POLITECNICO DI TORINO

Master of Science Degree in Industrial Production and Technological Innovation Engineering

Master of Science Thesis

MAPPING, DIMENSIONING AND CREATION OF BUFFER FOR AN EFFICIENT PRODUCTION STOCK MANAGEMENT BASED ON THE WORLD CLASS LOGISTICS METHOD. FCA SPA CASE.

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Abstract

The thesis covers the theme of buffer management within a manufacturing production system, following the concept of kaizen and WCM. The project took place in the FCA's Mirafiori Powertrain Plant, concentrating on the internal logistics processes, especially the interconnection between the two main areas within the Plant, production and assembly.

The ultimate aim of the project is to improve internal logistic stream by establishing tailored management approaches to each and every individual production lines, found inside the Plant. The project itself is continuously improving and ever evolving, adapting the nested PDCA cycle. Hence, a constant monitoring and adjustment is required. Within the first chapter, introduction and the background of FCA, specifically the Mirafiori Powertrain Plant will be unveiled. Within the same chapter, it will be discussed in detail the products of Mirafiori Powertrain Plant. Whilst the second chapter will disclose the theories and instruments used in this project to reach the target.

The practical work will be introduced and discussed in details within the third chapter, which is divided into two subchapters. A deeper discussion about the internal logistic of Mirafiori Powertrain Plant will be initiated, followed by the problem's description and criticality of the project. Using the method explained in the last sub chapter, the fourth chapter will be divided into two subchapters, which will include the first stages of the method adapted: Plan – Do. In this chapter, every single detail will be laid out and discussed, from planning phase, execution, monitoring and initial adjustments. After planning stage, the implementation of the plan will be discussed in the next chapter. Under the phase Do, presentation and consultation with the direct stakeholders of the project will be held to reach a mutual agreement. This chapter will be closed by the implementation of the plans and proposals.

The Check phase consists of observation and revision, if required, of the of the completed areas. The method of control and revisions will be discussed in details. Afterwards, within the Act phase where a further extension of the project will be proposed. Finally, the thesis will then be concluded by the review of the outcome and suggestion for future implementation.

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1. Introduction

1.1. FCA

Società Anonima Fabbrica Italiana di Automobili Torino – FIAT, was established on July 11th, 1899. Founded in the late 1800s, Fiat rapidly became one of the world's leading industrial groups. The first car the company produced was the 4 HP. A year later, in the 1900 the first plant was inaugurated and production reached 24 cars per year.

In the middle of 2009, Fiat Group and Chrysler Group made a global strategic alliance, which made them enter into a period of major changes. Chrysler Corp., was established in 1925 in the United States by industry visionary Walter P. Chrysler. This alliance aimed at creating synergies through optimization of the respective manufacturing footprints and their global supplier base. The companies also began sharing their technologies and access to new markets.

This alliance has generated successful outcomes. In under two years, Chrysler Group achieved an impressive turnaround and was able to fully repay the loans received from the U.S. and Canadian governments, six years ahead of schedule.

As for FIAT, the company decided to demerger its capital goods businesses and create two distinct entities, Fiat and Fiat Industrial. By the end of this period (2009), Fiat and Chrysler had achieved full integration and created a unified organization, even if it was not yet proven on paper.

At the beginning of 2014, Fiat Group finally acquired 100% ownership in Chrysler Group, thus creating a smooth and concrete path to complete the union between the two groups, in both technical and financial terms. The merger gave birth to a multi-national organization which operates in an enormous scale across 140 countries and employs approximately 240,000 people. The full integration facilitated the current global automaker to pursue their strategic objectives, while consistently delivering on the key financial targets set out in the plan.

Fiat Chrysler Automobiles (FCA) designs, engineers, manufactures and sells vehicles and related parts and services, components and production systems worldwide through 159 manufacturing facilities, 87 R&D centers, and dealers and distributors in more than 140 countries. Its brands include Abarth, Alfa Romeo, Chrysler, Dodge, Fiat, Fiat Professional, Jeep, Lancia, Ram, Maserati and Mopar, the parts and service brand. Their global components segment includes Comau (production systems), Magneti Marelli (components) and Teksid (iron and castings). Lastly, Maserati which represents their global luxury segment.

Additionally, retailers, dealer financing, leasing and rental services related to and in support of the group's business are provided through subsidiaries affiliated to the group or by financial partners (such as captive companies, affiliates, joint ventures and other specialized providers).

FCA is enlisted in the New York Stock Exchange as "FCAU" and in the Mercato Telematico Azionario as "FCA". Having a worldwide market segment, the group activities are divided into four major regional operating segments, which divide further its mass-market automotive brands. These regions are NAFTA, LATAM, APAC and EMEA. The EMEA region of FCA supports all sector in Europe, Middle East and Africa. The functions includes design, engineering, development, manufacturing, distribution and sale of the mass-market vehicles.

