.
- Simplify the composition of the product. A simple product takes less time to manufacture.

2.3.2.2.2. MTO or Make To Order

In this production system the operations necessary to manufacture a product are carried out after the reception of the customer's order. In some cases, even the materials and components that make up the product are purchased upon receipt of a particular order. The ability to personalize the product is greater than in ATO. It differs from ATO (Assembly To Order) in that the article is totally or partially produced by the company (not just assembled) (Carro Paz & Gonzales Gomes, 2011).

In exclusive productions or under this design, the client wants a unique product, so it is impossible to maintain a stock of final products, for this reason inventory management is not a problem in this type of production.

This production system is based on the pull production approach, when the demand of the product determines how much to produce, i.e. production under sales orders, in this case the sizes of the production orders are small, low costs are generated by inventories , and a low risk due to obsolescence of the product. The Figure 9 represents the pull approach.

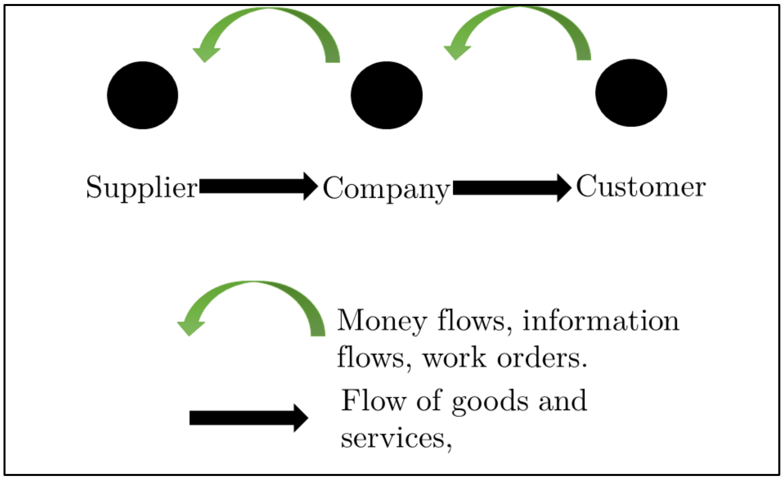


Figure 9. Pull System

Own construction.

This approach is convenient when competing for innovation and flexibility, and its implementation requires quick information from the points of sale, as well as a fast and flexible production system. The disadvantages of this approach are the need to have capacity for periods of peak demand, lower economies of scale and transportation than the traditional push approach (Muñoz, 2009).

The important thing is to shorten the term that the client takes to have the product. Therefore, management must be directed to ensure that all resources are available at the appropriate time when they are needed and thus save time. These systems must base their strategy, therefore, on the punctual fulfillment of the tasks, since the uncertainty will generate more cost and will prolong the time necessary to finish the product (Andino, 2015).

2.3.2.2.3. ATS or Assembly to Order

In the productions by assembly, multiple products are made based on coupled modules, which corresponds to the options offered. The possibility of maintaining a stock with all the combinations of modules as final products is unfeasible, but that leads to having a lot of inventory of components to be able to have production availability (Andino, 2015).

That is to say, instead of final products, a stock of different components must be kept in stock, so that, when the demand arises, we take the modules and add a few raw materials for their assembly and have all the final products desired by the client.

The modules can be manufactured, or acquired in completely or in part, that is, we would be faced with an MTS production system that buys or manufactures modules according to estimates of the final product demand. Therefore, the production by assembly is made up of two parts, an MTS production and an MTO phase (Andino, 2015). These processes produce products that are not very standardized, or with a certain diversity among them, with relatively low unit costs, since multiple products are manufactured, the organization of resources is the most difficult point of these processes, so that it can occur and occur with often, that several resources are requested to operate different products.

2.3.2.2.4. ETO or Engineering To Order

It is defined as the range of standard products offered with the availability of modifications and customizations. The products require engineering and each order of a client results in a single set of elements, materials and routines. (Andino, 2015)

Currently, consumers demand the products instantaneously and do not as waiting times are extended. The reality is that products with a high degree of customization have longer waiting times, becoming the main disadvantage for its rapid distribution. Consumers increasingly want to be more involved in the production process of their products and want to be part of the process, because few companies are dedicated to the ETO world, mainly due to their high complexity, they have a competitive advantage in customer acquisition and loyalty.

Therefore, the management of these systems should be based on avoiding, or resolving the multiple bottlenecks - saturated resources - that will originate in the assembly phase. Precisely, this is where the strategy of management must be emphasized, that is, to use the minimum resources to the maximum without damaging the dates committed to the clients. Since these systems are capable of producing variety with acceptable levels of quantity, it is for this reason that they are subject to improvement and one more detailed analysis.

2.3.2.3. ***Production Process continuity***

2.3.2.3.1. Continuous flow production system

We refer to those processes where the product flow always follows a predetermined sequence of operations, established by the characteristics of the product. Are those in which the manufacturing process is carried out constantly because the raw material flows continuously through the plant to achieve the finished product (Andino, 2015). The scenario of continuous processes occurs mainly when they are going to manufacture substances or materials in which their raw material must be subjected to different instances of thermodynamic, chemical, physical or a combination of them. Substances manufactured through continuous processes cannot be counted, and in some cases are intangible.

These processes adapt well to those cases that are required to produce counter-stock, because the standardization of the product allows to fix the sequence of operations in advance and during the life of the product. The same standardization forces to dedicate a specific machinery, whose cost is therefore high.

The following figure shows in a simple way the way in which the products pass through the N process operations. The implementation of this type of production systems is called product-oriented, since everything in the process is conditioned to the assembly sequence of the product.

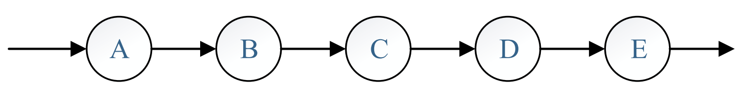


Figure 10. Continuous flow production system

Own construction

Within this type of processes, we can make other classifications:

- Continuous processes: they are those that produce without any pause and without transition between operations. They are processes that treat a single very standardized product. Therefore, its efficiency is very high but its flexibility is very low.

- Processes in series: in these processes, a transition is distinguished between the operations, which are clearly differentiated from one another, and in addition require, in general, different resources for each operation. In general, products are manufactured with a common base, called family, from which modifications are derived, which the options are offered to customers.

2.3.2.3.2. Discreet

They are those in which a sequence of actions in time is involved, and which happen according to a programmed logic. The predominant signals in discrete processes are binary signals (On-Off). On the other hand, discrete processes can accelerate, slow down or stop without major consequences. Its objective is the production of discrete objects or elements that can be counted (Casanovas & Cuatrecasas, 2012).

In discrete industrial processes, manufacturing is carried out sequentially through which different parts and components are assembled until the finished product is obtained. The transformation of matter that is done in these cases is mainly physical (Casanovas & Cuatrecasas, 2012).

These are processes in which the products have to alternate their routes frequently to receive the necessary operation at moment. This means, that the displacements and waiting for the resource to be free are also frequent, so the non-operating times tend to be much longer than in the previous processes. This translates into low efficiency, although on the contrary, and because they are structured, they have greater flexibility.

2.3.3. Evolution of management systems

According to (Andonegi, 2005), systems management have evolved over time. The first computers were manufactured through technological development projects during the Second World War, in order to cover some military needs. These early machines were expensive to be used in the industry, but with time, the technology improved, increasing speed and calculation capacity, thus lowering costs.

In the 1950s, computers began to expand in universities and by the end of this decade, these computers for industrial use, began to work in the business environment. Later, the first attempts to apply this technology to materials management arose. In 1959, Bosch developed an application that may are the first approximation to what was later known as Material Requirements Planning (MRP). Subsequently, the concept of software as a product begins to be commercially viable. The evolution of systems management is show in the Figure 11.

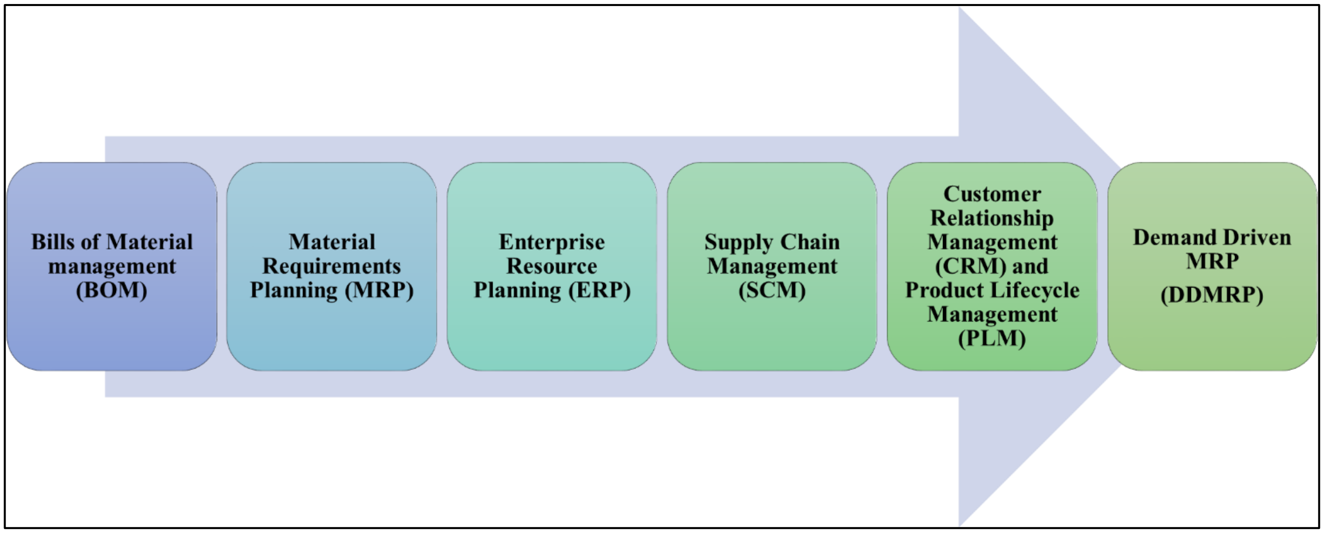


Figure 11. Evolution of systems management.

Own construction

*2.3.3.1. **Bill of materials***

The management practices used in the 60s were based on the traditional models of point of order and economic lot of purchase. In this context, the first systems that deal with the management of dependent demand arise, that is, the management of products whose decomposition implies that the quantity demanded of a component depends on the quantities demanded of all the final products in which it takes part (Delgado & Marin, 2000).

This is how the methodology of BOM (Bill of Materials) came about, which is a list of the quantities of components, ingredients and materials needed to make a product. The individual plans not only describe the physical dimensions, but also any special process, as well as the raw materials that constitute each component part of the product (Andonegi, 2005).

Figure 12 shows the scheme for the realization of a BOM where all the articles that are above a level are called parents, and the articles that are below the level are called components or children.

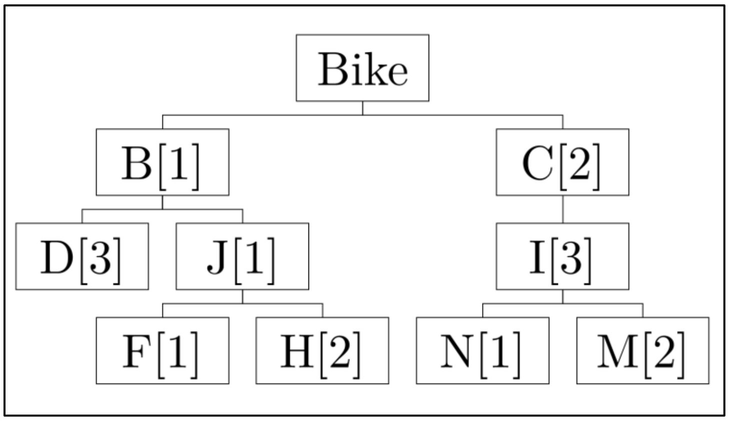


Figure 12. BOM of Materials.

Own construction

2.3.3.2. ***Material Requirements Planning (MRP)***

The MRP (Material Requirements Planning), or material requirements planning, is a system that is based on the planning of the production process and the control of inventories in order to manage the most efficient way possible. The main objective of the MRP is the administration of the production of a company with the objective of having the needs of materials in the exact moment to produce the products (Delgado & Marin, 2000).

The MRP focuses on the time and capacity of company in its production process to determine what is needed. MRP's are necessary for companies with different suppliers that have different characteristics and delivery times. They are responsible for calculating the quantities of materials and when we have to acquire it. All this accompanied by the financial information that it entails so that we value the results of our activity at all times. That is, the MRP system is built around the BOM and its validity depends on its accuracy (Delgado & Marin, 2000).

Joseph A. Orlicky is considered the father of the modern MRP. According to Orlicky's definition, the MRP consists of a series of procedures, decision rules and registers designed to convert the Production Master Program into net needs for each planning period (Delgado & Marin, 2000). The MRP system definition diagram is shown on the next Figure:

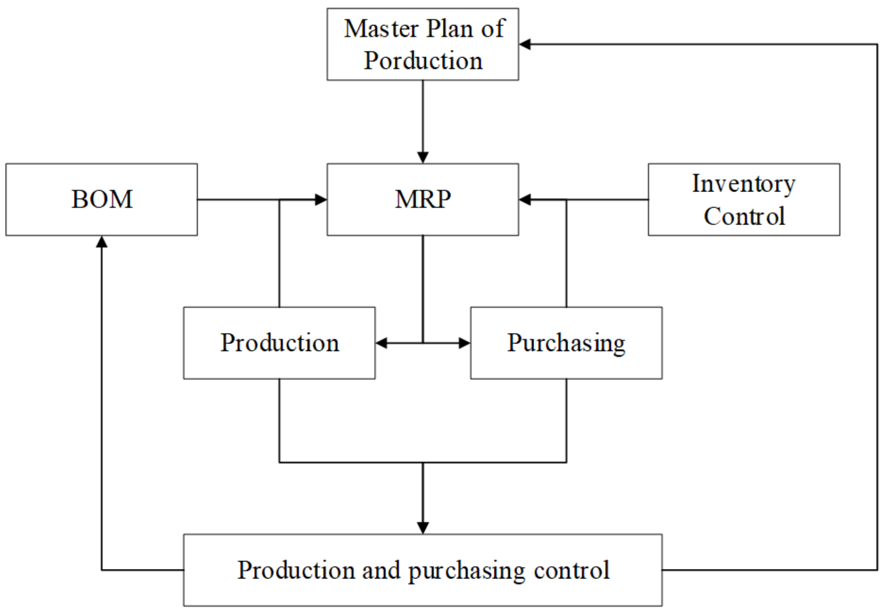


Figure 13. MRP Structure.

Taken from: (Andonegi, 2005)

2.3.3.3. ERP

Over the last two decades, the planning of manufacturing resources has contributed to the development of business management practices beyond the improvements introduced in the planning of materials and production. This contribution is related to two characteristic phenomena of the end of the century such as: the use of computer systems and the adoption of integrated management systems (Andonegi, 2005).

The ERP are business resource planning systems (Enterprise Resource Planning in English) that are responsible for systematizing the operations of different areas of the company, such as production, finance, distribution or human resources, among others. In this way, exhaustive control of all actions is taken and decisions can be made with more information.

That is, ERP applications is process management to the extent that the information system is the platform from which the process is managed and defines how that process should be. To a certain extent, the information system can be the best tool to modify a process and to introduce improvements in it.

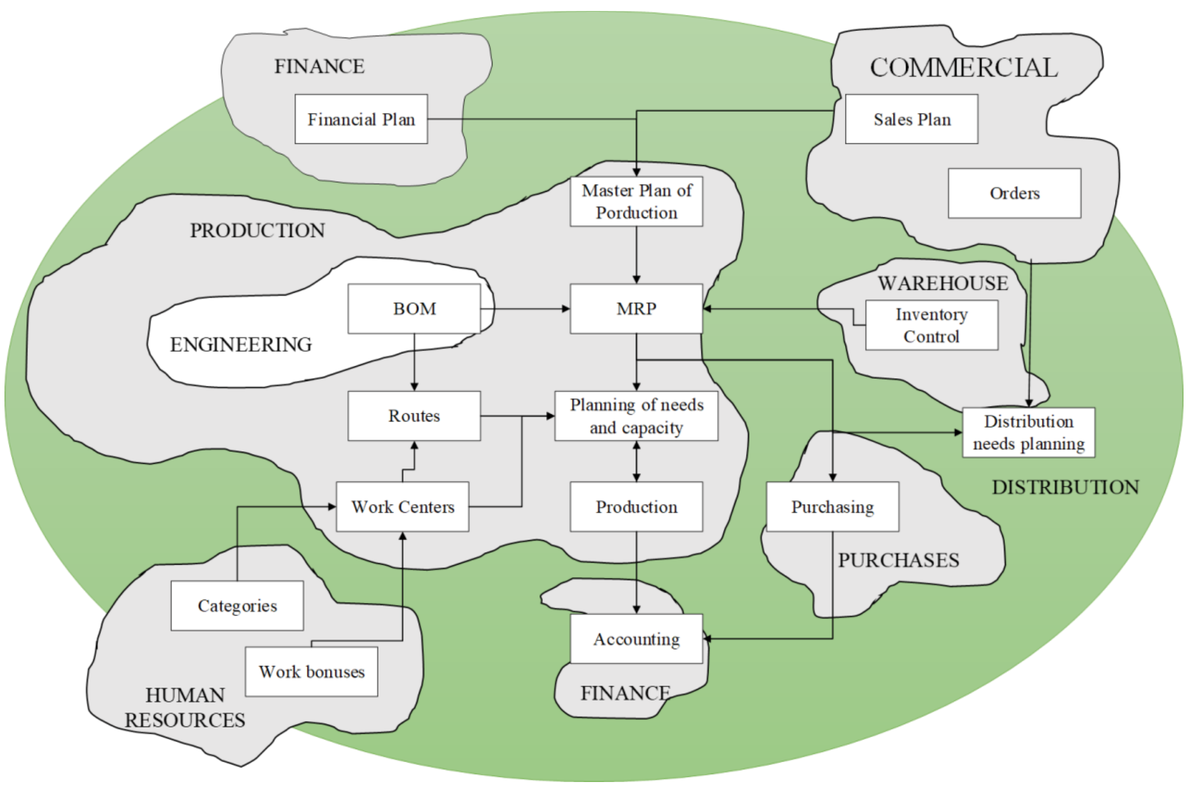


Figure 14. ERP Structure.

Taken from: (Andonegi, 2005)

*2.3.3.4. **Supply Chain Management***

The new model of management system introduced in the last decade is the management system of the supply chain. This, addressed in the preceding section, deals with the connection between ERP systems of different organizations that today is a fundamental element. There is the exchange of information and content by all the agents involved in a logistics channel, from raw materials to finished products.

2.4. DDMRP

As cited by (Ptak & Smith, 2016) the Demand Driven Material Requirement Planning (DDMRP) is the ability to "sense changing customer demand and adapt planning and production while pulling from suppliers all in real time."

At the same time, (Ptak & Smith, 2016) defined the Demand Driven Material Requirements Planning as a "formal multi-echelon planning and execution method to protect and promote the flow of relevant information and materials through the establishment and management of strategically placed decoupling point stock buffers".

The DDMRP is a methodology based on other conventional methods. The next Figure shows "the methodological foundation for DDMRP".

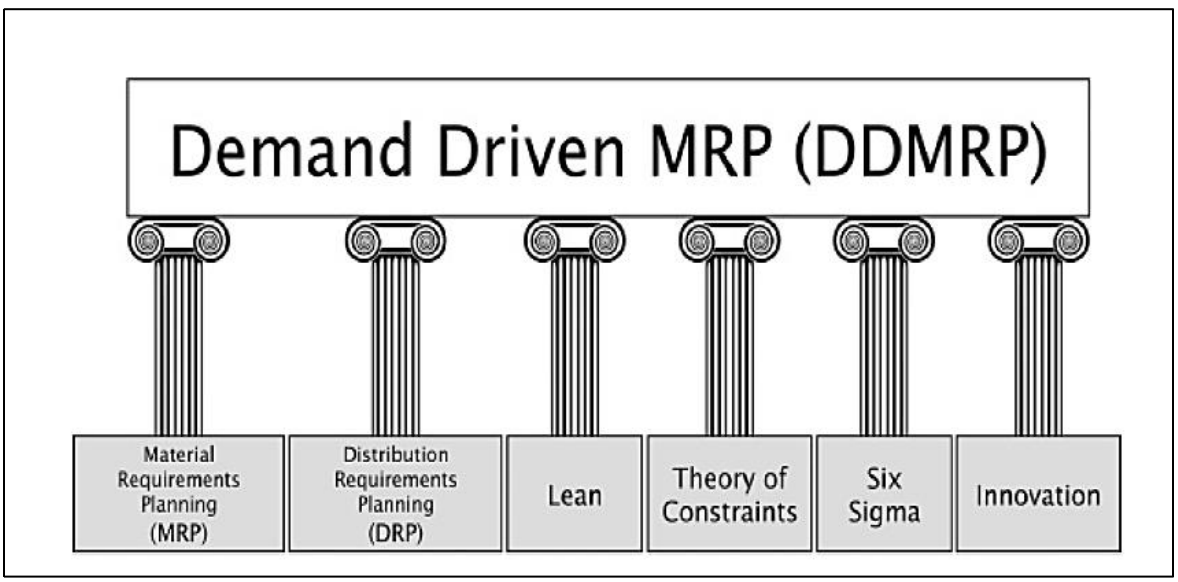


Figure 15. Methodological foundation for DDMRP.

Taken from: (Ptak & Smith, 2016)

As cited by (Ptak & Smith, 2016), the DDMRP methodology combines some of the still relevant aspects of MRP and DRP with the pull and visibility emphases found in Lean, Theory of Constraints, and the variability reduction emphasis of Six Sigma. The final component of this fusion requires a few key innovations that are unique to DDMRP.

2.4.1. Methodological foundation for DDMRP

- ***Material Requirements Planning:***

  As cited by (Román, 2017), the DDMRP will change with respect to the traditional MRP, especially in how much and when companies will need the material. Now with the DDMRP, the material requirements will vary according to the demand. In the traditional MRP, companies based their material planning on what had happened in the past and from there, they planned the future. Now with the DDMRP, organizations base the planning on the demand variation day by day, and they will plan the requirements of materials according to how their need for materials changes every day. Their orders and demand for material will vary according to what they need and for this, the DDMRP implemented a new concept for traditional MRPs such as buffers.

- ***Distribution Requirements Planning:***

  According to (Mendez & Pinzón) the DRP is an administrative process that determines the inventory needs in the different localities (the different points of the distribution logistics chain) and ensures that the sources of supply are able to meet the demand. It allows coordinating the replenishment of the stocks of the distribution centers.

  On the other hand, (Román, 2017) explained that the DRP determine what, how much, when to dispatch to the sales points and ask the manufacturing plant. In addition, the DRP integrates the information of inventories and activities of the supply chain and the system of planning and control of operations.

The DDMRP is based on the principles of the DRP and will add the necessary buffer to improve this system and thus be able to satisfy the requirements when necessary taking into account the present variability. This is intended to improve delivery times or orders receipt and avoid wasting time and material. (Román, 2017)

- ***Lean:***

According to (Ptak & Smith, 2016), "*the Lean approach establishes Kanban positions, which are independent inventory positions typically placed at each resource position. The Kanbans are sized according to a required takt time rate. This rate can be established through a forecast or past consumption. The Kanbans are connected with "loops" that provide easy-to-interpret signals for each position to produce or not produce*".

As mentioned by (Román, 2017), Kanban systems consist of a set of ways to communicate and exchange information between the different operators of a production line, of a company, or between supplier and customer. Its purpose is to simplify communication, streamlining it and avoiding errors caused by lack of information.

(Román, 2017) Says that Kanban system in the DDMRP can will be introduced in the necessary places inside the Bill of Materials or production chain. In this case, the Kanban could be placed in the BOM as a buffer, which at the time the company needs material, this system send information to suppliers to provide the components at the right time.

- ***Theory of Constraints:***

As cited by (Ortíz, 2013), the Theory of Constraints (TOC) is a tool that was first described by the physicist Eliyahu Goldratt because of the combination of systemic thinking techniques, queuing theory and simulation, through which have generated substantial improvements in the management of restrictive resources (bottlenecks) of business organizations.

TOC assumes three indicators called "exploitation parameters" which are throughput (speed at which a productive system generates money), inventory (money that the organization has invested in all the things it intends to sell) and operating expenses (money that invests the organization in transforming the inventory into net income) (Ortíz, 2013)

Theory of Constraints follows a methodology composed of a series of phases: first, it is necessary to identify the system's restrictions; then, it is necessary to exploit these restrictions, which implies looking for the best way to obtain the greatest possible production of the restriction. As a next step, it is required that everything be subordinated to the previous restriction, which implies that the whole scheme must work at the rhythm that marks the restriction. As a fourth step, the restrictions of the system must be raised, which shows a permanent improvement in the level of activity of the organization. Finally, if a restriction is removed in the previous stages, it must return to the first step. (Ortíz, 2013)

According to (Gupta & Snyder, 2009) TOC is based to these five-focusing steps (FFS) for continuous improvement mentioned previously, but also is based to a technique: “drum-buffer-rope” (DBR) for production planning, and ‘buffer management’ for production control

The Drum-buffer-rope is the generalized technique used to manage resources with the purpose of maximize throughput. The drum is the rate or pace of production set by the system’s constraint. The buffers establish the protection against uncertainty so that the system can maximize throughput. The rope is a communication process from the constraint to the gating operation that checks or limits material released into the system to support the constraint. (Gupta & Snyder, 2009)

In the other hand, the Buffer management is a process in which all expediting in a shop is driven by what is scheduled to be in the buffers (constraint, shipping, and assembly buffers). By expediting this material into the buffers, the system helps avoid idleness at the constraint and missed customer due dates. In addition, the causes of items missing from the buffer are identified, and the frequency of occurrences is used to prioritize improvement activities. (Gupta & Snyder, 2009)

- ***Six Sigma:***

  According to (Arias, Portilla, & Castaño, 2008), Six Sigma is a work philosophy and a business strategy, which is based on the approach to the client, in an efficient management of data, methodologies and robust designs, which allows to eliminate the variability in the processes and reach a level of defects less than or equal to 3 or 4 defects per million. The Six Sigma philosophy recognizes that there is a direct correlation between the number of defects, the waste costs and the level of customer satisfaction. The Six Sigma statistically measures the ability of the process to operate free of defects or failures.

  The Six Sigma will influence the DDMRP when controlling the variability of the process. Through this method of continuous improvement, we will try to reduce the variability of the processes for the better functioning of the DDMRP. (Román, 2017)

As cited by (Ptak & Smith, 2016), the Demand Driven Material Requirement Planning has five sequential components. The next Figure show these components, their sequence, and how they relate with these concepts: “position, protect, and pull.”

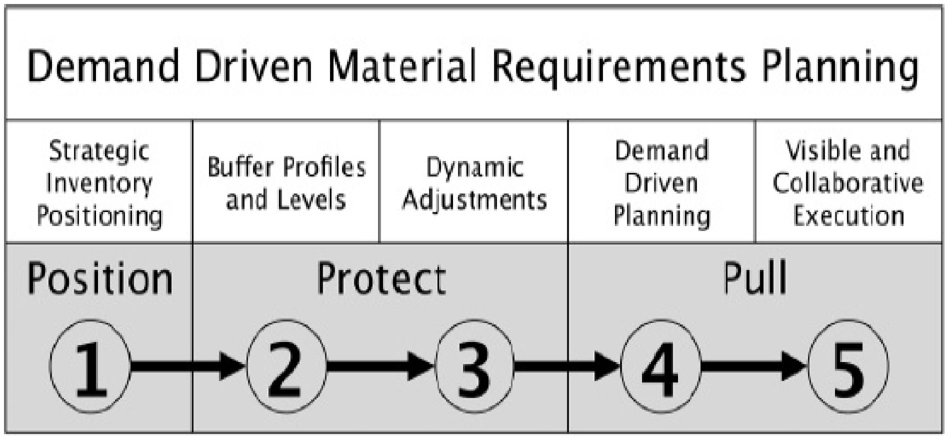


Figure 16. The five components of DDMRP

Taken from: (Ptak & Smith, 2016)

According to the authors (Ptak & Smith, 2016), the first three components essentially define the initial and evolving configuration of a Demand Driven Material Requirements Planning Model. Strategic inventory positioning will determine where the decoupling points are placed. Buffer profiles and levels will determine the amount of protection at those decoupling points. Dynamic adjustments define how that level of protection flexes up or down based on operating parameters, market changes, and planned or known future events.

The fourth and fifth elements define the actual operational aspects of a DDMRP system: planning and execution. In DDMRP, demand driven planning is the process by which supply orders (purchase orders, manufacturing orders, and stock transfer orders) are generated. Visible and collaborative execution is the process by which a DDMRP system manages open supply orders.

2.4.2. Components of DDMRP

*2.4.2.1. **Strategic inventory positioning***

(Ptak & Smith, 2016) Say that the key to protecting and promoting the flow of relevant information requires the use of decoupling points. Decoupling enables a bidirectional benefit—it mitigates the demand signal distortion (relevant information) and supply continuity variability (relevant materials) inherent in the bullwhip effect.

That is why a supply chain or organization must consider a series of factors that allow placed the right decoupling points to maximize the firm effectiveness.

Positioning factors

As cited by (Ptak & Smith, 2016), the selection of these points is a strategic decision that affects the performance of the supply-demand network in many regards: service, working capital, expedite-related expenses, cash flow, and ultimately return on investment. The positioning factors are:

- **Customer Tolerance Time:** This is the time the typical customer is willing to wait before seeking an alternative source. Customer tolerance time also can be referred to as demand Lead Time. (Ptak & Smith, 2016)

- **Market Potential Lead Time:** This Lead Time will allow an increase of price or the capture of additional business through either existing or new customer channels. Be aware that there could be different stratifications of market potential Lead Time. Properly segmenting the market will maximize the possible revenue potential for the company and provide excellent revenue growth control. (Ptak & Smith, 2016)

- **Sales Order Visibility Horizon:** The sales order visibility horizon is the period in which companies typically become aware of sales orders or actual dependent demand. Often the sales order visibility either matches or exceeds customer tolerance time. The longer the visibility to sales orders, the better the capability of the environment to see potential spikes and derive relevant demand signal information. In many cases, relevant requirements are obscured from planners because all demand (including planned orders based on forecast and safety stock requirements) is aggregated together for aggregate planning purposes. (Ptak & Smith, 2016)

- **External variability:** External variability considers both demand and supply variability.

  Variable Rate of Demand
  This refers to the potential for swings and spikes in demand that could overwhelm resources (capacity, stock, cash, etc.). This variability can be

calculated by a diversity of equations or determined heuristically by experienced planning personnel. If the data required for mathematical calculation do not exist, companies can also use these criteria (Ptak & Smith, 2016):

- ✓ High-demand variability: Products and parts that are subject to frequent spikes within the customer tolerance time.
- ✓ Medium-demand variability: Products and parts that are subject to occasional spikes within the customer tolerance time.
- ✓ Low-demand variability. Products and parts that have little to no spike activity. The demand is stable within the customer tolerance time.

Variable Rate of Supply

This is the potential for and severity of disruptions in sources of supply or specific suppliers. This can also be referred to as supply continuity variability. It can be calculated by examining the variance of promise dates versus actual receipt dates. If the data required for mathematical calculation do not exist, the following heuristics can be used (Ptak & Smith, 2016):

- ✓ High supply variability: Frequent supply disruptions
- ✓ Medium supply variability: Occasional supply disruptions
- ✓ Low supply variability: Reliable supply

- **Inventory Leverage and Flexibility:** According to (Ptak & Smith, 2016), there are places in the integrated bill of material (BOM) structure (matrix bill of material) or the distribution network that provide a company with the most available options as well as the best lead time compression to meet the business needs. Within manufacturing, these places are typically represented by key purchased materials, subassemblies, and intermediate components. This becomes more critical in environments with BOMs that are deeper and more complex (broader) and have more shared components and materials.

- **Critical Operation Protection:** As cited by (Ptak & Smith, 2016), similar to how variability can impact a bill of material, the longer and more complex the routing structure and dependent chain of events (including interplant transfers), the more important it can be to protect identified key areas. These types of operations include areas where there is limited capacity, or where quality can be compromised by disruptions, or where variability tends to be accumulated or amplified.

There are some concepts that are important to consider them for this phase of the methodology implementation:

Manufacturing Lead Time (MLT): As describe by (Ptak & Smith, 2016), MLT is the total time required to manufacture an item, exclusive of lower level purchasing Lead Time. For make to order products, it is the length of time between the release of an order to the production process and shipment to the final customer. For make to stock products, it is the length of time between the release of an order to the production process and receipt into inventory.

Cumulative Lead Time (CLT): According to (Ptak & Smith, 2016), CLT is the longest planned length of time to accomplish the activity in question. It is found by reviewing the Lead Time for each bill of material path below the item; whichever path adds up to the greatest number defines cumulative Lead Time.

Purchasing Lead Time (PLT): As cited by (Ptak & Smith, 2016), PLT is the total Lead Time required to obtain a purchased item.

Routing structure: As it is shown by (Ptak & Smith, 2016), a "routing," is information detailing the method of manufacture of a particular item. It includes the operations to be performed, their sequence, the various work centers involved, and the standards for setup and run.

Decoupling points: Cited by (Ptak & Smith, 2016), these points are the locations in the product structure or distribution network where strategic inventory is placed to create independence between processes or entities.

Decoupled Lead Time (DLT): According to (Ptak & Smith, 2016), DLT is a new form of Lead Time. This is the longest cumulative coupled Lead Time chain in a manufactured item's product structure. It is a form of cumulative Lead Time but is limited and defined by the placement of decoupling points within a product structure.

DLT is calculated by summing all the manufacturing and purchasing Lead Times in that chain. *The decoupled Lead Time always includes the manufacturing Lead Time of the parent.*

Matrix Bill of Material: As cited by (Ptak & Smith, 2016), this matrix is a chart made up from the bills of material for a number of products in the same or similar families. It is arranged in a matrix with components in columns and parents in rows (or vice versa) so that requirements for common components can be summarized conveniently.

2.4.2.2. ***Buffer profiles and levels***

According to (Ptak & Smith, 2016), the protection at the decoupling point is called a buffer. Buffers are the heart of a DDMRP. This methodology employs three types of stock buffering methods at decoupling points. The type of method used is based on whether a part is classified "replenished," "replenished override," or "min-max."

- **Replenished parts:** Replenished parts use strategic and dynamic decoupling point buffers. These parts are managed by a dynamic three-zone color-coded buffer system for planning and execution. The buffer levels are calculated by a combination of globally managed traits relative to the buffer profile into which the part falls and a few critical individual part attributes. These factors are adjusted within defined intervals. (Ptak & Smith, 2016)

- **Replenished override parts:** Replenished override parts are strategic and static decoupling point buffers. These parts are managed by a static three-zone color-coded buffer system for planning and execution (as opposed to calculated and dynamic for the replenished parts). Parts are assigned to this category when there are defined limitations (space, process related, and/or cash) or dictated levels of inventory (customer agreements, policy restrictions, etc.) within the planning environment. Without the dynamic nature of the buffer, the color-coding system becomes that much more important for planners to prioritize planning- and execution-related activity. (Ptak & Smith, 2016)

- **Min-max parts (MM):** The min-max designation is for nonstrategic and readily available stocked parts and stock-keeping units (SKUs). There is still a role for traditionally defined MM tactics in DDMRP. Min-max buffers in DDMRP are managed by a simpler two-zone color-coded system that can be dynamically altered or adjusted in the same way as replenished parts. (Ptak & Smith, 2016)

Cited by (Ptak & Smith, 2016), all parts' buffer levels are determined by summing the zones that comprise them. Zones are stratifications or layers in the buffer that serve specific purposes and have unique calculations. The next Figure show the buffer zones:

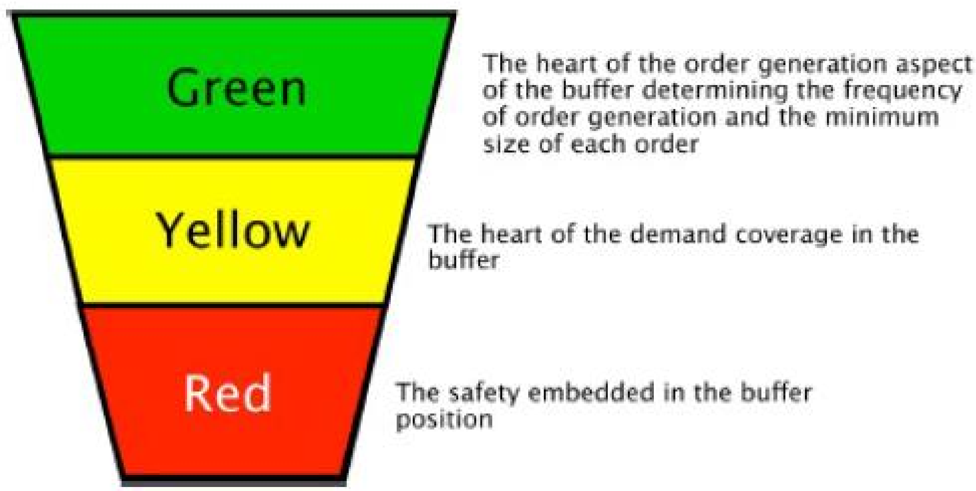


Figure 17. Buffer zones

Taken from: (Ptak & Smith, 2016)

There are some important parameters for obtain the final buffers. These are:

2.4.2.2.1. Buffers profiles

As defined by (Ptak & Smith, 2016), a buffer profile is a grouping of parts that have similar characteristics. Buffer profiles allow for the practical and effective global management of massive quantities of strategically decoupled parts. Buffer profiles are families or groups of parts for which it makes sense to devise a set of rules, guidelines, and procedures that can be applied the same way to all members of a given buffer profile.

According to (Ptak & Smith, 2016), these families should not be confused with the traditional notion of product or marketing families, which tend to be components or end items grouped by like characteristics in terms of physical configuration or markets. With buffer profiles, the familial connection is made based on three specific factors.

Factor 1: Item Type

(Ptak & Smith, 2016) Says that item type becomes the primary designator for globally managing families of parts. The groupings will be made by determining whether an item is manufactured (M), purchased (P), or distributed (D).

The three item types (manufactured, purchased, and distributed) are typically the minimum number of item type designations a large supply chain entity should have. There can be others if applying the above criteria leads us to the creation of more. For example, in some environments, a distinction can be made between end item manufactured items and intermediate manufactured items with regard to the above criteria. This may call for a different classification called intermediate (I). (Ptak & Smith, 2016).

Factor 2: Lead Time

According to (Ptak & Smith, 2016), Lead Time is segmented into at least three categories: short, medium, and long. These designations are relative to the company's specific environment and part type. Typically, there is a large distribution spread in the size of lead times associated with purchased parts. There are differing circumstances that dictate what the parameters defining short, medium, and long within any particular environment will be.

Cited by (Ptak & Smith, 2016), the Lead Time category will then be used to supply a "lead time factor" to parts within a profile. The Lead Time factor is a percentage of ADU within the decoupled Lead Time of the part. This Lead Time factor will affect green and red zone calculations for every strategic part within a certain profile.

The following Table show recommended Lead Time factor ranges assigned to the different Lead Time categories (Ptak & Smith, 2016)

Long Lead Time	20 to 40% Average Daily Usage (ADU) x Decoupled Lead Time (DLT)
Medium Lead Time	41 to 60% ADU x DLT
Short Lead Time	61 to 100% ADU x DLT

Table 2. Lead Time factor ranges

Taken from: (Ptak & Smith, 2016)

According to (Ptak & Smith, 2016), the longer the Lead Time of the part, the smaller the Lead Time factor should be. A smaller Lead Time factor produces a smaller green zone calculation. Since the green zone determines average order size and frequency, a smaller Lead Time factor will lead to smaller and more frequent orders. DDMRP is about creating and protecting the flow of information and materials. For long Lead Time parts, the methodology is attempting to create a frequent demand signal relating to actual requirements and a corresponding supplying “pipeline” delivering a steady stream of supply orders.

Factor 3: Variability.

As defined by (Ptak & Smith, 2016), variability assignment is the next level of assignment. At a minimum, variability can be divided into three segments—high, medium, and low—with the two dimensions of demand and supply variability.

The next Figure illustrates how buffers at different stages within a manufacturing process can experience different levels and types of variability depending on their relationships with each other. (Ptak & Smith, 2016)

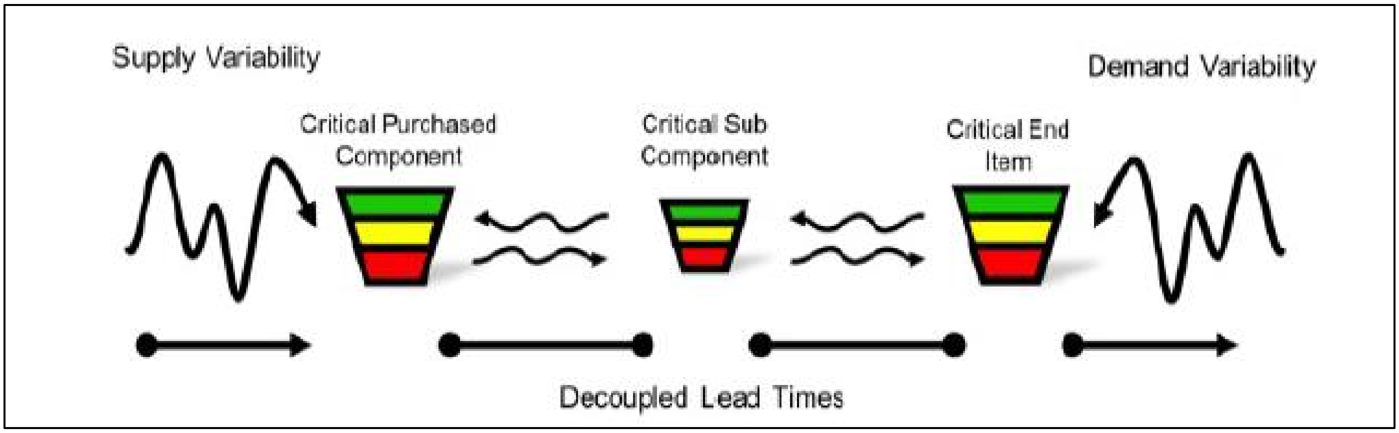


Figure 18. Levels and types of variability

Taken from: (Ptak & Smith, 2016)

The variability category will then be used to supply a "variability factor" to parts within a profile. The next Table shows the variability factor ranges within each category.

High Variability	61 to 100%+ Of Safety Base
Medium Variability	41 to 60% Of Safety Base
Low Variability	0 to 40% Of Safety Base

Table 3. Variability factor ranges

Taken from: (Ptak & Smith, 2016)

As cited by (Ptak & Smith, 2016), based on these three factors (part type, Lead Time category, and variability category), there are 36 basic buffer profiles. Depending on the manufacturing environment, there could be even more derivations and permutations than this. The following Figure shows the basic buffer profiles:

Lead Time Category		Part Type: Purchased	Manufactured	Distributed	Intermediate	Variability Category
	Short	PSL	MSL	DSL	ISL	Low
		PSM	MSM	DSM	ISM	Medium
		PSH	MSH	DSH	ISH	High
	Medium	PML	MML	DML	IML	Low
		PMM	MMM	DMM	IMM	Medium
		PMH	MMH	DMH	IMH	High
	Long	PLL	MLL	DLL	ILL	Low
		PLM	MLM	DLM	ILM	Medium
		PLH	MLH	DLH	ILH	High

Figure 19. Basic buffer profiles.

Taken from: (Ptak & Smith, 2016)

2.4.2.2.2. Individual Parts Attributes

According to (Ptak & Smith, 2016), the individual part attributes are properties or numerical values that are specific to the part itself. Many of these properties or values will be calculated from the current part master information. In DDMRP, there are three specific part attributes that will determine buffer levels for purchased, intermediate, and manufactured buffered items: Average Daily Usage, Lead Time and Minimum Order Quantity.

Average Daily Usage (ADU):

Average daily usage is a calculated rate of use for each specific part. It is a cornerstone of the buffer equations. Significant changes to the part's ADU will often yield significant impacts to the calculated buffer zones. (Ptak & Smith, 2016)

Lead Time:

Another critical individual part input into the buffer equation is the part's unique Lead Time as measured in discrete units of time (most often in days). For any manufactured or intermediate item, this Lead Time should be the decoupled Lead

Time of the part. For purchased parts, the purchasing Lead Time from the part master should be used. (Ptak & Smith, 2016)

Minimum Order Quantity (MOQ):

As cited by (Ptak & Smith, 2016), ordering policies (minimums, maximums, and multiples) complicate planning and supply scenarios but are a fact for planners. Many of these ordering policies are based on valid data and sound assumptions; many are not. It is a given that there will be parts and SKUs that do require minimum order quantities. Minimum order quantities (MOQs) can affect buffer levels, especially when they are large in relation to the rate of use. These are called “significant” MOQs and will have a direct impact on the sizing of the buffer through the green zone.

2.4.2.2.3. Calculating Buffer Levels and Zones

According to (Ptak & Smith, 2016), buffers are composed of three color-coded zones: green, yellow, and red. Each zone has a specific purpose and will vary in size and proportion depending on the combination of the buffer profile and the individual part.

The Green Zone:

As discussed by (Ptak & Smith, 2016), the green zone is the heart of the supply order generation process embedded in the buffer and will determine the average order frequency and typical order size for the part. One of three factors determines the green zone. Whichever factor yields the greatest number determines the size of the green zone.

- ✓ **Option 1: An Imposed or Desired Minimum Order Cycle**

An order cycle is simply the number of expected days between orders. It can be an imposed factor using a product-scheduling wheel or be a desired average number of days between orders. The equation for calculating the green zone based on order cycle is simply ADU $\times$ desired or imposed order cycle days. (Ptak & Smith, 2016)

✓ **Option 2: Using a Lead Time Factor**

A green zone can be calculated using the Lead Time factor. This Lead Time factor is expressed as a percentage of usage within a full Lead Time of the part. The formula for producing the green zone value using this technique is decoupled Lead Time × ADU × Lead Time factor. (Ptak & Smith, 2016)

✓ **Option 3: Minimum Order Quantity**

If the green zone is about supply order generation and frequency and the part has a minimum order quantity, then the minimum order quantity can be relevant in determining the green zone. In short, the green zone should never be less than the minimum order quantity. If the minimum order quantity yields the largest value as a green zone, then that minimum order quantity is deemed significant. The minimum order quantity must be compared against the desired order cycle quantity value and the value created by using the Lead Time factor. (Ptak & Smith, 2016)

The Yellow Zone:

According to (Ptak & Smith, 2016), the yellow zone is the heart of the inventory coverage in the buffer. It is the easiest and most straightforward zone to calculate in a buffer. The yellow zone is always calculated as ADU multiplied by the decoupled Lead Time.