There are 67 production plants across Europe (mainland), 35 of them are located in Italy. This project is focusing on the operation of the Mirafiori Powertrain Plant.

1.2. Mirafiori Powertrain Plant

This plant is located in Turin, Italy, home to FIAT. Over the last two decades, this plant has been producing the C514 Transmission as its main product. The product portfolio of this particular plant consists of different types of transmission including 5M, 6M, MTA, AWD and a kit with components of a transmission to be sent to another FCA's Powertrain Plant.

There are 250 different components required to produce the finished product, the C514 Transmission. 80% of the components are bought from an from an external suppliers and the rest, 20%, are components produced within the Plant.

The plant is comprised of five main parts, Machining area, Heat Treatment area, Assembly area, Warehouse and Shipping area, with additional spaces meant for offices, clinics and other supporting functions. There are approximately 50 different components produced in the plant, such as shafts, gears and other components which form a transmission. They are produced from 11 production lines.

1.2.1. Power Transmission System

The Power Transmission System is the final stage of the engine generated power within a car. This system couples the engine and the wheels. It drives and adapt the output shaft rotation to reach the desired speed or torque ratio, allowing a wider range of speed. Moreover, it enhances the performance as the engine has its own RPM limit and maximum performance value.

The Power Transmission Systems is composed out of three major blocks, the clutch, the gearbox or so-called transmission and the differential. Each one of the blocks has a specific role transmitting power from the engine to the wheels ensuring appropriate rotation speed and torque.

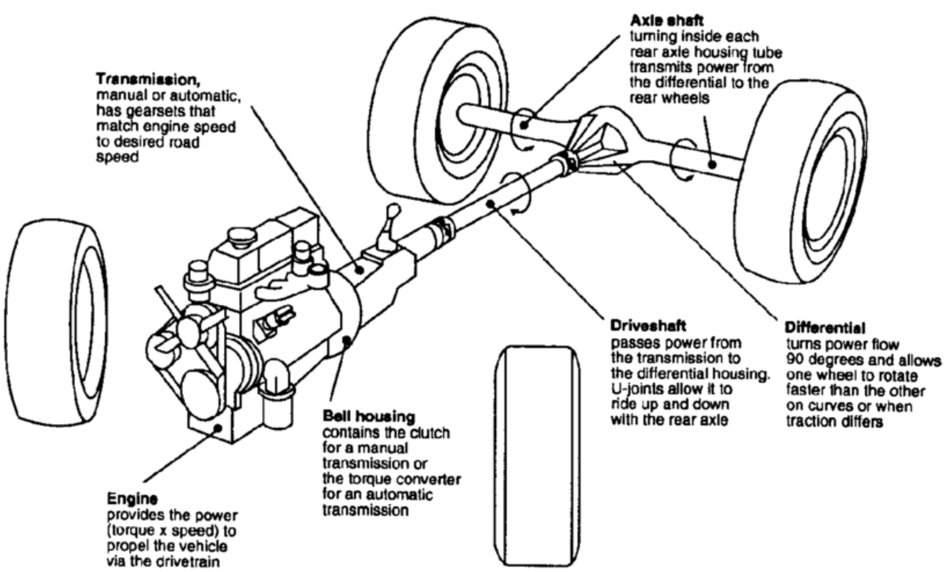


Figure 1-1: Primary Elements in Powertrain System (Gillespie, 1992)

The clutch is used to connect and disconnect one subsystem that produce torque to another subsystem that will use the torque to produce work. In a car, the first subsystem is the engine and the second one is the transmission. Since the engine has a rotation limit, the transmission is needed to provide controlled application of the power transmitted. In motor vehicles, the output of the internal combustion from the engine is adjusted to different condition to the drive wheels by the transmission. A transmission with multiple gear ratios to enable them to switch between the ratios as the speed varies. The switch could be done manually or automatically. It is common also to provide directional, forward and reverse, control.

The transmission in motor vehicles is generally connected by a clutch or fluid coupling to the engine crankshaft. It is partly because internal combustion type of engines cannot run below a particular speed. The wheels driver is none other than the output of the transmission which is transmitted to one or more differentials through the driveshaft. The primary purpose of a differential is to permit the wheels (at the ends of an axle) to rotate at different speeds. This is done essentially to avoid slippage while the wheel turns as it changers the direction of rotation. Moreover, the differential may also provide gear reduction.

1.2.2. Types of Transmissions

Manual Transmission (MT)

As the name suggests, this type of transmission lets the driver select manually the gear ratios, using both a moveable gear selector and a driver-operated clutch.

The manual transmission is connected to the engine by a clutch, which when disengaged (by pressing the hand lever or foot pedal) removes torque from the system. Whenever the clutch is engaged, power is delivered, through an input or the so-called Primary shaft which is separated from the primary cluster, to the transmission and which can rotate at a different speed to the cluster. The cluster is made out of gears which can be moved either to engage or disengage from fixed gears on the output (secondary) shaft. This secondary shaft is usually located below the cluster gears and supported by roller bearings in its casing. The speed of the vehicle, on the other hand can be maintained or increased using less power from the engine, by using progressively smaller gear ratios.

Modern versions of this transmission have five or six forward (plus one reverse) gears. This type of transmission is also known as a "stick shift" or a "standard" transmission. Within this project, they will be refer to as 5M and 6M, mainly refer to the plant in which these components are produced (Mirafiori Powertrain Plant) as well as to preserve the Italian terms of the components (cinque marce and sei marce).

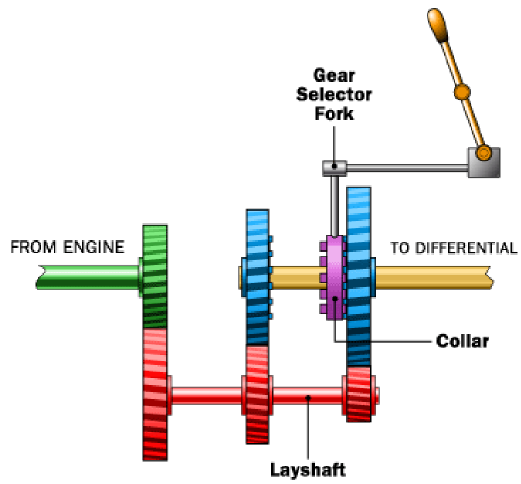


Figure 1-2: Manual Transmission Gear Mechanism (Transmission Repair Cost Guide Team, 2015)

Gear Selection/Mechanism

The primary, or the so-called input, shaft has only one gear engaging with another gear on the secondary shaft. The "Neutral" position is when the transmission is running and the clutch is engaged, but no gears are engaged between the two shafts.

As an example, when shifting to the first gear, the gear on the primary shaft is slowed down by a synchronisation mechanism and is aligned with the gear on the secondary shaft. One gear must be disengaged to allow another one to be engaged. When the clutch is re-engaged, rotational energy is transferred from the transmission to the axles by the drivetrain.

Advantages

- Extremely robust and able to handle high torque loads.
- Very reliable, relatively easy to service, maintain, and repair.

- Valuable driving aid to drivers when manoeuvring in the off-road environment is provided by the link between driving wheels and the engine. This mechanism is provided by allowing the use of engine braking while descending slippery slopes.
- Most affordable to be repaired

Disadvantages

- Learning curve – difficulties for drivers who are used to automatic transmission

Automatic Transmission (AT)

This type of transmission uses a torque converter, planetary gear set and clutches or bands to shift through a vehicle's forward gears automatically. Within the automatic transmission, the hydraulically operated control systems are electronically managed by a computer within the vehicle’s system instead of the clutch and gear stick.

Some automatics allow the driver a limited amount of manual control over the vehicle (aside from choosing a forward, reverse or neutral mode), for example allowing the driver to control upshifts and downshifts by utilizing buttons or paddles on the steering wheel or the gear selector. Normally, all the driver has to do is shift the selector from Park (P) or neutral (N), into Drive (D), this way the gear shifting will take place without any additional input and under normal driving conditions. Common names for such transmissions are "shiftable automatic," "Tiptronic" and "autostick”.

Gear Selection/Mechanism

With this type of transmission, the gear selection depends on many operational conditions, including the vehicle speed, the engine speed and the performance mode.

Along with the selection of the driver assist systems, such as:

- Traction control
- Stability control
- Automatic/autonomous braking
- Cruise control

When all the necessary conditions are met, along with an arrangement between the Engine Management and Transmission Control systems, pressurized transmission fluid is automatically channelled to mechanisms that drive sets of planetary gears and clutches, which are approximately analogous to the gear ratios found in this type of transmission.

A torque converter, which is a mechanism consists of two freely rotating parts, is what provides the rotational energy. Two halves of the converters are positioned closely together, one being attached to the engine and the other to the primary shaft. The rotational energy influences the fluid which circulates between the torque, which in turn impacts the transmission side of the converter. As a result to the shearing strength of fluid, the torque is transferred from the engine to the transmission.

Within the previous/older version of automatic transmission, a mechanism using an internal fluid which pressures overcoming spring tension, closing one circuit before opening another, is used to perform the shifting action. However, this type of control system produced a rough and bumpy shifts. Thus, to provide an almost seamless shifting, the modern system moderate the action of the controlling valve shuttles.