The Red Zone:

As cited by (Ptak & Smith, 2016), the red zone is the embedded safety in the buffer. The higher the variability associated with the part or SKU, the larger the red zone will be. Calculating the red zone requires three sequential equations:

1. Establish the "red base": The red base is established by multiplying the Lead Time factor by the Average Daily Usage by the Lead Time. The Lead Time factor corresponds to the same ranges used for the green zone calculation but can have a different numerical value. (Ptak & Smith, 2016)

2. Establish the "red safety": The red safety is calculated as a percentage of the red base. The percentage used is determined by the variability factor. Like the Lead

Time factor, there are ranges of variability factors depending on whether a part experiences high, medium or low variability. (Ptak & Smith, 2016)

3. **Calculate the total red zone by adding the red base to the red safety.** (Ptak & Smith, 2016)

CHAPTER 3: DAYCO EXPLANATION

3.1. The automotive Industry

The automotive industry represents a significant portion of the global economic activity with extensive upstream and downstream linkages to many diverse industries and sectors (Karmokolias, 1990). For this reason, many developing countries that aim to develop rapidly through industrialization have regarded the automotive industry as the best way to achieve this objective.

The automotive industry has had a very rapid change in the recent years. The methods of production and management have revolutionized the sector by computer-aided design, automation, flexibility of assembly lines and the large supply of companies that are part of the auto parts sector, who have assumed greater responsibility for the design and production of component systems, while striving to improve quality standards and reduce costs (Karmokolias, 1990).

In this sense, analyzing the automotive sector of recent years, it can be found that the world production of automobiles in 2017 amounted to 97 million units (cars and light vehicles), according to data from the International Organization of Automobile Manufacturers (OICA, for its acronym in French), with respect to the 95 million units sold in 2016. The following Figure shows the sales since 2001 and the possible growth trend forecast for the next years.

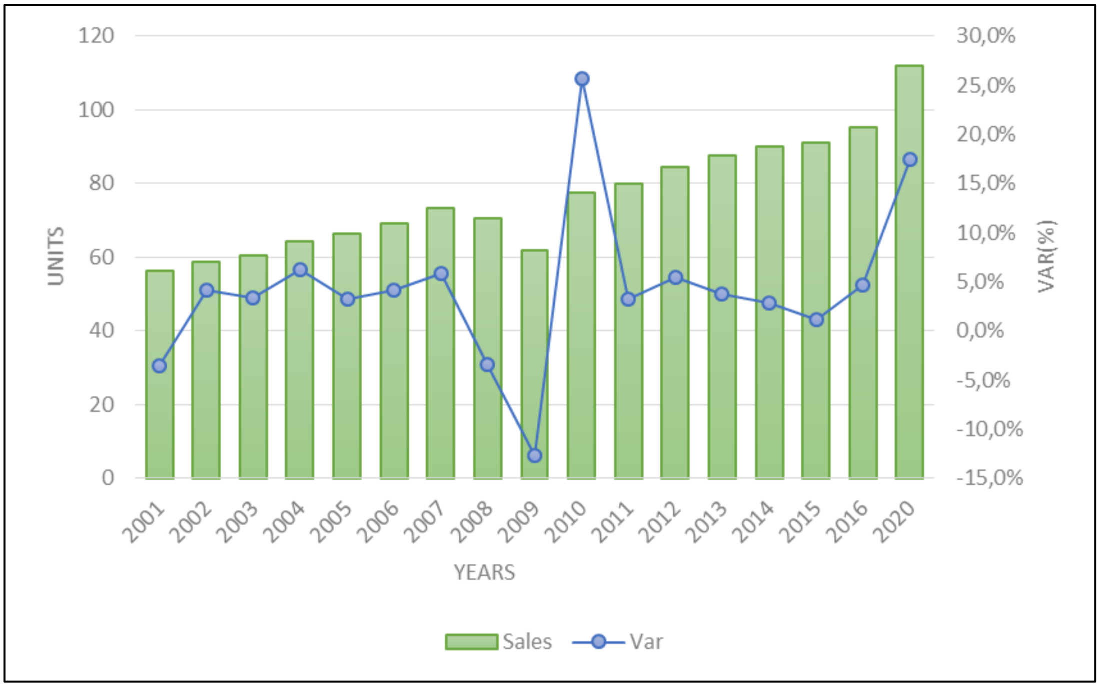


Figure 20. Automotive Industry Sales

Own construction

Analyzing the automotive market in the world, it can be seen that the undisputed leader continues to be China with 30 million units sold approximately, with a share close to 30%, and a positive growth of 3.9%. Under China, the USA is positioned with a value close to 12 million units, 13% of global market share, of vehicles sold in 2017 exceeded by more than 50% by China. Under the USA, Japan and Germany are positioned respectively. In fact, the ranking in general doesn't change much during the last years, where undoubtedly the big producer of cars is Chinese. Italy, on the other hand, in 2017, sold approximately 1.200 units of vehicles located below Russia, last in the graph shown below.

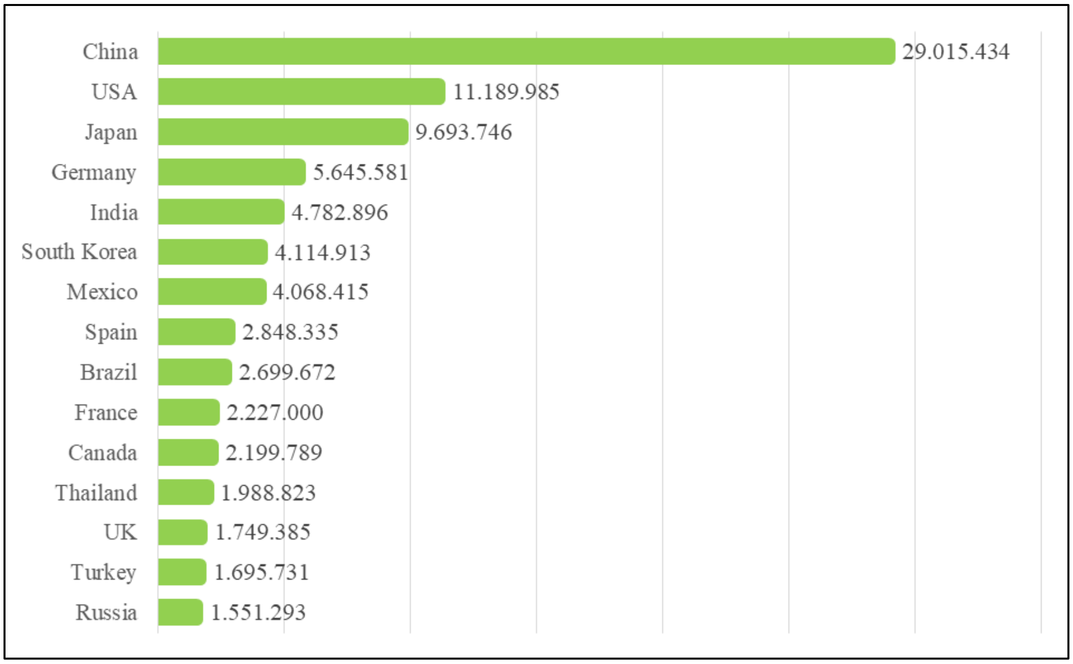


Figure 21. Production of vehicles

*Own construction. *Millions of Units*

In terms of blocks, the recomposition highlights the advance of the Asia-Oceania region, with a production of 46 million units in 2016 (50.7% of the total) that places it as the predominant region worldwide. For its part, America ranks second thanks to the production of countries such as the US, Mexico and Brazil.

Global vehicle sales		
Region	**2015**	**2016**
Global	89.684.608	93.856.388
Russia, Turkey & Europe	10.035.989	20.134.829
America	25.688.159	25.549.212
Asia, Oceania and Middle East	43.410.904	46.857.884
Africa	1.549.556	1.314.463

Figure 22. Global Vehicle Sales

Own construction

Regarding imports, the USA is the largest buyer, with a total value of 284.8 billion dollars; followed by Germany and the United Kingdom. Italy for its part is ranked eighth in total imports for 2016. In exports, Germany is the country that exports the most vehicles in the world, followed by Japan and the United States.

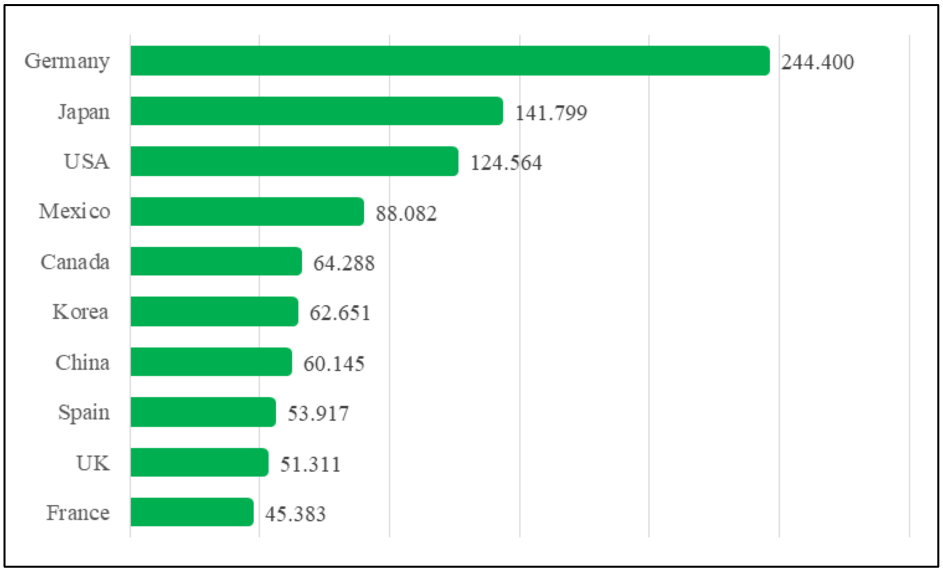


Figure 23. Major automobile exporters

Own construction. *Millions of dollars*

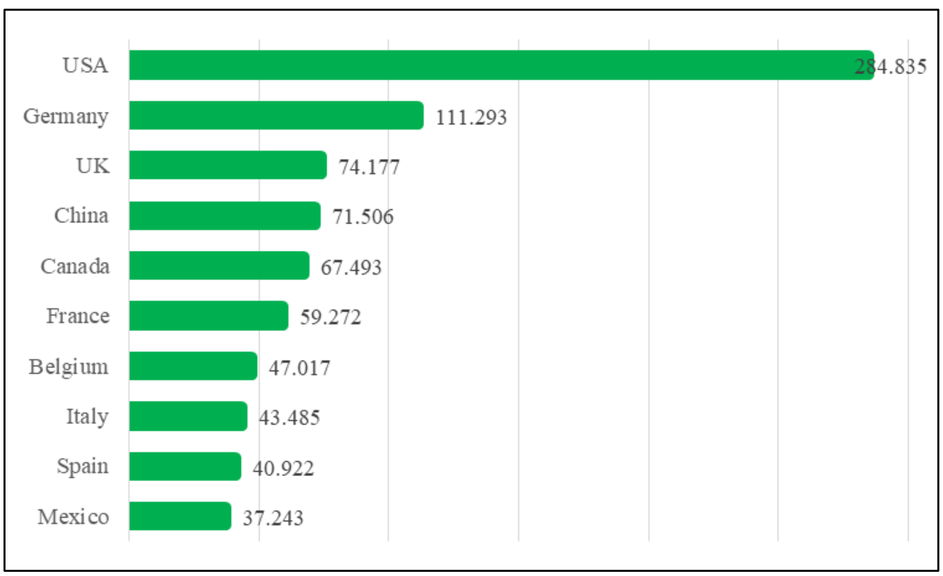


Figure 24. Major automobile importers

Own construction. *Millions of dollars*

Analyzing according to data provided by Focus2Move, a company specialized in the collection of data from the automotive industry worldwide, it can be identified that the car brand sold in the world during 2017 was Toyota. In the year 2017 Toyota imposed a sales record to overcome 8.7 million vehicles, this is 2.4 percentage more compared to 2016. Although, the Japanese brand has a wide gap with respect to the second place, Volkswagen shortened it because it delivered 6.8 million vehicles; this is 4.7 percentage more than in 2016.

Ford for its part in 2017 sold 6.1 million vehicles that meant a decrease of 1.2 percentage respect the last year. Where there were changes of position was in the fourth and fifth place, although the difference is 20.000 units, Honda could climb a step leaving Nissan down. Those who did not have a good year were Hyundai and Kia, who recorded the strongest declines within the Top 10. The following table shows the most sold brands during 2017 worldwide in the automotive industry.

Rank	Brand	Sales 2017	Var (%)
1	Toyota	8,713,629	2.4%
2	Volkswagen	6,832,840	4.7%
3	Ford	6,165,704	-1.2%
4	Honda	5,162,598	8.2%
5	Nissan	5,142,398	4.4%
6	Hyundai	4,400,042	-9.0%
7	Chevrolet	4,136,061	-0.1%
8	Kia	2,816,802	-8.4%
9	Renault	2,681,392	10.5%
10	Mercedes-Benz	2.551.374	10,1%
11	Peugeot	2.084.458	1,3%
12	BMW	2.077.316	3,9%
13	Audi	1.871.789	0,0%

Rank	Brand	Sales 2017	Var (%)
14	Fiat	1.646.695	7,9%
15	Maruti	1.614.351	14,1%
16	Mazda	1.569.037	2,1%
17	Suzuki	1.534.653	8,0%
18	Changan	1.468.144	5,0%
19	Buick	1.463.871	-1,6%
20	Jeep	1.444.626	-1,1%

Table 4. 20th Main Brands

Own construction

3.2. Automotive industry and the auto-parts market in Italy

In Italy, the automotive industry is registering a recovery phase of the sales units since the previous two years. For Europe and especially Italy, the challenge is to maintain a growing production volume and accelerate the renewal of the vehicle fleet in order to maintain a positive sales margin. The invoiced in the automotive sector increased by 5.7 percentage compared to the average of 2016. The automotive production sectors have the following billing results: the manufacture of automotive vehicles generates an increase of 4.2% and the manufacture of bodyworks, trailers and semi-trailers increased by 10.6%, mainly driven by the foreign component.

According to the preliminary data of ANFIA(Associazione Nazionale Filiera Industria Automobilistica), obtained between the various companies producing vehicles, in 2017 the domestic production of vehicles generated an increase of 3.5% compared to 2016, registering 1’142.210 units sold, as reported in the following Table:

	Sales			Var 17/16	% export of Prod
	2015	2016	2017		
Vehicle	663.139	712.971	742.642	4,2%	56%
Commercial Vehicle	317.365	344.358	332.112	-3,6%	79%
Industrial Vehicle	33.719	45.976	67.456	46,7%	93%
Total	1.014.223	1.103.305	1.142.210	3,5%	65%

Table 5. Sales in Italy

Own construction

In the previous Table, the column referring to exports represents the quantity of production that is destined for export. The volumes of automobiles destined abroad represent 56% of the national production, 79% of the commercial vehicles produced are destined to foreign markets, while 93% of the industrial vehicles (trucks and buses) produced in Italy are exported. In general, 65% of national production is destined to foreign markets.

In 2017, the total orders of the automotive sector show an increase in the trend of 6.8%, the largest contribution to growth is derived mainly from external demand, which registered an increase of 9.6%, while the internal market grew by 4.8%. According to the above, for 2017 there were exported 742.418 vehicles, generating a growth of 3.6%. In that sense, national demand and exports have boosted national production and the automotive industry in general in 2017. In this year, the value of exports of the motor vehicle sector amounts to € 23.69 billion, representing the 5.3% of the total exported in Italy and an increase of 11.3% compared to 2016. On the other hand, imports generated € 33.27 billion euros, representing 8.3% of total Italian imports, 9.7% more than in 2016.

One of the problems of the Italian market is the concentration of foreign companies present in the territory, for example foreign car manufacturers have a market share of 71.5%, which determines the strong negative balance of the trade balance, unlike France and Germany, where the penetration of foreign manufacturers is much lower. For example, French groups own 24% of the Italian car market and German brands 22%. Making a comparison with France, French manufacturers have a market share of 54.5% and foreigners 45.5%. In Germany, the automotive industry comprises 69% of German brands (of which 61% of cars manufactured in Germany) and 31% of foreign brands. Also for other types of vehicles (trucks, buses, trailers and semi-trailers), that is, the presence of foreign brands in Italy is very high, which limits the sales of Italian companies.

On the other hand, analyzing the auto parts market in Italy we realize that innovation in the automotive industry has assumed an important role in the last decades. The introduction of ever more advanced components in the production process has given another facet to the production of automobiles. The market for automotive components has represented in Italy one of the sectors of specialization of the national industry for more than 20 years.

The main areas of automotive research are also electronics, automation technologies, connections, materials, power systems, motor and distribution. According to ISTAT data, in 2016 the volume of the manufacture of parts and components for motor vehicles sector increased by 5%, with a 7.6% growth generated by the domestic market and 2.1% by external markets.

The imports and exports of auto parts market can be seen in Figure 25. As can be seen in 2016, the total value of exports of components reached around € 19.97 billion, with an increase of 0.3%, while the total value of imports of automotive components amounted to € 14.440 million, with an increase of 2.8% compared to 2015. The positive balance generated was € 5.55 million, with a reduction of 5.7% compared to the € 5,860 million reached in 2015. The main destinations for imports and exports are show in Figure 26 and Figure 27.

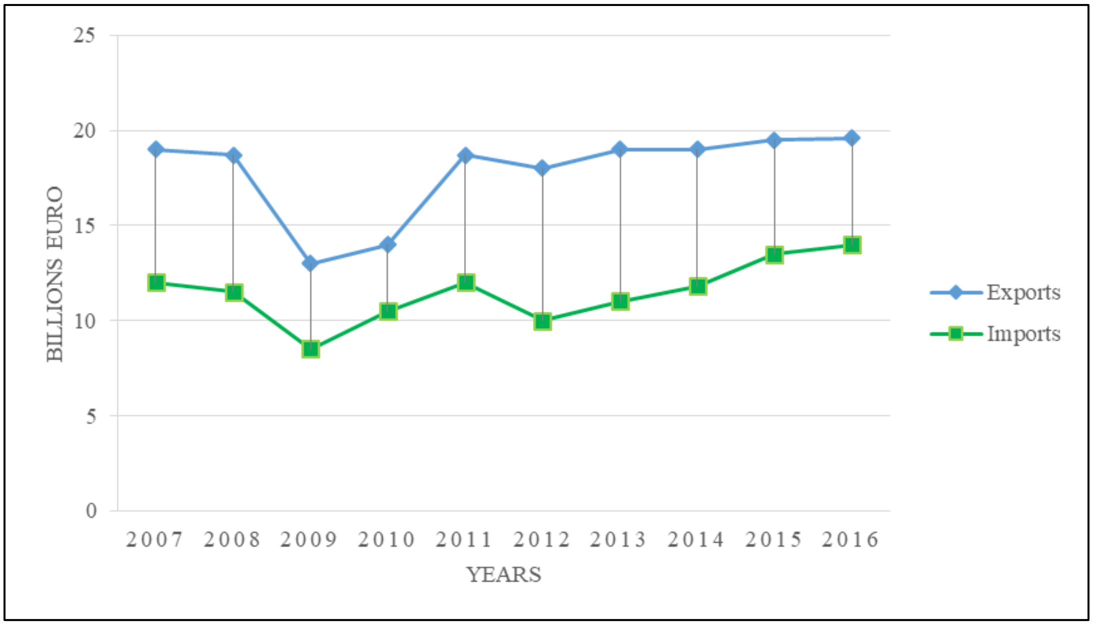


Figure 25. Italy, trade parts and accessories for vehicles

Own construction

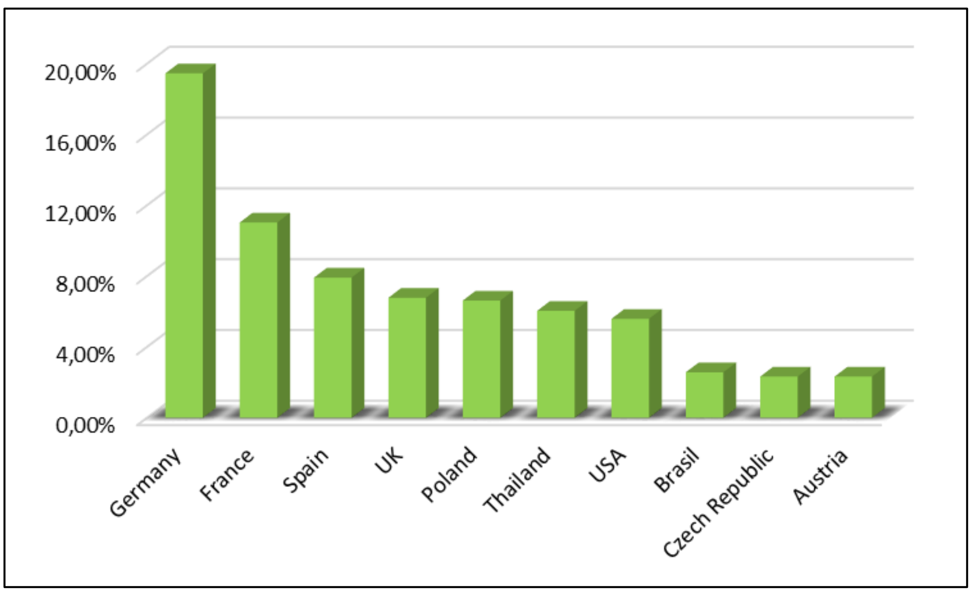


Figure 26. Italy, export components. Top 10 countries-destination

Own construction

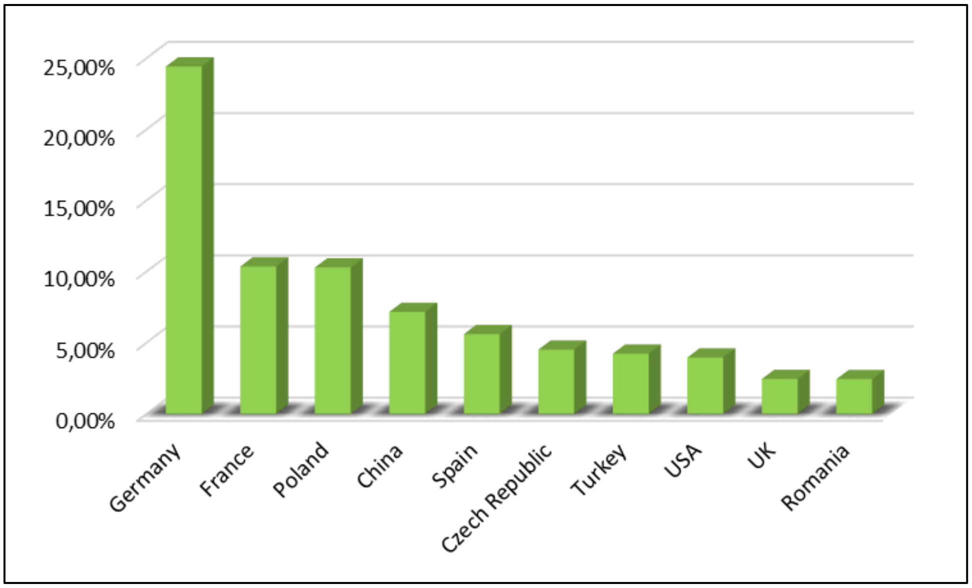


Figure 27. Italy, import components. Top 10 countries-origin

Own construction

The following Table shows the total imports and exports in euros for the vehicle components market in Italy.

Components	January/June 2016		January/June 2017	
	Import	Export	Import	Export
Engine	1.402.276.746	1.993.991.464	1.530.903.501	2.092.654.635
tires, inner tubes, pieces of rubber	814.772.968	611.630.382	832.764.517	635.777.982
electrical and related components	921.071.420	920.240.613	993.527.392	971.004.492
sound reproducing equipment	115.883.741	18.599.358	102.240.291	16.437.905
mechanical parts, glasses, accessories	4.072.340.171	6.850.022.656	4.464.740.602	7.176.365.218
TOTAL	7.326.345.046	10.394.484.473	7.924.176.303	10.892.240.232

Table 6. Parts and accessories for motor vehicles - commercial interview for macro-classes of products

Own construction

3.3. About 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.

Today, Dayco is a global manufacturer of engine timing belt drive, accessory belt drive and continuously variable transmission products, systems and solutions. With more than 4.500 employees and more than 50 manufacturing plants, distribution centers, technology centers and sales offices in 20 countries, Dayco has utilized its global footprint to establish relationships with all original equipment (OE) engine manufacturers and more than 1,500 distributors worldwide.

During the past years, Dayco has expanded its business by opening manufacturing and distribution facilities, and by completing strategic acquisitions, which resulted in the addition of new products as well as enhanced manufacturing, engineering and distribution capabilities.

In this moment, Dayco has around a Billion of euro in revenues, generated through the following locations and employers (see Table 7 and Table 8) .The actual World Headquarters is in Troy, Michigan.

LOCATIONS	LAUNCHED	NUMBER OF ASSOCIATES
Chieti, Italy	1974	238
Colonnella, Italy	1989	73
Manoppello, Italy	Acquired by Dayco in 1993	241
Walterboro, South Carolina	1973	129
Williston, South Carolina	1977	273
Córdoba, Argentina	1995	168
Guiyang, China	2011	165
Suzhou, China	2011	215
Ivrea, Italy	1999	570
Manresa, Spain	Acquired by Dayco in 2001	102
Tychy, Poland	2013	384
Hillsdale, Michigan	Acquired by Dayco in 2013	19
Mt. Pleasant, Michigan	Acquired by Dayco 2013	172
Roseville, Michigan	Acquired by Dayco in 2009	56

Table 7. Dayco Locations

Taken from: Dayco data.

	LOCATIONS	LAUNCHED	NUMBER OF ASSOCIATES
	San Luis Potosi, Mexico	2013	127
	Springdale, Arkansas	1985	176
	Wagga Wagga, Australia	Acquired by Dayco in 2013	40
	Contagem, Brazil	2000	99
	Itapira, Brazil	2001	131
	Manesar, India	2010	147
	Suzhou, China	2012	215
Distribution Centers	Concord, Canada	2008	16
	Fayetteville, North Carolina	2014	85
	Memphis, Tennessee	2015	350
	Mexico City, Mexico	2014	30
	Burolo, Italy	2006	118
	Córdoba, Argentina	1998	30
	São Paolo, Brazil	2000	140
	Suzhou, China	2011	8
	Hallam, Australia	1979	37
	Barcelona, Spain	2012	–
	Birmingham, UK	2015	–
	Strasbourg, France	2014	–

Table 8. Distribution Centers

Taken from: Dayco data.

3.3.1. History

Dayco is an important American automotive company founded in Dayton, Ohio in 1905.

When Dayco, then known as Dayton Rubber Manufacturing Company, opened for business on May 17, 1905, it was a dream come true for the five seasoned industrialists who founded the company. After a modest beginning manufacturing garden hose and canning jar rubber sealing rings, Dayco has grown into a global company that develops new products, improves established products and increases manufacturing and distribution efficiencies.

The Figure 28 shows some important milestones in Dayco over time:

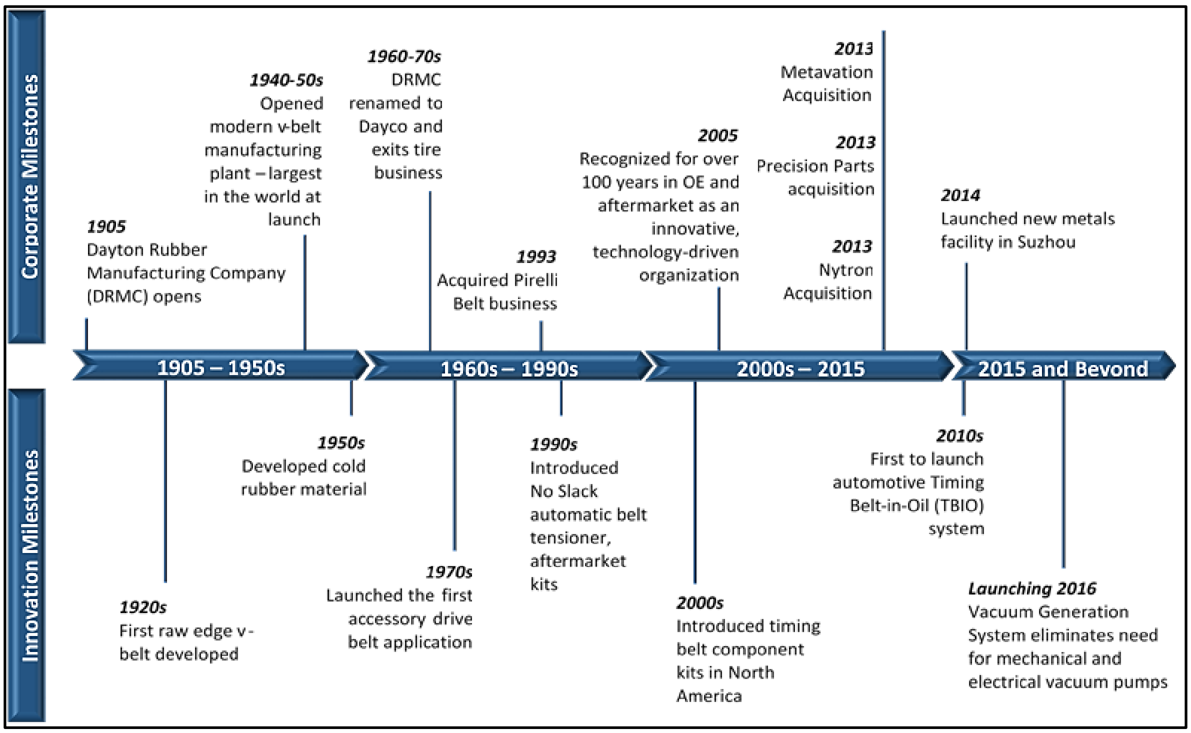


Figure 28. Dayco' History

Taken from: Dayco data

3.3.2. 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 its products, its customer relationships, and within the DNA of the company.
- **A bias towards 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 driven to help its customers succeed and to improve how end-users live and work.

3.3.3. Values that guide their behavior

- Responsiveness: Dayco is 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 themselves.
- Ingenuity: Dayco excel at finding new ways of getting the job done. They relish challenges and strive to meet them head-on. Dayco is 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: Dayco 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 is around the corner and prepare to take advantage of new opportunities. They have always been good at looking ahead. They have not endured for more than 100 years by waiting around for

change to come to them; rather, They have learned that standing still is not an option, and they push ourselves 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.

3.4. Where is Dayco

Dayco has in the world 50 locations across 20 countries. The Figure 29 shows the principal geography positions with the respective countries in where Dayco have presence. In addition, it can be observed the revenue that Dayco obtain through the end markets, where it can see that the European market is the most profits for the company with the 46% of revenues.

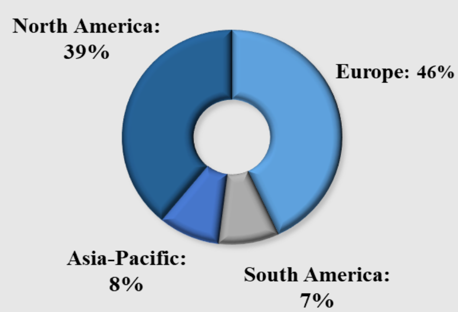
GEOGRAPHY POSITIONS	COUNTRIES	REVENUE BY GEOGRAPHY
North America	❖ United State ❖ Canada ❖ Mexico	
South America	❖ Brazil ❖ Argentina	
Europe/ Middle East/ Africa	❖ Italy ❖ Poland ❖ Spain ❖ United Kingdom ❖ France ❖ Germany ❖ Portugal ❖ Sweden ❖ Russian Federation ❖ Turkey ❖ United Arab Emirates ❖ Serbia	
Asia/ Pacific	❖ Australia ❖ China ❖ India ❖ Japan	

Figure 29. Dayco Locations.

Taken from: Dayco data

The next Figure shows the Global Footprint of Dayco: countries with their respective workplaces quantity that is their sales offices, manufacturing plants, distribution centers, aftermarket offices and technical centers

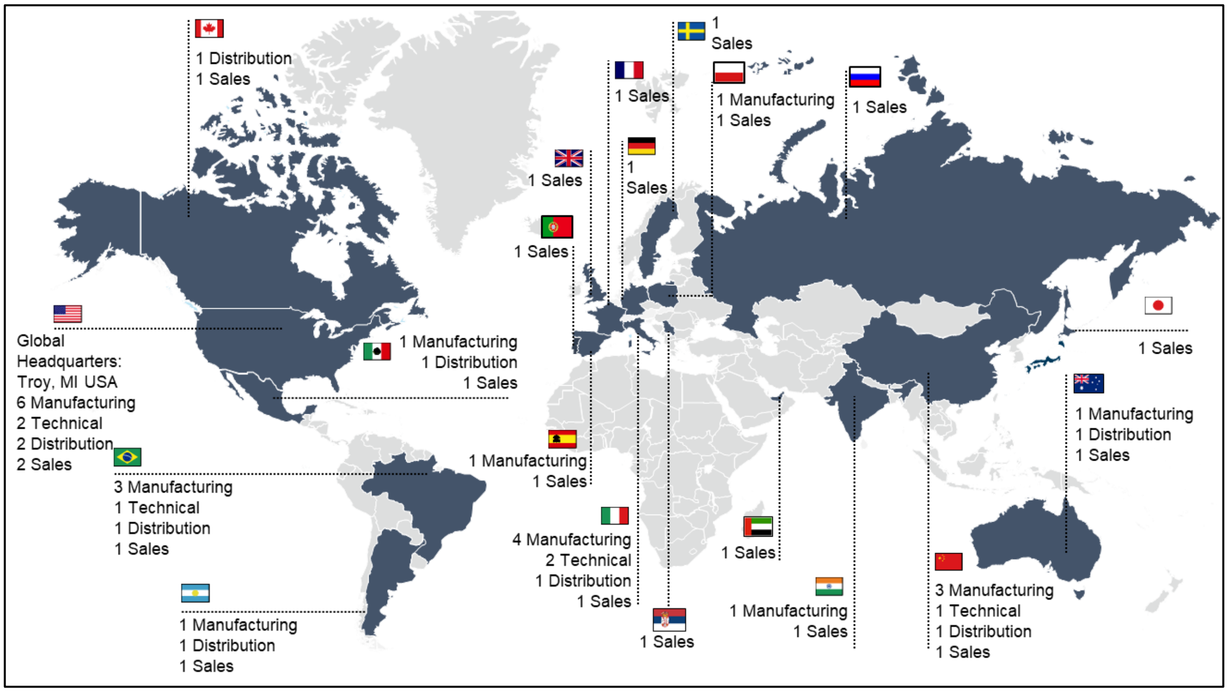


Figure 30. Global Footprint

Taken from: Dayco

3.5. Products:

Dayco has Broad Product Range Built (Business unit), divided in Rigid (like Pulleys and Tensioners) and flexible Components.

The principal end- markets to which are directed Dayco' products are Commercial vehicles, Off-Highway Vehicles, Industrial Engines and Light Duty Vehicles.

3.5.1. Timing Belts:

Supplies synchronized power from the engine crankshaft to the camshaft or other internal engine components. Timing belts are designed both for applications in diesel and petrol engines, and are fitted both on motorcars and industrial vehicles.

With the use of new materials, the belts can be made in various structures and tooth profiles, to guarantee the performance of modern vehicles.

Available structures:

- Chloroprene: first generation belt, usually not subject to high stresses, such as temperatures over 70°C or high workloads.
- HSN: structure characterized by its optimal resistance to high temperature up to 130°C and pulsing loads.
- HT: the belt cloth is coated with a highly abrasion-resistant PTFE film, designed to reduce to a minimum the cloth wear on the lap and on the sides of the teeth. This structure guarantees the belt maximum service life on engines with high injection pressure. Available for TDI Audi and VW engines and on TDCi Ford, Dci Renault and JTDm Fiat. For some applications, a cloth is applied on the tooth back to compensate for and increase resistance to side wear.

Figure 31. Timing Belts

Taken from: Dayco Web

3.5.2. PV / V-Belts:

It principal function is conveys power from the engine to accessories. PV belts are designed for the Ausiliari transmissions of motorcars, commercial vehicles, industrial vehicles, buses. All Dayco PV belts are made in EPDM material (Ethylene-Propylene- Diene- Monomers)

The main features are:

- Flexibility for use on small diameter pulleys.

- Dimensions allowing the use of a single belt for controlling several Ausiliari components.
- Power transmission, including with the back of the belt, in particular in case of “double rib”.
- High operating temperature range to guarantee an increased life.

Besides the traditional transmission systems with PV belts and tensioners, Dayco operates in both the original equipment and aftermarket sectors with elastic PV belt designed for some engines with fixed center distance and limited belt length. These belts do not require any external tensioning system (tensioners).

Available for Fiat, Alfa, Peugeot, Citroen, Ford and Volvo engines.

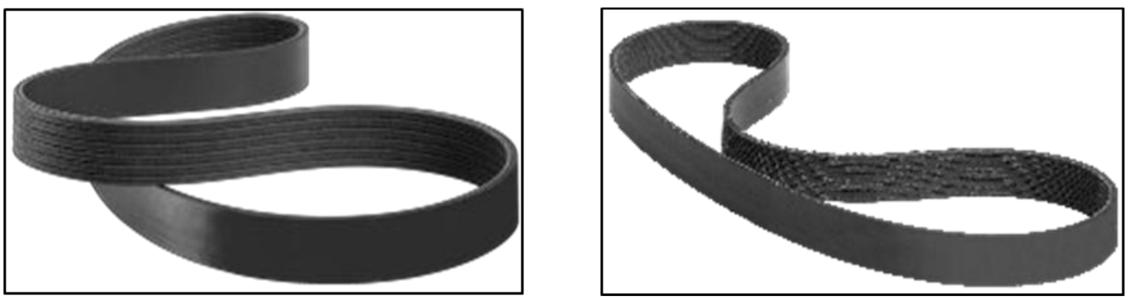


Figure 32. PV-Belts

Taken from: Dayco Web

Figure 33. V-Belts

Taken from: Dayco Web

3.5.3. Tensioners

The tensioners supplies and maintains a constant tension on the accessory and primary drive belts

Figure 34. Tensioners

Taken from: Dayco Web

The main types are:

- Fixed tensioners: The final tension on the belt is applied on assembly and remains constant over time. The belt tension is therefore determined when it is assembled.
- Automatic tensioner: spring-loaded or hydraulic. These are dynamic tensioners, which, once they are installed, can adapt to and improve the belt tensioning according to the engine stress, in any operating condition.

3.5.4. Pulleys

The Pulleys are used to guide and route the belt for the drive system. One of the most important kind is:

Guide-pulleys: these pulleys, with or without bracket, allow the correct guiding of the belt in its route. They are very important as they support part of the system stresses.

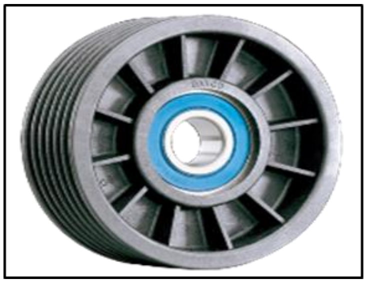
 

Figure 35. Pulleys.

Taken from: Dayco Web

3.5.5. Dampers

The Dampers are used to reduce noise, vibration and harshness, such as crankshaft twisting from the engine firing pulses.

Figure 36. Dampers.

Taken from: Dayco Web

3.5.6. Decouplers

The Decouplers decreases drive belt vibration and reduces belt slippage.

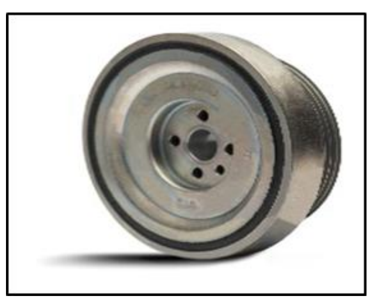


Figure 37. Decouplers.

Taken from: Dayco Web

3.5.7. Aftermarket Kits

Are a kit of components, which including a timing belt, water pump, tensioner and pulley.

Figure 38. Aftermarket Kits.

Taken from: Dayco

3.5.8. Hose and Hydraulics

Are the Aftermarket fluid transfer hoses, hydraulic hoses and couplings.

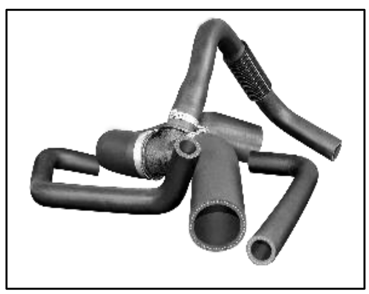


Figure 39.Hose and Hydraulics.

Taken from: Dayco

In the next Tables, it can see the Facilities (Belt Product, Mechanical Product and Distribution centers) with the key products, the respective location and end market (per the two first facilities), in the case of distribution centers the Table only show the location and the Shipping Capacity.

FACILITIES	LOCATIONS	KEY PRODUCTS	MARKET(S)
BELT PRODUCT	Chieti, Italy	Accessory drive belts	Auto OE (Original Equipment), AM
	Colonnella, Italy	Timing and CVT belts	Auto OE, AM
	Manoppello, Italy	Timing belts	Auto OE, AM
	Walterboro, South Carolina	Accessory belts, CVT belts, V-belts	Industrial OE, AM
	Williston, South Carolina	Timing belts, accessory belts, v-belts	Industrial OE, Auto OE, AM
	Córdoba, Argentina	Accessory belts and timing belts	Auto OE
	Guiyang, China	Accessory belt and v-belts	Auto OE, Industrial OE, AM
	Suzhou, China	Accessory belts and timing belts	Auto OE, AM

Table 9. Facilities- Belt product.

Taken from: Dayco

FACILITIES	LOCATIONS	KEY PRODUCTS	MARKET(S)
MECHANICAL PRODUCT	Ivrea, Italy	Decouplers, idlers and tensioners	Auto OE, Industrial OE
	Manresa, Spain	Dampers, pulleys and pressed parts	Auto OE
	Tychy, Poland	Dampers and decouplers	Auto OE
	Hillsdale, Michigan	Rubber strips for dampers	Auto OE
	Mt. Pleasant, Michigan	Dampers	Auto OE
	Roseville, Michigan	Springs	Auto OE, Industrial OE, AM
	San Luis Potosi, Mexico	Dampers	Auto OE
	Springdale, Arkansas	Tensioners, idlers and VGS	Auto OE, Industrial OE, AM
	Wagga Wagga, Australia	Dampers and pulleys	AM
	Contagem, Brazil	Dampers, idlers and tensioners	Auto OE, Industrial OE
	Itapira, Brazil	Idlers and tensioners	Aftermarket
	Manesar, India	Dampers, tensioners and idlers	Auto OE
	Suzhou, China	Dampers, tensioners and idlers	Auto OE, AM

Table 10. Facilities- Mechanical product.

Taken from: Dayco Web

FACILITIES	LOCATIONS	SHIPPING CAPACITY
DISTRIBUTION CENTERS	Concord, Canada	2.2 million units annually
	Fayetteville, North Carolina	3.5 million units annually
	Memphis, Tennessee	21.6 million units annually
	Mexico City, Mexico	1.6 million units annually
	Burolo, Italy	18.5 million units annually
	Córdoba, Argentina	9 million units annually
	São Paolo, Brazil	7.5 million units annually
	Suzhou, China	700.000 units annually
	Hallam, Australia	1.9 million units annually
	Barcelona, Spain	1.1 million units annually
	Birmingham, UK	130.000 units annually
	Strasbourg, France	1.3 million units annually

Table 11. Facilities- Distribution centers.

Taken from: Dayco

3.6. Customers:

Dayco Europe work in these principal business units:

- First plant, channel through which the company directly sells its products to customers, which Include automotive, that is the commercial vehicle market and Industrial, that has refer to heavy load vehicle.

- Aftermarket, channel through the company sells its products to the component resellers. Is a non-original replacement market (it can say that are generic pieces because in this case the products do not have the logo of any customer. This market generates a significant income for the company.

Having said that, the main customers of the company for these markets are:

For the industrial market:

- Fiat (FPT)
- Deutz
- Man
- Volvo/ Renault truck
- Scania

For the Automotive:

- Ford
- Fiat
- Peugeot
- Volkswagen (VW)
- Bayerische Motoren Werke (BMW)

The next Figure shows a wider range of Dayco's customers:

Figure 40. Principal Dayco´s customers.

Taken from: Dayco

3.7. Competitors:

Dayco Europe works in a sector where there is not a great variety of important competitors that can easily take it quota from the market. Even so, there are certain strong competitors, with which Dayco leads in the sector.

These principal competitors of Dayco are:

- **Gates** an American company founded in 1911. Gates has more than 13.500 employees, more than 100 locations in 30 countries. This company is the most important and directly competitor for Dayco, because is the only one that produces both pulleys and tensioners.
- **Litens Automotive Group** a Canadian company founded in 1979
- **Schaeffler Group**, a German company founded in 1946. This company has around 86.000 employees worldwide and theirs revenues are near € 13 billion.

CHAPTER 4: DAYCO IVREA

In Italy Dayco has presence in the following places: Chieti, Colonnella, Manoppello, Burolo e San Bernardo d'Ivrea, which is one of the manufacturing plant most important, where the company produces principally the pulleys and tensioners that is to say the rigid components mentioned above. This plant was open in 1999 and have around 600 employers. Actually Ivrea represents around 15% of total Dayco' revenues.

Dayco Ivrea uses the information system AS/400 for its data management; it is there where the information provided by each departments that intervene in the operation of the company is stored and updated. However, of this system, the flow of information between the areas and processes is given.