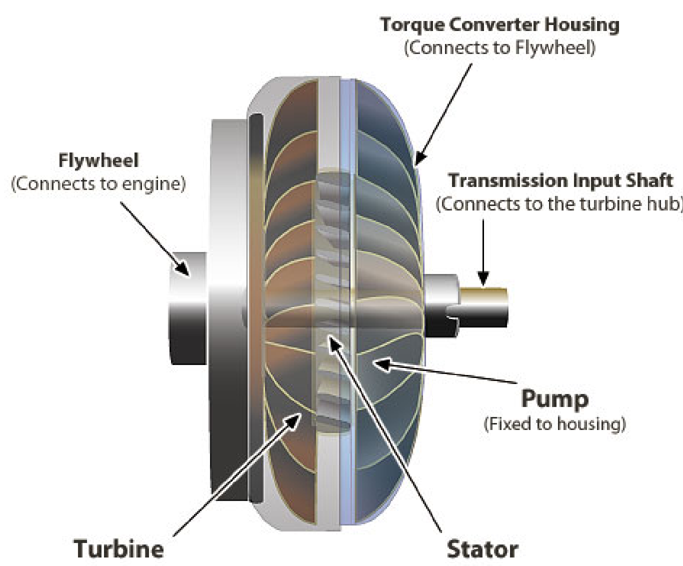


Figure 1-3: Automatic Transmission Gear Mechanism (Transmission Repair Cost Guide Team, 2015)

Advantages

- Very easy to use
- Provides a comfortable driving experience
- In terms of performance and fuel economy, the modern automatic transmissions match the manual ones

Disadvantages

- Due to a variety of possible issues, some of which are not related whatsoever to itself, this type of transmission is complex and prone to failures, malfunctions and unsatisfactory performance
- More expensive to maintain over a vehicle's lifetime
- Expensive to repair. A replacement is often more affordable

Semi-Automatic or Automated Manual Transmission (AMT)

The semi-automatic or also known as “automatic manual” or “clutch-less manual” transmission, is a hybrid between a fully automatic and manual transmission. Like a manual transmission, this transmission also employs a mechanical clutch; however, the action of the clutch is not controlled by the driver via the clutch pedal but is rather automated using electronic, pneumatic or hydraulic controls. Sometimes referred to as a "Direct Shift Gearbox" ("DSG") or a "Sequential Manual Gearbox" ("SMG"), this transmission allows for either fully automatic forward gear shifts or manual shifts through the gear selector or through buttons or paddles on the steering wheel.

These basic principles in this semi-automatic have been applied to heavy commercial vehicles for many years. The latest designs provided lightning-fast and almost undetectable gearshifts. Although the design of these systems varies, these types of transmission rely on microprocessors, with the help of electrically operated actuators and servos, to control the mechanical gear ratio changes. Initially, these transmissions were limited to high-end supercars due to their expensive cost, but nowadays, an increasing number of manufacturers, such as FCA, are fitting them to mid-range cars.

Gear Selection/Mechanism

Employing two clutches, also called the dual clutch system, allows an uninterrupted power flow from the engine. One clutch controls the gearshifts on even numbered gears while the other one controls the odd ones and reverse. The driver is not required to operate a clutch, but still has to initiate a gearshift using a shifter or paddles located behind the steering wheel.

Advantages

- Smoother shifting, thus, driving experience
- No energy losses due to slippage in torque converters nor during the time lag of manual shifts

Disadvantages

- Due to a variety of possible issues, some of which are not related whatsoever to itself, this type of transmission is complex and prone to failures, malfunctions and unsatisfactory performance
- More expensive to maintain over a vehicle's lifetime
- Very expensive to repair. A replacement is often more affordable

Continuously Variable Transmission (CVT)

This transmission has a continuously variable drive ratio (as opposed to conventionally stepped gear ratios) and uses belts, pulleys and sensors rather than gears to maintain a steady acceleration curve with no pauses for gear changes. In other words, this type of transmission does not use gears to produce various vehicle speeds at different engine speeds. Instead, it relies on a belt (made of rubber or metal) which runs over pulley, which varies their effective diameters. These pulleys will alter their diameters (one increases whilst the other one decreases its effective diameter) by the exact same amount, in order to keep the belt at its optimum tension. This mechanism is precisely analogous to the effect created when gears with different diameters are engaged. Finally, thanks to the application of the belt, a CVT can keep the engine in its optimum power range, thereby increasing efficiency and gas mileage.

Gear Selection/Mechanism

An infinite combination of ratios can be produced, thanks to the mechanism of the two pulleys, since one is driven by the engine and the other one is connected to the drive shaft. This permits it to run consistently at the most efficient speed regardless of the load placed upon it. This advantage is obtained thanks to the microprocessor-controlled sensors which quantify load variations. Finally, by adjusting both pulleys, the optimum operating speed can be maintained without any input from the driver.