4.1. Supply Chain Processes of Dayco Ivrea

The Ivrea's plant is compose for many departments like Manufacturing, quality of control, human resource, finance and supply chain that is the area object of this study. The Supply Chain in Ivrea is compose by the following processes:

- Purchasing
- Production schedule
- Customer service
- Packing/ Customs

The most relevant processes for the development of the thesis were production scheduling and purchases. The next Figure shows the general process of the supply chain:

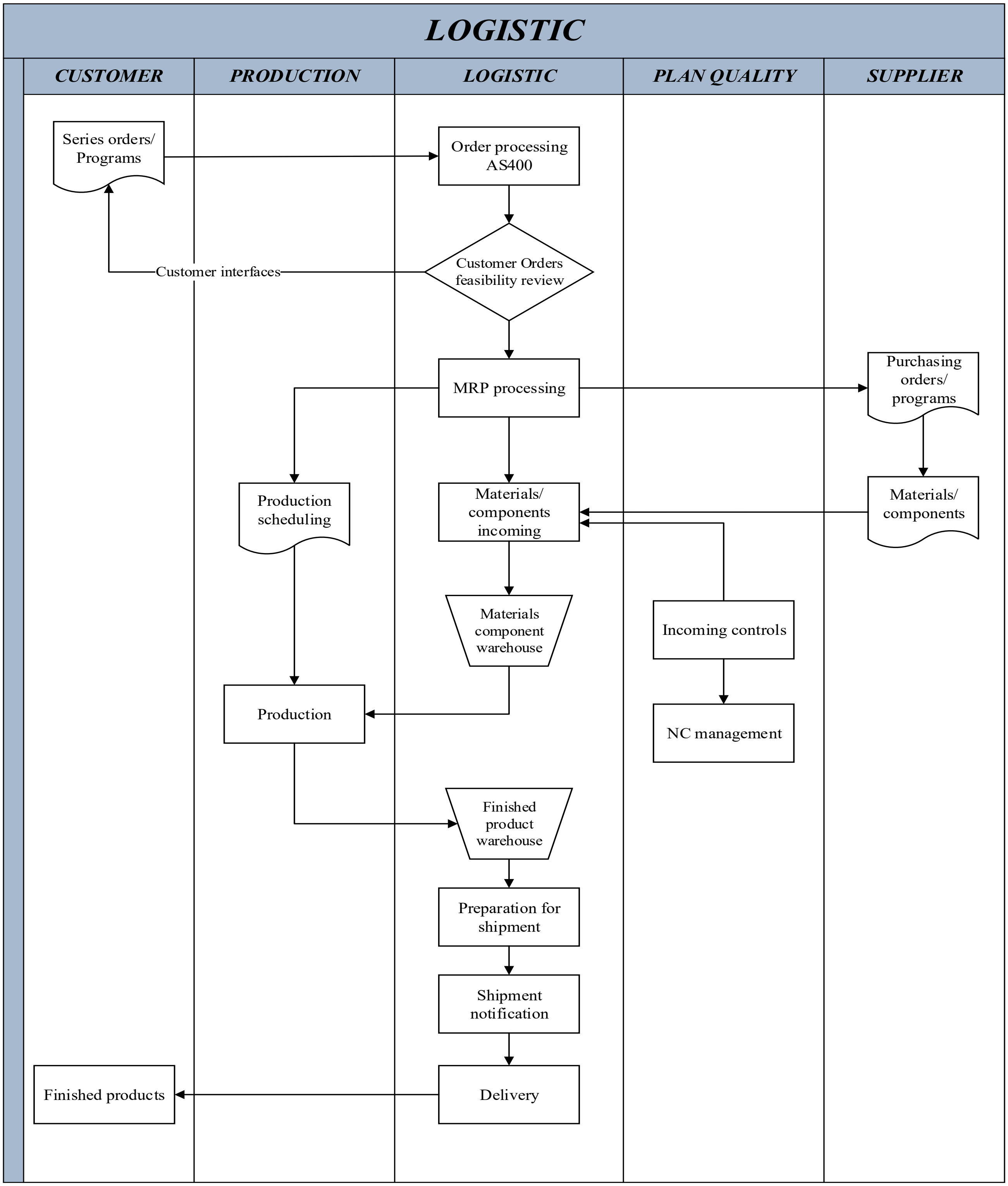


Figure 41. Flow chart Logistic department.

Taken from Dayco.

4.1.1. Purchasing process in Dayco

After having a general vision of what is purchasing and its importance to the business, following it is explained the reality of purchases in this company.

In Dayco Europe, this department is composed by five people, where there are two responsible of the indirect materials and service purchase, other two responsible to acquire the production parts (direct materials), and the last one must work in the purchasing costs.

Inside this division, these people must to perform two global functions that are Program management and Yearly Routine.

*4.1.1.1. **Program management***

For the development of this function, it must be taken into account that, there are two types of processes depending on the kind of request received, either an open order or a close order. An open order is an order that regulate the serial production, that means is a scheduling. Conversely, a close order is an order limited to a single activity, it means an order that the company does just one time.

4.1.1.1.1. When the purchasing department receive an open order

In this case, the process begins with the arrival of an E.C.R that is related to the modification of an existing product or a NPA that is related with the startup of a new product. These are internal documents, in which the technical department declares that a specific component had generated a Bill of Materials (BOM).

After that, the purchasing strategies of the project are established, which means that the responsible must decide factors such as: the possible suppliers that have the most appropriate technology available for the development of the product and can also offered to the firm the best price-quality ratio on the market.

After defining a list of possible suppliers, the purchasing department proceeds with the Request for Quotation (RFQ) that includes the Cost Breakdown (CBD). Once all the analyze them, through a Business Case (BC) that consist in compare prices, quality and technologies used by each supplier in their process, machinery and materials, to finally choose only one or some ones.

Subsequently, the data of the selected suppliers are used to make a financial analysis of the project and to elaborate the Cost Pack (Document where there are financial indices such as: Earnings before Interest, Taxes, Depreciation, and Amortization (EBITDA), Earnings before Interest and Taxes (EBIT), and Net Income (NI)). At the same time, the purchasing office must establish commercial agreements with 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 respective responsible for its approval. In the case it is reject, this department should do a technical, production and suppliers review and remake the financial analysis. In the other case, the process continues with the development phase that consist in improve the prices and technologies in order to do more attractive and robust the proposal for the customers. If the cost are less than the Cost Pack, the responsible send the order to the supplier. Because of this, the system creates the Tooling kick off- TKO that is an order number for the equipment request and the Project kick off- PKO that is a Production Part Approval Process (PPAP) request.

To finalize the agreements, the company and the supplier sign the contract, document where the stakeholders must indicate and define all this supply clauses:

Nomination: general rules of supply, validity of the agreement, technical rules, cooperation with Dayco, rules of behavior until and after the start of the production, volumes forecast, investments, production capacity and Security stock, equipment line , tools, prices and delivery conditions, payments and competitiveness clauses, warranty, line stops, recall campaign and preventive measures, insurance, term and termination, intellectual property

However, if the cost are not less than the Cost Pack, the department should do a technical, production and suppliers review, until prices and technologies are optimized.

At this stage, the process continues doing the PPAP order, which consists in asking the first pieces that will go into quality control for its approval. If is necessary an equipment investment for the supplier, the purchasing department must do a RDA (Purchasing Request, by its initials in Italian). If the quality of the parts is rejected, the defects must be reported to the supplier asking them to apply the changes and again send back the parts (this process must be repeated until the quality is accepted); in the opposite case, the process ends doing the prices lists and the percentage assignment.

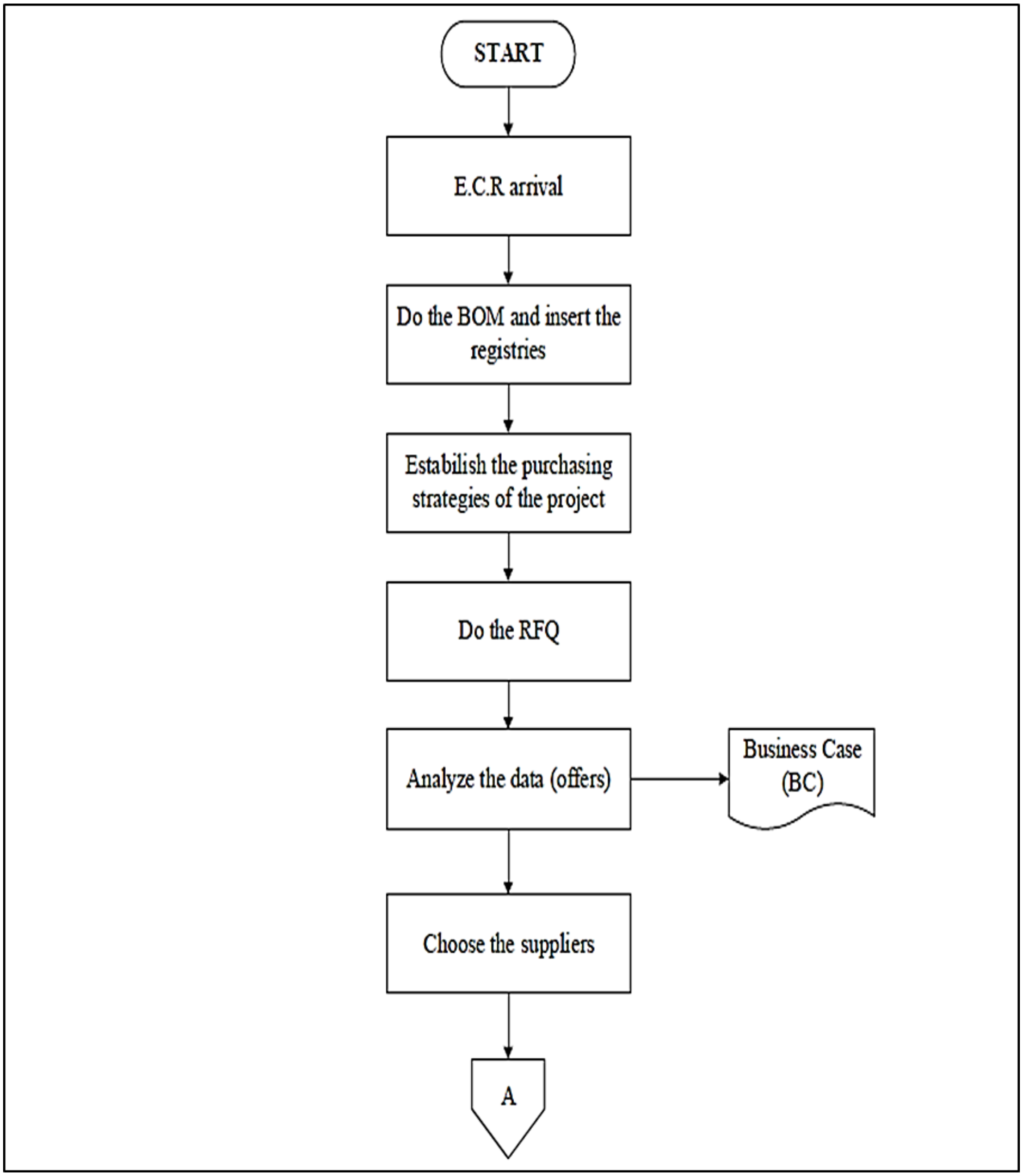


Figure 42. Flow Chart Purchasing Process. First Case. (Part I)

Own construction.

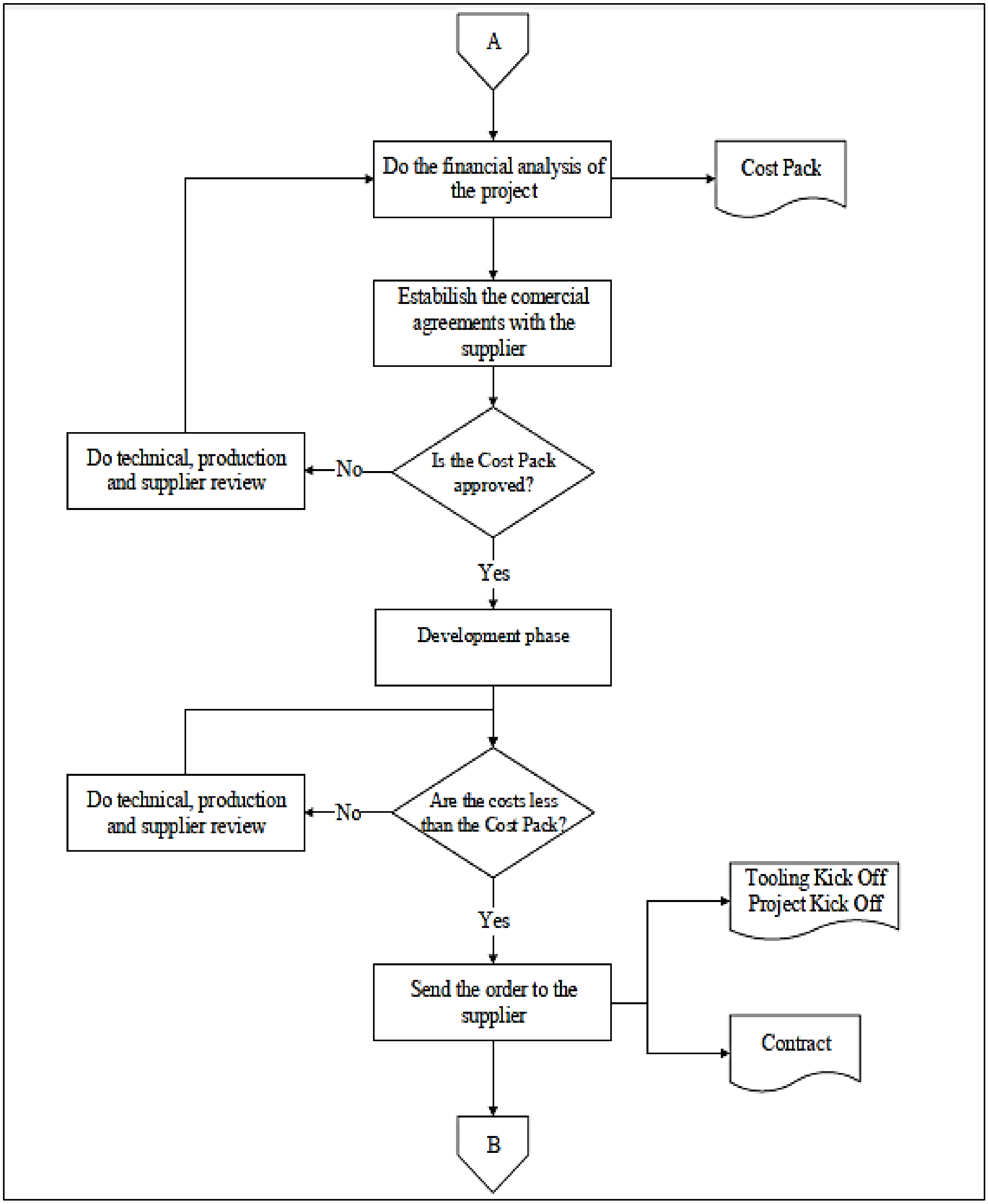


Figure 43. Flow Chart Purchasing Process. First Case. (Part II)

Own construction.

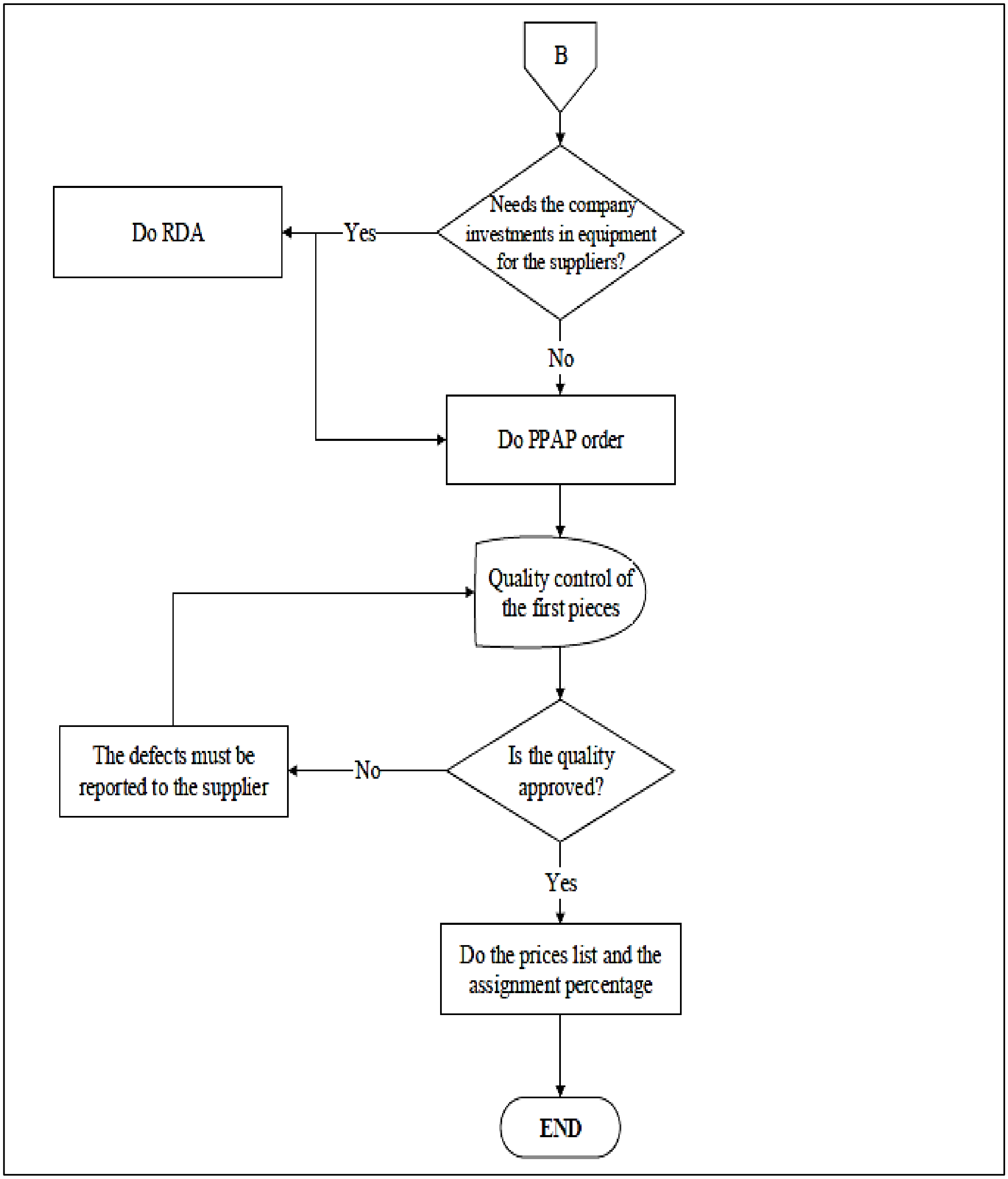


Figure 44. Flow Chart Purchasing Process. First Case. (Part III)

Own construction

4.1.1.2. ***When the purchasing department receive a close order***

In this case, the process begins with the arrival of a company necessity (that in Dayco is call activity) that could be a service or an indirect material. If there are no costs to the outside of the company, the department can proceed with the operations and the process ends. If instead there are costs, the purchasing office continue doing the RFQ, data analysis and selection of the supplier (through the business case). If the business case shows that the project could not bring more benefit to the company, the process finishes. Nevertheless, when it shows more benefit, the responsible should do the financial analysis (Cost Pack) and wait its approval, to finally do the RDA.

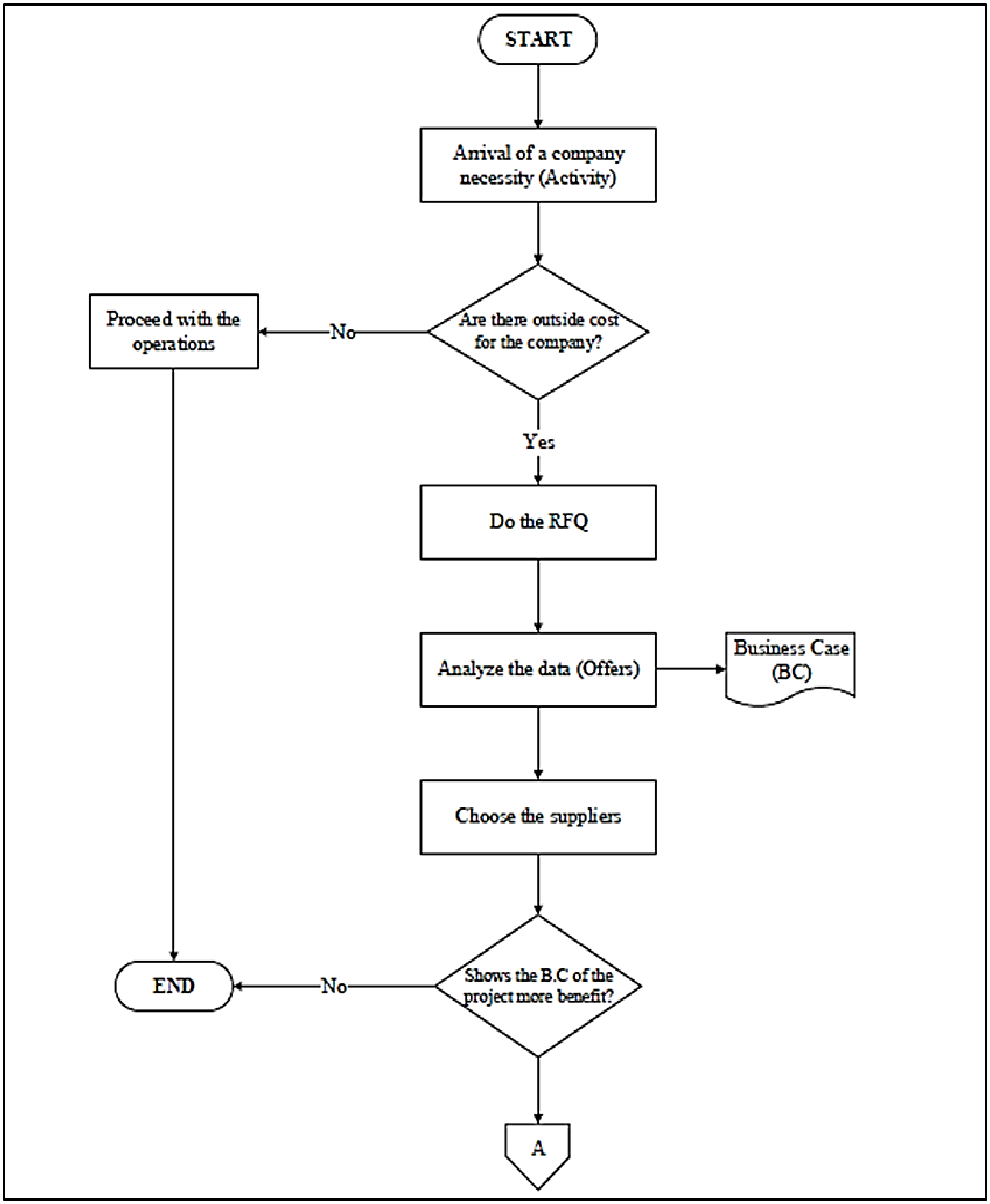


Figure 45. Flow Chart Purchasing Process. Second case. (Part I)

Own construction

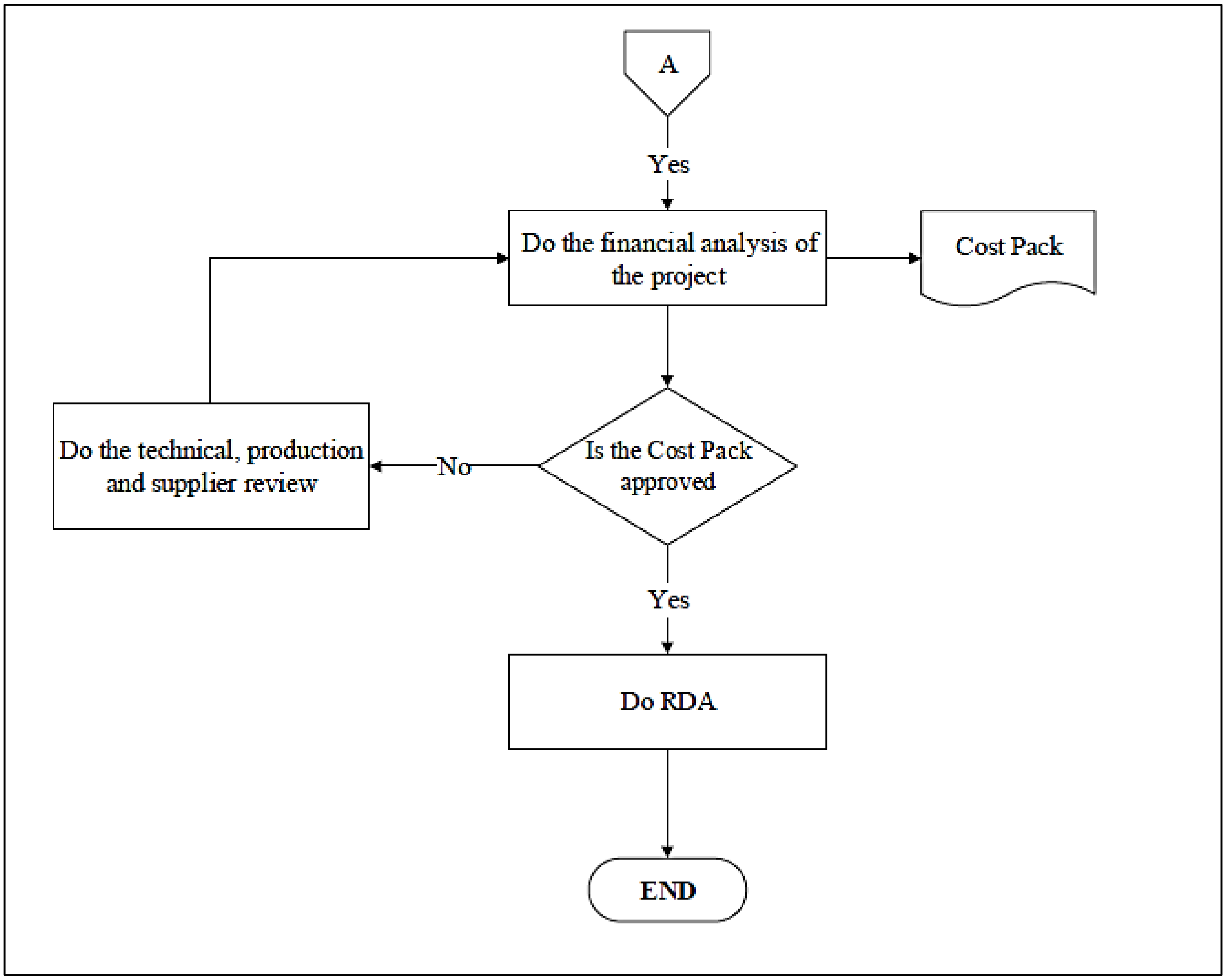


Figure 46. Flow Chart Purchasing Process. Second case. (Part II)

Own construction.

4.1.2. Yearly Routine

This global function of the purchasing department refers to the management of this division's performance. Said management is carried out through the analysis of the Budget inflation and the revision of Supplier relationship.

4.1.2.1. Budget inflation

The budget is based on the forecasts of sales volumes of the customers' products (which are the forecasts of purchases by the customer of its different components for the next year, that is, its market forecasts). These data are entered in the system and after that, the department have to explore all the Bill of Materials of the individual components. Then the budget of the purchase materials of the individual components is pulled out with their respective volumes. Subsequently the responsible take a "picture" of the budget, which says at the price of this year with the volumes of the next year the company, will spend this amount of money.

The Budget Inflation is calculated by the difference between the Budget calculated with the volumes and prices of the next year and the Budget calculated with the same volumes and the prices of the current year. It indicates the deviation of the value of components that Dayco buys compared to the previous year or compared to an average price. This inflation in Dayco is called PPV- Purchase Price Variance.

This analysis is mainly influenced by two macroeconomic variables, which certainly do not depend of the company, since these variables are indicators that a country takes into account in order to understand its economic reality in relation to other countries. These economic indexes influence what will happen in the reality of any company that needs import or export any good.

In Dayco, these variables are:

- Raw material (RM) monitoring: indicator that allows observing the variation (in prices) of the raw material for each Commodity, which refers groups of suppliers that perform a certain type of common products or processes.
- FX monitoring: is the variation of the exchange rate, where it should be analyzed if said change is advantageous or disadvantageous for the company.

This inflation impact can be higher or lower. Once this value is obtained, the problem of the purchasing department is try to minimize it the more possible if there is an increase, on the contrary if there is a reduction, the responsible should be try to increase it.

This is done negotiating the RM and FX monitoring or intervening on new possibilities that are:

- Long Term Agreements (LTA): are purely commercial contracts that work through discounts achieved by restrictions and extensions of the collaboration between the stakeholders.
- Indexation: means to implement a protective mechanism on the raw material. The price of the raw material on the purchase price is linked to the fluctuations of the market, That is to say, if the raw material is increased, the price increases, on the contrary if the Raw material is reduced the price decreases. It should be defined a control indicator of the shared raw material, where the purchasing department controls it quarterly together with the supplier and in this time its value is calculated.
- With agreements: Other different kinds of agreements.

Another thing that intervenes and is not within the PPV, but serves to reduce its impact (if these are a growth) or increase their beneficial effect (if these are a decrease), are the COP (Cost out Of Program)

The COP are activities raised in order to obtain a savings (benefit) for the company. The most common activities are: transfer the production from one supplier to another, not based on existing suppliers, otherwise based on new suppliers and new-targeted activities. Other activity can be change the percentage of assignment of suppliers. The COP are also a performance index for purchasing office.

4.1.2.2. ***Supplier relationship***

The supplier relationship is based on Commercial, Technical, Quality and Supply level aspects.

- Commercial: the department must have knowledge if the prices to which they are acquiring the components are the best in the market.
- Technical: the department should know what components are being sold them and what pieces should be asked
- Quality: It must be verified that the parts that the supplier sends are in good condition
- Supply level: It must be verified that the supplier is filling the delivery terms.

4.1.3. Actual Production Scheduling

In Dayco, the work shifts are arranged as follows: four shifts of 6 hours or three shifts of 8 hours from Monday to Friday, while on Saturdays the company works 21 hours in total and if is necessary the firm can schedule a production shift of 6 hours on Sundays.

The company has a general classification of its production lines:

- "Auxiliari", which is a set of lines where the secondary tensioners are manufactured.
- "Distribuzione", which is the set of lines where the primary tensioners are assembled.
- "Isole", which is a set of unitary stations where spherical bearings are assembled.
- "Prince", where particular projects are produced.

The lines that belong to each of the categories can be seen in the following Figure:

Figure 47. Production lines.

Own Construction.

In Dayco, the actual production scheduling is done manually each Friday morning referring to the updated customer's orders book, where the Planning department check and calculate the next week demand and forecasted shipment dates (this demand and dates are given by customers previously, since the demand is dependent). The company was decide to do the production scheduling weekly since, both the deviation in the customers' orders and the capacity of production lines are variables, and with a programmed week, the responsible can manage better the changes produced.

The process begin when the programmers receive the blocked orders that are like a "photography" of the customers' orders in the system, then they extract from it the list of items that are made per line, and next verify if the stock is sufficient to cover the demand.

Following production schedule is drafted and the MRP feasibility plan is launched. For this step to take place, the programmers should start with the schedule taking into account that the plant work around 22, 5 hours per day, because there are the breaks for the employees.

The calculations must be made based on the real capability and the hourly rate of machines, what it means how many pieces assembly the machines per hour. This data are provided by the industrialization and production department, through tables founds on AS/400 system.

In this moment in the supply chain department, there are two production programmers; one is in charge the production lines where are moves relatively fewer codes but he has longest batches to complete, while the second programmer have lines with more codes but shorter lots.

In the AS / 400 System, the responsible find a production program with all the data loaded automatically. This program shows an MRP that does not take into account the restrictions of the system, that is to say, calculates the components production with an infinite plant's capacity; therefore, the programmers must manage all the data in a non-automated way. In the system, the programmers can see all the customers' orders and the stock that there is of each one of the references that they need to program. The programmers must take into account when would have missing components and the delivery scheduled date of each order, with the purpose to decide which products should be manufactured for the following week, because if the delivery date is not close, the programmer must exclude it's, and schedule the products most urgent.

The products that are scheduled are entered into the respective production lines, in order to satisfy all customers. In the company there is no established a priorities system, which the responsible manage the orders, so the programmer must do the job based on the type of product and customer. For this reason, First Plant products must always be programmed first, while aftermarket products and spare parts can be programmed a little later if conditions do not allow them to be programmed instantly (it can be spaced out). Although it must be taken into account that if a spare parts or aftermarket product has high similarity with the first plant product, they must be produced in sequence. The programmers must make the least possible changes placing the similar products as close as possible, since a change in the production line takes around 1 hour, with which an important part of manufacturing is lost.

When they deciding which final products should be manufactured, the programmers must also know the Bill of Material of each of them, to know if the actual components stock is sufficient to cover the demand for products that are already programmed in the lines. In case that the raw material is not in stock, the person in charge should contact the suppliers in order to reach agreements and receive a part of the components as soon as possible. The programmers know that there are components that assemble in various final products, so they must have enough of these parts so that the production can be carried out in the indicated time.

Next, if feasibility plan is not executable due to material shortage or capacity, the production schedule is revised and amended by planning people. Then the production schedule for the whole week is again checked for feasibility if approved it will be released. If this happens, the productions schedule is released to Production department and should be revised again and amended and finally the production schedule is confirmed and the production plan activated

The next Figure, show the general process of the schedule production in the company:

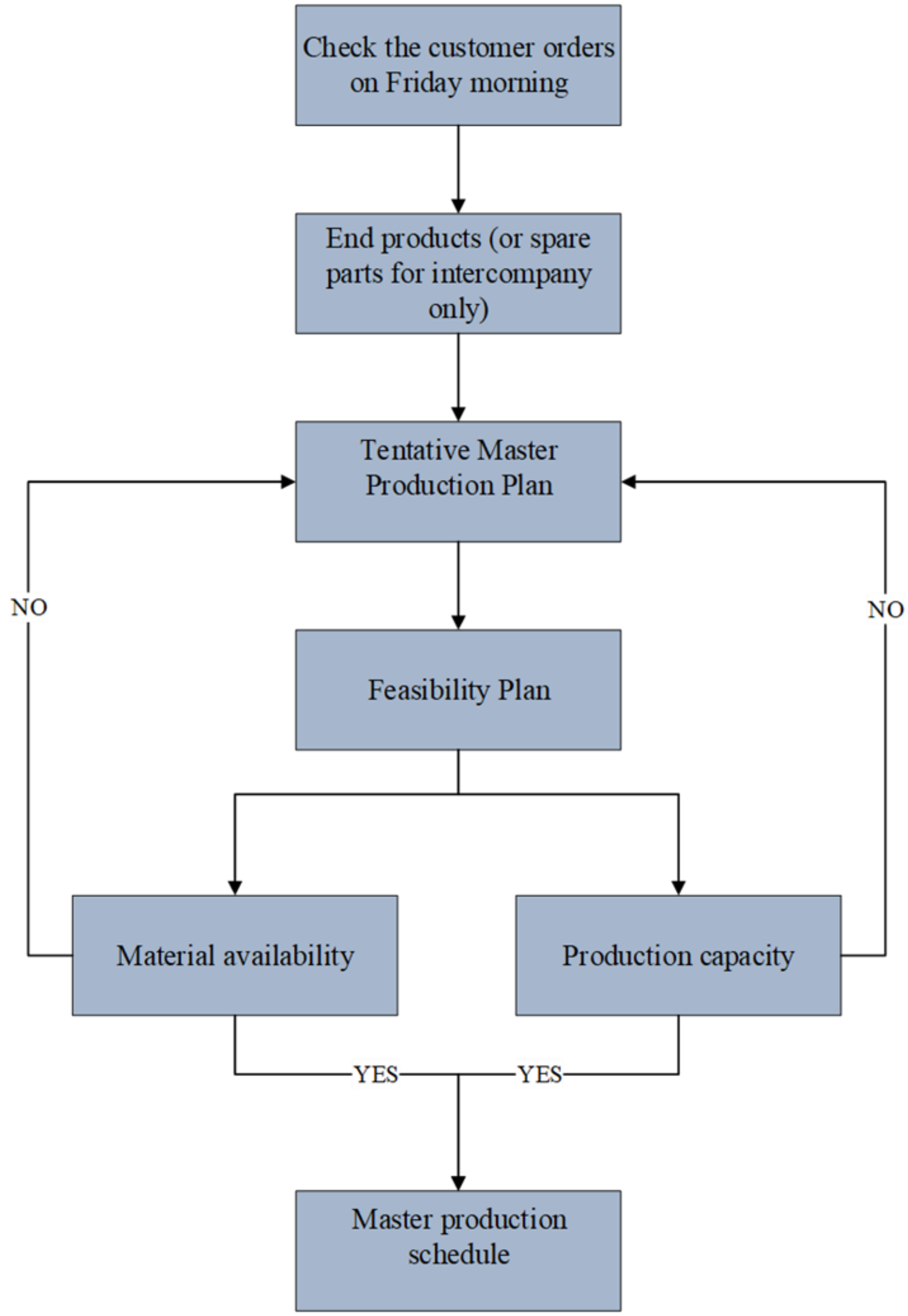


Figure 48. Scheduling production.

Taken from Dayco's data

4.1.4. Customer Service

The customer service is the main connection that Dayco has with its client portfolio, that is, it is the first contact between each customers and the company, for which this area must intervene transversally in all departments that make up the firm. The customer service works as a constant support for each processes involved in the production, from the moment that the customer order arrives until the final delivery of the products.

The customer service develops several main functions within the Supply Chain department, which are:

- To receiving and updating the customer's orders in the system. These orders, if the client so requires, can become daily while the orders sent to the suppliers are updated if necessary weekly, when the production scheduling must be carried out.
- To verify the orders portfolio, that is, determine if the data entered in the system are correct.
- To have a daily contact with the customers, in order to communicate them any type of anomaly that occurs in the processes related to production
- Constant tracking of the orders sent by each one of the customers, from the moment in which the company receives the order, until the products are sent and received by the client. This is done in order to comply with the logistical standards, which are those specific directives given by each of the clients. Some of the most important specifications are packing mode, structure of the labels, type of identification for each merchandise and the shipment ways.
- To update of the customer portal. The responsible must go to the client platform in order to consult and update relevant data, such as, verify that the parts are delivered correctly to the customer, and that these products are in an appropriate state
- Management of transport that are required urgently by the company.
- To be in continuous communication with the inventory management department. The customer service area is responsible for giving the

corresponding guidelines to the inventory management area, in order to meet all the requirements specified by the customer.

4.1.5. Packing

This area is the main responsible for managing the processes related to customs, where the person in charge must review some information such as the type of merchandise, the custom code, customs declaration, merchandise value and Incoterms. In turn, this department is responsible for carrying out the respective control of the raw material that arrives at the company, which allows to verify the current status of the pieces and the quantity of components shipped (that means the order made to the supplier is complete).

Another function of the responsible for this area is the packaging management of both the raw materials that constantly arrive at the company, as well as the final products. In turn, the packing area must verify the availability of places within the storage warehouse and suitable consumables components such as pallets, in order to be able to later store the components and the final products to be sent to the customer. It should be noted that this department does not manage the aforementioned; the person in charge only verifies that the information is correct.

CHAPTER 5: IVREA PLANT'S DIAGNOSIS

The production plant of Dayco Ivrea works with a production system known as Assembly to Order (ATO). This type of system uses a hybrid methodology, where the company works under a Make to Stock system (MTS), because it manages inventories of the components that will later be assembled or processed, but in turn, the firm also works under a Make to Order system (MTO), because it does not manage final product inventories.

In order to learn more about the production system and the actually situation of the company, a small diagnosis will be carried out, analyzing aspects such as the production lines and their capacity, the main bottlenecks, the behavior of the suppliers Lead Time and the products portfolio.

5.1. Production Lines

5.1.1. Capacity

As mentioned above, the Ivrea plant has 23 production lines classified into four categories named: Ausiliari (lines where the secondary tensioners are assembled), Distribuzione (lines where the primary tensioners are assembled), Isole (simple stations where a bearings category are assembled) and Prince (stations where a particular project are assembled). The first two classifications being the most important and therefore the subject of our analysis.

In order to perform certain analyzes of interest, the company calculates the lines' capacity in two different ways. The first of these includes set up times, which is known as the real or effective capacity of the process. The second way to obtain the capacity excludes setup times, and is known as the nominal capacity of the lines.

The following Figures show the effective and nominal lines' capacity in addition to the actual quantity of product issued by each of them.

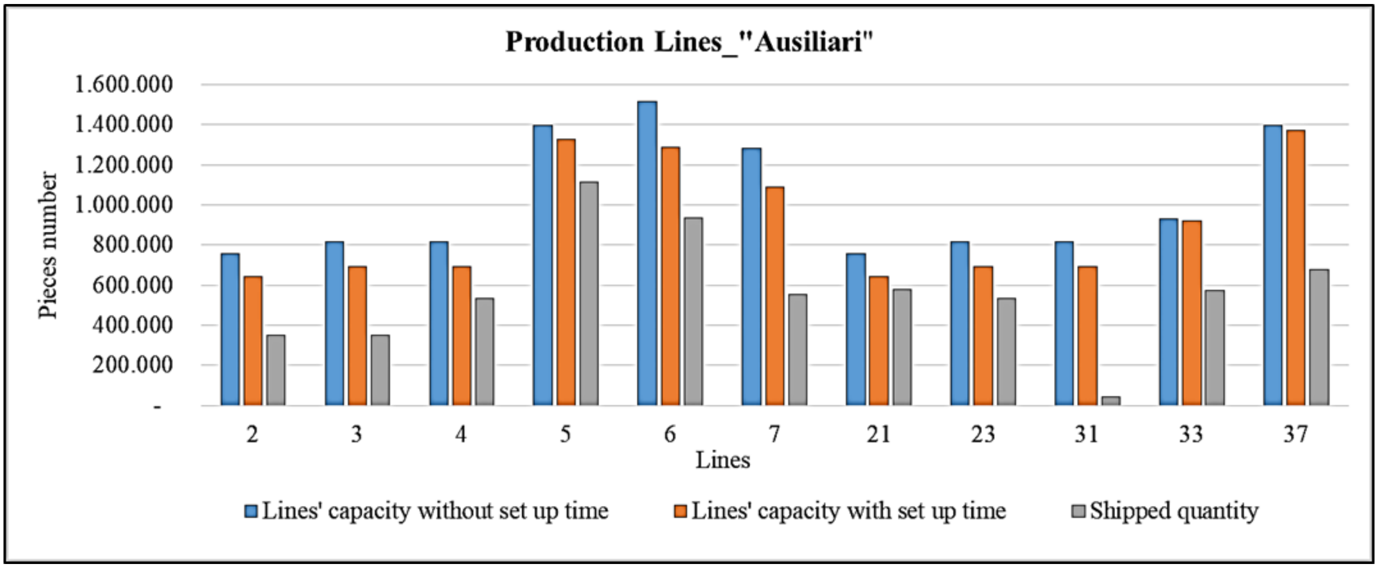


Figure 49. Capacity Lines and shipped quantity.

Own construction

As can be seen in the Figure, in the "Ausiliari" production lines, there is a common denominator: the nominal capacity is for obvious reasons slightly higher than the real capacity of the lines and, in turn, the production of parts is much smaller than its effective capacity. This gap can be observed notably in the lines: 2, 3, 6, 7, 33, 37 and especially in line 31, where only 6% of the products were shipped in relation to the calculated line capacity. Later it will delve into the causes that explain the loss of production that occurs in the plant.

The company calculated that the production lines have a general efficiency of 87%, value with which an estimate of the production of parts was obtained. The data show that in reality, this efficiency can be much lower than estimated, which leads to a significant decrease in the hourly production of parts and therefore to a significant reduction in the quantity of product shipped in relation to the capacity of the plant.

The following Table shows the hourly production of each "Ausiliari" lines taking into account the calculated efficiency of 87% and its real efficiency, where this effective efficiency was calculated based on the relationship between the quantity of assembled products and the actual capacity of the line.

"Ausiliari"			
Line	**Calculated hourly production based on 87% of efficiency**	**Real efficiency**	**Real hourly production**
2	130	54%	70
3	140	51%	71
4	140	77%	108
5	240	84%	201
6	260	73%	189
7	220	51%	111
21	130	90%	116
23	140	77%	108
31	140	6%	9
33	160	62%	100
37	240	50%	121

Table 12. Hourly production and efficiency.

Own construction

On the other hand, the data collected from the "Distribuzione" lines are shown in the following Figure:

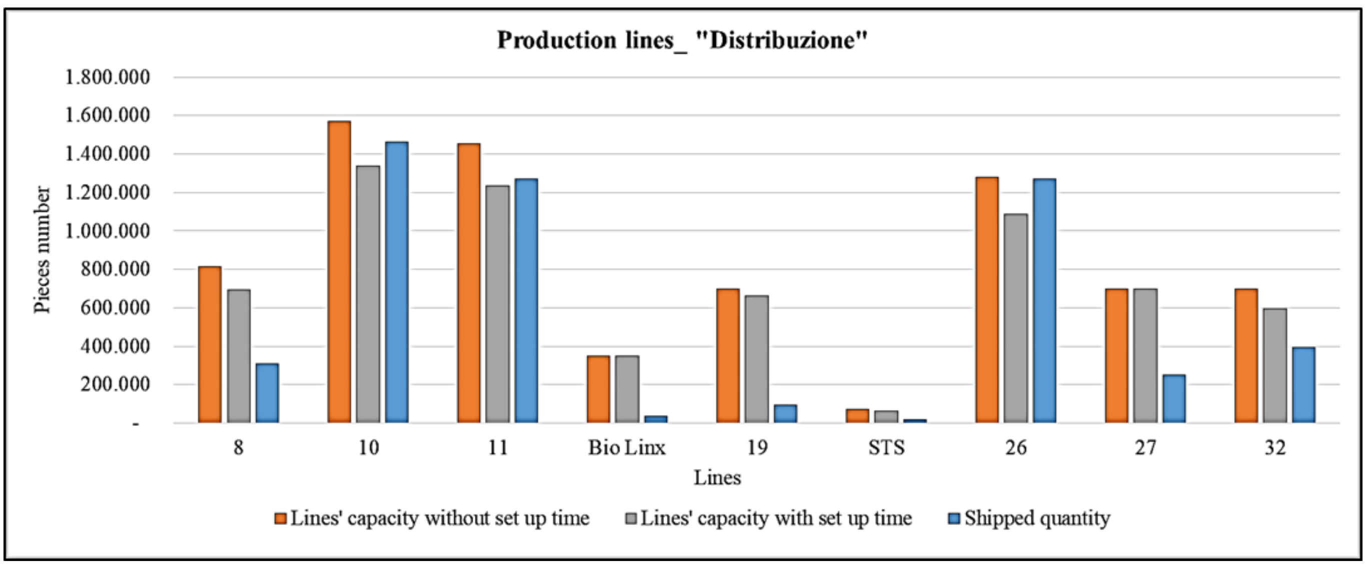


Figure 50. Capacity lines and shipped quantity.

Own construction.

Unlike the "Ausiliari" lines, in the "Distribuzione" category there are three lines (10, 11 and 26) where the quantity of products sent is greater than the actual capacity of the lines. The rest of the lines in this category follow the same behavior as the previous line category, where the quantity shipped is much less than the effective capacity. The Table below shows the calculated hourly production of the "Distribuzione" lines:

"Distribuzione"			
Line	**Calculated hourly production based on 87% of efficiency**	**Real efficiency**	**Real hourly production**
8	140	45%	62
10	270	110%	296
11	250	103%	257
Bio Linx	60	11%	6
19	120	14%	17
STS	12	29%	3
26	220	117%	257
27	120	36%	43
32	120	66%	80

Table 13. Hourly production and efficiency.

Own construction

As can be seen in the Table, only three lines exceed the efficiency of 87%, the rest of them have a very low efficiency, mainly the Bio Linx and 19 lines, with a real production efficiency of 11% and 14% respectively.

In the aforementioned production lines, we can find that the company considers some of them as saturated lines and others are considered critical production lines. These lines and the cost centers are shown in detail in the following Table:

Production Lines	Line	Cost centers
Ausiliari	2	203/2
	3	203/3
	4	20304
	5	20305
	6	203/A
	7	20307
	14	20314
	21	20321
	23	20323
	31	20331
	33	20333
	37	20337
Distribuzione	8	20908
	10	20910
	11	20911
	Bio Linx	20918
	19	20920
	STS	20924
	26	20926
	27	20927
	32	20932

Table 14. Saturated and critical lines.

Own construction

As general information, the cost centers are an identification of the line and its category, where 203 represents the category "Ausiliari" and the 209 represent the category "Distribuzione".

As for the lines that are considered saturated or critical, the company have the next information:

- The lines that are considered saturated (indicated with brown color in the previous Table), are those where the quantity of production orders that must be carried out surpasses the real capacity of the line. The lines that present this characteristic are the lines 2 and 5 of the category "Ausiliari" and the lines 10 and 11 of the class "Distribuzione".

- The lines that are considered critical (marked with red color), are those production lines where the quantity of orders that must be made is very close to the real capacity that machines have currently. For Dayco, only two lines that belong to the "Ausiliari" category are considered critical: line 7 and line 21.

It can be said that approximately 20% of the total final products that the company assembles are produced in the critical and saturated lines, which is a representative percentage.

5.1.2. Causes of production loss

In the company, there are a series of causes observed by the production department that lead to significant manufacturing losses. The main causes that were found were:

- Machines' Maintenance: In some companies, this can be a very important cause of loss of production. In Dayco, due to the machines' maintenance, the plant stops producing around 865.124 pieces per year, which represents a loss of 10.4% of the total production.

- Production' inefficiency: Inefficiency is one of the causes of the recurrent loss of production in the company; therefore, the production department estimated some of the main factors that originate it. The most important causes are long set-up times, employee training, meetings and medical visits, boss interventions, quality tests, extra processing, reprocessing and micro interruptions. The biggest loss of time in the inefficiencies is given by the set up times with 31% of the total time, followed by micro interruptions with 26% and boss interventions with 18%. On the other hand, training, extra processing and quality tests are those that represent a lower percentage with 1%, 2% and 5% respectively.

  Because of these inefficiencies in production, the plant stops producing around 1.374.649 per year, which represents 16.5% of the total production loss.

- Lack of components: According to the data provided by the company, due to the lack of components, the Ivrea plant no longer produces around 155.944 pieces per year, which represents only the 1.9% of the total production loss.

  Being in contact with the scheduling production area, it was observed that in the current situation of the company, the lack of components should represent a greater percentage in the loss of production. This is due to, there are recurrent situations in which the responsible must reprogram the production for the lack of components or have immediate contact with the supplier, in order to reach agreements and thus get a certain amount of the pieces quickly. This indicator does not show its real value, because the lack of material is not recorded correctly by the area in charge.

- Lack of personnel: The lack of personnel is another cause of production loss and has caused the company to lose around 1.297.079 pieces, which represents 15.5% of the total of pieces not assembled.

- Machines' uselessness: The Company contemplates that finally is the machines' uselessness, due to factors mentioned above such as: interruptions for both preventive and corrective maintenance of the machines, lack of components, which can become quite recurrent, lack of personnel, no machines scheduling.
- The machines' uselessness represent a 55.7% of total production loss, with around 4.650.217 pieces no produced.

  The machinery uselessness instead of being considered as a cause should be counted as one of the main consequences of the recurring problems mentioned above. Most of these causes mean that the machines are stopped for a considerable time or that their percentage of use is significantly reduced.
  In addition to the unused of the machines, other consequences that these factors can bring are delays in deliveries (which becomes frequent especially when the products are classified as aftermarket or replacement), constant production reprogramming, unproductive of the plant and increased costs.

Taking into account all the causes of production loss, the percentage of time of stoppages in the machines was calculated, in order to determine which are the most affected lines, which can become the recurrent causes and the relationship with the saturated or critical lines in the process, which are a production restriction.

The following Figure shows the percentage of stoppages in the lines.

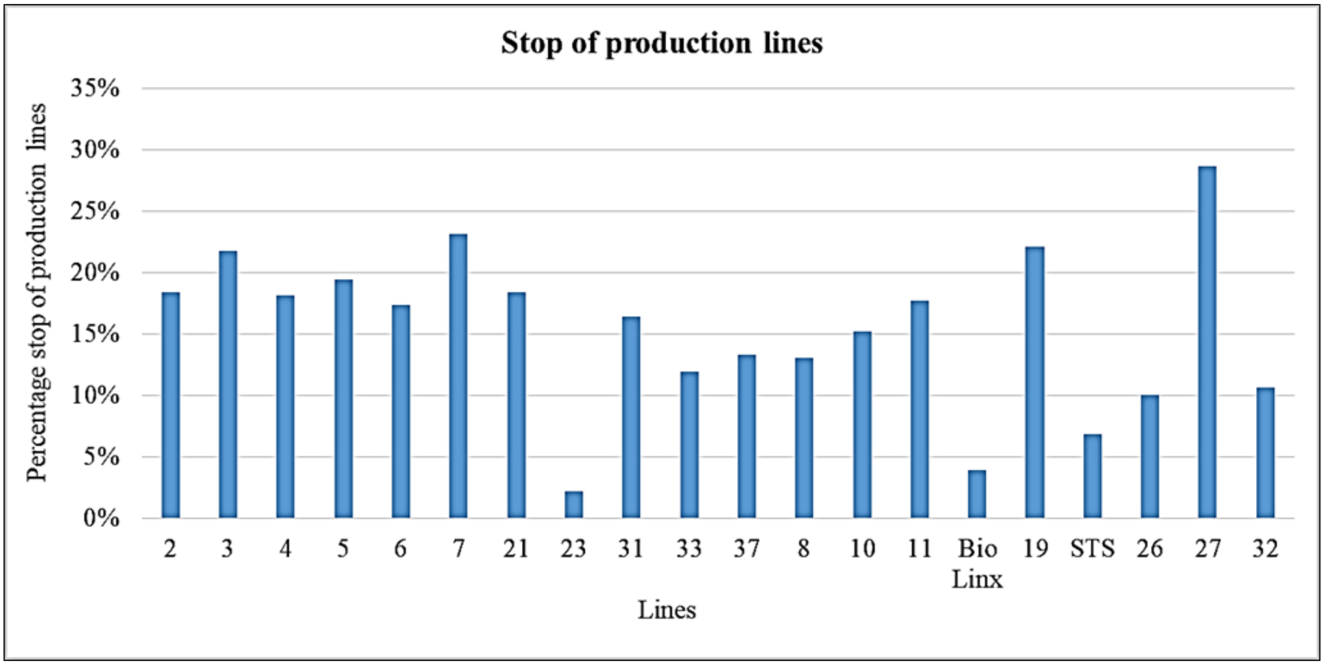


Figure 51. Percentage stop of production lines.

Own construction

As can be seen in the Figure, the line with the longest uselessness with a 29% of stoppages is line 27. Analyzing the data it was found that the main cause of this stoppages is the lack of personnel, which mentioned above, it represents a large percentage of the total loss of production parts. Following is line 7, which is a critical line. In this line, it was observed that the main cause is also the lack of personnel, followed by inefficiency in production. In the other critical and saturated lines, there is also a significant percentage of unproductive times, which change between 15% and 19%.

5.2. Production bottleneck

In the company, based on the experience of the employees and the company's data, a series of possible bottlenecks that affect the correct functioning of the production has been established. The most relevant bottlenecks are:

- *Machine breaks due to lack of preventive maintenance:* The lack of maintenance of the machines causes over time that the parts that compose it wear out and a series of failures occur during the production process. When the machine breaks, it can remain inactive for a considerable time, which is why the production process must stop and with it, the volume of production (output) decreases.
- *Insufficient capacity:* The production lines sometimes do not have enough capacity to process all customer orders, which may have fluctuations a little higher than the forecasts that the company had established. This bottleneck causes the rethinking of the production schedule; since the MRP generated by the business system does not take into account these capacity restrictions, (The MRP states that the company can process all orders with a capacity that could be called infinite, which in reality does not exist). This can generate possible defaults in the deliveries of customer orders.
- *Out of date equipment and no more available spare parts:* The obsolete equipment decreases the production capacity of the company, generating inactivity times that leads to a marked reduction in the output that the company should generate.
- *Production change while producing:* It may happen that while production planning is taking place it changes, causing significant time loss, higher costs and delays. This situation should always be avoided.
- *Set up times:* The long set up times causes that the production is affected, because as it was mentioned previously, in the company the changes in the lines last around a 1 hour, which entails to a remarkable reduction in the hourly pieces production.
- *Staff availability (understaffing):* With the lack of personnel, the production capacity decreases, with which possible delays are generated. Sometimes,

those responsible for planning in Dayco must modify the production program due to the lack of available personnel.

5.3. Lead Times suppliers

Suppliers are a fundamental link in the supply chain, as their behavior and the variability in their deliveries are critical factors that directly influence the subsequent processes of their customers.

Dayco Ivrea handles a considerable number of suppliers, some of them located at great distances such as suppliers from the United States or China. This can make that the Lead Times of components are sometimes very long, which can cause delays in production.

Given that the Lead Times are differentiating elements within the programming of the company's processes, and play an important role in responding appropriately with the delivery times raised to the customer, it was decided to make an analysis of their status. With the data provided by the purchasing department, which is in charge of managing this data, the following graph was constructed and showing the behavior of suppliers Lead Times of Dayco Ivrea.

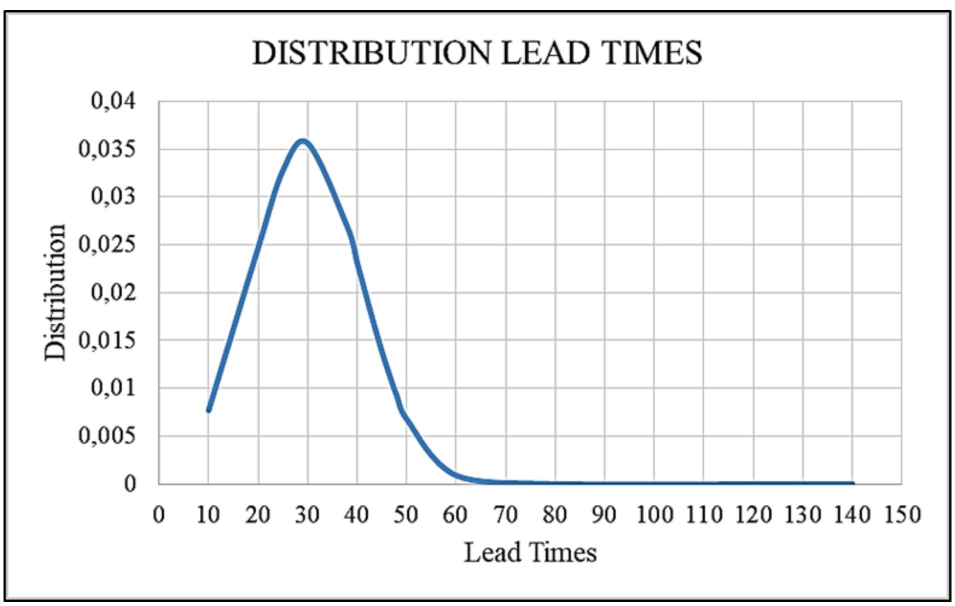


Figure 52. Behavior of suppliers Lead Times.

Own construction

As can be seen in the Figure, the Lead Times vary between 10 and 140 days, depending on many factors such as the geographical position in which the supplier is located as mentioned earlier or the complexity of the parts that are supplied. In turn, it can be noticed that most of these times are concentrated in the center of the graph, which is between 20 and 40 days. As a statistical data, it was found that the standard deviation of these data is 11, 2 days.

5.4. Causes and Effect diagram

With the Ishikawa or fishbone diagram, it can seek to understand what are the possible causes that lead to important failures in the production planning in Dayco Ivrea. The next Figure shows the Ishikawa diagram.

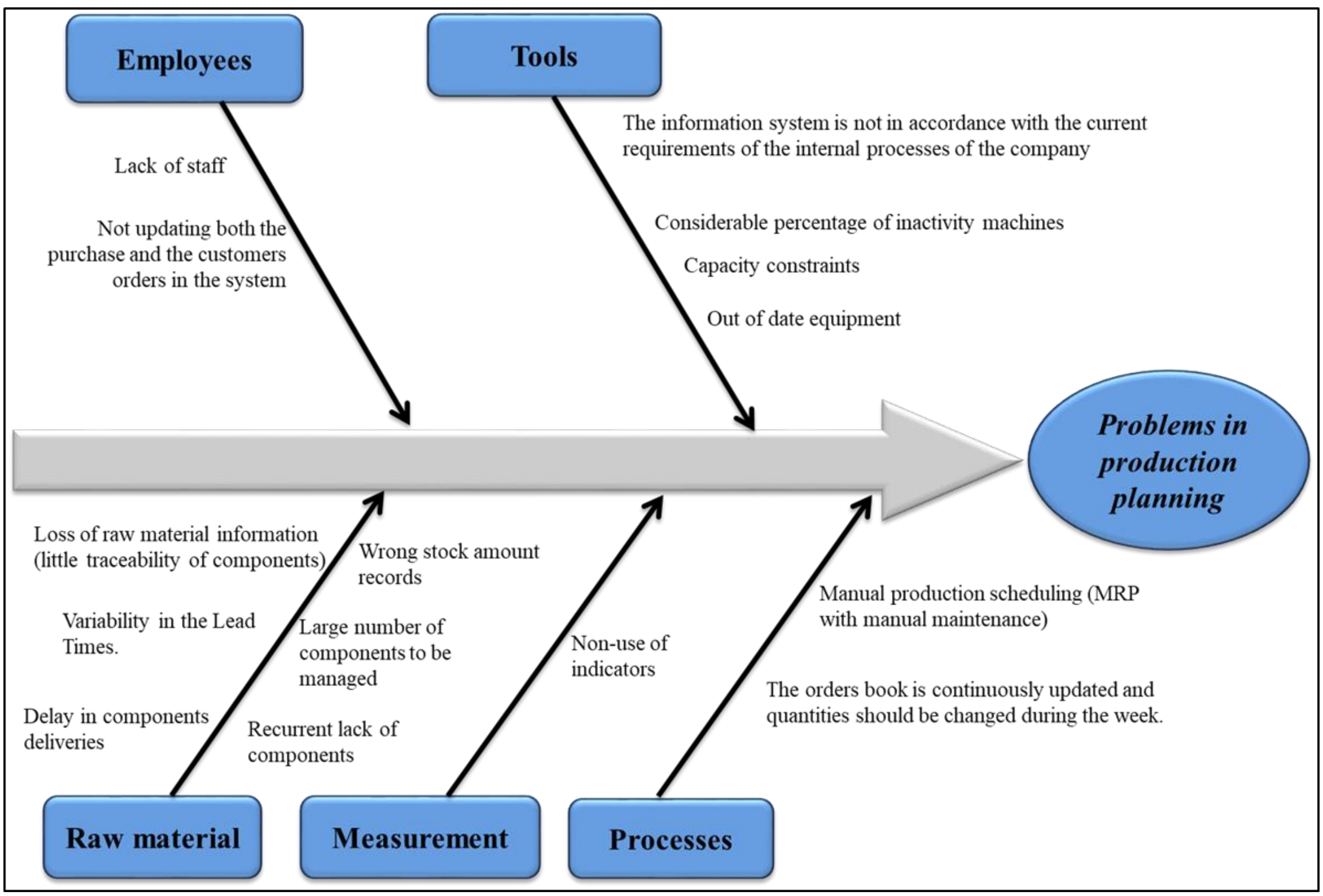


Figure 53. ***Fishbone diagram.***

Own Construction.

As can be seen in the previous Figure, there are a series of macro categories in which the most important causes were classified:

- ***Processes:***

  - ✓ As mentioned above, the production schedule is not automated, the system only shows the general data that helps in the programming and the MRP must have a manual maintenance due to the actual conditions in which the company works. In the firm, the production plan is verified by MRP for the availability of materials, for which the verification of said components may be outdated and misleading.
  - ✓ In this production plant, the orders book is continuously updated and quantities should be changed during the week. The forecasts shown by the system are often variable and with these, the production programmer can only observe and account the deviations presented in the customers' orders. Since the programming of the production is done weekly and manually, these forecasts are not considered part of the planning, on the contrary, these forecasts are useful to send the programs to the suppliers; based on them the company makes its orders.

- ***Measurement:***

  - ✓ In the company, an adequate indicator system is not established, because although there is a series of indicators proposed, these do not reflect the actual conditions of the firm and are not used by those responsible in order to determine improvements in the processes.

- ***Raw material:***

  - ✓ Taking into account the concept of traceability, which is defined as the process used to track all the incoming elements that are used to create, modify or transform a product. It can be said that the company sometimes loses the information of components that are going to be part of the production process, since actually only about 40% of all the components have an established and reliable traceability.

- ✓ There is actually a lot of variability in the Lead Time of the components. These times are previously established with the suppliers, but maybe change depending on the needs or emergencies that arise in the production area. In turn, few data are available of suppliers Lead Times, since the manual management of these data makes it difficult to update and maintain them.
- ✓ By observations made to the processes that are related to production scheduling, it can be said that there are recurrent delays in the delivery of parts by suppliers. The company has a record of the components that are in delay, but do not account for the exact time in which the supplier takes to replace those parts.
- ✓ Sometimes there is a materials shortage due to wrong stock amount records. The lack of constant updating in the database or collection and correct accounting these quantities, can become a factor that is repeated periodically in the company.
- ✓ The company has a large number of components, which makes it difficult to manage them correctly. Materials requirements calculation for all levels of the Bill of Materials corresponding approximately to 1500 components.

CHAPTER 6: METHOD AND RESULTS

As mentioned above, one of the important factors in the production planning is the raw material. In this, the suppliers lead times of some components are high and the variability inherent in these times is considerable, as well as the variability that can occur in the demand of products by customers.

In addition, the company's current MRP does not take into account the capacity restrictions that the plant has, nor does it take into account the quantity of components available in the warehouse at its time of execution. That is why, in order to solve these problems by better management of raw material stock, the implementation of the methodology Demand Driven Material Requirement Planning (DDMRP) is proposed.

The first step to start with the implementation of the methodology, was to find a method that would allow to cleansing the data and thus be able to choose the products with which to work. It was decided to carry out an ABC classification of the final products, where the selection criterion was sales, since the company does not have demand data.

The following Table summarizes the main information obtained from the ABC classification and the Figure 54 shows the Pareto chart.

ZONE	QUANTITY OF ELEMENTS	% PRODUCTS	% ACCUMULATED	% SALES	% ACCUMULATED SALES
A	71	9,47%	9,47%	64,74%	64,74%
B	146	19,47%	28,93%	25,25%	89,99%
C	533	71,07%	100,00%	10,00%	100,00%
TOTAL	750	100,00%		100,00%	

Table 15. Results of ABC products classification.

Own construction.

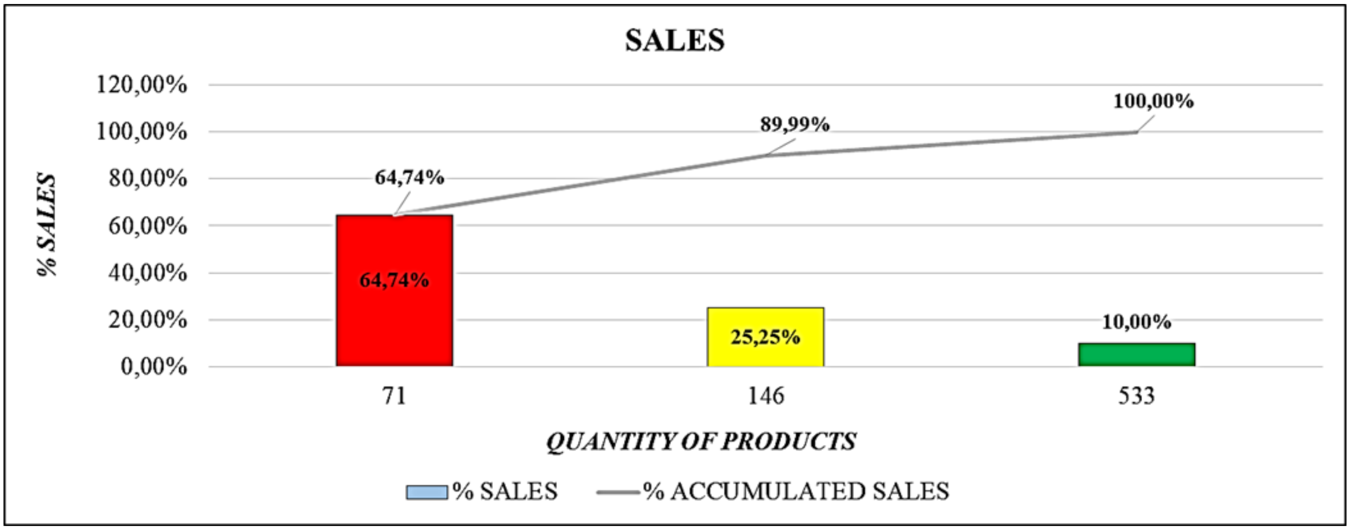


Figure 54. Pareto Chart of ABC products classification.

Own construction.

As can be seen in the Table and the Figure above, classification A covered a total of 71 products, which represent 9.47% of the total products, but 64.74% of the company's total sales, which makes the products immersed in this category are the subject of our study. On the other hand, classification B contains 146 pieces, which represents 19.47% of the total products and 25.25% of the total sales. Finally, there is category C, which is composed of the largest number of products: 533 but represent the lowest percentage in sales: 10%.

As a selection criterion, only the 71 products in category A were taken into consideration, which are as mentioned before the products that represent the highest percentage in sales for the company. Then, in order to determine which the most important products of that category were, another election criterion was used, where it was determined which of the products of the classification A should be assembled in the critical or saturated lines. From this last depuration of data, 23 final products were obtained with which the DDMRP methodology was implemented. The selected products are shown below:

PRODUCT	LINES' CLASSIFICATION	TYPE OF PRODUCT
T1802GA	Ausiliari	First Plant
T0L134FA	Distribuzione	First Plant
T0L228LA	Distribuzione	First Plant
T4802GA	Ausiliari	First Plant
T0L111DA	Distribuzione	First Plant
T0928EA	Ausiliari	First Plant
T0230VA	Ausiliari	First Plant
T9L134EB	Distribuzione	Aftermarket
T0L372FA	Distribuzione	First Plant
T0L0445AB	Distribuzione	First Plant
T2674EA	Ausiliari	First Plant
T9L111FA	Distribuzione	Aftermarket
T0838DB	Ausiliari	First Plant
T1L134FA	Distribuzione	Spare parts
T0427MA	Ausiliari	Spare parts
T0L28MA	Distribuzione	First Plant
T1L372FA	Distribuzione	Spare parts
T0L0430BA	Distribuzione	First Plant
T01203BA	Ausiliari	First Plant
T0L0686AA	Distribuzione	Aftermarket
T2L111DA	Distribuzione	Spare parts
T9L372EA	Distribuzione	Aftermarket
T2L78RA	Distribuzione	First Plant

Table 16. ***End products.***

Own construction.

The previous Table shows the classification of the lines where it can be observed that eight of the final products are manufactured in the "Ausiliari" production lines, the others in the "Distribuzione" lines. On the other hand, most of the products belong to the First Plant, market for which the company has priority regarding the delivery time of the products.

Of the 23 final products that were found by the above-mentioned classification criteria, 219 components (raw material) were obtained with which this study will be carried out.

To continue with the implementation of the DDMRP methodology to the components obtained, two main steps should be considered: the Strategic Inventory Positioning and the definition of their levels.

6.1. Strategic Inventory Positioning

The first step was to start as mentioned in the theoretical framework with the strategic positioning of the Buffers. To determine this strategic position, it is necessary to have the graphic structure (in the form of a tree) of bill of materials (BOM), which was built manually based on the information provided by the AS/400 system.

It is also important to have the routing structure for the products, with which it can have a complete view of the processes through which each of the components goes through to reach the final products. This structure has great importance, because through it is possible identify the points of convergence and divergence found in the productive processes and at the same time the most important Lead Times, with which it can be positioned in a more adequate and complete way the buffers . Unfortunately, the company does not have such information, so for the strategic positioning of the stocks only the list of materials built was used.

6.1.1. Positioning Factors

As cited in the book Demand Driven Material Requirement Planning (Ptak & Smith, 2016), the 6 factors shown below must be applied systematically through the bill of materials, the routing structure, manufacturing facilities and the supply-demand network, in order to determine the best decoupling positions for purchases, production and final products. In the Dayco' case, buffers will not be positioned in the end products.

In addition, taking into account the Manufacturing Lead Time (MLT), the Purchasing Lead Time (PLT) and Cumulative Lead Time (CLT), values inserted in the structure of the BOM, it was obtained that:

- ***Customer Tolerance Time:*** As Dayco is a company immersed in the automotive sector, the customer tolerance time is not applicable, since with the automobile houses important contracts for the supply of the products are signed, which in case of not being respected, would apply heavy penalties to the company.

  In addition to these penalties, there are problems with the IATF certification (applied to the automotive industry), which studies the company's performance and if the results are affected by heavy delays, this certification is put at risk and, therefore, the supply to the entire sector. Due to the above, Dayco considers that the customer tolerance index is equal to zero.

- ***Market potential Lead Time:*** for Dayco this factor could not be applied, since by reducing the delivery time of the products, customers do not have an inclination to pay more for the components they need nor will they increase their orders, since the purchase orders are already in place established. These orders can change, but this depends on the behavior of the market and the needs of the client.

- ***Sales Order Visibility Horizon:*** in Dayco, the system shows at least two months of forecasts given by customers, as mentioned above. As the company works based on a dependent demand, the customer makes these forecasts. The number of months of forecasts that the programmer can observe in the system depends on each client, some of them can let the company know up to 6 months or more of forecasts. The person in charge can see all the customer orders of the first two months separated by weeks, the rest of the forecasts are shown monthly. It can be considered that the visibility in the orders can become relatively low, which is why it is difficult to have a good capacity so that the environment can observe the possible peaks in demand, obtaining relevant data from it.

It must be borne in mind that orders can become very variable from one week to the next, so the production schedule as mentioned above must be done manually.

- ***External Variability***

- ✓ **Variable rate of demand:** Since the company is not responsible for predicting or analyzing the demand, the mathematical methods currently used to construct forecasts with which to determine a variable behavior in customer demand can not be applied, which is why it had to be determined said variability analytically. It can be said that the company manages an average variability, where the peaks in demand are occasional.

  There are no frequent peaks in orders that could collapse the company's resources, but there is also no stable demand, as the requirements of customers can vary as mentioned between weeks.

- ✓ **Variable rate of supply:** The Company does not have the records where the promised delivery dates of the components by the suppliers and their actual date of receipt can be observed, for which the variability of the offer could not be determined mathematically. Analytically, and through a file provided by the purchasing department, where there is a slight evaluation of some suppliers, it was determined that, in general, the variability in the supply is medium. From there, some of the suppliers that according to the evaluation tend to have higher variability in their deliveries were determined, with which they could become unreliable suppliers in the future. With this criterion, it was decided to implement buffers in the following components:

COMPONENTS	PRODUCT	DESCRIPTION
TB075EB	T0230VA	ARM
TB300DA	T0838DB	ARM
TB470AA	T1802GA	ARM
	T4802GA	
TBL170AA	T0L0430BA	ARM
TBL72AB	T0L0445AB	ARM
TF056B	T0230VA	PIVOT COVER
TF067HA	T0427MA	PIVOT COVER
	T2674EA	
TF151CA	T1802GA	SPRING CASE
	T4802GA	
TF155BB	T0838DB	SPRING CASE
TFL19E	T0L28MA	SUPPORT PLATE
TFL38EA	T0L0686AA	SUPPORT PLATE
TFL69BA	T0L228LA	SUPPORT PLATE
TGL17E	T0L28MA	PIVOT TUBE
TGL49KA	T0L0686AA	PIVOT TUBE
TKL139AB	T0L0430BA	END CAP
TKL14G	T0L28MA	END CAP
TKL28DB	T2L78RA	END CAP
TKL80CB	T0L228LA	END CAP
TL907AA	T0928EA	METAL PULLEY
TN008EA	T1802GA	DUST COVER
	T4802GA	
TN076AB	T01203BA	DUST COVER
TP062BA	T2674EA	BOLT
TP092A	T0230VA	BOLT
	T0427MA	
TP202AB	T2674EA	VITE TORX
TP205AA	T01203BA	BOLT
TP208AA	T0L228LA	BOLT
TP282BA	T0928EA	BOLT

Table 17. Components with medium-high supplier's variability.

Own construction.

- *Inventory Leverage and Flexibility:* as for the components in the production process, the springs and bushing are considered critical elements. The bushing are considered critical, since only two important suppliers are available for their supply, which are already reaching their capacity limit. For the springs, the situation is similar because an American establishment, which apart from having a distant geographical position has some capacity problems, provides them.

On the other hand, there is a variety of raw materials shared among the final products. Taking into account the above information, a selection was made of the components that meet these conditions, to which buffers were positioned, from which it was obtained that:

COMPONENT	FINAL PRODUCT NUMBER	FINAL PRODUCT	DESCRIPTION
TBL09G	3	T0L111DA	Arm
		T2L111DA	
		T9L111FA	
TBL51BC	3	T0L372FA	Arm
		T1L372FA	
		T9L372EA	
TCL13CA	3	T0L372FA	Plastic ring
		T1L372FA	
		T9L372EA	
TCL28B	3	T0L111DA	Support spring
		T2L111DA	
		T9L111FA	
TCL40AE	3	T0L372FA	Support spring
		T1L372FA	
		T9L372EA	
TCL82AB	3	T0L134FA	Support spring
		T1L134FA	
		T9L134EB	
TDL19E	3	T0L111DA	Main spring
		T2L111DA	
		T9L111FA	
TDL78FA	3	T0L372FA	Main spring
		T1L372FA	
		T9L372EA	
TEL10E	3	T0L111DA	Pivot bushing
		T2L111DA	
		T9L111FA	

COMPONENT	FINAL PRODUCT NUMBER	FINAL PRODUCT	DESCRIPTION
TEL127AA	3	T0L134FA	intermediate component- Washed bushing (Divergent point)
		T1L134FA	
		T9L134EB	
TEL12C	3	T0L372FA	Pivot bushing
		T1L372FA	
		T9L372EA	
TEL22B	3	T0L111DA	Intermediate component- Washed bushing
		T2L111DA	
		T9L111FA	
TEL37B	3	T0L111DA	Intermediate component- Dried bushing
		T2L111DA	
		T9L111FA	
TEL44A	3	T0L372FA	Intermediate component- Dried bushing
		T1L372FA	
		T9L372EA	
TEL45A	3	T0L372FA	Intermediate component- Washed bushing
		T1L372FA	
		T9L372EA	
TEL79AA	4	T0L0430BA	Bushing
		T0L134FA	
		T1L134FA	
		T9L134EB	
TFL17E	4	T0L0445AB	Support plate
		T0L111DA	
		T2L111DA	
		T9L111FA	
TGL10J	3	T0L111DA	Pivot tube
		T2L111DA	
		T9L111FA	
TGL116AB	3	T0L372FA	Intermediate component- Washed Pivot tube
		T1L372FA	
		T9L372EA	
TGL154AA	3	T0L372FA	Pivot tube
		T1L372FA	
		T9L372EA	
TGL30E	3	T0L111DA	Intermediate component- Assembly: Pivot tube + Platelet
		T2L111DA	
		T9L111FA	
TGL36D	3	T0L111DA	

COMPONENT	FINAL PRODUCT NUMBER	FINAL PRODUCT	DESCRIPTION
		T2L111DA	Intermediate component- Washed Pivot tube
		T9L111FA	
TGL41AC	3	T0L372FA	Pivot tube
		T1L372FA	
		T9L372EA	
TGL92AA	3	T0L134FA	Pivot tube
		T1L134FA	
		T9L134EB	
TKL10F	3	T0L111DA	End cap
		T2L111DA	
		T9L111FA	
TL469AB	3	T0L372FA	Metal pulley
		T1L372FA	
		T9L372EA	
TQ127A	3	T0L134FA	Intermediate component- Pulley cover
		T1L134FA	
		T9L134EB	

Table 18. . Raw material shared.

Own construction

As can be seen in the Table, these 27 components are raw materials shared between the end products and most of them are bushing or springs, which are critical pieces.

- *Critical operation protection:* in this case, for Dayco, the critical lines should be protected, because they determine the rhythm in the production and the speed in the plant. In turn to, internal operations such as sub-assemblies must be protected, so that production can be fluid in its operations.

  Through this criterion, no additional buffer was implemented. The critical lines are protected, since the products and components selected to apply this methodology are assembled in these critical points of the plant, and on the other hand, the most relevant sub-assemblies were protected by the above criteria.

Another important factor to strategically establish the buffers is to take into account the longer lead times, thus reducing a bit of the variability that the supplier may have and thus isolating it from the process. Using the Pareto principle, it was decided to establish some decoupling points in the BOM. In this case, a 90/10 ratio was used and it was found that around 90% of Lead Times suppliers are between 10 and 42 days.

Replenishment times greater than 42 days will be strategic points for the implementation of Lead Times. The following table shows the aforementioned:

LEAD TIMES	PERCENTAGE
10	6,40%
20	10,90%
25	17,47%
30	48,79%
38	1,38%
40	4,84%
42	2,42%
43	0,87%
45	2,60%
47	0,69%
48	0,69%
50	0,87%
60	0,52%
80	1,38%
140	0,17%

Table 19. Percentage of Lead Times.

Own construction

With this criterion, the following decoupling points were established for the process:

COMPONENT	PRODUCT
TKL79EA	T0L134FA
	T1L134FA
TFL54CA	T0L134FA
	T1L134FA
TL448AA	T0L134FA
	T1L134FA
TL983AA	T9L134EB
TKL144AB	T0L0445AB
TK105BA	T0838DB
TFL32D	T2L78RA

Table 20. High Suppliers Lead Times.

Own construction

Finally, taking into account the previously explained criteria, it was decided to implement 61 buffers, which represents 28% of the total components under study.

The previously selected buffers were entered in all the diagrams of the created Bill of Material. In order to illustrate the result of this implementation, the following Figures show the structure of two diagrams of the bill of materials with the decoupling points (buffers) introduced in the process and without the implementation of these strategic places, that is, the BOM that the company currently manages. The rest of them can be found in the appendix section.

First BOM diagram: Product T0L134FA

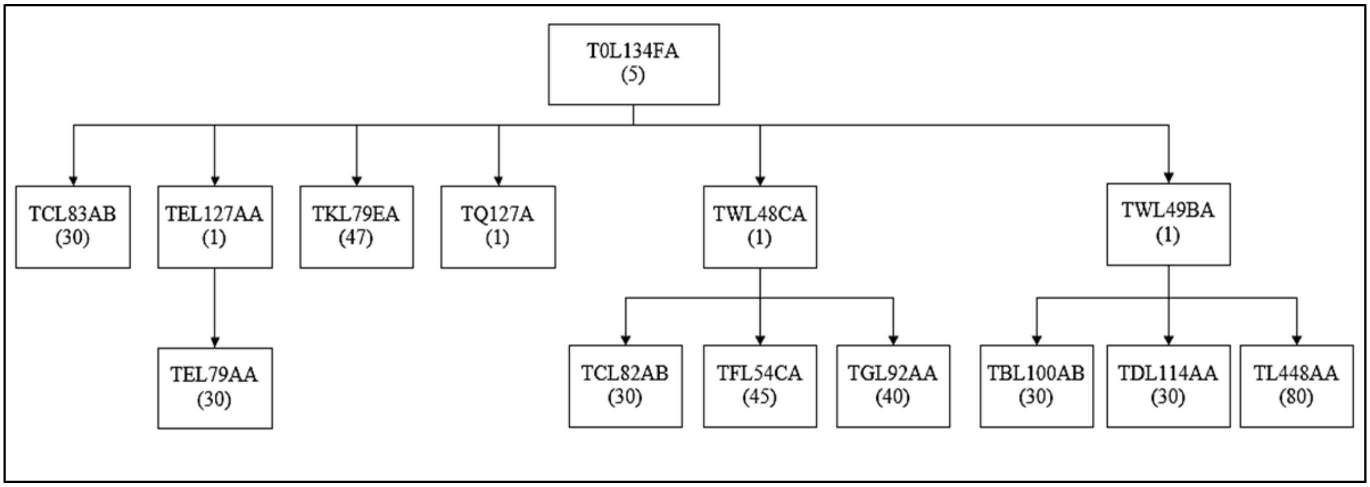


Figure 55. Bill of Material (TOL134FA).

Own construction.

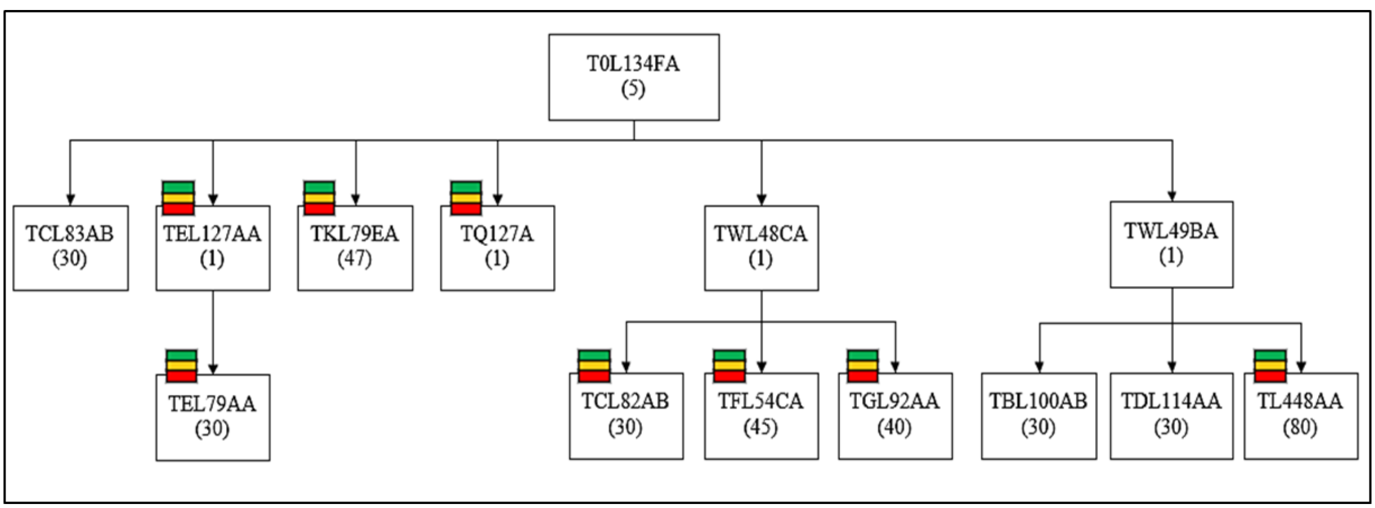


Figure 56. Bill of Material with buffers (TOL134FA).

Own construction.

Second BOM diagram: Product T0L111DA

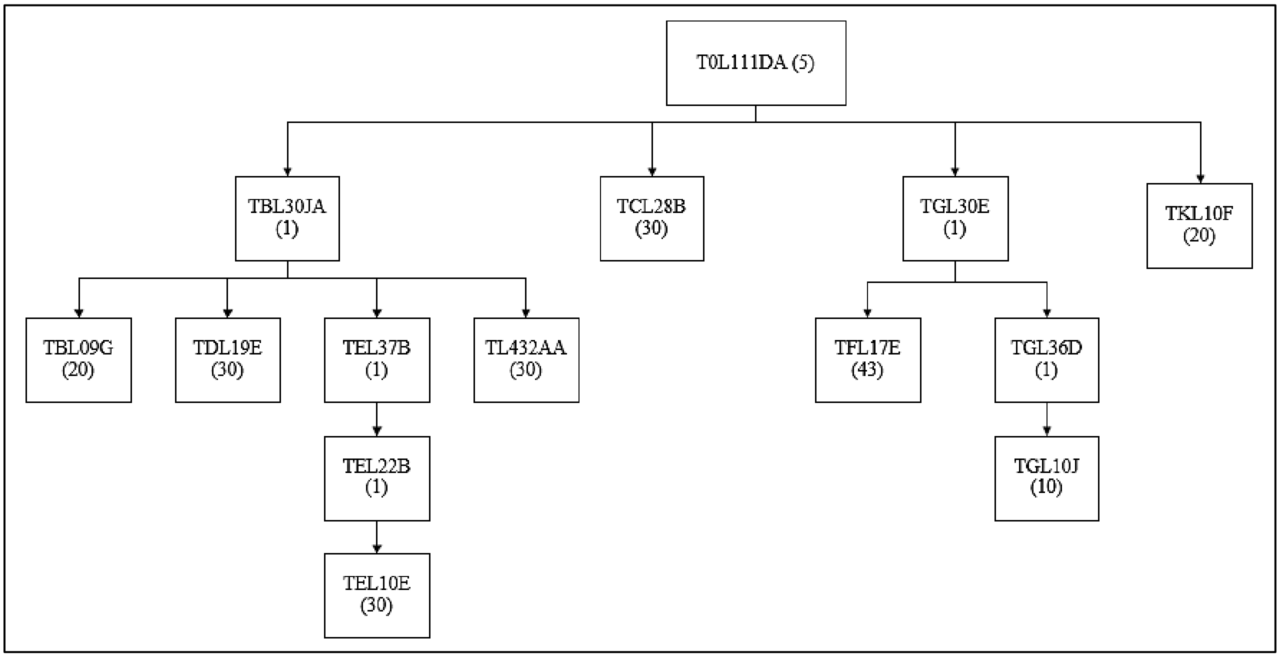


Figure 57. Bill of Material (T0L111DA).

Own construction.

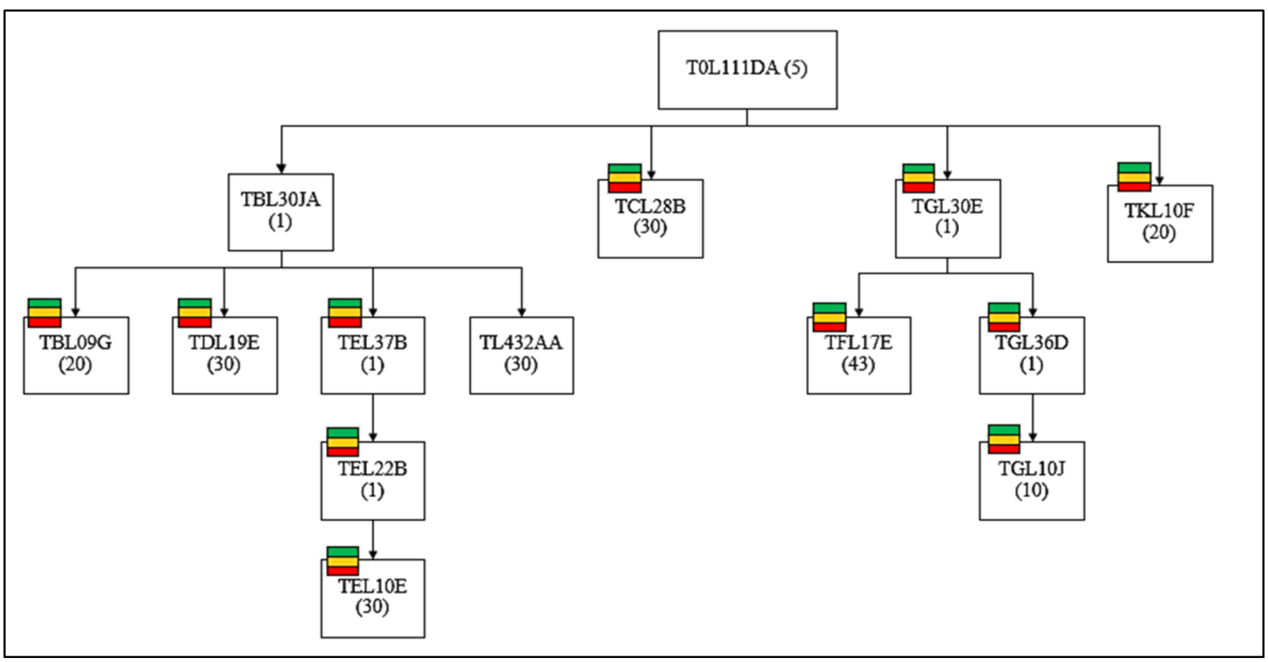


Figure 58. Bill of Material with buffers (T0L111DA).

Own construction.

Taking into account the buffers that were implemented so far in the BOM diagrams, a new form of Lead Time was obtained, known as Decoupled Lead Time (DLT) or Actively Synchronized Replenishment Lead Time (ASRL), replacement time that can become an indicator of the benefits that the implementation of said inventories brings.

In order to illustrate these concepts, the previous Figures are taken into account.

Figure 55 shows the structure of the BOM of the product T0L134FA, which has a Cumulative Lead Time of 81 days, while with the implementation of the decoupling points the DLT is of 36 days noticing a notable reduction. The structure of the product T0L111DA shows a Cumulative Lead Time of 44 days while the DTL takes a value of 36 days.

The following Figure shows a comparison between the Cumulative Lead Time and the Decoupled Lead Time of the selected final products.