Advantages

- Constant and step-less acceleration throughout the engine's optimum operating range
- Eliminates shift shock, thus providing a comfortable ride
- Improved fuel efficiency
- Faster response to changing driving conditions such as variations in throttle and engine speed
- Eliminates energy losses associated with torque converters

Disadvantages

- Limited torque-handling ability which in turn results in unsuitableness to be used in off-road environments.
- Cannot provide engine braking

1.3. Mirafiori Powertrain Plant's Products Portfolio

The list of vehicles that use the transmissions produced from the Mirafiori Powertrain Plant is presented below

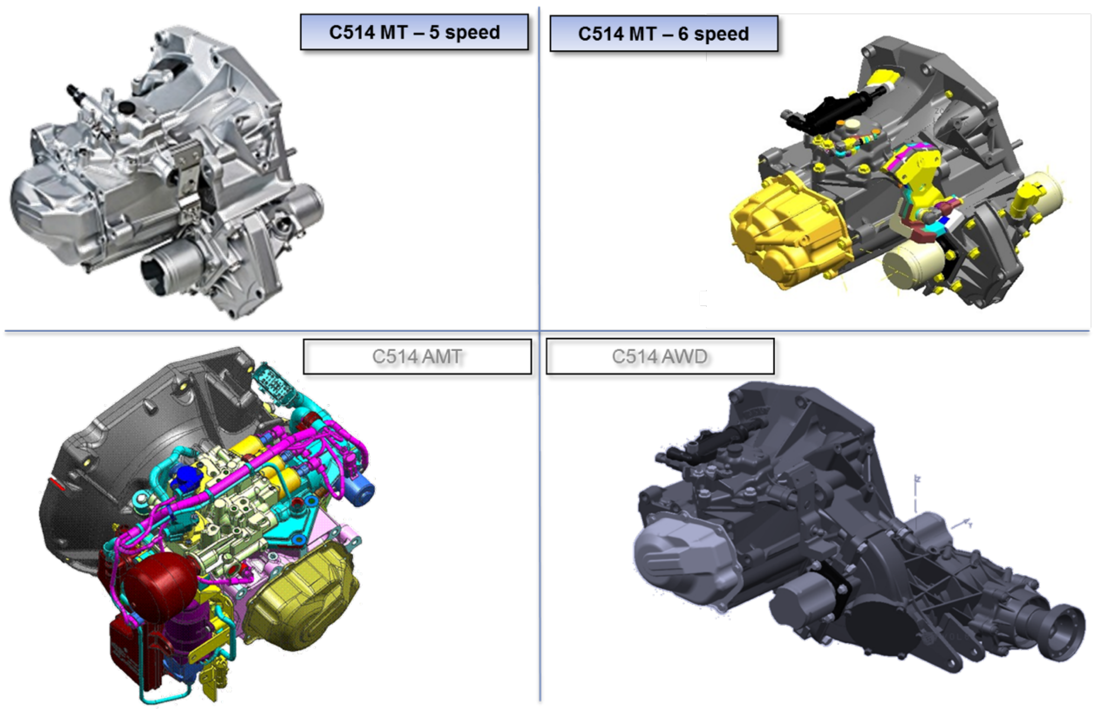


Figure 1-4: Products Portfolio

Within the table 1-1 and figure 1-5, are enlists types of car that uses the transmissions produced in Mirafiori Powertrain Plant.

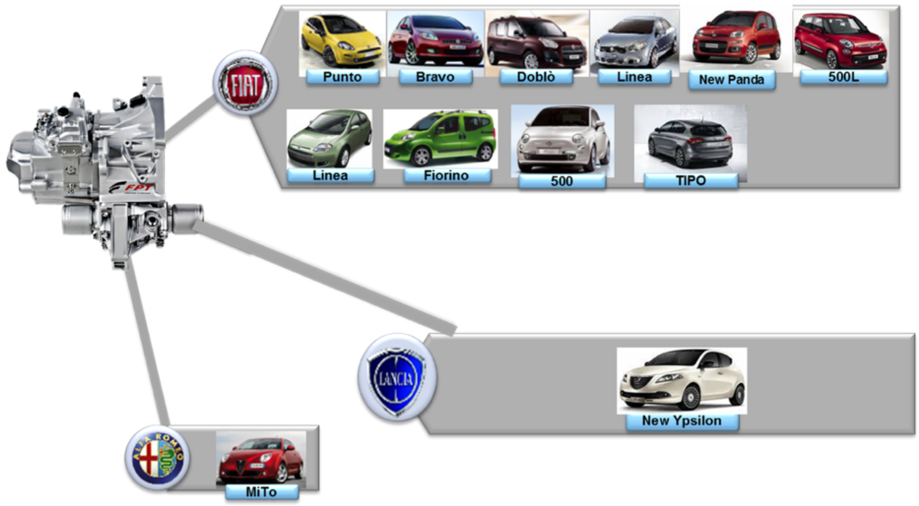


Figure 1-5: Cars with Transmission C514

5 speeds manual transmission is considered to be the product used by most of the end users, hence the highest sales percentage. The 6 speeds manual transmission ranks the second in terms of sales, is approximately 13% of overall product sales. The sales percentage of AWD transmission, until the end of 2017, was the lowest.