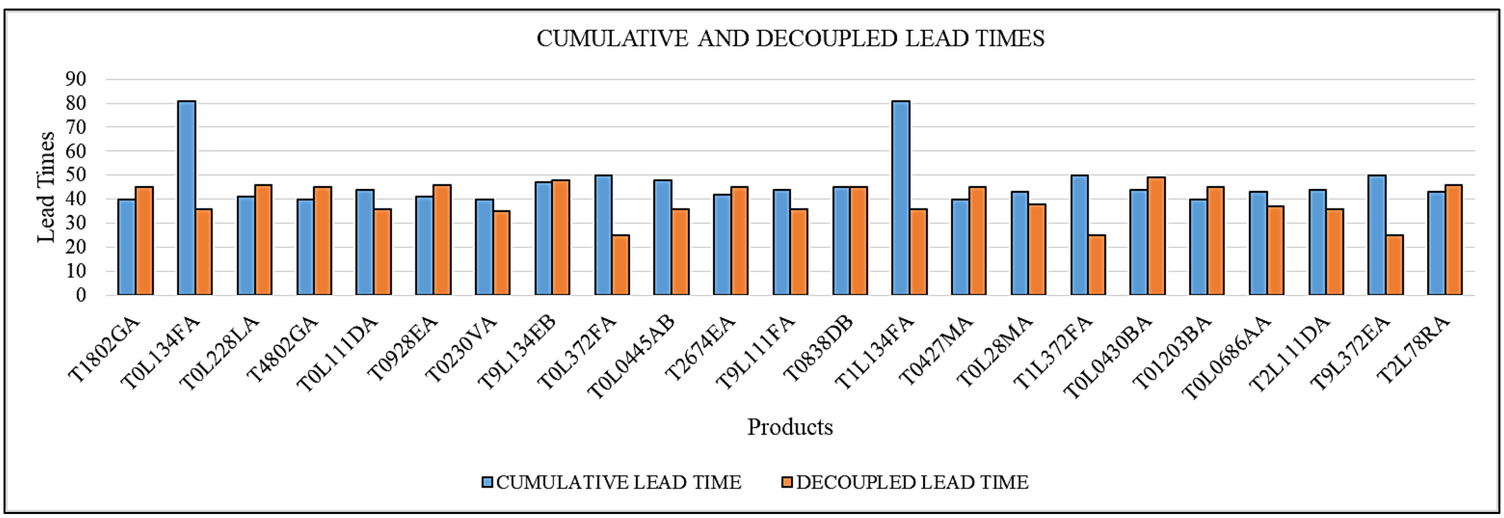


Figure 59. Cumulative and decoupled Lead Times.

Own construction

As can be seen, the implementation of buffers plays an important role to achieve a significant reduction in the lead times of some products, especially in these: T0L134FA, T0L372FA, T1L134FA, T1L372FA and T9L372EA. In general, it can be see that a little more than half of the products Lead Times are reduced with the decoupling points' implementation. It can now be said that in some cases the DLT of the products becomes larger because these always include the manufacturing Lead Time of the parent (end product).

A clear example is the product T0L134FA as mentioned above, that there is a CLT that does not take into account the decoupling points for the process, which would be equal to 81 days, because the Lead Time of component TL448AA is very high (80 days). On the other hand, by strategically positioning some buffers, the DLT would have a value equal to 36 days, thus reducing 42% of the delivery time of said product.

As they expose it in their book (Ptak & Smith, 2016), many companies have a significant amount of shared parts or components, places where Bill of Materials overlap. This fact, combined with the concept of Decoupled Lead Time, shows opportunities that were previously far from most of these companies. In order to determine if there are still possible strategic positions to implement the buffers, the BOM Matrix was made, which shows the relationship between the components and their "parents", which can be both components and final products.

Because of the application of the BOM Matrix to the final 23 products and their components (219 pieces), it can be said that the strategic position of the buffers before mentioned is the correct one. One of the things that is sought with the implementation of the BOM Matrix is to find new important decoupling points in the critical path of each product and its components, in order to reduce significantly the total Lead Time and thus have no end product inventory. As the company does not have inventory of final product, no analysis of new strategic positions for new components that would allow decoupling said products, as proposed by the Matrix, was carried out. Furthermore, when introducing the DLT in this matrix, no relevant places were found where to locate another one decoupling points.

6.2. Buffer profiles and levels

Buffers are the fundamental basis of DDMRP systems. As mentioned in the theoretical framework, the DDMRP uses some storage methods of buffer. For Dayco, the Replenished Parts system could be used, where the buffers divided into 3 zones for the correct planning should be strategic and dynamic.

To calculate the level of the three zones of the buffers: Green, yellow and red, a combination must be made between two important factors that are the buffer profiles and the individual part attributes.

6.2.1. Factors that influence the level of buffers

*6.2.1.1. **Buffer profiles***

As mentioned, the profiles are those groupings that can be done between the items, looking for certain representative characteristics in them. Within these profiles, the following factors were taken into account:

- ***Item Type:*** The company does not handle inventory of final product, which only took into account two categories of items: the purchased parts and the intermediate pieces that are those parts that require some type of procedure before being used in the final product, such as the components that are sub-assemblies or pieces that must be washed, dried or that require some change in their structure.

- ***Lead Time:*** To determine if the Lead Time of each of the pieces was short, medium or long, the following classification of these times was considered as observed in the company.

LEAD TIME	
DAYS	**CLASSIFICATION**
0-21	Short
22-42	Medium
43 +	Long

Table 21. Lead Time classification.

Own construction

- ***Variability:*** For this factor, only the variability of the supply of the pieces was taken into account. To carry out its classification, as for the Lead Time, a heuristic order was proposed according to the data provided by the company, which in this case showed a rating given to the suppliers by the purchasing office.

VARIABILITY	
QUALIFICATION	**CLASSIFICATION**
86-100	Low
53-85	Medium
0-52	High

Table 22. Variability classification.

Own construction

Because of the implementation of the aforementioned categories, the classification of the pieces can be seen in the following Table.

	BUFFER PROFILES					
COMPONENT	ITEM TYPE	LEAD TIME	LEAD TIME FACTOR	VARIABILTY	VARIABILITY FACTOR	ITEM FINAL CLASSIFICATION
TBL09G	Purchase (p)	Short	0,8	Medium	0,5	PSM
TBL51BC	Purchase (p)	Long	0,3	Medium	0,5	PLM
TCL13CA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TCL28B	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TCL40AE	Purchase (p)	Medium	0,5	High	0,85	PMH
TCL82AB	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TDL19E	Purchase (p)	Medium	0,5	Low	0,33	PML
TDL78FA	Purchase (p)	Medium	0,5	Low	0,33	PML
TEL10E	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TEL127AA	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TEL12C	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TEL22B	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TEL37B	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TEL44A	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TEL45A	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TEL79AA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TFL17E	Purchase (p)	Long	0,3	Medium	0,5	PLM
TGL10J	Purchase (p)	Short	0,8	Medium	0,5	PSM
TGL116AB	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TGL154AA	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TGL30E	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TGL36D	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TGL41AC	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TGL92AA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TKL10F	Purchase (p)	Short	0,8	High	0,85	PSH
TL469AB	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TQ127A	Intermediate (I)	Short	0,8	Medium	0,5	ISM
TB075EB	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TB300DA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TB470AA	Purchase (p)	Medium	0,5	High	0,85	PMH
TBL170AA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TBL72AB	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TF056B	Purchase (p)	Short	0,8	High	0,85	PSH
TF067HA	Purchase (p)	Short	0,8	High	0,85	PSH
TF151CA	Purchase (p)	Medium	0,5	High	0,85	PMH
TF155BB	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TFL19E	Purchase (p)	Medium	0,5	High	0,85	PMH
TFL38EA	Purchase (p)	Medium	0,5	High	0,85	PMH

	BUFFER PROFILES					
COMPONENT	ITEM TYPE	LEAD TIME	LEAD TIME FACTOR	VARIABILTY	VARIABILITY FACTOR	ITEM FINAL CLASSIFICATION
TFL69BA	Purchase (p)	Medium	0,5	High	0,85	PMH
TGL17E	Purchase (p)	Medium	0,5	High	0,85	PMH
TGL49KA	Purchase (p)	Medium	0,5	High	0,85	PMH
TKL139AB	Purchase (p)	Short	0,8	High	0,85	PSH
TKL14G	Purchase (p)	Short	0,8	High	0,85	PSH
TKL28DB	Purchase (p)	Short	0,8	High	0,85	PSH
TKL80CB	Purchase (p)	Short	0,8	High	0,85	PSH
TL907AA	Purchase (p)	Medium	0,5	High	0,85	PMH
TN008EA	Purchase (p)	Short	0,8	High	0,85	PSH
TN076AB	Purchase (p)	Medium	0,5	High	0,85	PMM
TP062BA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TP092A	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TP202AB	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TP205AA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TP208AA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TP282BA	Purchase (p)	Medium	0,5	Medium	0,5	PMM
TKL79EA	Purchase (p)	Long	0,3	Medium	0,5	PLM
TFL54CA	Purchase (p)	Long	0,3	Medium	0,5	PLM
TL448AA	Purchase (p)	Long	0,3	Medium	0,5	PLM
TL983AA	Purchase (p)	Long	0,3	Medium	0,5	PLM
TKL144AB	Purchase (p)	Long	0,3	Medium	0,5	PLM
TK105BA	Purchase (p)	Long	0,3	Medium	0,5	PLM
TFL32D	Purchase (p)	Long	0,3	Medium	0,5	PLM

Table 23. Buffer profiles

Own construction

The next Figure shows in a summarized way the result of the components' classification according to the categories previously seen.

LEAD TIME CATEGORY	VARIABILITY CATEGORY	ITEM TYPE: PURCHASED	ITEM TYPE: INTERMEDIATE
SHORT	LOW		
SHORT	MEDIUM	TBL09G, TGL10J	TEL127AA, TEL22B, TEL37B, TEL44A, TEL45A, TGL116AB, TGL154AA, TGL30E, TGL36D, TQ127A
SHORT	HIGH	TKL10F, TF056B, TF067HA, TKL139AB, TKL14G, TKL28DB, TKL80CB,TN008EA	
MEDIUM	LOW	TDL19E, TDL78FA	
MEDIUM	MEDIUM	TCL13CA, TCL28B, TCL82AB, TEL10E, TEL12C, TEL79AA, TGL41AC, TGL92AA, TL469AB, TB075EB, TB300DA, TBL170AA, TBL72AB, TF155BB, TN076AB, TP062BA, TP092A, TP202AB, TP205AA, TP208AA, TP282BA	
MEDIUM	HIGH	TCL40AE, TB470AA, TF151CA, TFL19E, TFL38EA, TFL69BA, TGL17E, TGL49KA, TL907AA	
LONG	LOW		
LONG	MEDIUM	TBL51BC, TFL17E, TKL79EA, TFL54CA, TL448AA, TL983AA, TKL144AB, TK105BA, TFL32D	
LONG	HIGH		

Figure 60. Summary of buffer profiles.

Own construction

As can be seen in the Figure, the category with the largest number of components is the Purchased- Medium- Medium (PMM) followed by Intermediate- Short- Medium (ISM), Purchased- Medium- High (PMH) and Purchased- Long-Medium (PLM).

6.2.1.2. ***Individual part attributes***

The individual part attributes that were taken into account to determine the buffer zone levels were Average Daily Usage (ADU), Lead Time and Minimum Order Quantity (MOQ). With the data provided by the company, the following results were obtained:

	INDIVIDUAL PART ATTRIBUTES		
COMPONENTS	**ADU**	**LEAD TIME/ DECOUPLED LEAD TIME**	**MOQ**
TBL09G	1.254	20	20.000
TBL51BC	1.288	50	60.000
TCL13CA	1.288	30	10.000
TCL28B	1.254	30	9.600
TCL40AE	1.288	30	11.764
TCL82AB	2.019	30	16.000
TDL19E	1.254	30	6.481
TDL78FA	1.288	30	6.481
TEL10E	1.254	30	8.173
TEL127AA	2.019	1	
TEL12C	1.288	30	8.173
TEL22B	1.254	1	
TEL37B	1.254	1	
TEL44A	1.288	1	
TEL45A	1.288	1	
TEL79AA	2.290	30	9.308
TFL17E	1.534	43	21.000
TGL10J	1.254	10	2.688
TGL116AB	1.288	1	
TGL154AA	1.288	1	
TGL30E	1.254	1	
TGL36D	1.254	1	
TGL41AC	1.288	40	50.000
TGL92AA	2.019	40	30.000
TKL10F	1.254	20	20.000
TL469AB	1.288	30	1.620
TQ127A	2.019	1	
TB075EB	630	25	1.296
TB300DA	259	30	1.728
TB470AA	2.565	30	25.000
TBL170AA	271	25	4.725
TBL72AB	280	30	2.592
TF056B	630	20	2.000
TF067HA	680	20	2.000
TF151CA	2.565	30	2.500
TF155BB	259	30	2.592
TFL19E	159	42	20.000
TFL38EA	389	42	20.000

	INDIVIDUAL PART ATTRIBUTES		
COMPONENTS	**ADU**	**LEAD TIME/ DECOUPLED LEAD TIME**	**MOQ**
TFL69BA	1.239	40	20.000
TGL17E	159	30	4.407
TGL49KA	389	30	11.371
TKL139AB	271	20	20.000
TKL14G	159	20	20.000
TKL28DB	361	20	20.000
TKL80CB	1.239	20	20.000
TL907AA	245	30	25.650
TN008EA	2.565	20	10.000
TN076AB	89	38	10.000
TP062BA	407	40	13.000
TP092A	903	40	13.000
TP202AB	407	42	12.000
TP205AA	89	40	13.000
TP208AA	1.239	40	13.000
TP282BA	245	40	13.000
TKL79EA	1.462	47	25.000
TFL54CA	1.462	45	25.000
TL448AA	1.462	80	7.000
TL983AA	557	45	15.600
TKL144AB	280	48	8.000
TK105BA	259	45	6.000
TFL32D	361	43	47.000

Table 24. ADU, Lead Time and MOQ.

Own construction.

From the previous Table it was observed that the Average Daily Usage in the production process varies between 89 and 2.565 parts. The pieces with the highest value of the ADU are TB470AA, TF151CA, TN008EA and those with the lowest value are TN076AB and TP205AA. This ADU was calculated based on historical data of the company, since there are no forecasts. The ADU of components was calculated as the sum of the final products and the amount that is needed of each piece for its assembly. The fact that these components maybe are sold on its own was not taken into account.

The following Figure shows the behavior adopted by the ADU of the 61 components under study.

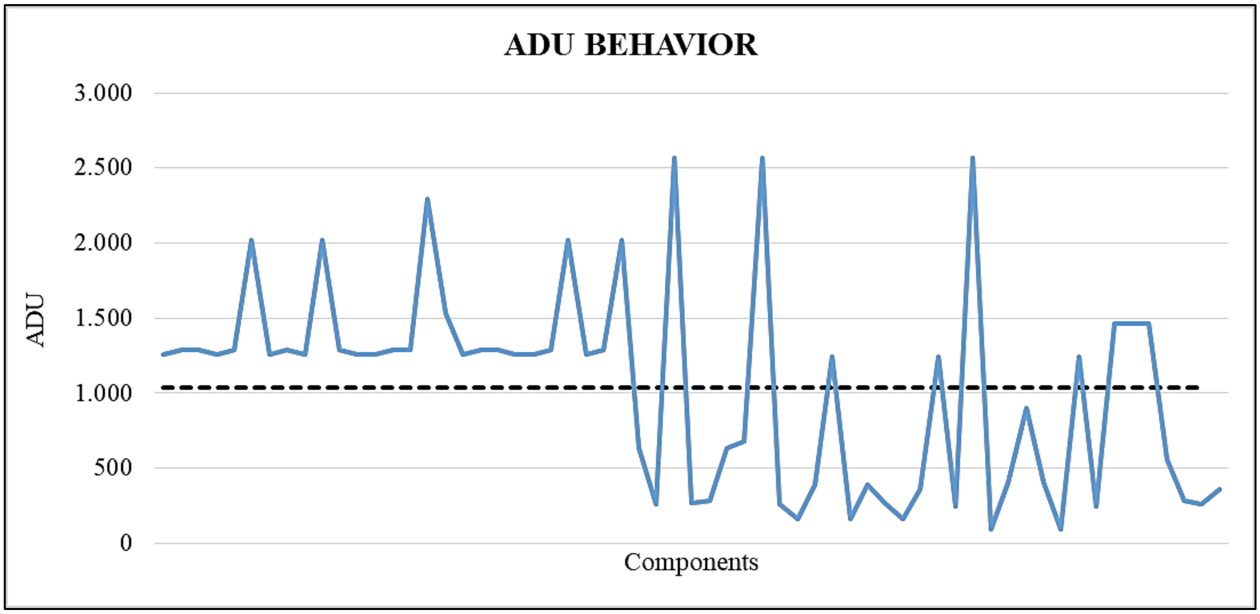


Figure 61. ADU Behavior.

Own construction

As can be seen in the Figure, the behavior of the ADU is quite variable; it is an unstable series where you can see an extensive gap between the data obtained, since several of the components have an ADU rather high while those others very pretty low. The data shows peaks far from the average, which is 1035 pieces per day. This analysis could be carried out in a robust manner if the current demand data and future demand forecasts are available with which to observe how much the data is adjusted to the actual behavior that the company has at the time.

As for the minimum order quantity MOQ, it can be said that there are also large differences in their values, where the item with the highest MOQ is the TBL51BC and the component with the lowest value is the TB075EB with 60,000 and 1,296 respectively.

6.2.2. Buffers levels

Based on the criteria described above (Profiles of the buffers and individual parts attributes), the pertinent calculations were carried out to determine the correct levels of each one of the areas of the proposed buffers.

For the calculation of the green zone for each one of the buffers as set out in the book of (Ptak & Smith, 2016), these three important criteria were taken into account: the minimum order cycle, which in this case would be of 8 days, since the production schedule in the company is carried out weekly. Another criterion that was evaluated was the Lead Time factor and finally the minimum order quantity. Through these criteria, three different calculations were obtained for the green zone level, after which the criterion chosen for the level with the highest value was chosen.

The yellow zone, as the theory indicates, is the easiest area to calculate, and only the value of the ADU and Decoupled Lead Time is taken into account.

Finally, the calculations were made for the red zone, for which the red base was first established, then the red security and finally the final level of the red zone was obtained.

In order to show a schema with the data of one of the proposed buffers, the component TL448AA was taken as an example, which is part of the Bill of Material of the product T0L134FA previously shown. The next Table shows the information:

BUFFER WORKSHEET (TL448AA)			
Average Daily Usage (ADU)	1.462	**Green Zone**	**35.086**
Buffer profiles	P, L (0,3), M (0,5)	**Yellow Zone**	**116.954**
Minimum Order Quantity (MOQ)	7.000	**Red Zone**	**52.629**
Order Cycle	8	**Total Buffer (Top of green)**	**204.669**
Lead Time	80		

Table 25. Buffer Calculation of component TL448AA.

Own construction.

The previous Table shows the calculations of the buffer with this data: buffer profiles, individual attributes of the pieces, the obtained zone levels and the calculation of the total buffer.

With the above data, you can establish certain relevant analyzes such as what is the average order frequency, which is defined as the relationship between the green zone and the ADU. For this particular component the order frequency is 24, which means that on average and without taking into account the immersed variability that exists in the component, the company can order on average this piece every 24 days

It can also observe the relationship that exists between the yellow zone and the green zone. For this component, an approximate value of three was obtained, which means that the company can expect to have three open orders of this piece at the same time at a given time, that is, three orders in transit. The complete data of all the components are shown in the appendices. The Figure 62 shows the component buffer size of TL448AA.

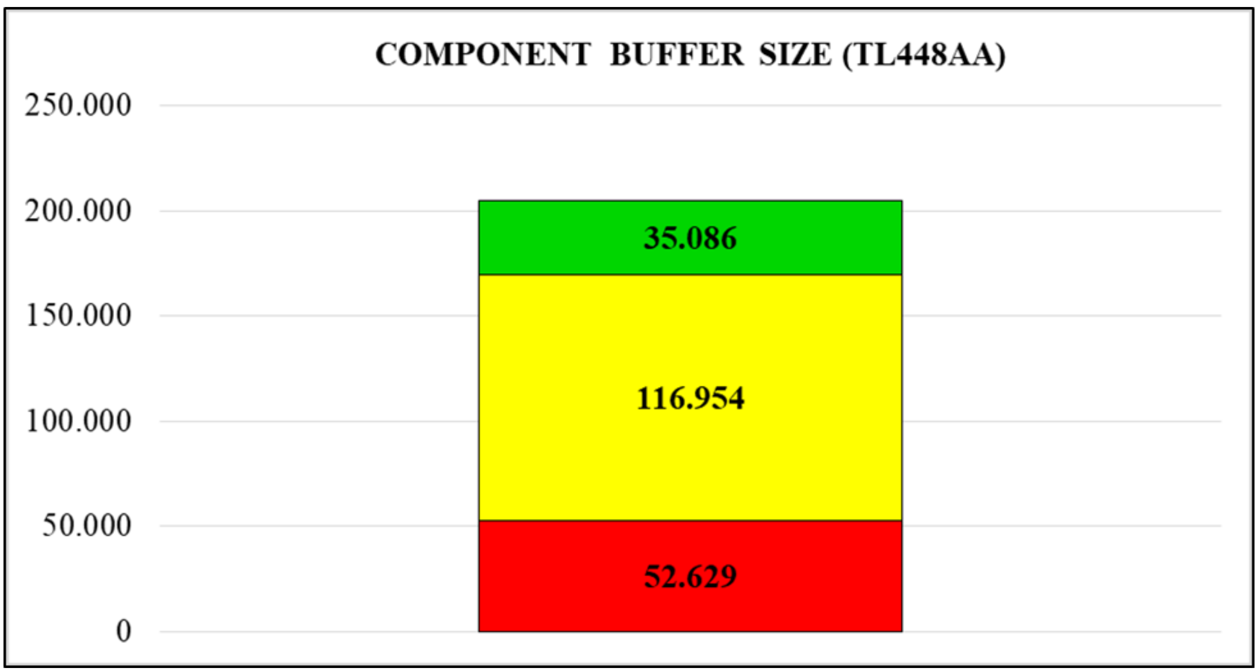


Figure 62. Component buffer size (TL448AA).

Own construction

Since the component -TL448AA has a long Lead Time; its corresponding Lead Time Factor has a small value, thus generating the green zone to be reduced. This indicates that for this piece, purchase orders will be smaller and more frequent. This is one of the concepts that distinguishes the DDMRP methodology from the traditional MRP, where a longer component Lead Time generate an increase in the stock.

The following Figures show the proposed buffers of the previously products presented.

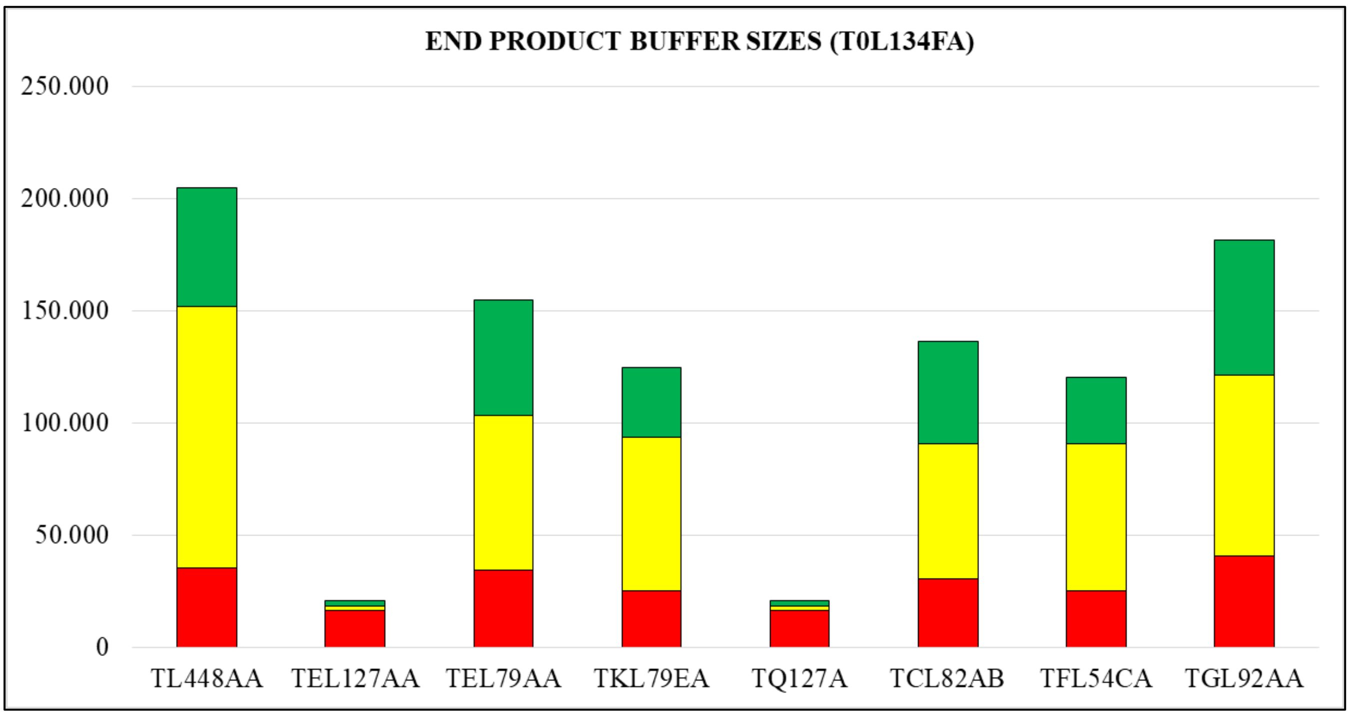


Figure 63. End Product Buffer Sizes(T0l134FA)

Own construction

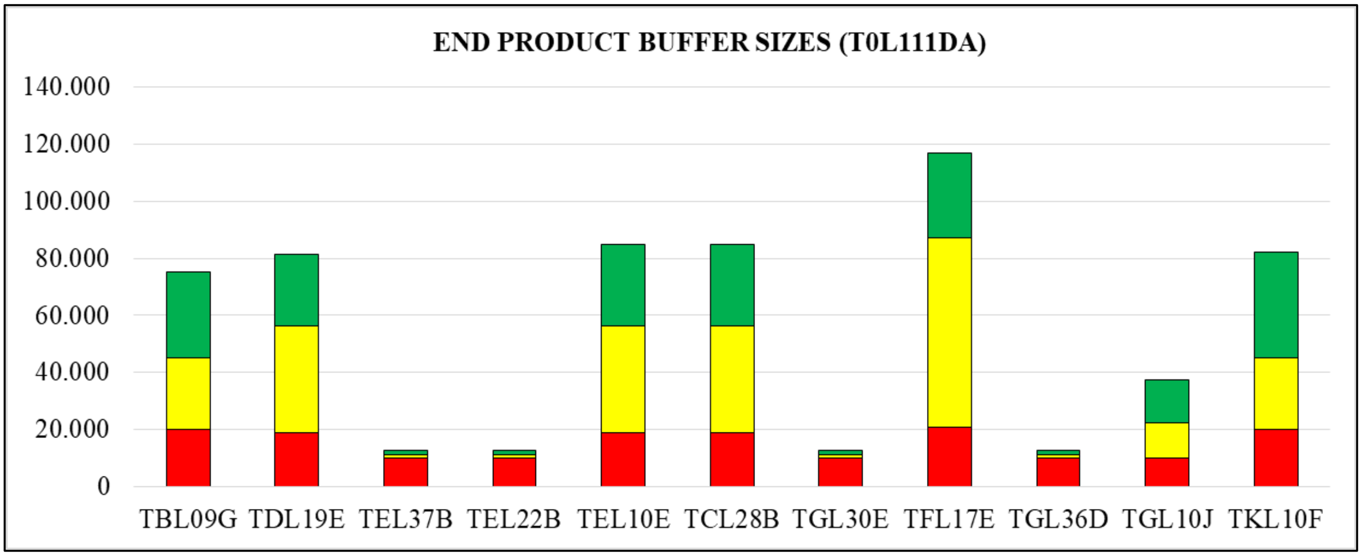


Figure 64. End Product Buffer Sizes(T0l111DA)

Own construction

Either as mentioned above, the proposed buffers become dynamic due to unexpected or programmed changes in the indicators on which they were built, due to changes in the parameters that make up the buffer profiles or the individual attributes of the pieces. It is not known that the company has programmed changes in these parameters, so it was decided to perform a kind of scenario in order to illustrate how the TL448AA component could change if there were future changes in the ADU and Lead Time.

It was then started by analyzing how the buffer varies due to the ADU growth, a parameter that is interesting to analyze since its value impacts all the areas that make up the buffer. The ADU cannot have significant changes in short periods, for which small changes were proposed in periods of 15 days.

As can be seen in the following Figure, since the ADU is a parameter that does not undergo significant modifications, this buffer would have a behavior that could be called seasonal, as there would be no drastic changes to be taken into account.

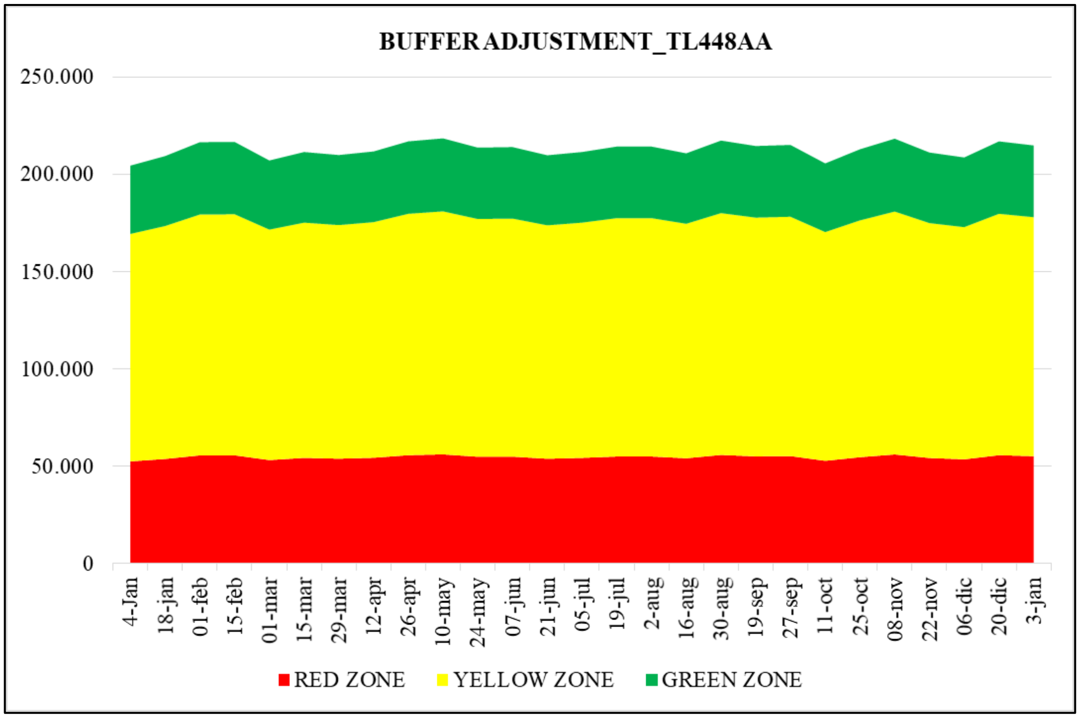


Figure 65. Buffer adjustment. ADU growth.

On the other hand, if the company experienced a significant decrease in Lead Time, which could be due to new agreements with the current suppliers or because a new supplier was found with a better capacity as mentioned in the literature, the stock of component TL448AA would suffer a considerable decrease, which becomes important for the company. The following Figure shows this reduction in the component's buffer.

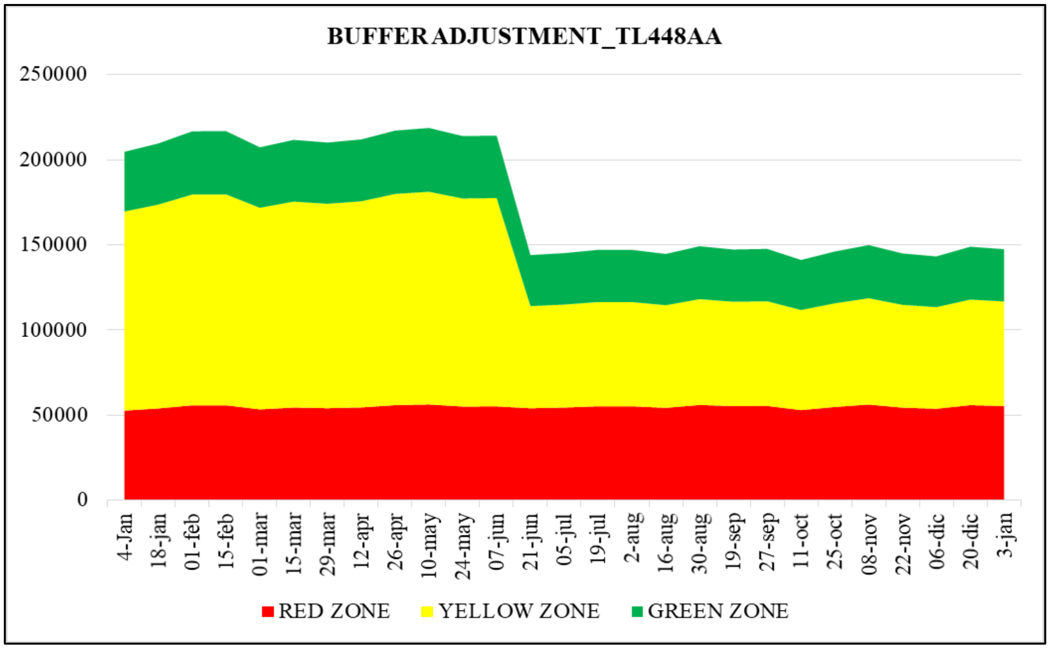


Figure 66. Buffer adjustment. Lead Time compression.

It is not illustrated how the buffer would change if the MOQ were taken into account, because for this component the value of said parameter would not cause changes.

6.3. Demand Driven Planning

Continuing with the implementation of the DDMRP methodology, the phase called Demand Driven Planning was carried out, with which the main purpose is to determine the size and frequency of the supply orders generated by the system.

To illustrate this concept, the calculations were applied to the component that has been worked with in the previous phases, the TL448AA.

As a first step, it is necessary to incorporate the demand into the daily planning equation of decoupled positions, an equation known as Net Flow, which as mentioned by (Ptak & Smith, 2016), was previously known as: "available stock equation".

As expressed by (Ptak & Smith, 2016), “the net flow equation provides the supply order generation recommendation signal (timing and quantity) for buffer replenishment. It is a key and unique aspect of DDMRP and should be performed daily on all decoupled positions”.

The Net Flow Position equation is equal to

On-hand + on-order – qualified sales order demand = net flow position (Ptak & Smith, 2016)

On-hand is the available inventory that company has to comply the daily production requirements, that is to say, is “the quantity of stock physically available”. (Ptak & Smith, 2016). On-order is the quantity of components (stock) that the company has ordered but that has not yet arrived its facilities. Finally, the qualified sales order demand is defined by (Ptak & Smith, 2016) as: “the sum of sales orders past due, sales orders due today, and qualified spikes”.

As cited by (Ptak & Smith, 2016), “In DDMRP, an order spike is a qualifying quantity of known cumulative daily demand within a qualifying time window that threatens the integrity of the buffer. That means the qualifying level (order spike threshold) and the qualifying time window (order spike horizon) must be defined”

To determine the order spike threshold there are some methods, but for the implementation of this concept to the decoupling point chosen, the most common formula was used: 50% of the red zone. On the other hand, the order spike horizon is defined as a Lead Time + 1 day.

The component TL448AA has an order spike threshold equal to 26,315 units and an order spike horizon of 81 days. If in those 81 days there will be a spike in the demand by the customer, that is, a value that exceeds 26,315 units, this should be added to the qualified sales order demand and therefore decrease the value of Net Flow equation

To continue with the implementation of this phase, the following values must be taken into account:

Top of Green (TOG): is the sum of the three zones that determine the buffer: red, yellow and green.

Top of Yellow (TOY): is the sum of the red and yellow zone of the buffer.

Top of Red (TOR): is the full amount of the red zone.

For our component, the following values were obtained:

TOR	TOY	TOG
52.629	169.583	204.669

Table 26. TOR, TOY and TOG values.

Own construction.

To determine the generation of the orders, the Net Flow Position must be compared with the TOY. If the Net Flow is less than the Top of Yellow, a supply order must be sent to suppliers. The orders' size are obtained by subtracting the Net Flow Position from the Top of Green.

In order to apply these concepts, the Supply Order Generation Based on Net Flow Position was built, for which a small simulation was carried out in order to illustrate how the system would behave by generating the supply orders in a period of 180 days. The results that were obtained were the following:

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
-66								78.500	Day 14
1	65,43%	58.000		78.500	2.595	2.595	133.905	70.764	Day 81
2	99,30%	55.405		149.264	1.430	1.430	203.239		Day 82
3	99,08%	53.975		149.264	448	448	202.791		Day 83
4	98,73%	53.527		149.264	721	721	202.070		Day 84
5	97,72%	52.806		149.264	2.077	2.077	199.993		Day 85
6	97,05%	50.729		149.264	1.363	1.363	198.630		Day 86
7	96,85%	49.366		149.264	418	418	198.212		Day 87

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
8	96,28%	48.948		149.264	1.166	1.166	197.046		Day 88
9	95,66%	47.782		149.264	1.263	1.263	195.783		Day 89
10	95,50%	46.519		149.264	314	314	195.469		Day 90
11	94,31%	46.205		149.264	2.439	2.439	193.030		Day 91
12	93,20%	43.766		149.264	2.277	2.277	190.753		Day 92
13	92,59%	41.489		149.264	1.244	1.244	189.509		Day 93
14	91,91%	40.245	78.500	149.264	1.396	1.396	188.113		Day 94
15	91,41%	117.349		70.764	1.031	1.031	187.082		Day 95
16	91,02%	116.318		70.764	799	799	186.283		Day 96
17	90,07%	115.519		70.764	1.932	1.932	184.351		Day 97
18	89,91%	113.587		70.764	329	329	184.022		Day 98
19	89,18%	113.258		70.764	1.497	1.497	182.525		Day 99
20	88,80%	111.761		70.764	772	772	181.753		Day 100
21	88,34%	110.989		70.764	952	952	180.801		Day 101
22	87,78%	110.037		70.764	1.141	1.141	179.660		Day 102
23	86,67%	108.896		70.764	2.271	2.271	177.389		Day 103
24	86,04%	106.625		70.764	1.301	1.301	176.088		Day 104
25	85,63%	105.324		70.764	820	820	175.268		Day 105
26	84,78%	104.504		70.764	1.748	1.748	173.520		Day 106
27	84,04%	102.756		70.764	1.517	1.517	172.003		Day 107
28	83,21%	101.239		70.764	1.697	1.697	170.306		Day 108
29	81,99%	99.542		70.764	2.498	2.498	167.808	36.861	Day 109
30	99,16%	97.044		107.625	1.727	1.727	202.942		Day 110
31	98,24%	95.317		107.625	1.884	1.884	201.058		Day 111
32	97,37%	93.433		107.625	1.782	1.782	199.276		Day 112
33	96,31%	91.651		107.625	2.163	2.163	197.113		Day 113

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
34	95,79%	89.488		107.625	1.055	1.055	196.058		Day 114
35	94,80%	88.433		107.625	2.034	2.034	194.024		Day 115
36	94,28%	86.399		107.625	1.058	1.058	192.966		Day 116
37	93,50%	85.341		107.625	1.594	1.594	191.372		Day 117
38	93,05%	83.747		107.625	929	929	190.443		Day 118
39	92,40%	82.818		107.625	1.325	1.325	189.118		Day 119
40	91,50%	81.493		107.625	1.837	1.837	187.281		Day 120
41	90,86%	79.656		107.625	1.315	1.315	185.966		Day 121
42	89,91%	78.341		107.625	1.954	1.954	184.012		Day 122
43	89,66%	76.387		107.625	509	509	183.503		Day 123
44	88,32%	75.878		107.625	2.734	2.734	180.769		Day 124
45	87,20%	73.144		107.625	2.300	2.300	178.469		Day 125
46	86,41%	70.844		107.625	1.618	1.618	176.851		Day 126
47	85,61%	69.226		107.625	1.627	1.627	175.224		Day 127
48	85,34%	67.599		107.625	556	556	174.668		Day 128
49	84,50%	67.043		107.625	1.724	1.724	172.944		Day 129
50	83,58%	65.319		107.625	1.891	1.891	171.053		Day 130
51	82,50%	63.428		107.625	2.193	2.193	168.860	35.809	Day 131
52	99,10%	61.235		143.434	1.840	1.840	202.829		Day 132
53	98,86%	59.395		143.434	494	494	202.335		Day 133
54	97,87%	58.901		143.434	2.027	2.027	200.308		Day 134
55	96,92%	56.874		143.434	1.940	1.940	198.368		Day 135
56	96,32%	54.934		143.434	1.225	1.225	197.143		Day 136
57	95,41%	53.709		143.434	1.876	1.876	195.267		Day 137
58	94,20%	51.833		143.434	2.475	2.475	192.792		Day 138
59	93,26%	49.358		143.434	1.917	1.917	190.875		Day 139

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
60	92,15%	47.441		143.434	2.264	2.264	188.611		Day 140
61	91,13%	45.177		143.434	2.098	2.098	186.513		Day 141
62	90,36%	43.079		143.434	1.574	1.574	184.939		Day 142
63	89,37%	41.505		143.434	2.020	2.020	182.919		Day 143
64	88,22%	39.485		143.434	2.364	2.364	180.555		Day 144
65	87,06%	37.121		143.434	2.365	2.365	178.190		Day 145
66	85,92%	34.756		143.434	2.347	2.347	175.843		Day 146
67	84,81%	32.409		143.434	2.268	2.268	173.575		Day 147
68	83,69%	30.141		143.434	2.284	2.284	171.291		Day 148
69	83,29%	27.857		143.434	830	830	170.461		Day 149
70	82,82%	27.027		143.434	948	948	169.513	35.156	Day 150
71	99,40%	26.079		178.590	1.226	1.226	203.443		Day 151
72	98,33%	24.853		178.590	2.191	2.191	201.252		Day 152
73	98,16%	22.662		178.590	339	339	200.913		Day 153
74	97,76%	22.323		178.590	833	833	200.080		Day 154
75	97,31%	21.490		178.590	922	922	199.158		Day 155
76	96,26%	20.568		178.590	2.147	2.147	197.011		Day 156
77	95,71%	18.421		178.590	1.122	1.122	195.889		Day 157
78	95,08%	17.299		178.590	1.296	1.296	194.593		Day 158
79	94,68%	16.003		178.590	817	817	193.776		Day 159
80	93,53%	15.186		178.590	2.350	2.350	191.426		Day 160
81	92,64%	12.836	70.764	178.590	1.829	1.829	189.597		Day 161
82	91,65%	81.771		107.826	2.020	2.020	187.577		Day 162
83	90,92%	79.751		107.826	1.495	1.495	186.082		Day 163
84	90,10%	78.256		107.826	1.666	1.666	184.416		Day 164
85	89,88%	76.590		107.826	462	462	183.954		Day 165

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
86	89,67%	76.128		107.826	430	430	183.524		Day 166
87	88,56%	75.698		107.826	2.268	2.268	181.256		Day 167
88	87,35%	73.430		107.826	2.476	2.476	178.780		Day 168
89	86,33%	70.954		107.826	2.088	2.088	176.692		Day 169
90	85,76%	68.866		107.826	1.169	1.169	175.523		Day 170
91	85,27%	67.697		107.826	996	996	174.527		Day 171
92	84,98%	66.701		107.826	594	594	173.933		Day 172
93	84,31%	66.107		107.826	1.382	1.382	172.551		Day 173
94	83,83%	64.725		107.826	982	982	171.569		Day 174
95	83,17%	63.743		107.826	1.346	1.346	170.223		Day 175
96	82,58%	62.397		107.826	1.210	1.210	169.013	35.656	Day 176
97	99,40%	61.187		143.482	1.225	1.225	203.444		Day 177
98	98,85%	59.962		143.482	1.120	1.120	202.324		Day 178
99	98,50%	58.842		143.482	728	728	201.596		Day 179
100	97,68%	58.114		143.482	1.669	1.669	199.927		Day 180
101	97,29%	56.445		143.482	812	812	199.115		Day 181
102	97,10%	55.633		143.482	387	387	198.728		Day 182
103	95,97%	55.246		143.482	2.300	2.300	196.428		Day 183
104	95,43%	52.946		143.482	1.107	1.107	195.321		Day 184
105	95,19%	51.839		143.482	494	494	194.827		Day 185
106	94,87%	51.345		143.482	656	656	194.171		Day 186
107	94,25%	50.689		143.482	1.269	1.269	192.902		Day 187
108	93,47%	49.420		143.482	1.607	1.607	191.295		Day 188
109	93,21%	47.813	36.861	143.482	528	528	190.767		Day 189
110	92,23%	84.146		106.621	2.008	2.008	188.759		Day 190
111	91,08%	82.138		106.621	2.353	2.353	186.406		Day 191

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
112	89,89%	79.785		106.621	2.427	2.427	183.979		Day 192
113	89,58%	77.358		106.621	646	646	183.333		Day 193
114	88,87%	76.712		106.621	1.450	1.450	181.883		Day 194
115	88,04%	75.262		106.621	1.685	1.685	180.198		Day 195
116	87,47%	73.577		106.621	1.182	1.182	179.016		Day 196
117	86,39%	72.395		106.621	2.200	2.200	176.816		Day 197
118	85,24%	70.195		106.621	2.358	2.358	174.458		Day 198
119	85,04%	67.837		106.621	406	406	174.052		Day 199
120	84,56%	67.431		106.621	977	977	173.075		Day 200
121	83,52%	66.454		106.621	2.132	2.132	170.943		Day 201
122	82,22%	64.322		106.621	2.674	2.674	168.269	36.400	Day 202
123	99,73%	61.648		143.021	546	546	204.123		Day 203
124	99,07%	61.102		143.021	1.362	1.362	202.761		Day 204
125	98,49%	59.740		143.021	1.179	1.179	201.582		Day 205
126	97,88%	58.561		143.021	1.257	1.257	200.325		Day 206
127	97,27%	57.304		143.021	1.252	1.252	199.073		Day 207
128	96,30%	56.052		143.021	1.980	1.980	197.093		Day 208
129	96,14%	54.072		143.021	334	334	196.759		Day 209
130	95,08%	53.738		143.021	2.164	2.164	194.595		Day 210
131	94,91%	51.574	35.809	143.021	352	352	194.243		Day 211
132	94,32%	87.031		107.212	1.209	1.209	193.034		Day 212
133	93,55%	85.822		107.212	1.561	1.561	191.473		Day 213
134	93,15%	84.261		107.212	822	822	190.651		Day 214
135	92,34%	83.439		107.212	1.661	1.661	188.990		Day 215
136	91,54%	81.778		107.212	1.642	1.642	187.348		Day 216
137	90,72%	80.136		107.212	1.668	1.668	185.680		Day 217

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
138	90,39%	78.468		107.212	670	670	185.010		Day 218
139	90,12%	77.798		107.212	565	565	184.445		Day 219
140	89,66%	77.233		107.212	931	931	183.514		Day 220
141	89,32%	76.302		107.212	711	711	182.803		Day 221
142	88,77%	75.591		107.212	1.111	1.111	181.692		Day 222
143	88,12%	74.480		107.212	1.344	1.344	180.348		Day 223
144	87,35%	73.136		107.212	1.573	1.573	178.775		Day 224
145	86,96%	71.563		107.212	803	803	177.972		Day 225
146	86,30%	70.760		107.212	1.343	1.343	176.629		Day 226
147	85,27%	69.417		107.212	2.101	2.101	174.528		Day 227
148	84,95%	67.316		107.212	659	659	173.869		Day 228
149	84,67%	66.657		107.212	569	569	173.300		Day 229
150	84,03%	66.088	35.156	107.212	1.311	1.311	171.989		Day 230
151	83,80%	99.933		72.056	470	470	171.519		Day 231
152	82,58%	99.463		72.056	2.500	2.500	169.019	35.650	Day 232
153	99,58%	96.963		107.706	850	850	203.819		Day 233
154	99,42%	96.113		107.706	345	345	203.474		Day 234
155	98,54%	95.768		107.706	1.793	1.793	201.681		Day 235
156	98,32%	93.975		107.706	460	460	201.221		Day 236
157	97,30%	93.515		107.706	2.081	2.081	199.140		Day 237
158	96,17%	91.434		107.706	2.305	2.305	196.835		Day 238
159	95,93%	89.129		107.706	501	501	196.334		Day 239
160	95,43%	88.628		107.706	1.022	1.022	195.312		Day 240
161	94,52%	87.606		107.706	1.854	1.854	193.458		Day 241
162	93,62%	85.752		107.706	1.844	1.844	191.614		Day 242
163	92,95%	83.908		107.706	1.368	1.368	190.246		Day 243

DAY	PLANNING PRIORITY	ON HAND	DELIVERY	ON ORDER	SALES ORDERS DUE	QUALIFIED DEMAND	NET FLOW POSITION	ORDER	REQUEST DATE
164	92,34%	82.540		107.706	1.255	1.255	188.991		Day 244
165	91,82%	81.285		107.706	1.073	1.073	187.918		Day 245
166	90,85%	80.212		107.706	1.976	1.976	185.942		Day 246
167	90,20%	78.236		107.706	1.328	1.328	184.614		Day 247
168	89,39%	76.908		107.706	1.669	1.669	182.945		Day 248
169	88,48%	75.239		107.706	1.862	1.862	181.083		Day 249
170	87,91%	73.377		107.706	1.152	1.152	179.931		Day 250
171	86,83%	72.225		107.706	2.208	2.208	177.723		Day 251
172	86,52%	70.017		107.706	637	637	177.086		Day 252
173	85,76%	69.380		107.706	1.552	1.552	175.534		Day 253
174	84,64%	67.828		107.706	2.307	2.307	173.227		Day 254
175	83,44%	65.521		107.706	2.450	2.450	170.777		Day 255
176	82,74%	63.071	35.656	107.706	1.434	1.434	169.343	35.326	Day 256
177	99,72%	97.293		107.376	574	574	204.095		Day 257
178	99,16%	96.719		107.376	1.137	1.137	202.958		Day 258
179	98,75%	95.582		107.376	843	843	202.115		Day 259
180	98,08%	94.739		107.376	1.384	1.384	200.731		Day 260

Table 27. Simulation of Supply Order Generation Based on Net Flow Position. Own construction.