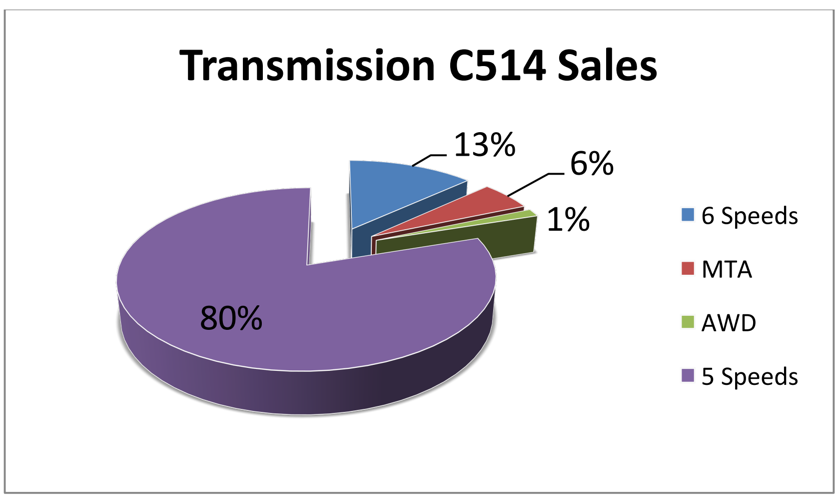


Chart 1-1: Sales Percentage of Mirafiori Powertrain Plant

The finished products are mostly delivered to distributors or clients across Europe. Almost 50% of the transmissions are distributed to Tychy's body shop, Poland. Nevertheless, the biggest consumer, or also called end users, is still Italian FCA's body shops.

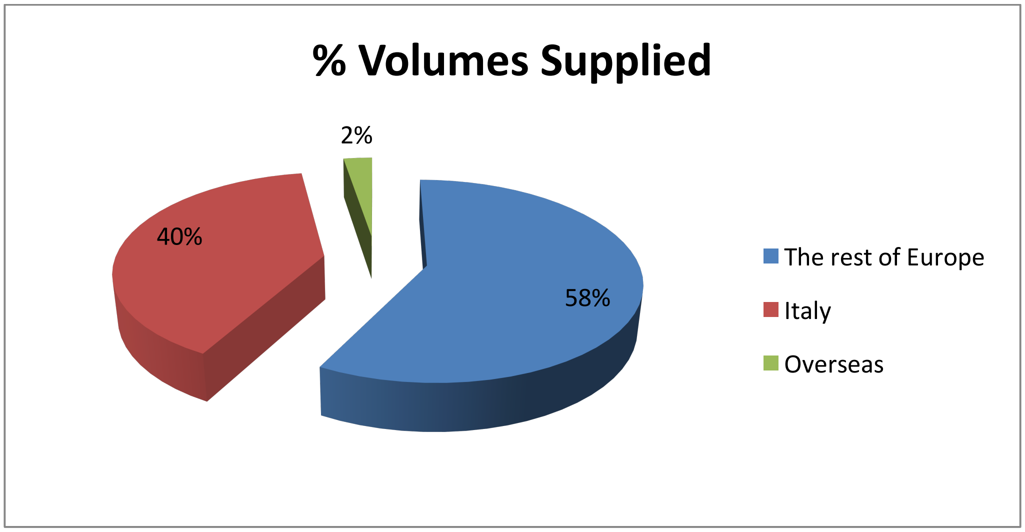


Chart 1-2: Supply Percentage of Mirafiori Powertrain Plant

Distribution lines are done by trucks, train and ship. Land shipment is done using trucks and is arranged to send/supply the finished products to Italian customers, Mirafiori, Pomigliano and Melfi auto shops. On the other hand, these transmissions are shipped using trains to customers in Serbia and Poland. Lastly, by ship, these transmissions are distributed to the customers across Turkey, Mexico, Brazil and Argentina.

1.4. Transmission Kits

The Mirafiori Powertrain Plant acts also as a supplier for another FCA's plant. Other than producing the C514 Transmission, the Plant also produces a kit which builds another type of transmission in another plant. One complete kit is a set of gearbox which is composed out of different components, such as shafts and rods. This type of kits assembled are those meant to go to the 4x4 and C510 type of transmissions. Once prepared within this plant, this transmission kits are sent to another FCA's transmission producing plant, Termoli. The order for this product came in weekly and the deliveries are done daily.

2. Theories and Instruments

2.1. Introduction to Logistic

The logistic system is a combination of infrastructures, equipment, personnel and the operational policies, which allows the flow of goods and information from procurement of the raw materials to the distribution of products to customers. (J. Heskett, R. Shapiro, Harvard Business School)

It is a set of information flow altogether with the material flow which satisfy customers' requests, by making the right components or products, in the right place, on the right time, with the right quantity and also quality, at least the one expected or requested by the customers. In other words, logistic has a broader scope than just traditional material handling or material management, storage and transport. In fact, it involves three distinguished process within a company: commercial and sales, manufacturing, buying raw materials and other components constituent of the finished goods, and distribution. This extended point of view towards the company is pivotal to be able to achieve the objectives of the seventh pillar of WCM, which are:

- Increasing customer satisfaction, regarding products' quality and also the consignment time
- Reducing the cost of capital invested on intermediate or the semi-finished goods and Work In Progress goods
- Reducing the movement or transportation costs, which within the automotive field is particularly high

Precisely in this sense, the Logistic Pillar of WCM is to be considered integrated within Customer Service. Logistic helps to manage in an organic way and arrange the whole operational cycle of one or multiple companies, through these functions:

- Material Management (Handling)
- Production Management
- Distribution Management

With its main objective to guarantee a higher level of service meaning better services to clients, whilst providing them high quality products, with the least waiting time and at a minimum price. The main objective of logistic consists of synchronizing the production in order to precisely satisfy client's demand. The three Logistics' principle are to synchronize the production with sales to satisfy demand completely, to minimize storages creating a continuous flow of materials and finally to minimize materials movement.

2.1.1. Logistic Areas

In a production plant it is necessary to separate different logistics areas based on their function. Each of them needed to be set up and managed with different approach according to its function. Principal Logistic areas inside the Mirafiori Powertrain Plant are:

- Loading and Unloading Piers – where the raw materials (for raw materials) and the Buy materials arrive and also from where the finished products are sent away.
- Warehouses – it is where the stock of the finished products are kept.
- Buffer – safety stock of various types of materials within the Plant, ranging from raw materials, WIP, finished components, WIP transmission to the finished products, the C514 Transmissions.
- Picking Area – in this area the Buy material arrived and are categorized into classes which in turn gives the information about each specific route and schedule to be transported to the assembly line. Some of these materials/ components are unloaded from their original packaging (the packaging they come in with from the supplier) and placed/loaded into a standard packaging provided within the Plant, while other are transferred as it is (with the original packaging) to assembly line.
- Kitting Area – here components coming from an external supplier and those which are produced inside the Plant are sorted into Supermarket type of storage (with inclined cells). The kits assembled here are then transferred to the assembly line, based on the type of transmission to be assembled.

2.1.2. Logistic Flow

The two main/fundamental flows, which complements one another are the physical flow of material and the flow of information. These flows are complementary and go in the opposite direction, which could be seen from the graphical representation on Figure 2-1 below.

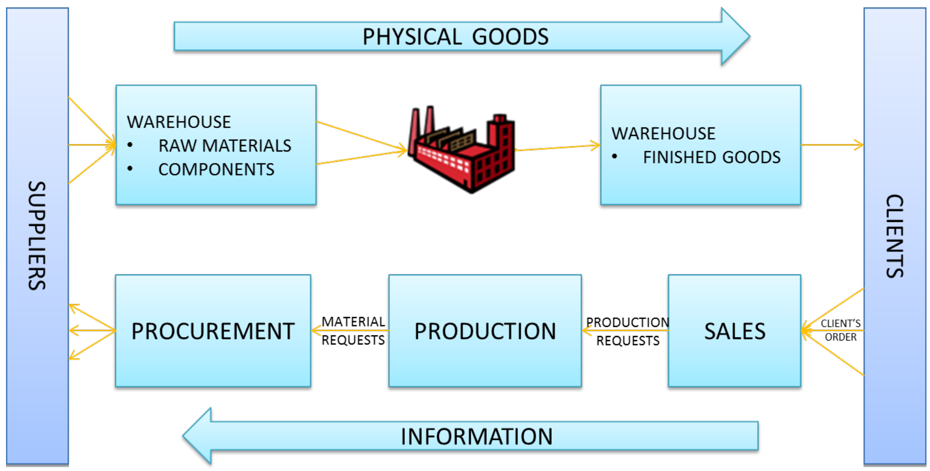


Figure 2-1: Logistic Flow Graphic Representation

2.1.3. Materials Management and Classification

The efficiencies of the material flow within a company, is what determines costs and profits of a company. Mismanagement could potentially cause loss, both in financial and production terms. Based on statistical studies, materials' cost has a major impact on the total production cost of the finished product. The weigh varies from 15% to 85%, depending on the industry of the company. There are several forms of materials to be considered:

- Raw materials – usually they are materials in the most basic forms, needed to be processed.
- Subassembly parts/components – additional components which are necessary to create the finished products.
- Work In Progress materials – they are classified as materials which are currently under process, within machining phase or under transformation phase.
- Toll Manufactured Goods – parts or components which are not processed or transformed within the current production plant, for one reason or another. Instead,

these parts are sent to an external party to be processed and will be transferred back after it.