The simulation was initialized with the following parameters: On-hand: 58,000 pieces and an order that was sent on day -66 for a value of 78,500, which must reach the company on the 14th day. How can it be observed in the previous Table, the first supply order is generated the first day, since the Net Flow Position is less than the TOY. This order must reach the company on day 81, for a value equal to 70,764 pieces. It can be noticed that the qualified sales order demand is equal to the sales order due, since there are no order spikes in the order spikes horizon proposed.

With the planning priority, the production programmer of Dayco could quickly observe which of the orders have greater importance, since this value shows the status of the buffer and in which zone it is. The lowest values of this status have been 66, 43% and 81.99%, both values being located in the yellow zone of the buffer.

It can also be noted that on average the supply orders are released every 24 days as illustrated above.

The following figure shows the behavior of the on-hand inventory and the Net Flow Position

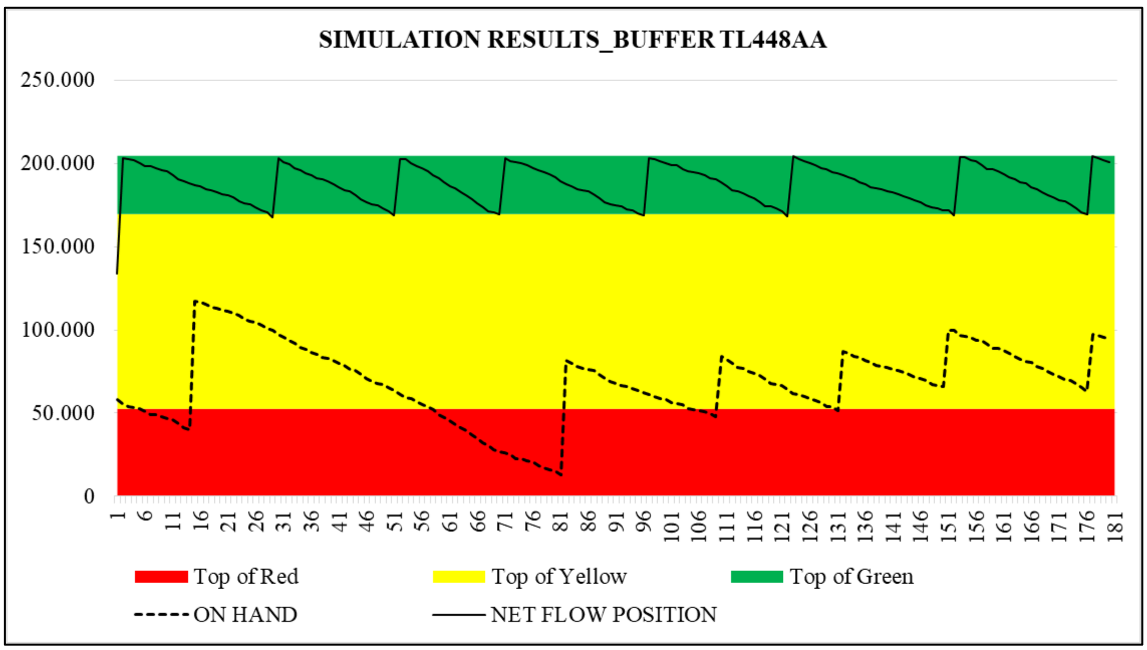


Figure 67. On-hand and Net flow position behavior.

Own construction.

As can be seen, On-hand inventory is mostly in the yellow zone and although this inventory reaches the red zone, no missing parts of this component are generated. As for the Net Flow position, it can be seen that when arriving at the yellow zone, a supply order is sent in order to replenish the stock and to have at all times the entire green area.

In order to determine the target component quantities to have, the average on-hand range was calculated. The minimum value is the Top of Red and the maximum is the sum of the green and red zone, of this it obtain that the optimal range of pieces is equal to the size of the green zone, which is 35.086 pieces. For the component, it find that:

	Min	Max
Average on-hand range	52.629	87.715

Table 28. Average on-hand range.

Own construction.

It was also found that the desired value of the inventory is 70.172 pieces, value obtained by adding the red zone and half of the green zone.

When the quantity of pieces is below or above the optimal range, the inventory enter in the warning zone, which indicates that in the future it can have excess stock (too much) or missing pieces (too little).

To determine the size of these warning zones, the following calculations were made: the low-level warning is composed of the values that go from zero to the top of the red zone, while the high-level warning is subtracting the yellow zone of the green zone. For the component TL448AA, the following result was obtained:

Warning	
low-level warning	52.629
high-level warning	81.868

Table 29. Warning zones.

Own construction.

In order to illustrate the behavior of the on-hand inventory in the ranges obtained, the following Figure was constructed

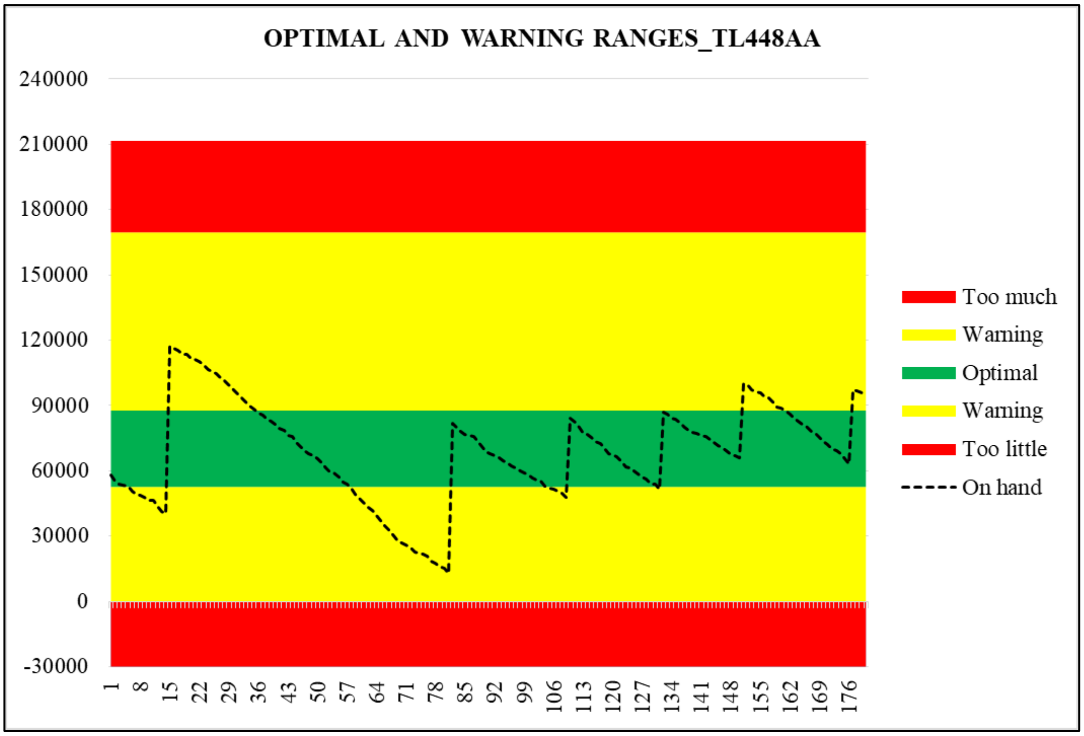


Figure 68. On-hand behavior within optimal and warning ranges. Own construction

If on-hand exceeds 169.583 pieces, it would enter in zone "too much", while if it reaches zero units or less, it would enter a state of shortages. As can be seen in the previous Figure, the on-hand was most of the time within the optimal range, but it was also above and below this range, (it entered the warning levels but did not reach the limits, neither "too much nor too little").

By having an estimated direct cost of € 2,70 per piece, it is obtained that the value of the average inventory is € 189.464.

CONCLUSIONS

The correct supply chain management turns out to be a determining factor for the adequate functioning of any company. Within this link, it can find that one of its pillars is the production scheduling. This programming should always work correctly, so that the plant improves its effectiveness and is able to meet the customers' requirements through proper inventory management that allows the company not to have too much (excesses) or too little (shortages). In turn, another fundamental pillar is purchases, which turn out to be the base of the chain. Proper management of purchases in a company would allow optimizing their processes and in turn obtain financial benefits for it.

With the Demand Driven Material Requirement Planning methodology, a better management of the components inventory of the Ivrea plant was achieved. Its implementation made it possible to find the appropriate decoupling points (which met the criteria) by which to maintain an inventory that meets the company's actual demand conditions. These decoupling points allowed firm to isolate the system a bit from the inherent supplier's variability as well as the variability of demand generated by customers. With this, the system will avoid maintaining a high stock of components because of the nervousness that these variabilities generate and that production programmers do not have to reprogram the production due to a lack of components in the plant as it happens repeatedly nowadays.

The DDMRP generates notable improvements over the current MRP with which the company works. The implementation of the buffers would become a big support mechanism for production programmers, since with the more generalized application of the method, the managers will be able to observe daily the status of each one of the inventories (in real time), prioritize the critical supply orders and maintain the status of each stock within the optimal range, as can be seen for the TL448AA component, which facilitates the construction of the weekly production plan.

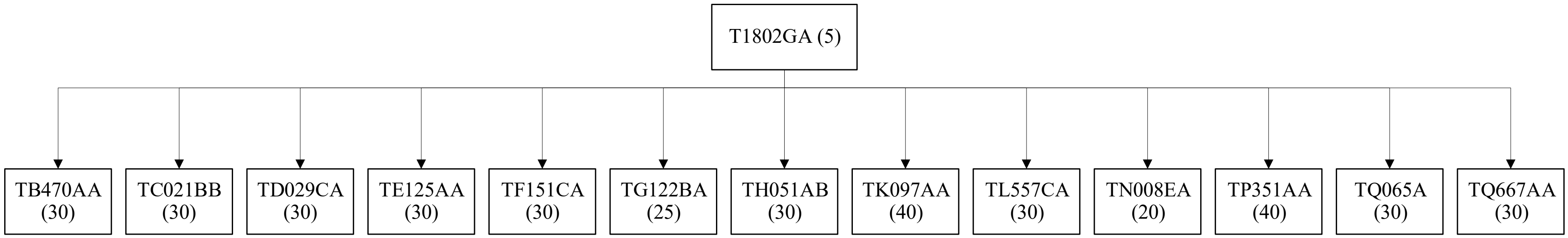
The implementation of the DDMRP also allows better characterizing the components, updating their information and recovering the data with which the company does not have in order to better manage the parameters that are needed.

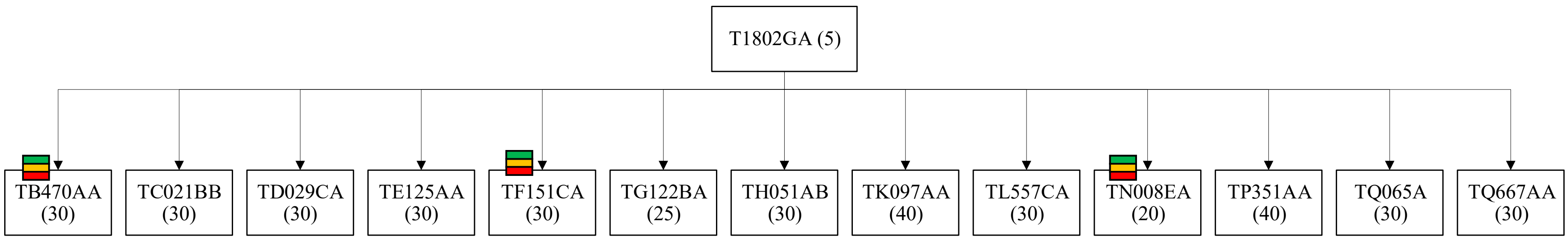
It was found that the theoretical Lead Time given by the company had a strong impact on the sizes of the decoupling points proposed, since the times are so large the buffers show their areas a little amplified. It is recommended to analyze these times better, because a reduction in them either by agreements with current suppliers or contracting new sources of supply, would generate a considerable decrease in buffers, generating greater benefit for the company

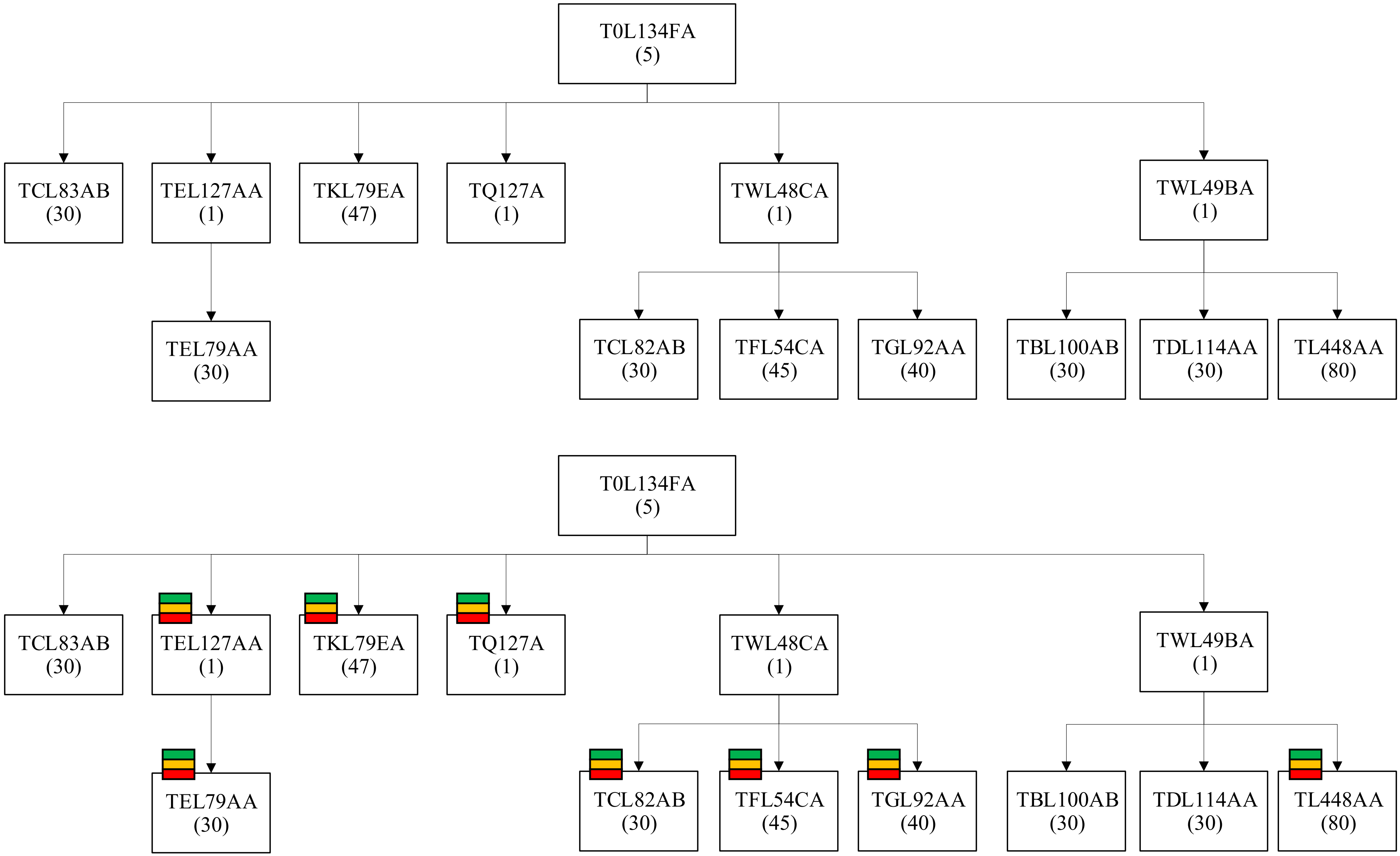
In the implementation of the methodology, there were many difficulties, including the little historical information that the company has about the parameters or data that were required. Another factor was the lack of standardization of information, where a clear example was that the Bill of Materials could not be viewed graphically (the company does not have such structures), which involved extensive manual work to begin with the application of the method. As a recommendation, the company must perform a better management of the data that is required, in order to replicate the methodology to all the components with which it has.

APPENDIX

Appendix 1. Bill of Material Structure



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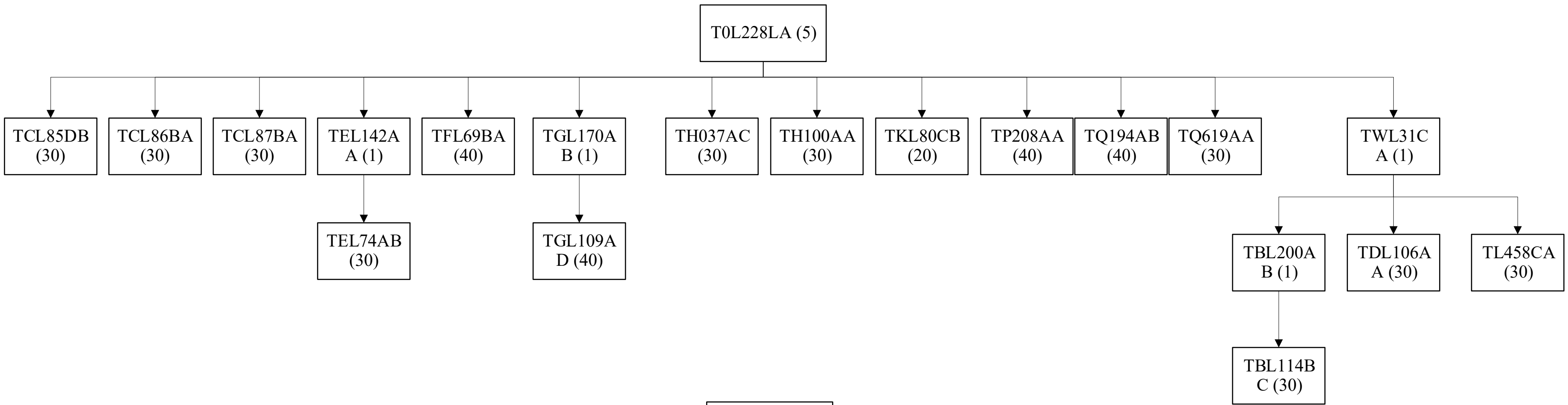
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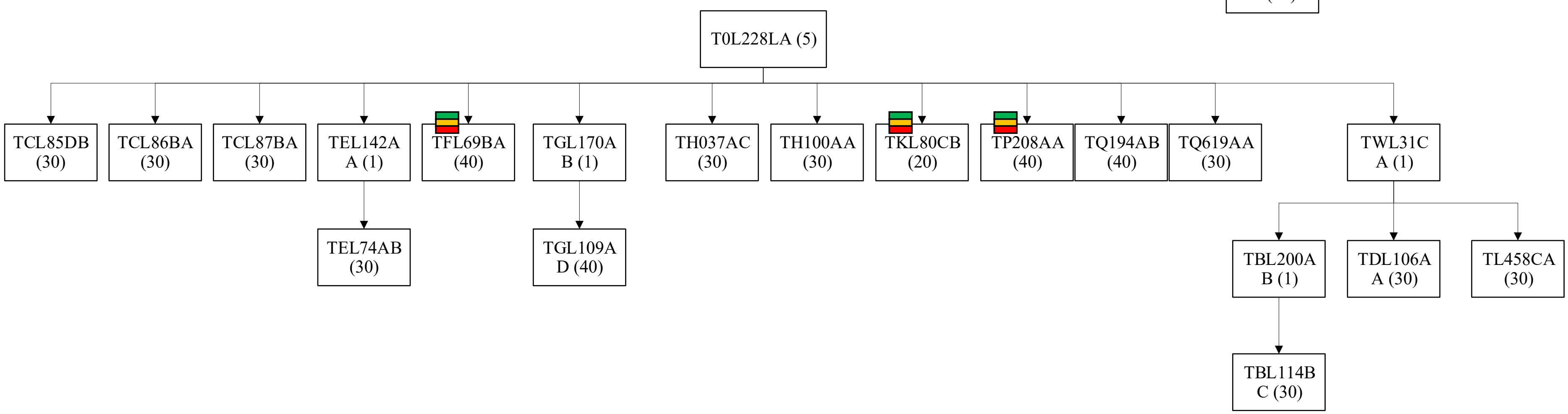
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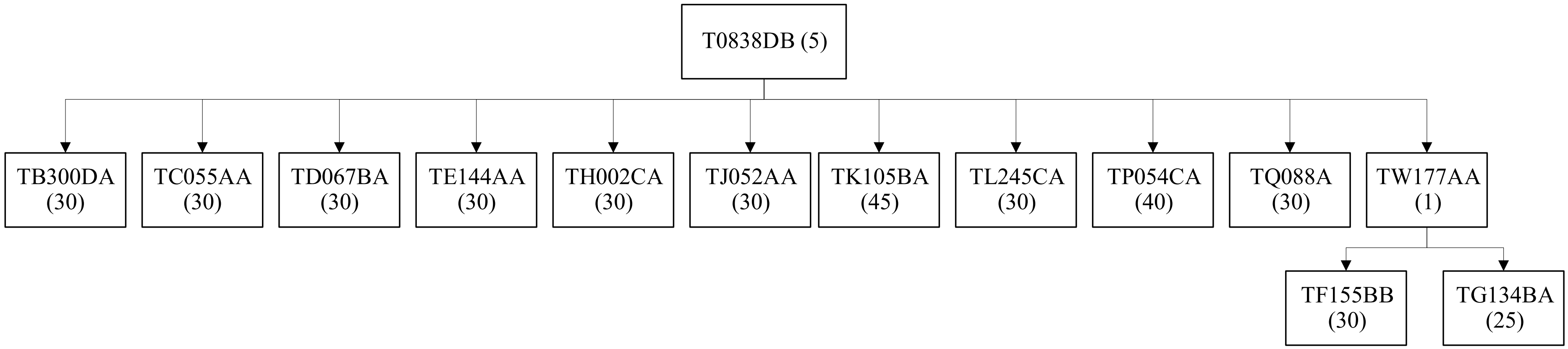
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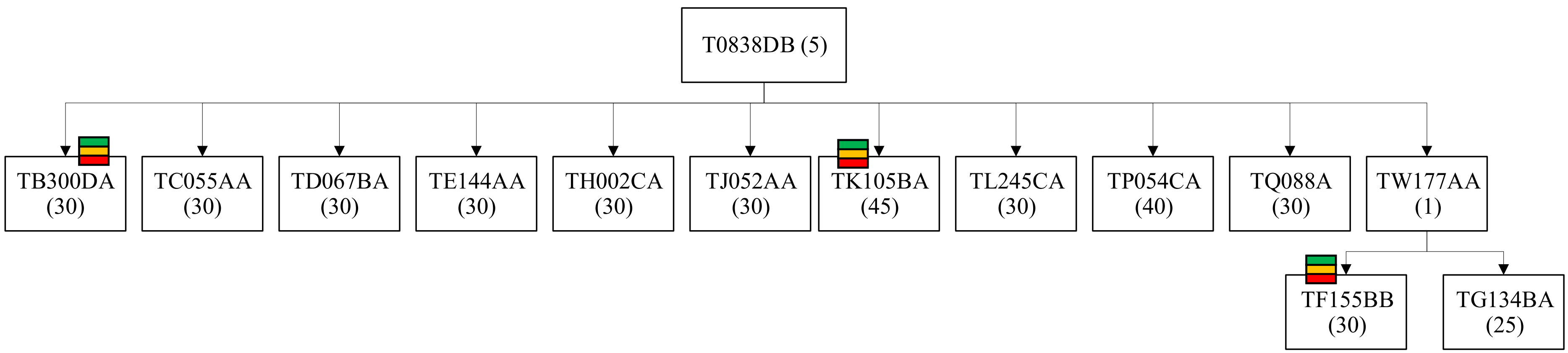
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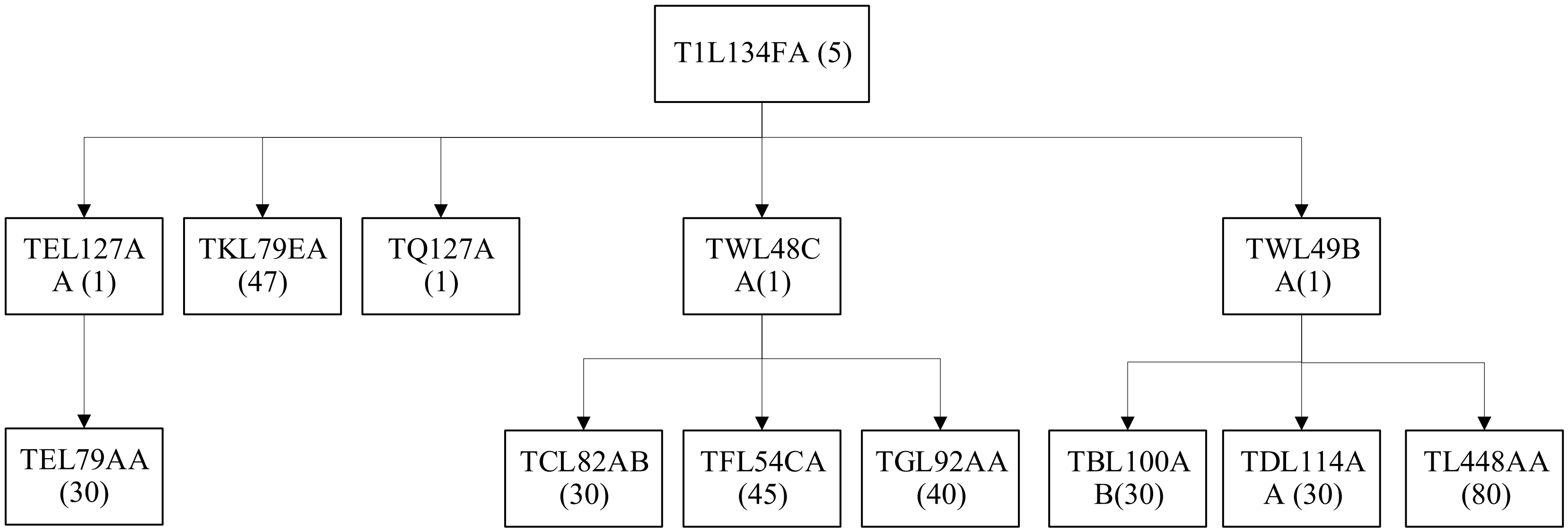
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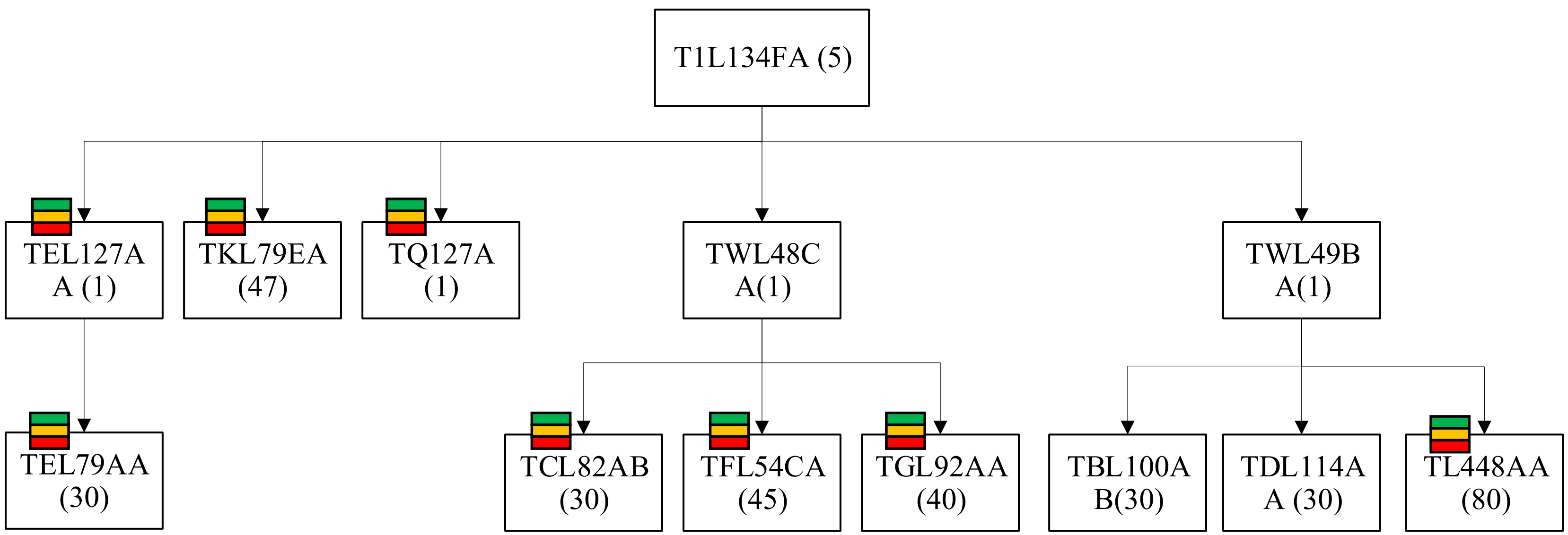
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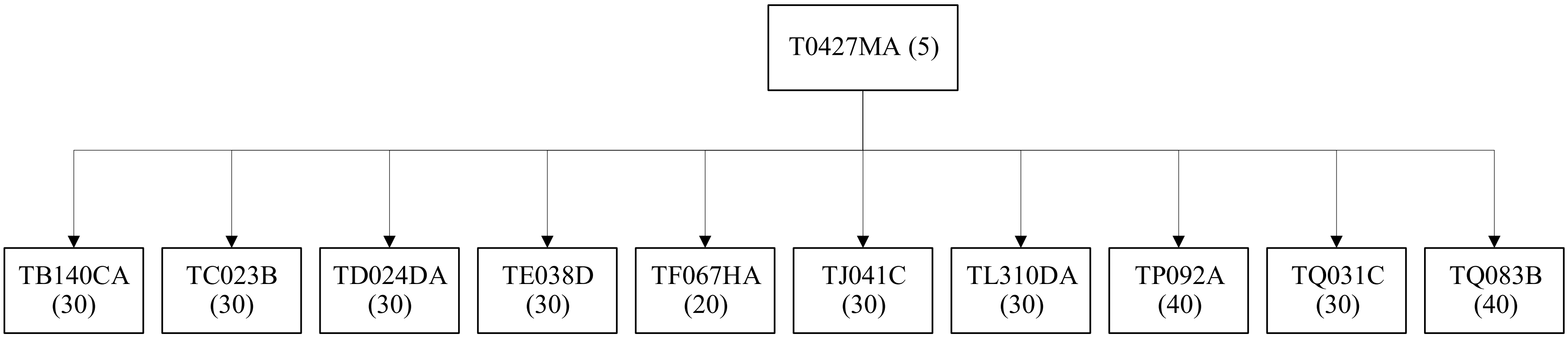
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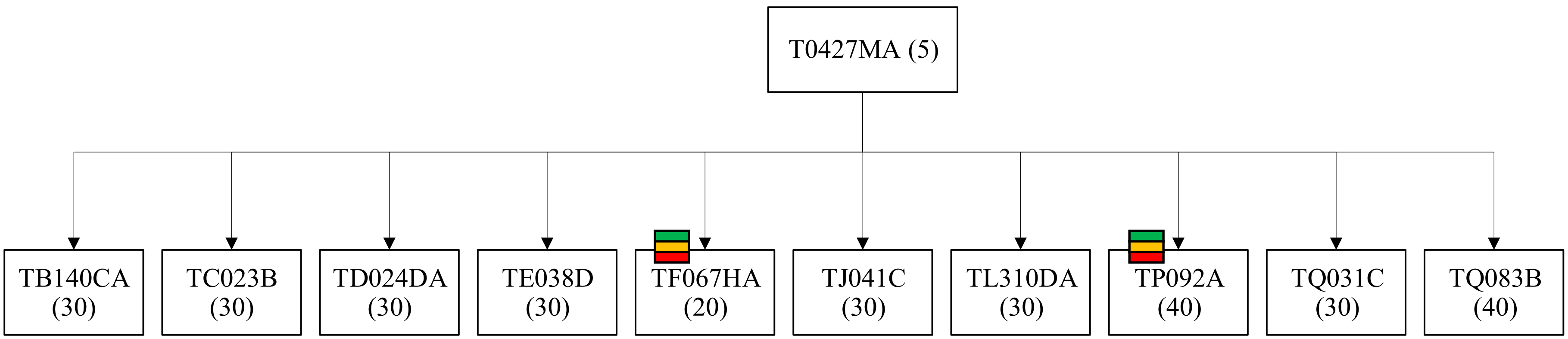
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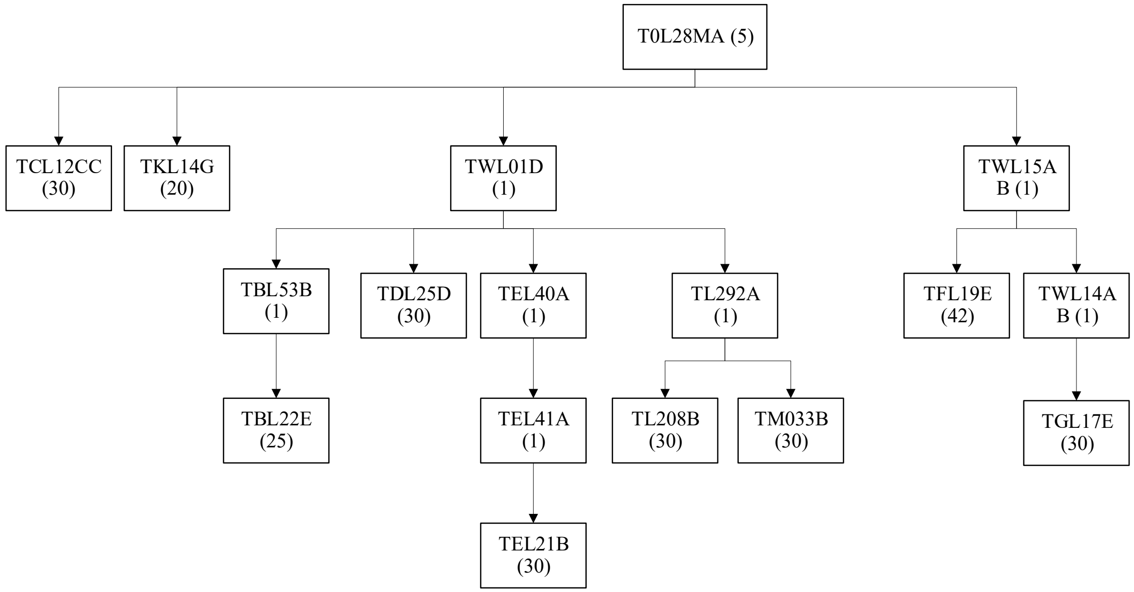
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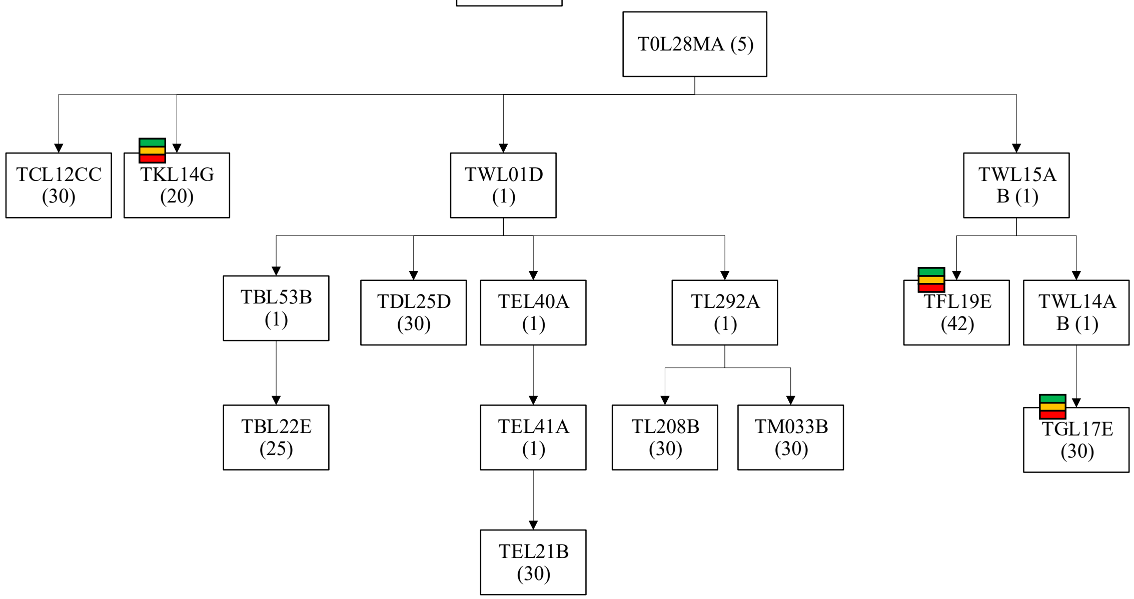
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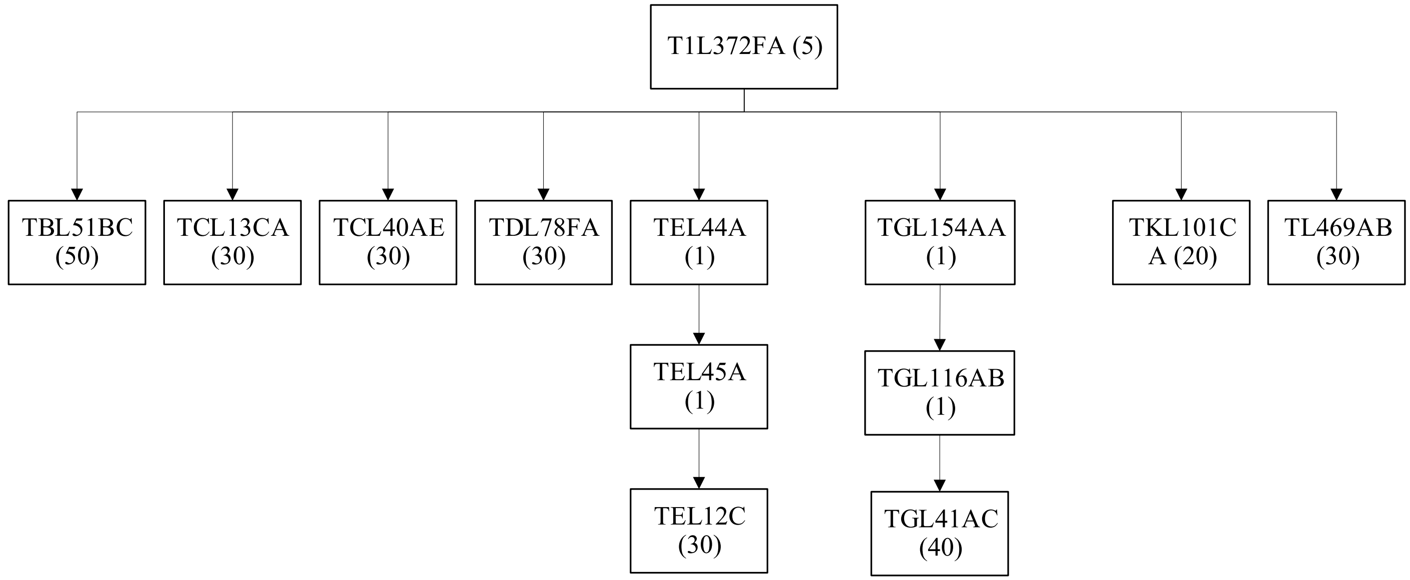
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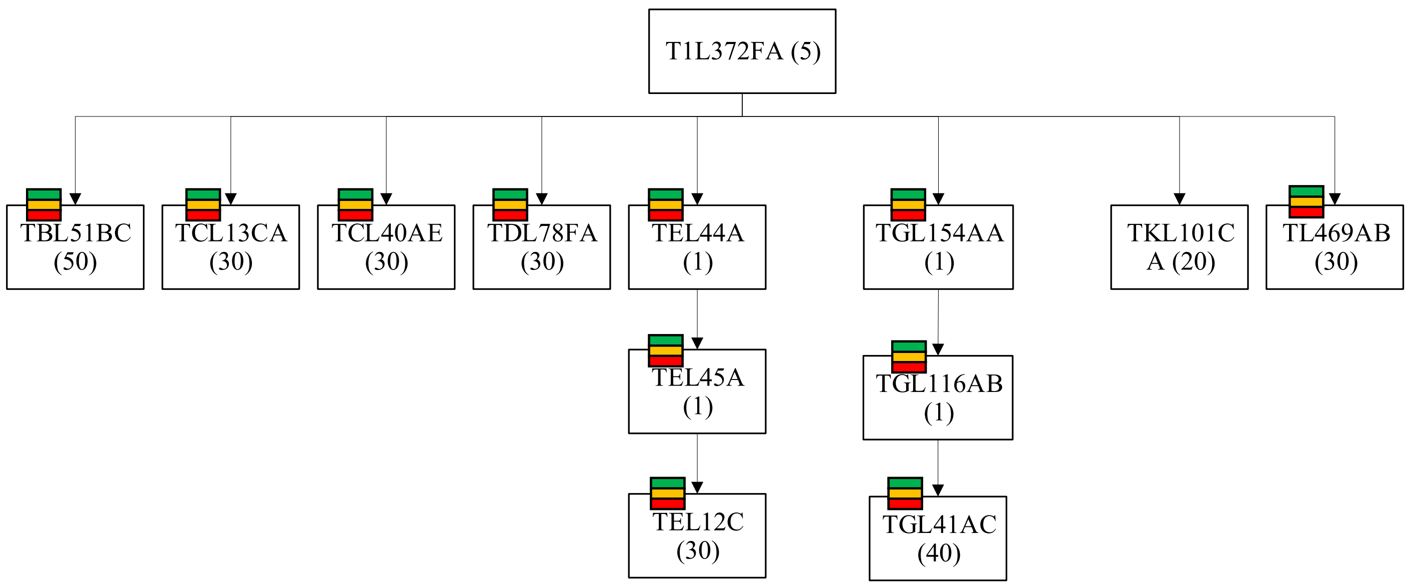
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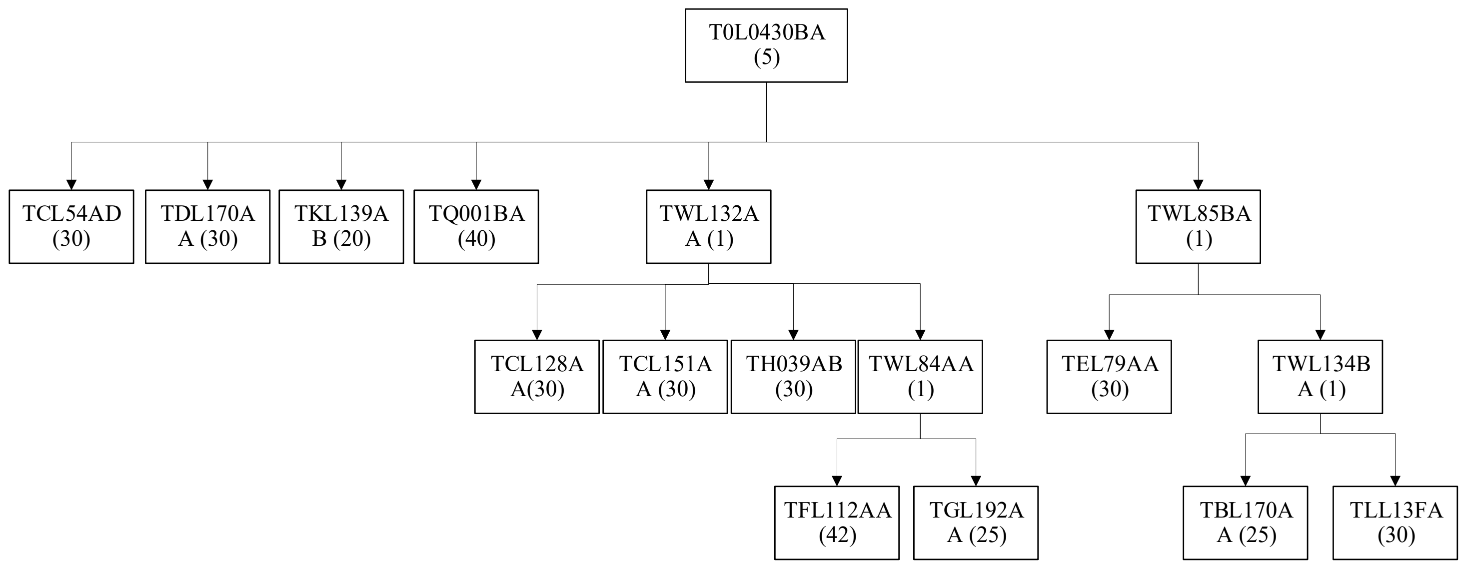
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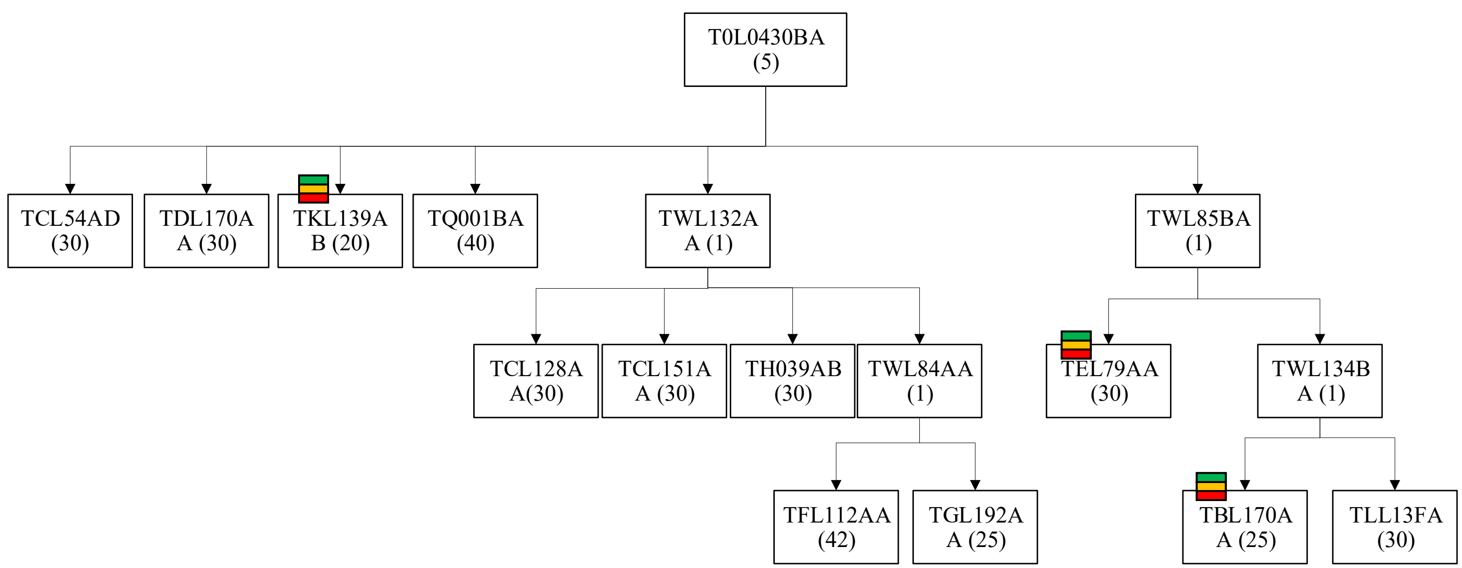
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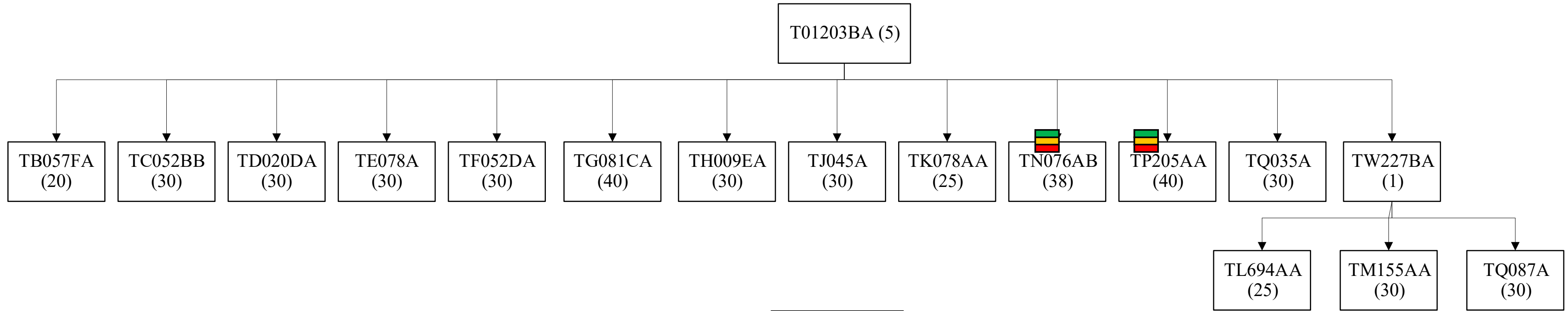

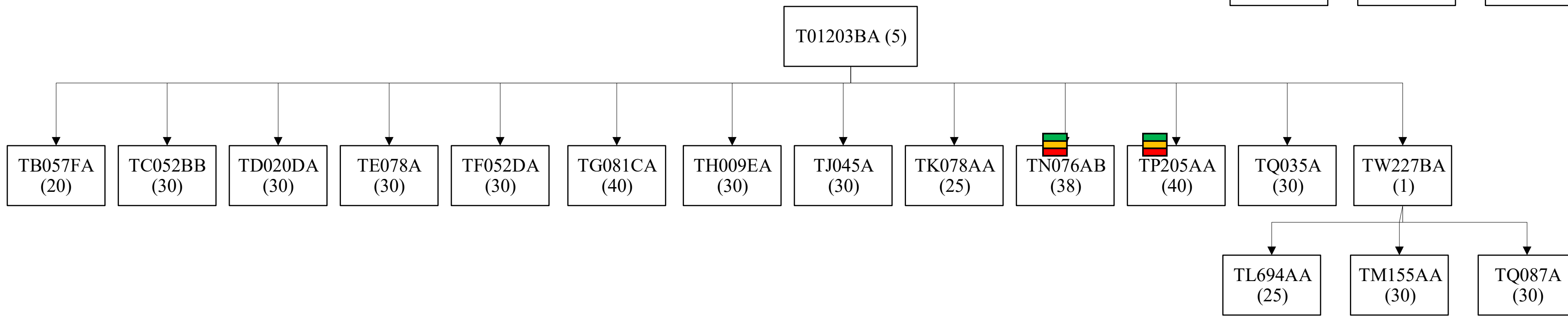

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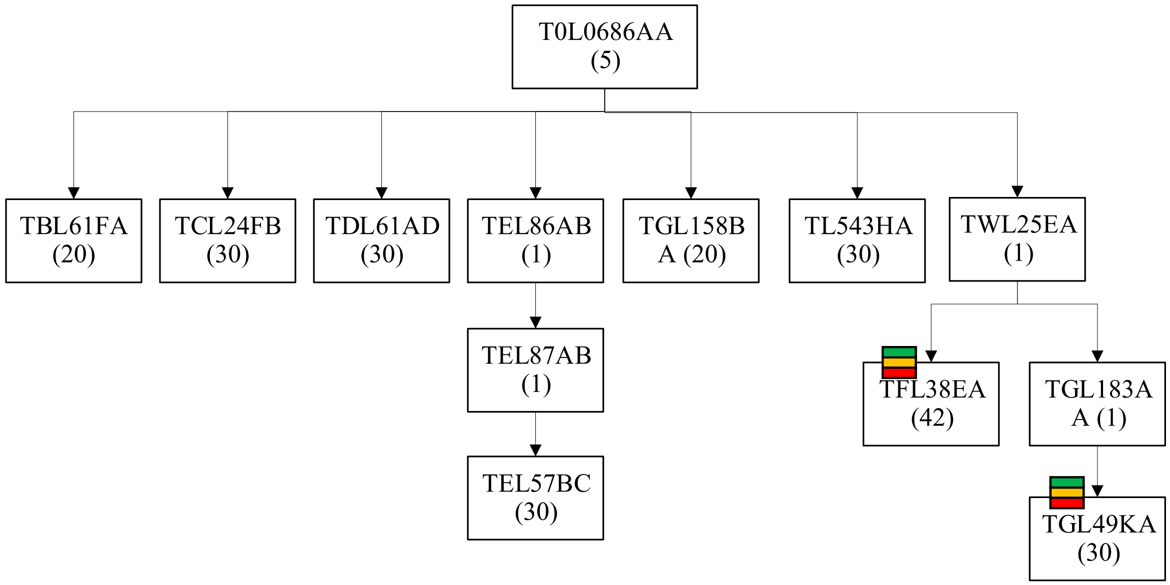
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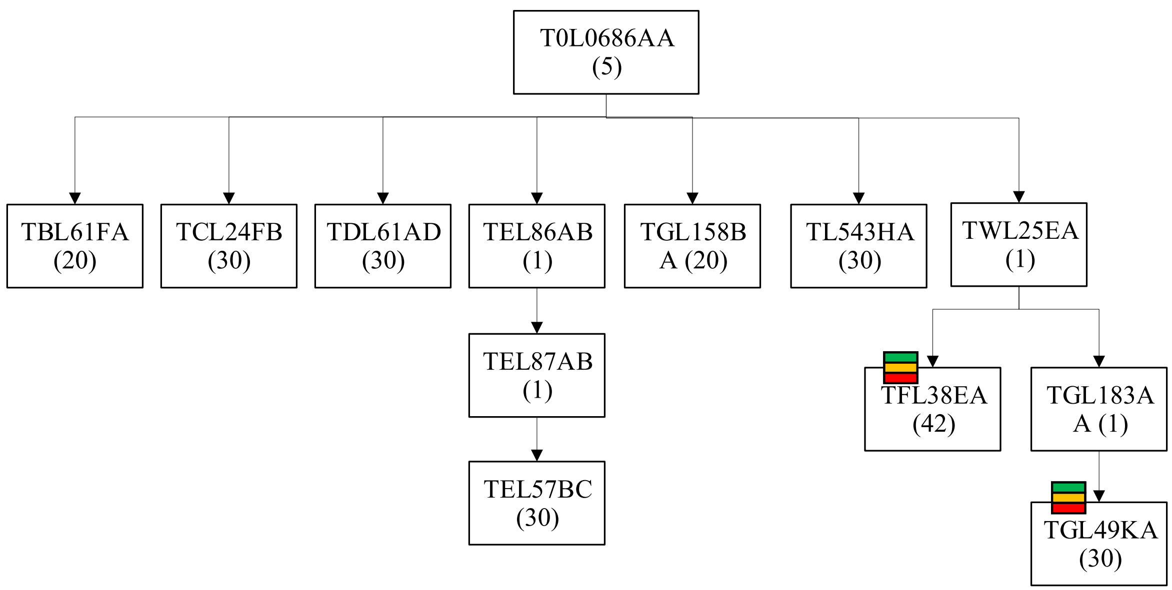
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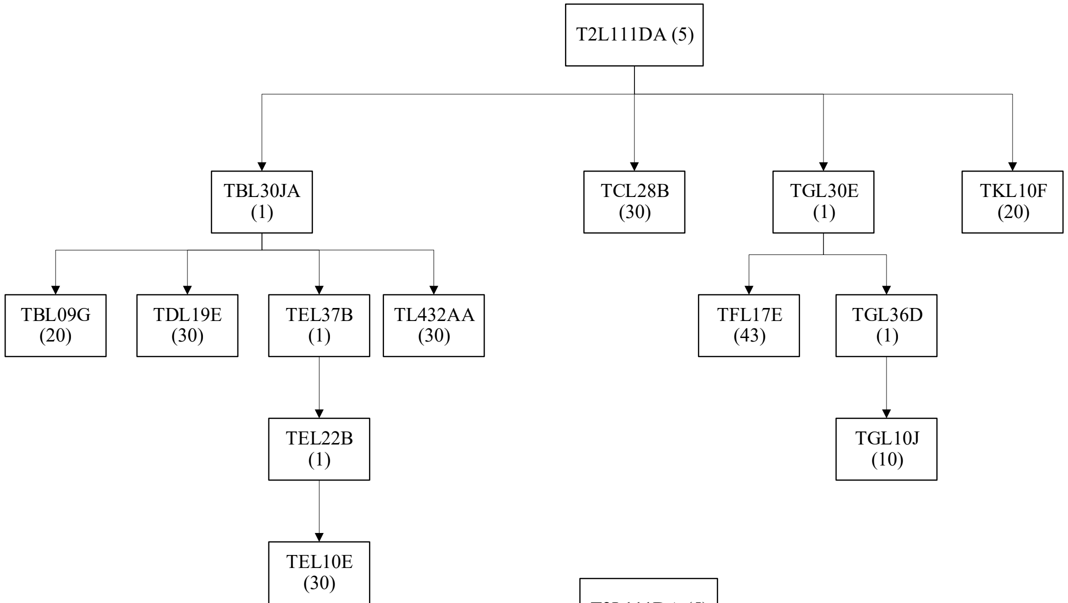
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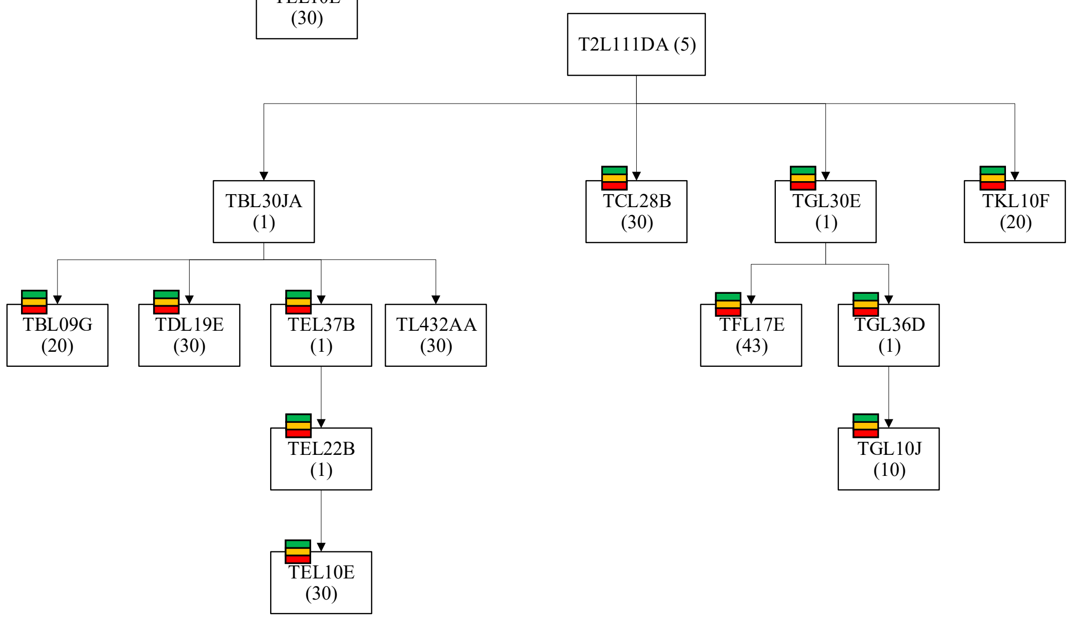
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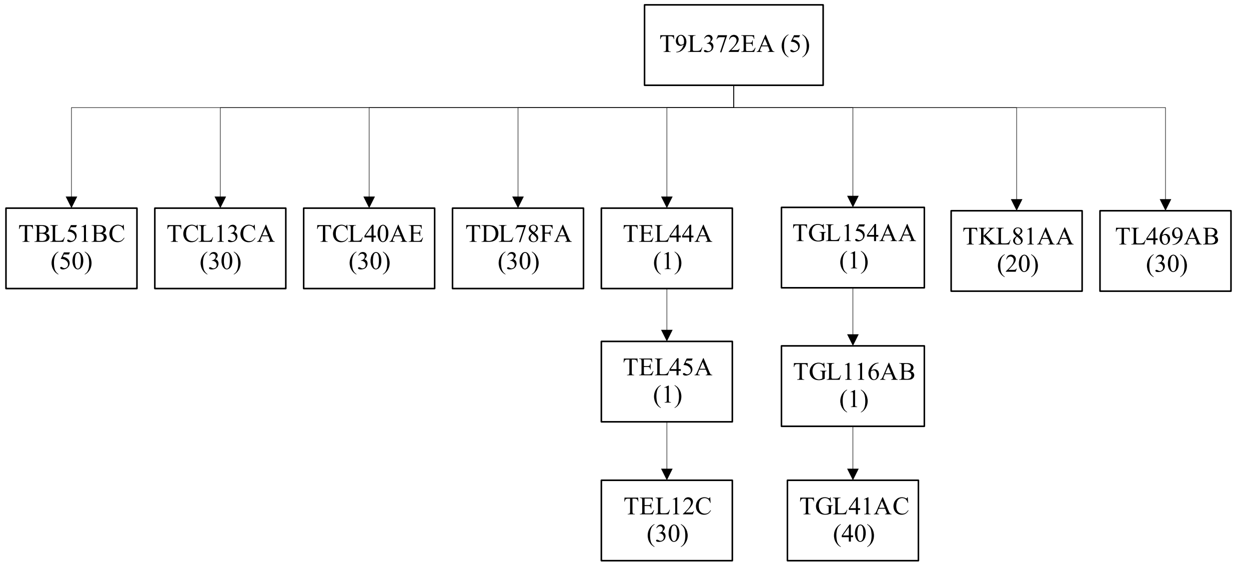
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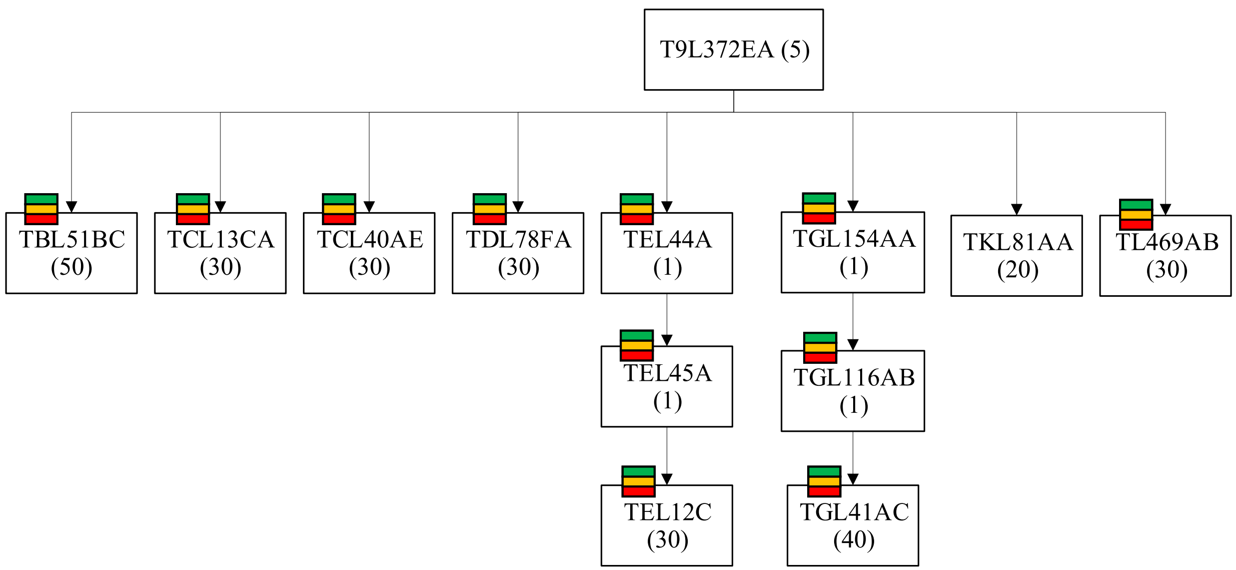
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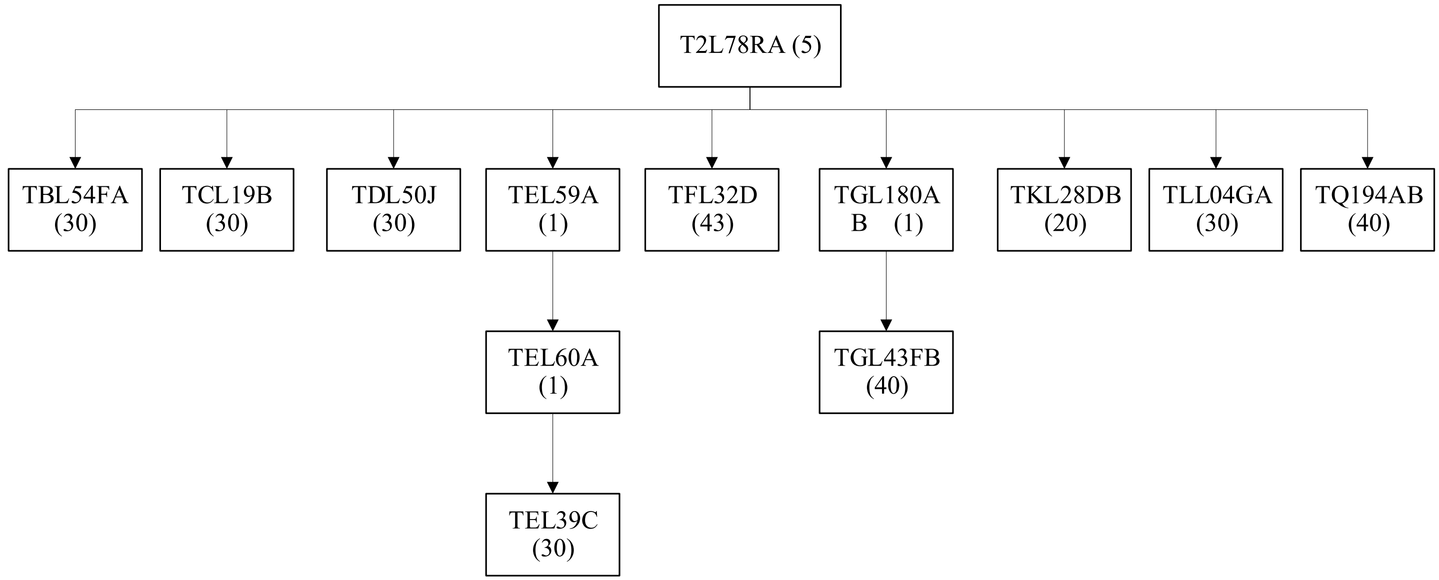
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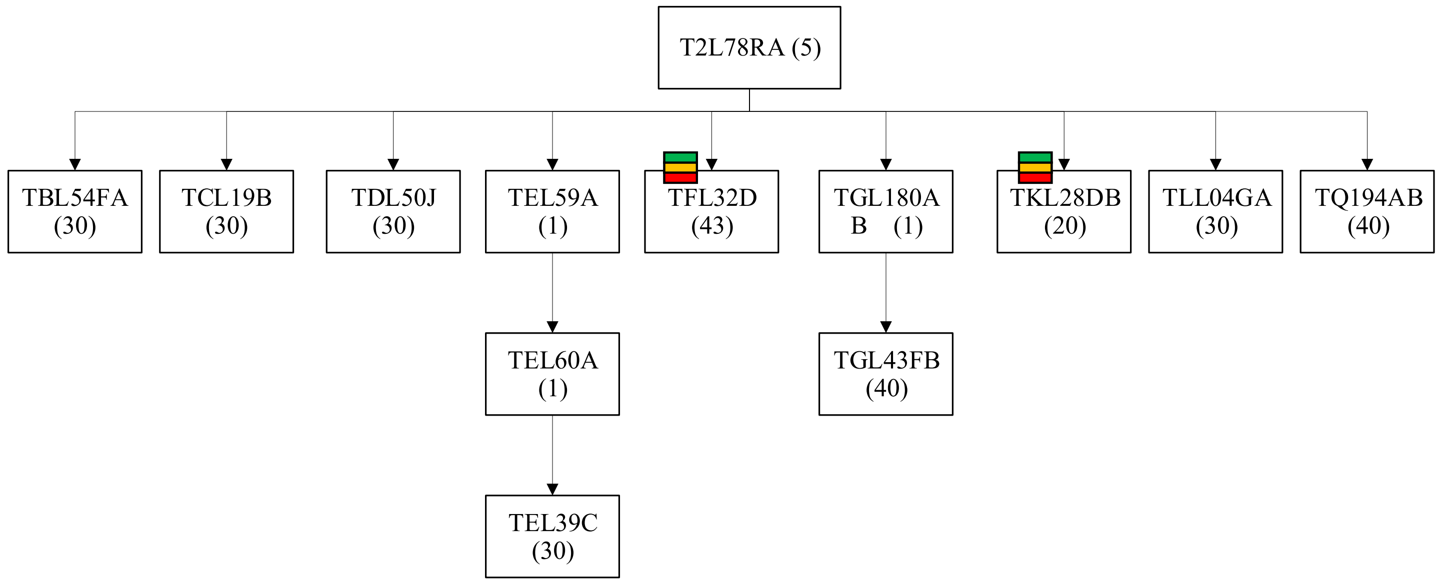
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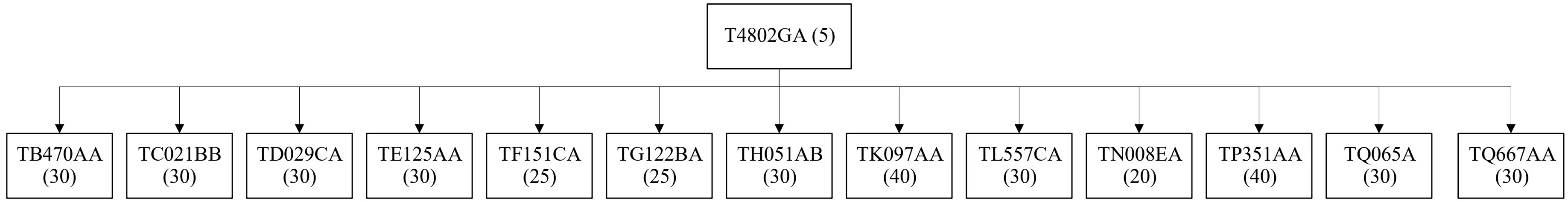

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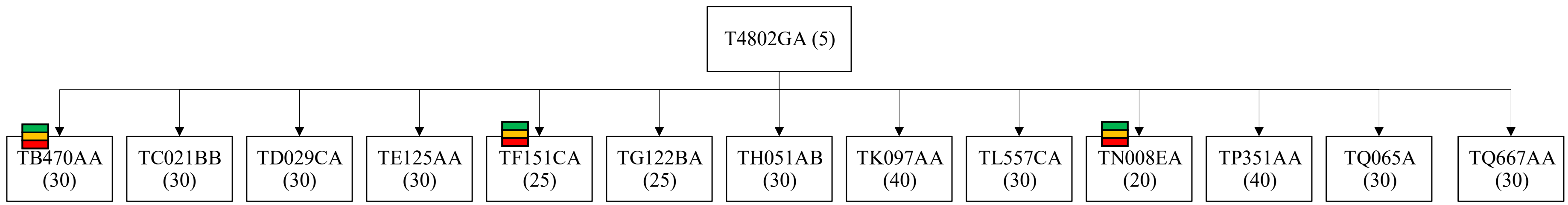

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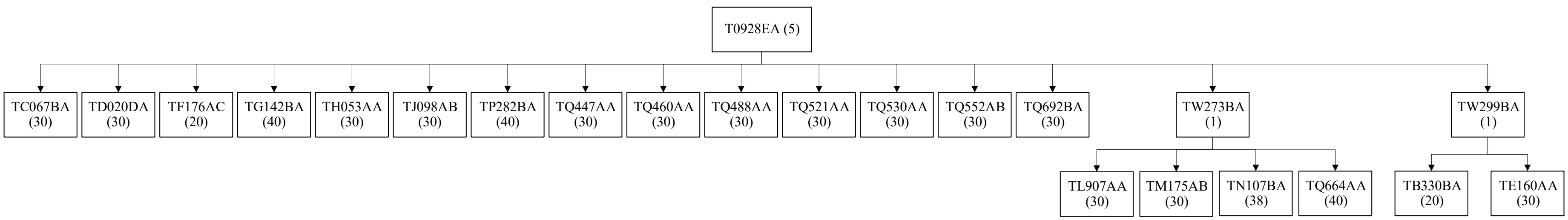

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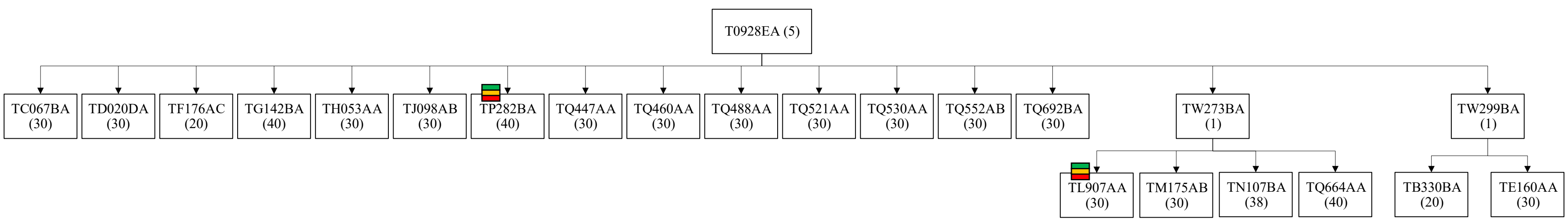

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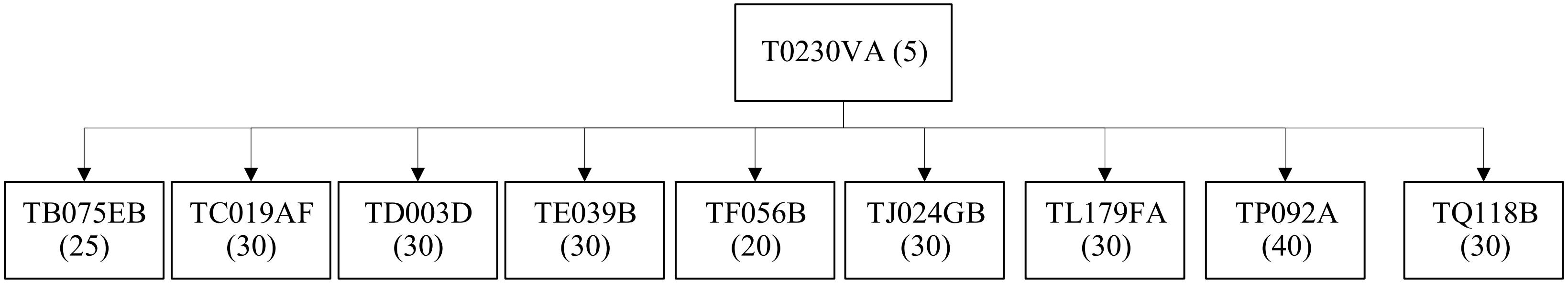
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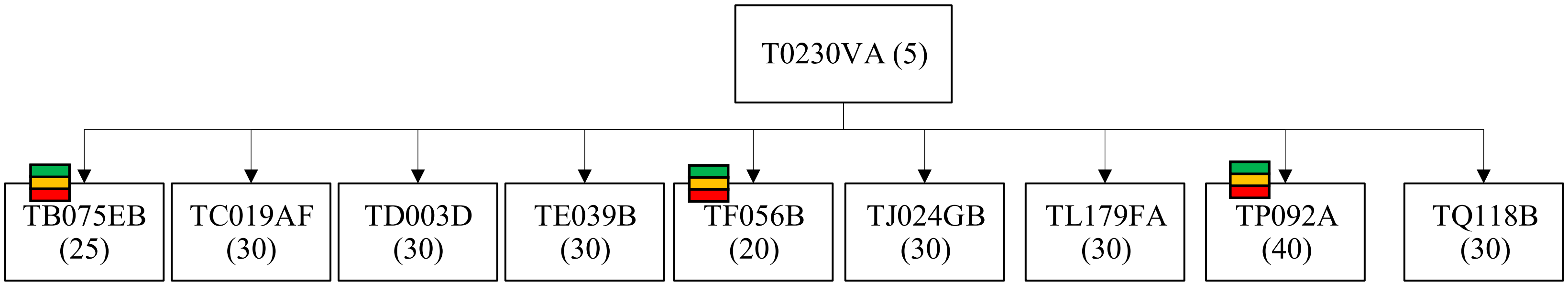
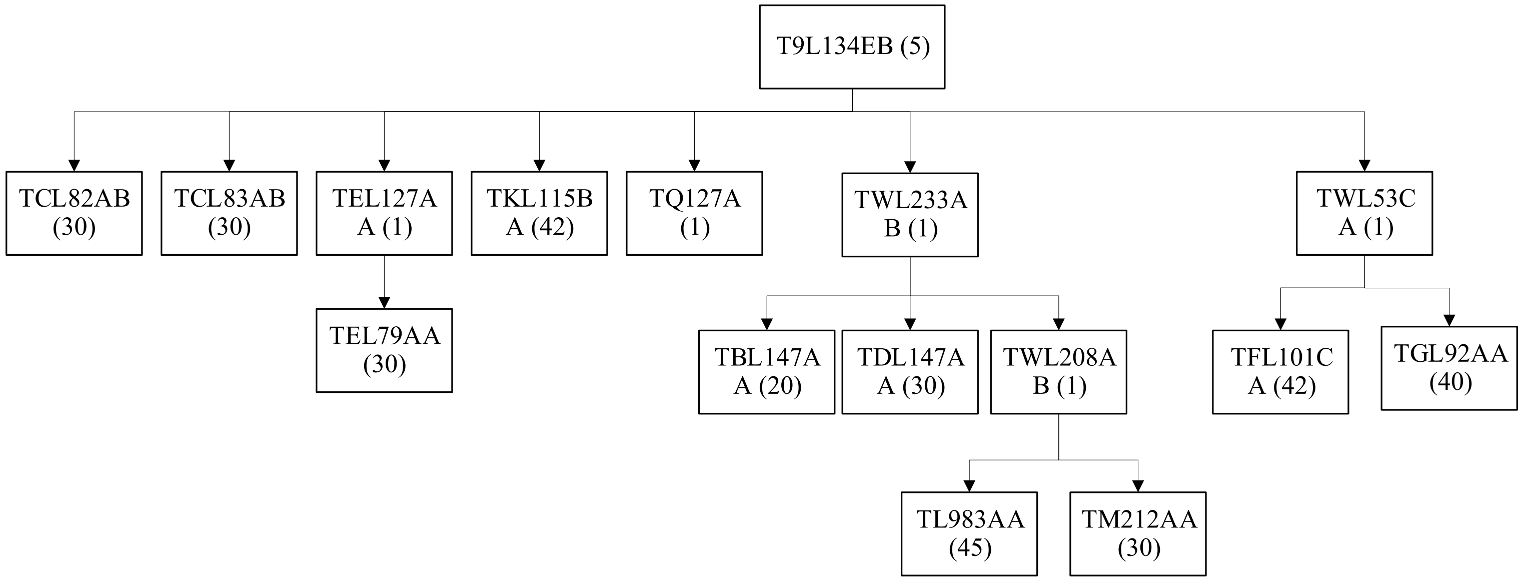
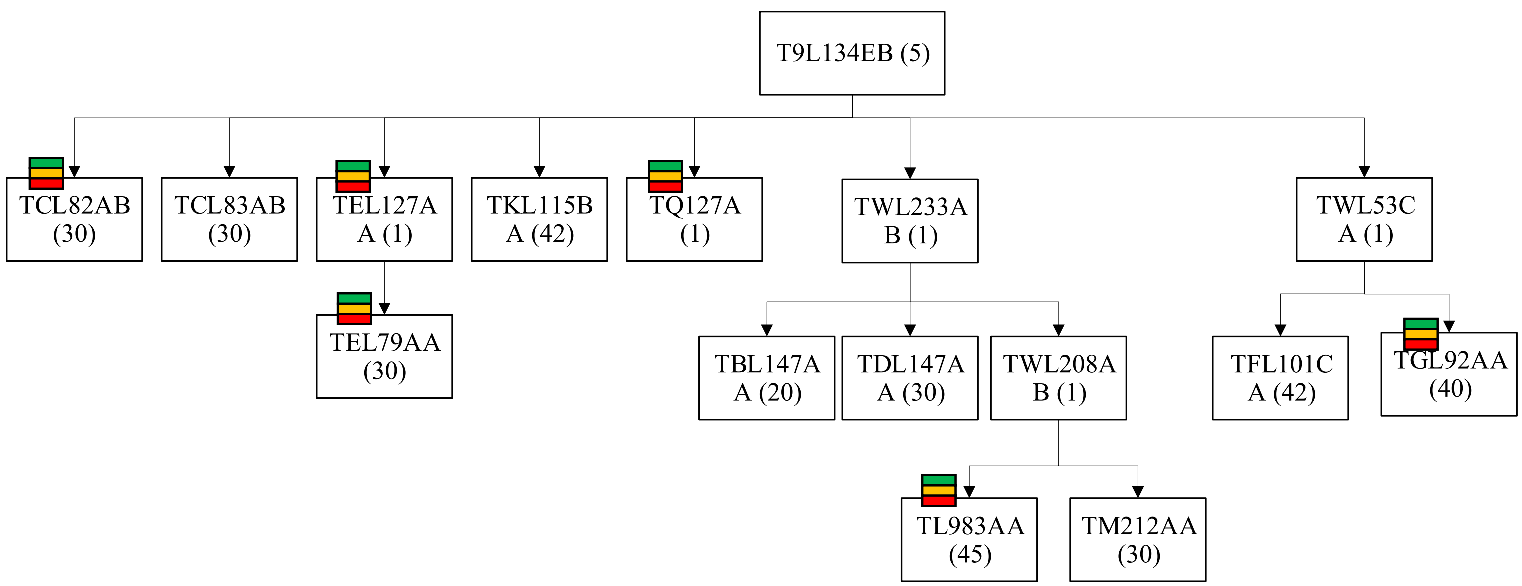
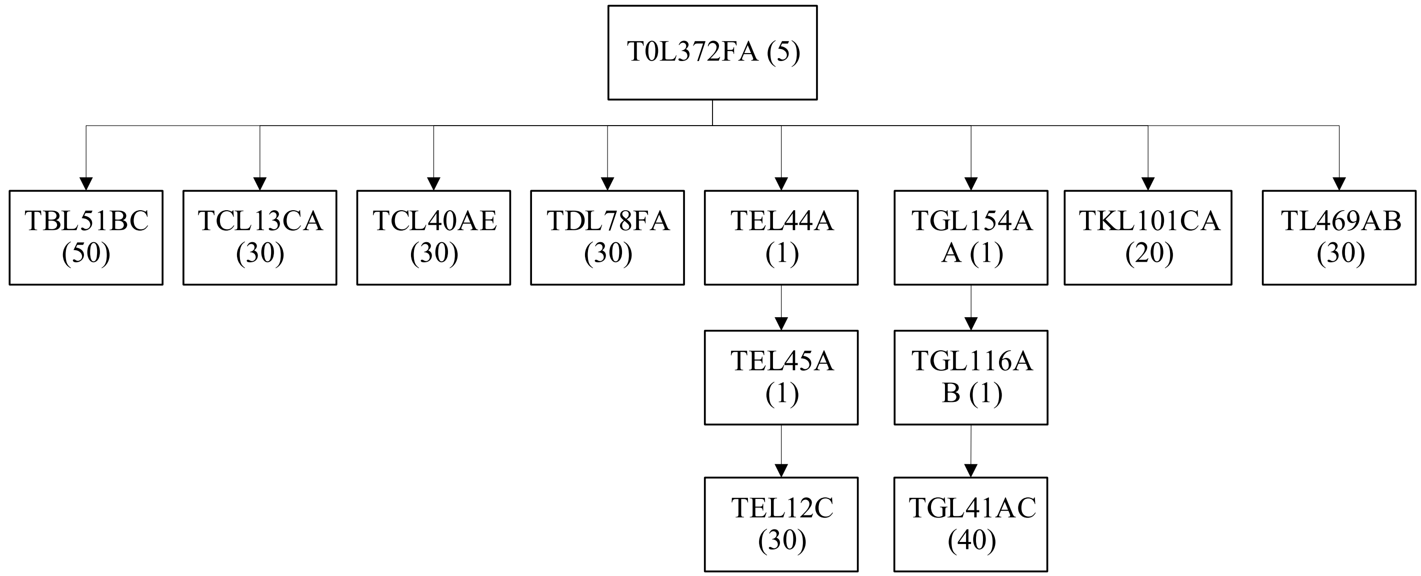
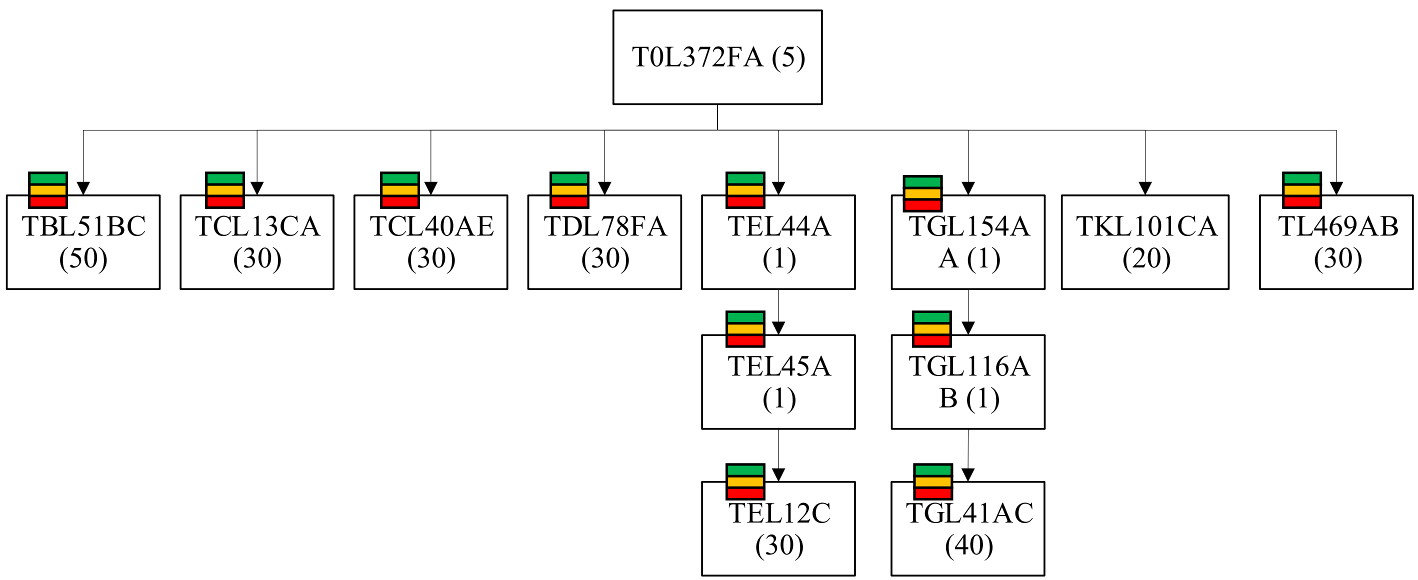

T0230VA (5)
TB075EB (25)
TC019AF (30)
TD003D (30)
TE039B (30)
TF056B (20)
TJ024GB (30)
TL179FA (30)
TP092A (40)
TQ118B (30)


T9L134EB (5)
TCL82AB (30)
TCL83AB (30)
TEL127A A (1)
TKL115B A (42)
TQ127A (1)
TWL233A B (1)
TWL53C A (1)
TEL79AA (30)
TBL147A A (20)
TDL147A A (30)
TWL208A B (1)
TFL101C A (42)
TGL92AA (40)
TL983AA (45)
TM212AA (30)


T9L134EB (5)
TCL82AB (30)
TCL83AB (30)
TEL127A A (1)
TKL115B A (42)
TQ127A (1)
TWL233A B (1)
TWL53C A (1)
TEL79AA (30)
TBL147A A (20)
TDL147A A (30)
TWL208A B (1)
TFL101C A (42)
TGL92AA (40)
TL983AA (45)
TM212AA (30)


T0L372FA (5)
TBL51BC (50)
TCL13CA (30)
TCL40AE (30)
TDL78FA (30)
TEL44A (1)
TGL154A A (1)
TKL101CA (20)
TL469AB (30)
TEL45A (1)
TGL116A B (1)
TEL12C (30)
TGL41AC (40)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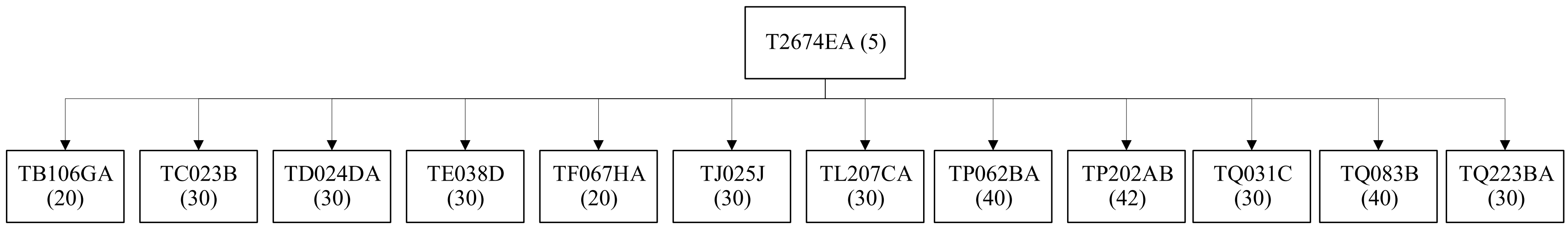
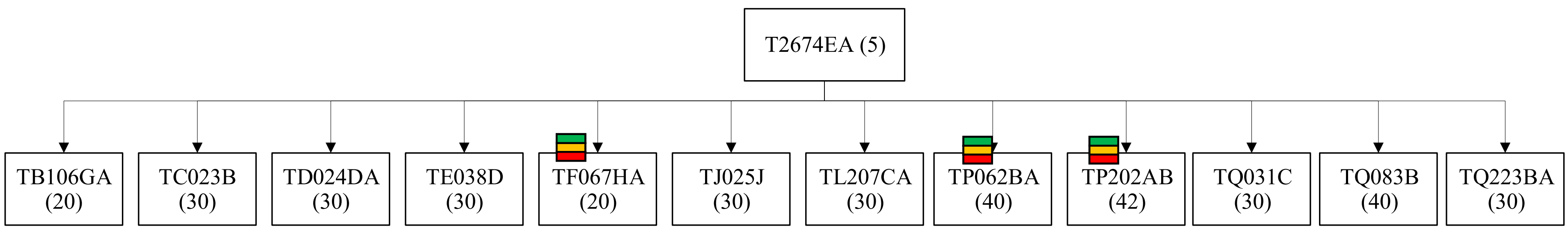
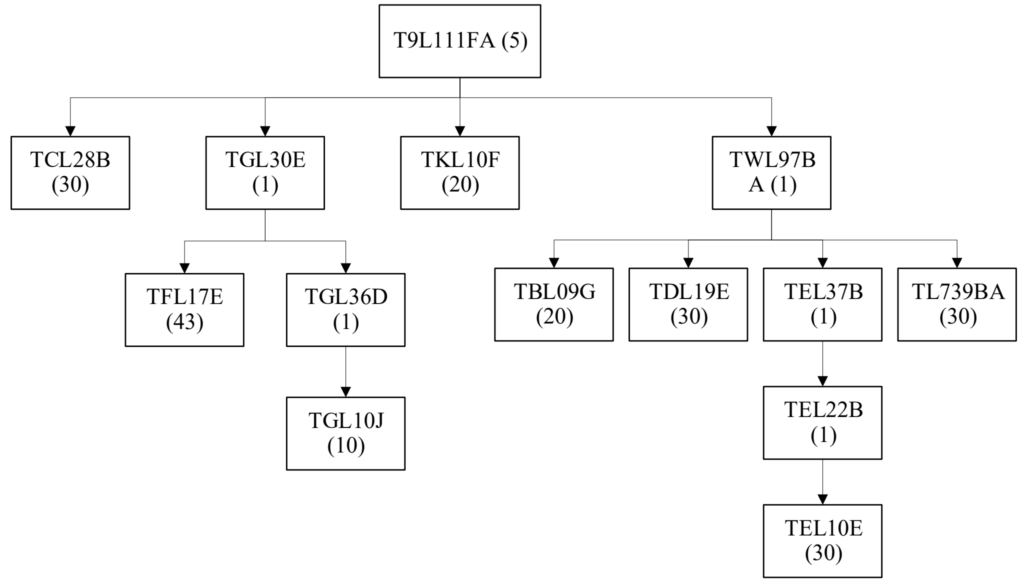
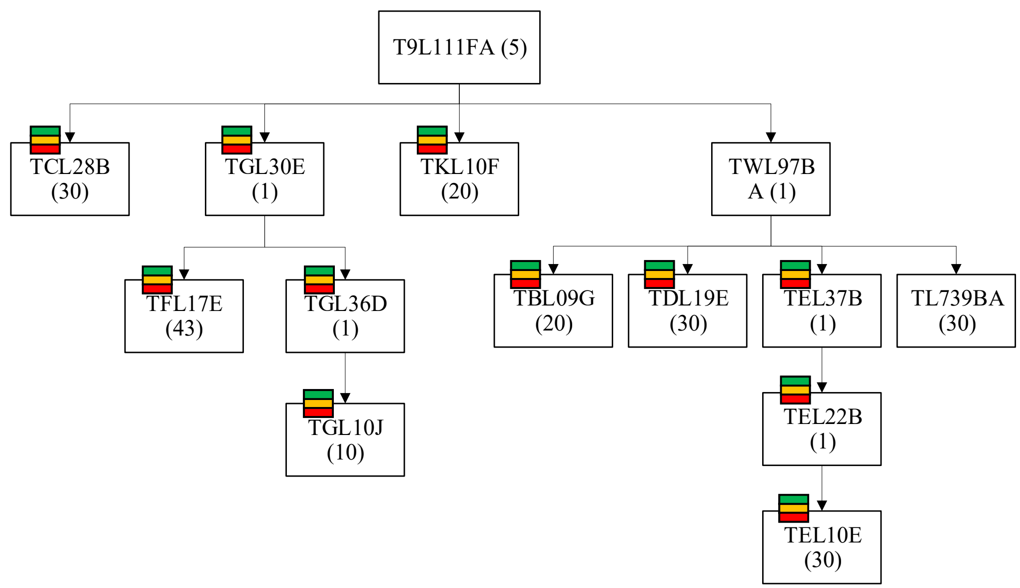
TBL51BC (50)
TCL13CA (30)
TCL40AE (30)
TDL78FA (30)
TEL44A (1)
TGL154A A (1)
TKL101CA (20)
TL469AB (30)
TEL45A (1)
TGL116A B (1)
TEL12C (30)
TGL41AC (40)


T2674EA (5)
TB106GA (20)
TC023B (30)
TD024DA (30)
TE038D (30)
TF067HA (20)
TJ025J (30)
TL207CA (30)
TP062BA (40)
TP202AB (42)
TQ031C (30)
TQ083B (40)
TQ223BA (30)

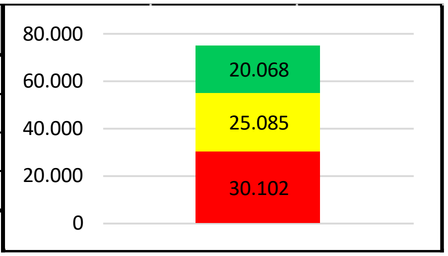

T2674EA (5)
TB106GA (20)
TC023B (30)
TD024DA (30)
TE038D (30)
TF067HA (20)
TJ025J (30)
TL207CA (30)
TP062BA (40)
TP202AB (42)
TQ031C (30)
TQ083B (40)
TQ223BA (30)


T9L111FA (5)
TCL28B (30)
TGL30E (1)
TKL10F (20)
TWL97BA (1)
TFL17E (43)
TGL36D (1)
TGL10J (10)
TBL09G (20)
TDL19E (30)
TEL37B (1)
TL739BA (30)
TEL22B (1)
TEL10E (30)

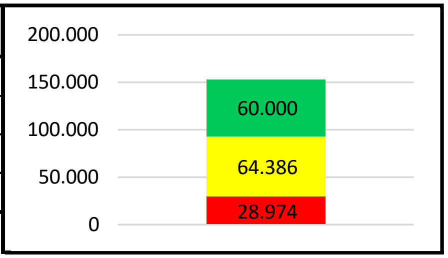

T9L111FA (5)
TCL28B (30)
TGL30E (1)
TKL10F (20)
TWL97BA (1)
TFL17E (43)
TGL36D (1)
TGL10J (10)
TBL09G (20)
TDL19E (30)
TEL37B (1)
TL739BA (30)
TEL22B (1)
TEL10E (30)

Appendix 2. Buffer Profiles

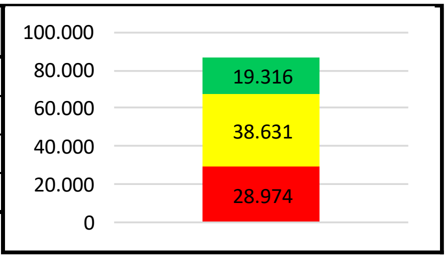
TBL09G			
Average Daily Usage (ADU)	1.254	Green Zone	20.068
Buffer profiles	P, S (0,8), M (0,5)	Yellow Zone	25.085
Minimum Order Quantity (MOQ)	20.000	Red Zone	30.102
Order Cycle	8	Total Buffer	75.256
Lead Time	20		



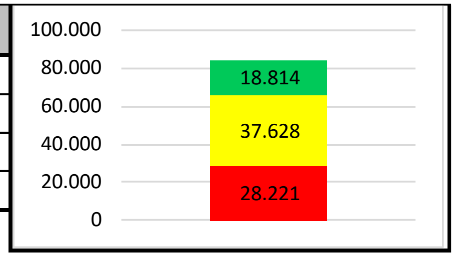
TBL51BC			
Average Daily Usage (ADU)	1.288	Green Zone	60.000
Buffer profiles	P, L (0,3), M (0,5)	Yellow Zone	64.386
Minimum Order Quantity (MOQ)	60.000	Red Zone	28.974
Order Cycle	8	Total Buffer	153.359
Lead Time	50		



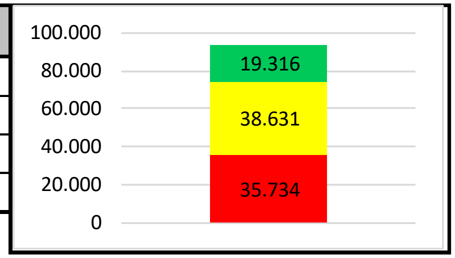
TCL13CA			
Average Daily Usage (ADU)	1.288	Green Zone	19.316
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	38.631
Minimum Order Quantity (MOQ)	10.000	Red Zone	28.974
Order Cycle	8	Total Buffer	86.921
Lead Time	30		



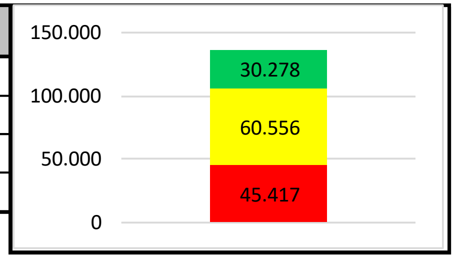
TCL28B			
Average Daily Usage (ADU)	1.254	**Green Zone**	**18.814**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**37.628**
Minimum Order Quantity (MOQ)	9.600	**Red Zone**	**28.221**
Order Cycle	8	**Total Buffer**	**84.663**
Lead Time	30		



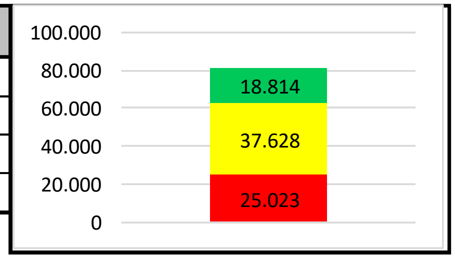
TCL40AE			
Average Daily Usage (ADU)	1.288	**Green Zone**	**19.316**
Buffer profiles	P, M (0,5), H (0,85)	**Yellow Zone**	**38.631**
Minimum Order Quantity (MOQ)	11.764	**Red Zone**	**35.734**
Order Cycle	8	**Total Buffer**	**93.681**
Lead Time	30		



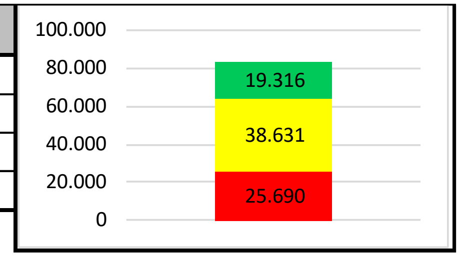
TCL82AB			
Average Daily Usage (ADU)	2.019	**Green Zone**	**30.278**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**60.556**
Minimum Order Quantity (MOQ)	16.000	**Red Zone**	**45.417**
Order Cycle	8	**Total Buffer**	**136.251**
Lead Time	30		



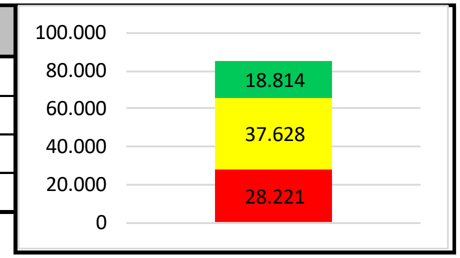
TDL19E			
Average Daily Usage (ADU)	1.254	**Green Zone**	**18.814**
Buffer profiles	P, M (0,5), L (0,33)	**Yellow Zone**	**37.628**
Minimum Order Quantity (MOQ)	6.481	**Red Zone**	**25.023**
Order Cycle	8	**Total Buffer**	**81.464**
Lead Time	30		



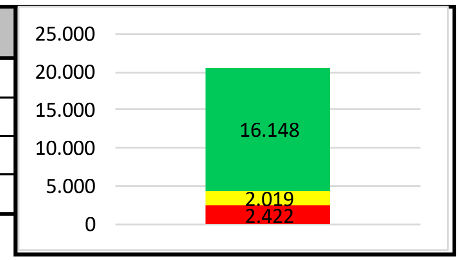
TDL78FA			
Average Daily Usage (ADU)	1.288	**Green Zone**	**19.316**
Buffer profiles	P, M (0,5), L (0,33)	**Yellow Zone**	**38.631**
Minimum Order Quantity (MOQ)	6.481	**Red Zone**	**25.690**
Order Cycle	8	**Total Buffer**	**83.637**
Lead Time	30		



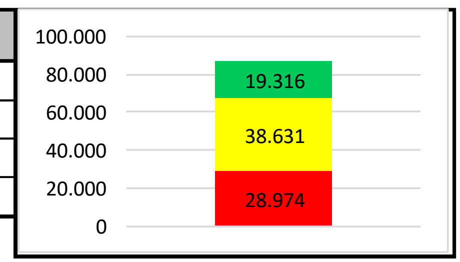
TEL10E			
Average Daily Usage (ADU)	1.254	**Green Zone**	**18.814**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**37.628**
Minimum Order Quantity (MOQ)	8.173	**Red Zone**	**28.221**
Order Cycle	8	**Total Buffer**	**84.663**
Lead Time	30		



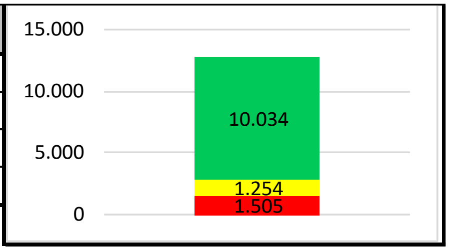
TEL127AA			
Average Daily Usage (ADU)	2.019	**Green Zone**	**16.148**
Buffer profiles	I, S (0,8), M (0,5)	**Yellow Zone**	**2.019**
Minimum Order Quantity (MOQ)		**Red Zone**	**2.422**
Order Cycle	8	**Total Buffer**	**20.589**
Lead Time	1		



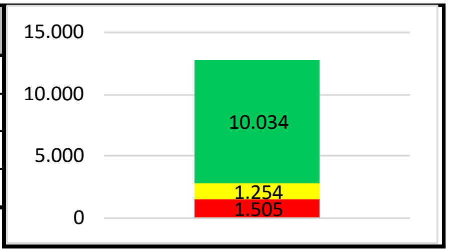
TEL12C			
Average Daily Usage (ADU)	1.288	**Green Zone**	**19.316**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**38.631**
Minimum Order Quantity (MOQ)	8.173	**Red Zone**	**28.974**
Order Cycle	8	**Total Buffer**	**86.921**
Lead Time	30		



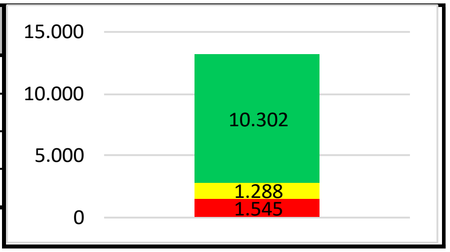
TEL22B			
Average Daily Usage (ADU)	1.254	Green Zone	10.034
Buffer profiles	I, S (0,8), M (0,5)	Yellow Zone	1.254
Minimum Order Quantity (MOQ)		Red Zone	1.505
Order Cycle	8	Total Buffer	12.793
Lead Time	1		



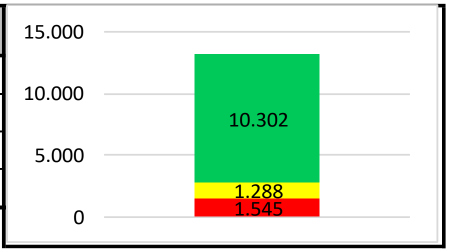
TEL37B			
Average Daily Usage (ADU)	1.254	Green Zone	10.034
Buffer profiles	I, S (0,8), M (0,5)	Yellow Zone	1.254
Minimum Order Quantity (MOQ)		Red Zone	1.505
Order Cycle	8	Total Buffer	12.793
Lead Time	1		



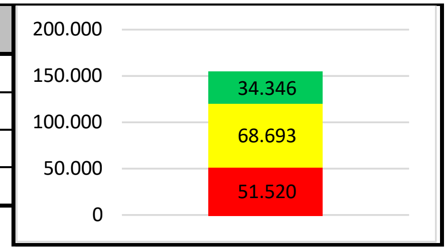
TEL44A			
Average Daily Usage (ADU)	1.288	Green Zone	10.302
Buffer profiles	I, S (0,8), M (0,5)	Yellow Zone	1.288
Minimum Order Quantity (MOQ)		Red Zone	1.545
Order Cycle	8	Total Buffer	13.135
Lead Time	1		



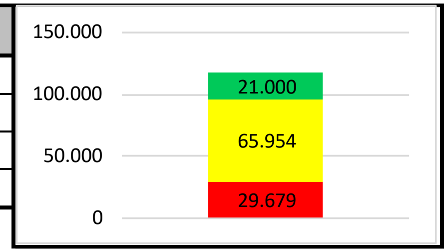
TEL45A			
Average Daily Usage (ADU)	1.288	Green Zone	10.302
Buffer profiles	I, S (0,8), M (0,5)	Yellow Zone	1.288
Minimum Order Quantity (MOQ)		Red Zone	1.545
Order Cycle	8	Total Buffer	13.135
Lead Time	1		



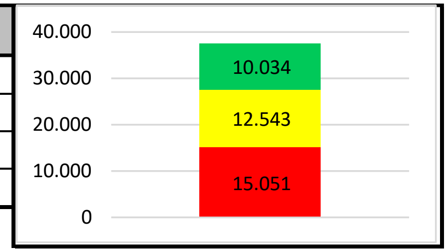
TEL79AA			
Average Daily Usage (ADU)	2.290	Green Zone	34.346
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	68.693
Minimum Order Quantity (MOQ)	9.308	Red Zone	51.520
Order Cycle	8	Total Buffer	154.559
Lead Time	30		



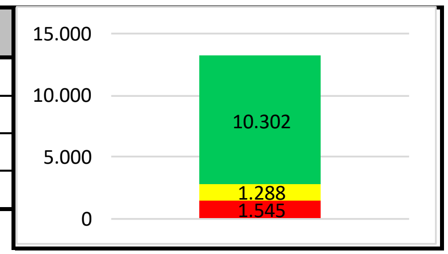
TFL17E			
Average Daily Usage (ADU)	1.534	Green Zone	21.000
Buffer profiles	P, L (0,3), M (0,5)	Yellow Zone	65.954
Minimum Order Quantity (MOQ)	21.000	Red Zone	29.679
Order Cycle	8	Total Buffer	116.633
Lead Time	43		



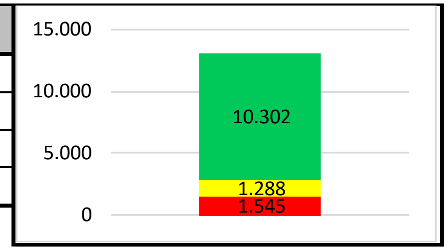
TGL10J			
Average Daily Usage (ADU)	1.254	Green Zone	10.034
Buffer profiles	P, S (0,8), M (0,5)	Yellow Zone	12.543
Minimum Order Quantity (MOQ)	2.688	Red Zone	15.051
Order Cycle	8	Total Buffer	37.628
Lead Time	10		



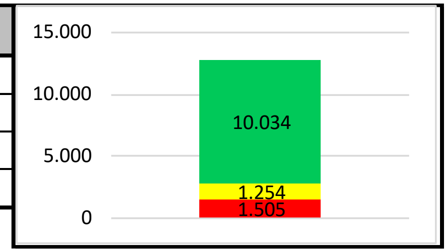
TGL116AB			
Average Daily Usage (ADU)	1.288	Green Zone	10.302
Buffer profiles	I, S (0,8), M (0,5)	Yellow Zone	1.288
Minimum Order Quantity (MOQ)		Red Zone	1.545
Order Cycle	8	Total Buffer	13.135
Lead Time	1		



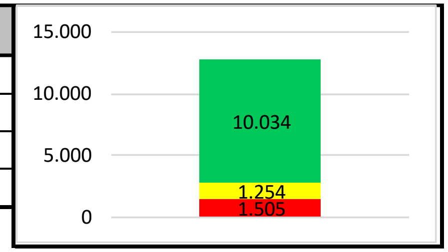
TGL154AA			
Average Daily Usage (ADU)	1.288	**Green Zone**	**10.302**
Buffer profiles	I, S (0,8), M (0,5)	**Yellow Zone**	**1.288**
Minimum Order Quantity (MOQ)		**Red Zone**	**1.545**
Order Cycle	8	**Total Buffer**	**13.135**
Lead Time	1		



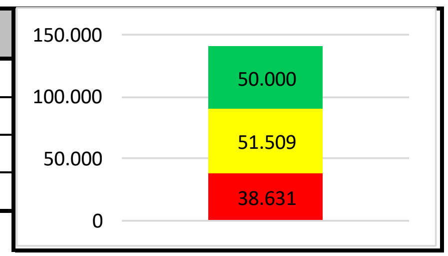
TGL30E			
Average Daily Usage (ADU)	1.254	**Green Zone**	**10.034**
Buffer profiles	I, S (0,8), M (0,5)	**Yellow Zone**	**1.254**
Minimum Order Quantity (MOQ)		**Red Zone**	**1.505**
Order Cycle	8	**Total Buffer**	**12.793**
Lead Time	1		



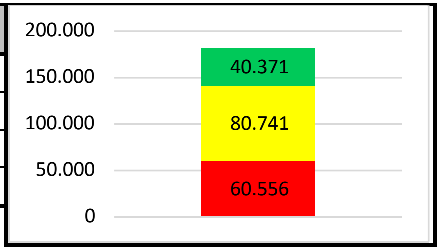
TGL36D			
Average Daily Usage (ADU)	1.254	**Green Zone**	**10.034**
Buffer profiles	I, S (0,8), M (0,5)	**Yellow Zone**	**1.254**
Minimum Order Quantity (MOQ)		**Red Zone**	**1.505**
Order Cycle	8	**Total Buffer**	**12.793**
Lead Time	1		



TGL41AC			
Average Daily Usage (ADU)	1.288	**Green Zone**	**50.000**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**51.509**
Minimum Order Quantity (MOQ)	50.000	**Red Zone**	**38.631**
Order Cycle	8	**Total Buffer**	**140.140**
Lead Time	40		

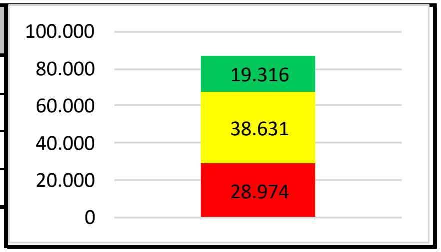


TGL92AA			
Average Daily Usage (ADU)	2.019	Green Zone	40.371
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	80.741
Minimum Order Quantity (MOQ)	30.000	Red Zone	60.556
Order Cycle	8	Total Buffer	181.668
Lead Time	40		

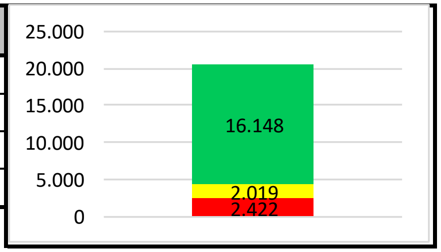


TKL10F			
Average Daily Usage (ADU)	1.254	Green Zone	20.068
Buffer profiles	P, S (0,8), H (0,85)	Yellow Zone	25.085
Minimum Order Quantity (MOQ)	20.000	Red Zone	37.126
Order Cycle	8	Total Buffer	82.280
Lead Time	20		

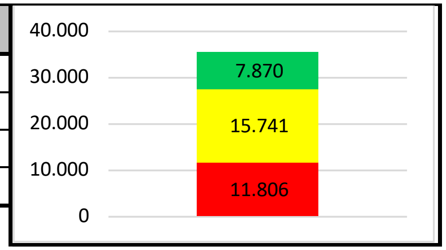
TL469AB			
Average Daily Usage (ADU)	1.288	Green Zone	19.316
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	38.631
Minimum Order Quantity (MOQ)	1.620	Red Zone	28.974
Order Cycle	8	Total Buffer	86.921
Lead Time	30		



TQ127A			
Average Daily Usage (ADU)	2.019	Green Zone	16.148
Buffer profiles	I, S (0,8), M (0,5)	Yellow Zone	2.019
Minimum Order Quantity (MOQ)		Red Zone	2.422
Order Cycle	8	Total Buffer	20.589
Lead Time	1		

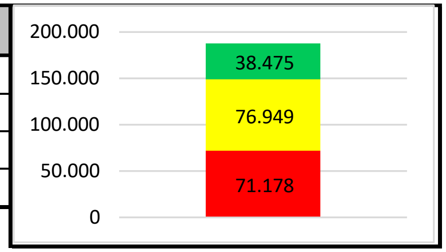


TB075EB			
Average Daily Usage (ADU)	630	**Green Zone**	**7.870**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**15.741**
Minimum Order Quantity (MOQ)	1.296	**Red Zone**	**11.806**
Order Cycle	8	**Total Buffer**	**35.417**
Lead Time	25		

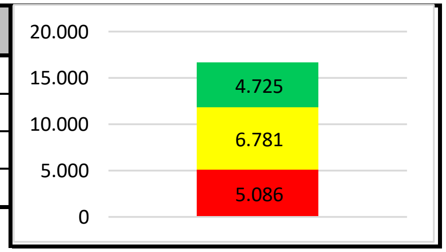


TB300DA			
Average Daily Usage (ADU)	259	**Green Zone**	**3.879**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**7.759**
Minimum Order Quantity (MOQ)	1.728	**Red Zone**	**5.819**
Order Cycle	8	**Total Buffer**	**17.457**
Lead Time	30		

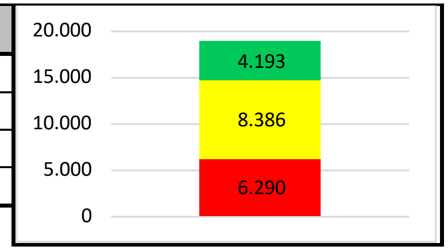
TB470AA			
Average Daily Usage (ADU)	2.565	**Green Zone**	**38.475**
Buffer profiles	P, M (0,5), H (0,85)	**Yellow Zone**	**76.949**
Minimum Order Quantity (MOQ)	25.000	**Red Zone**	**71.178**
Order Cycle	8	**Total Buffer**	**186.602**
Lead Time	30		



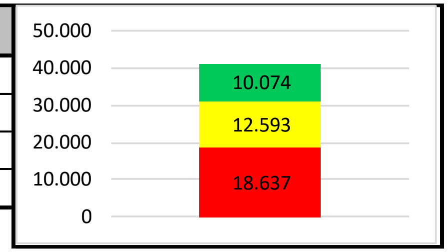
TBL170AA			
Average Daily Usage (ADU)	271	**Green Zone**	**4.725**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**6.781**
Minimum Order Quantity (MOQ)	4.725	**Red Zone**	**5.086**
Order Cycle	8	**Total Buffer**	**16.591**
Lead Time	25		



TBL72AB			
Average Daily Usage (ADU)	280	**Green Zone**	**4.193**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**8.386**
Minimum Order Quantity (MOQ)	2.592	**Red Zone**	**6.290**
Order Cycle	8	**Total Buffer**	**18.869**
Lead Time	30		

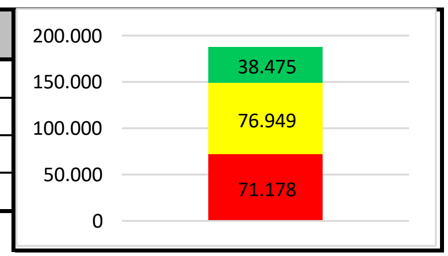


TF056B			
Average Daily Usage (ADU)	630	**Green Zone**	**10.074**
Buffer profiles	P, S (0,8), H (0,85)	**Yellow Zone**	**12.593**
Minimum Order Quantity (MOQ)	2.000	**Red Zone**	**18.637**
Order Cycle	8	**Total Buffer**	**41.304**
Lead Time	20		

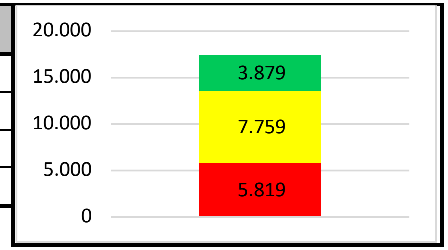


TF067HA			
Average Daily Usage (ADU)	680	**Green Zone**	**10.881**
Buffer profiles	P, S (0,8), H (0,85)	**Yellow Zone**	**13.601**
Minimum Order Quantity (MOQ)	2.000	**Red Zone**	**20.129**
Order Cycle	8	**Total Buffer**	**44.610**
Lead Time	20		

TF151CA			
Average Daily Usage (ADU)	2.565	**Green Zone**	**38.475**
Buffer profiles	P, M (0,5), H (0,85)	**Yellow Zone**	**76.949**
Minimum Order Quantity (MOQ)	2.500	**Red Zone**	**71.178**
Order Cycle	8	**Total Buffer**	**186.602**
Lead Time	30		

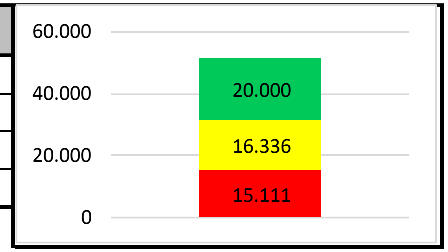


TF155BB			
Average Daily Usage (ADU)	259	Green Zone	3.879
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	7.759
Minimum Order Quantity (MOQ)	2.592	Red Zone	5.819
Order Cycle	8	Total Buffer	17.457
Lead Time	30		

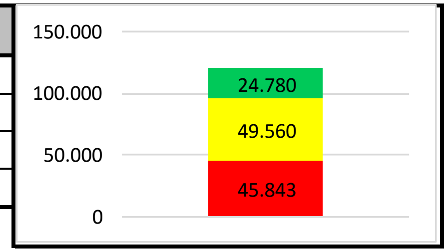


TFL19E			
Average Daily Usage (ADU)	159	Green Zone	20.000
Buffer profiles	P, M (0,5), H (0,85)	Yellow Zone	6.657
Minimum Order Quantity (MOQ)	20.000	Red Zone	6.158
Order Cycle	8	Total Buffer	32.815
Lead Time	42		

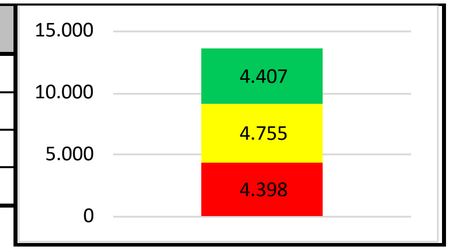
TFL38EA			
Average Daily Usage (ADU)	389	Green Zone	20.000
Buffer profiles	P, M (0,5), H (0,85)	Yellow Zone	16.336
Minimum Order Quantity (MOQ)	20.000	Red Zone	15.111
Order Cycle	8	Total Buffer	51.448
Lead Time	42		



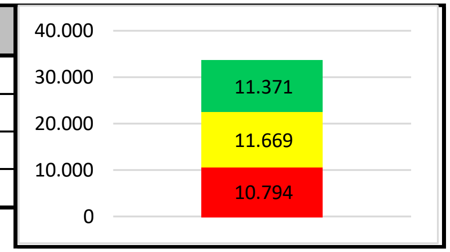
TFL69BA			
Average Daily Usage (ADU)	1.239	Green Zone	24.780
Buffer profiles	P, M (0,5), H (0,85)	Yellow Zone	49.560
Minimum Order Quantity (MOQ)	20.000	Red Zone	45.843
Order Cycle	8	Total Buffer	120.182
Lead Time	40		



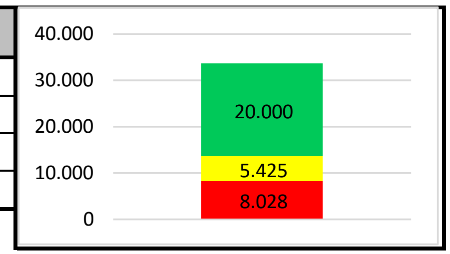
TGL17E			
Average Daily Usage (ADU)	159	**Green Zone**	**4.407**
Buffer profiles	P, M (0,5), H (0,85)	**Yellow Zone**	**4.755**
Minimum Order Quantity (MOQ)	4.407	**Red Zone**	**4.398**
Order Cycle	8	**Total Buffer**	**13.561**
Lead Time	30		



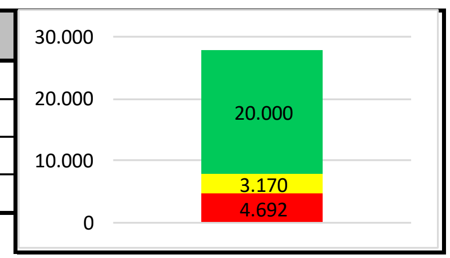
TGL49KA			
Average Daily Usage (ADU)	389	**Green Zone**	**11.371**
Buffer profiles	P, M (0,5), H (0,85)	**Yellow Zone**	**11.669**
Minimum Order Quantity (MOQ)	11.371	**Red Zone**	**10.794**
Order Cycle	8	**Total Buffer**	**33.834**
Lead Time	30		



TKL139AB			
Average Daily Usage (ADU)	271	**Green Zone**	**20.000**
Buffer profiles	P, S (0,8), H (0,85)	**Yellow Zone**	**5.425**
Minimum Order Quantity (MOQ)	20.000	**Red Zone**	**8.028**
Order Cycle	8	**Total Buffer**	**33.453**
Lead Time	20		



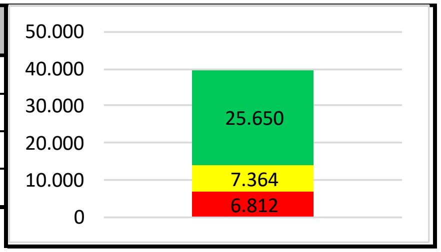
TKL14G			
Average Daily Usage (ADU)	159	**Green Zone**	**20.000**
Buffer profiles	P, S (0,8), H (0,85)	**Yellow Zone**	**3.170**
Minimum Order Quantity (MOQ)	20.000	**Red Zone**	**4.692**
Order Cycle	8	**Total Buffer**	**27.862**
Lead Time	20		



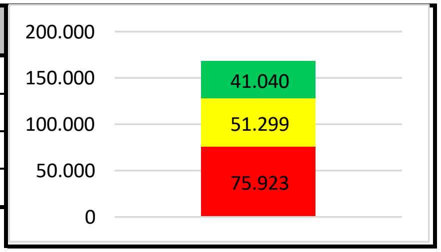
TKL28DB			
Average Daily Usage (ADU)	361	**Green Zone**	**20.000**
Buffer profiles	P, S (0,8), H (0,85)	**Yellow Zone**	**7.230**
Minimum Order Quantity (MOQ)	20.000	**Red Zone**	**10.700**
Order Cycle	8	**Total Buffer**	**37.929**
Lead Time	20		

TKL80CB			
Average Daily Usage (ADU)	1.239	**Green Zone**	**20.000**
Buffer profiles	P, S (0,8), H (0,85)	**Yellow Zone**	**24.780**
Minimum Order Quantity (MOQ)	20.000	**Red Zone**	**36.674**
Order Cycle	8	**Total Buffer**	**81.454**
Lead Time	20		

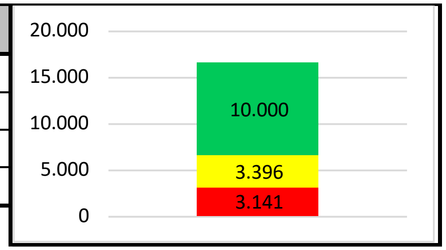
TL907AA			
Average Daily Usage (ADU)	245	**Green Zone**	**25.650**
Buffer profiles	P, M (0,5), H (0,85)	**Yellow Zone**	**7.364**
Minimum Order Quantity (MOQ)	25.650	**Red Zone**	**6.812**
Order Cycle	8	**Total Buffer**	**39.826**
Lead Time	30		



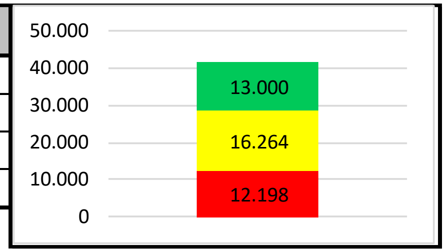
TN008EA			
Average Daily Usage (ADU)	2.565	**Green Zone**	**41.040**
Buffer profiles	P, S (0,8), H (0,85)	**Yellow Zone**	**51.299**
Minimum Order Quantity (MOQ)	10.000	**Red Zone**	**75.923**
Order Cycle	8	**Total Buffer**	**168.262**
Lead Time	20		



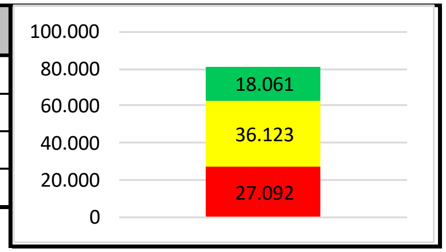
TN076AB			
Average Daily Usage (ADU)	89	**Green Zone**	**10.000**
Buffer profiles	P, M (0,5), H (0,85)	**Yellow Zone**	**3.396**
Minimum Order Quantity (MOQ)	10.000	**Red Zone**	**3.141**
Order Cycle	8	**Total Buffer**	**16.538**
Lead Time	38		



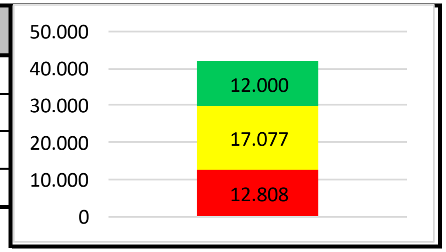
TP062BA			
Average Daily Usage (ADU)	407	**Green Zone**	**13.000**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**16.264**
Minimum Order Quantity (MOQ)	13.000	**Red Zone**	**12.198**
Order Cycle	8	**Total Buffer**	**41.462**
Lead Time	40		



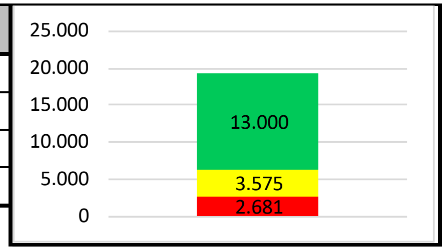
TP092A			
Average Daily Usage (ADU)	903	**Green Zone**	**18.061**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**36.123**
Minimum Order Quantity (MOQ)	13.000	**Red Zone**	**27.092**
Order Cycle	8	**Total Buffer**	**81.277**
Lead Time	40		



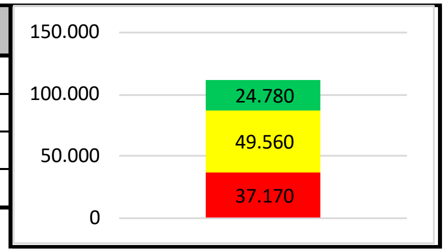
TP202AB			
Average Daily Usage (ADU)	407	**Green Zone**	**12.000**
Buffer profiles	P, M (0,5), M (0,5)	**Yellow Zone**	**17.077**
Minimum Order Quantity (MOQ)	12.000	**Red Zone**	**12.808**
Order Cycle	8	**Total Buffer**	**41.885**
Lead Time	42		



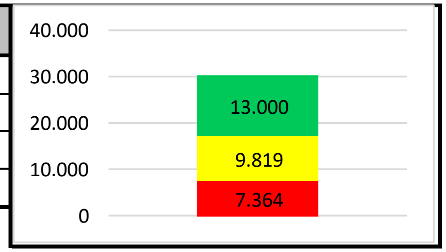
TP205AA			
Average Daily Usage (ADU)	89	Green Zone	13.000
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	3.575
Minimum Order Quantity (MOQ)	13.000	Red Zone	2.681
Order Cycle	8	Total Buffer	19.256
Lead Time	40		



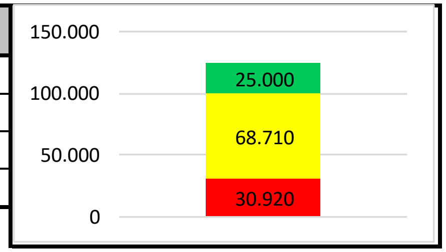
TP208AA			
Average Daily Usage (ADU)	1.239	Green Zone	24.780
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	49.560
Minimum Order Quantity (MOQ)	13.000	Red Zone	37.170
Order Cycle	8	Total Buffer	111.509
Lead Time	40		



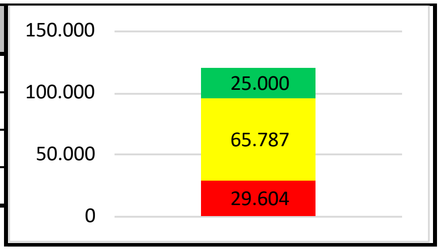
TP282BA			
Average Daily Usage (ADU)	245	Green Zone	13.000
Buffer profiles	P, M (0,5), M (0,5)	Yellow Zone	9.819
Minimum Order Quantity (MOQ)	13.000	Red Zone	7.364
Order Cycle	8	Total Buffer	30.183
Lead Time	40		



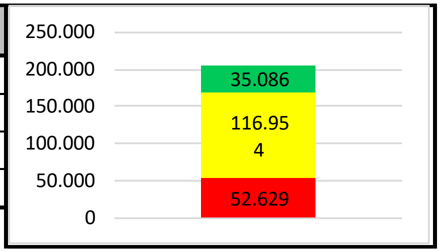
TKL79EA			
Average Daily Usage (ADU)	1.462	Green Zone	25.000
Buffer profiles	P, L (0,3), M (0,5)	Yellow Zone	68.710
Minimum Order Quantity (MOQ)	25.000	Red Zone	30.920
Order Cycle	8	Total Buffer	124.630
Lead Time	47		



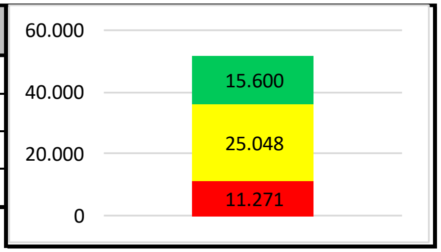
TFL54CA			
Average Daily Usage (ADU)	1.462	**Green Zone**	**25.000**
Buffer profiles	P, L (0,3), M (0,5)	**Yellow Zone**	**65.787**
Minimum Order Quantity (MOQ)	25.000	**Red Zone**	**29.604**
Order Cycle	8	**Total Buffer**	**120.391**
Lead Time	45		



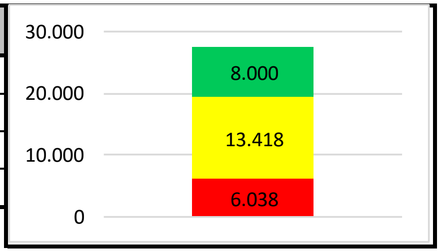
TL448AA			
Average Daily Usage (ADU)	1.462	**Green Zone**	**35.086**
Buffer profiles	P, L (0,3), M (0,5)	**Yellow Zone**	**116.954**
Minimum Order Quantity (MOQ)	7.000	**Red Zone**	**52.629**
Order Cycle	8	**Total Buffer**	**204.669**
Lead Time	80		



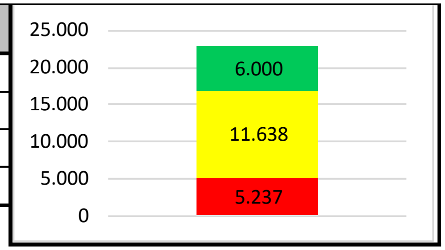
TL983AA			
Average Daily Usage (ADU)	557	**Green Zone**	**15.600**
Buffer profiles	P, L (0,3), M (0,5)	**Yellow Zone**	**25.048**
Minimum Order Quantity (MOQ)	15.600	**Red Zone**	**11.271**
Order Cycle	8	**Total Buffer**	**51.919**
Lead Time	45		



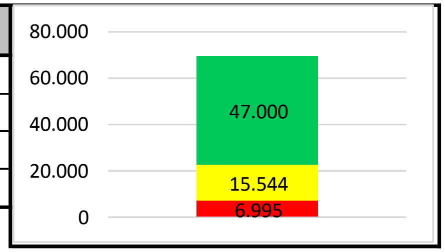
TKL144AB			
Average Daily Usage (ADU)	280	**Green Zone**	**8.000**
Buffer profiles	P, L (0,3), M (0,5)	**Yellow Zone**	**13.418**
Minimum Order Quantity (MOQ)	8.000	**Red Zone**	**6.038**
Order Cycle	8	**Total Buffer**	**27.456**
Lead Time	48		



TK105BA			
Average Daily Usage (ADU)	259	**Green Zone**	**6.000**
Buffer profiles	P, L (0,3), M (0,5)	**Yellow Zone**	**11.638**
Minimum Order Quantity (MOQ)	6.000	**Red Zone**	**5.237**
Order Cycle	8	**Total Buffer**	**22.875**
Lead Time	45		



TFL32D			
Average Daily Usage (ADU)	361	**Green Zone**	**47.000**
Buffer profiles	P, L (0,3), M (0,5)	**Yellow Zone**	**15.544**
Minimum Order Quantity (MOQ)	47.000	**Red Zone**	**6.995**
Order Cycle	8	**Total Buffer**	**69.538**
Lead Time	43		



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