- Finished goods – they are goods that have completed the manufacturing process but have not yet been sold or distributed to the end user.

In the manufacturing world, all the materials represent an investment which in turn means a prospect of profitability. The main objective of materials management is to know when to order and how much to order the materials, and eventually to determine the strategic stocks.

2.1.4. Storage

Inside a company's logistic chain, a storage has double roles as a container of stock and as a converter of incoming flow to an outgoing one. The last role, as a converter, concerns both the evolution of the products over time and the composition of the product or, in case of the most basic forms of components, the nature of the product.

Storages can contribute in increasing the production efficiency by reducing the costs, arise from Non-Productive Time (NPT) caused by raw materials or WIP shortages. For seasonal demand, storages provide as buffers. By maximising the production capacity and thus increasing the level of stock to be able to fulfill demand when it peaks. Other purposes of storage include the assurance of materials availability, both raw and work in progress materials, as a protection from increasing cost of raw materials and, finally, to be able to respond to unexpected inflation of demand.

As seen on figure 2-1, there are three types of storage or so-called warehouse, for raw materials, work in progress goods and finished goods. The one for work in progress goods is also called inter-operational storage or buffer, which decouples or separate stages of production. From economical and financial point of view, storage as a container definition is not considered as insignificant nor negligible cost, as the act of keeping storage or stock is categorized as unproductive, due to the fact that this is a Non Value Adding activity.

There are three group of costs correlated to stock keeping, time costs, space related costs and management costs. Time related costs are represented by capital cost and deterioration or degrading cost. This implies that these costs are strictly depended on the duration of the stock keeping inside the storage or warehouse. Space related costs depended on the cost of allocation (as an example rent). Finally, the management costs are represented by:

- Procurement costs, every time an order is placed towards the supplier there are several costs related to it induced by various activities involved, including the offer analysis, order issue, follow-up, order reception, check and control, and other activities.
- Movement costs are linked to internal movement activities which in turn are related to energy consumptions, transportation, storage method and equipment.
- Insurance costs including premiums relative to policy or protection against risks, such as fire risk or theft.
- Fixed-management costs are the expenditure on personals (blue collars), structure and transportation system.
- Stock-out costs is the marginal profit loss every time an order or a demand is not immediately fulfilled due to the lack of stock. This also takes into account the potential profit loss in case of customer attrition.

2.1.5. Stock and Stock Management

Stock is any item stored by a business for use in production or sales. A production stock is defined as a set of articles which contribute to produce or form the finished product, including raw materials, components, semi-finished products, finished products and various supplies.

Regardless the type of material stored or where it came from within the production cycle, a stock exists as a consequence of a shift between supply and demand. If any activity is aimed to balance the supply and demand, it will also affect the fluctuation of the stock level. The purpose of keeping stock is to guarantee the independency of different phases within a production cycle and to cope with demand fluctuation overtime. It also ensures the flexibility of the production plan, as a preventive measure of the delivery time variations and to profit from the optimum size of order. There are several types of stock:

- Cycle stock: this type of stock bind the fulfillment of the warehouse with demand. The goods arrive in bigger batch with lower frequency in order to fulfill the elevated demand requests in smaller batches (quantity).
- Seasonal stock: it is meant for goods with seasonal demand. It is deemed advantageous to build up or stock up when demand is low to be able to satisfy demand, later when it peaks.
- Pipeline stock: this type of stock includes goods that have left a firm's warehouse(s) but have not been bought by the ultimate consumers, customers, or users, and are therefore still within the firm's distribution chain. It is used to decouple the stages between production phases or in a distribution system.
- Safety stock: is used to compensate or make up for the uncertainty of demand and offer, caused by, as an example, delays in delivery, production system failures and fluctuation of demand.

On the other hand, an inventory management system is a set of policies and controls that monitor quantities of stock and determine which level to maintain, when to reintegrate them and the size of orders.

The objective of stock management is to determine the correct quantity and time to place an order or to produce, whilst minimizing the cost of stock management itself. Several essential elements regarding the stock management include the maximum allowable level of stocks, re-order intervals, order quantity, procurement lead time, consecutive order interval and consumption rate. There are several methods or approaches usually used in stock management, including:

- Materials Requirement Planning, this technique is used to determined quantity of needs and lead time, based on demand or needs. The method foresees the complete knowledge of the production plan, bills of materials, stock levels and procurement time, or lead time.
- Economic Order Quantity or EOQ, is a is a simple deterministic model which illustrates the trade-offs between ordering and inventory costs. This method foresees a continuous

control of stock. It is based on a fixed re-order quantity with various interval of time, depending on the fulfilment of the limit value of the stock. As the name explains, the aim is to minimize the total cost of inventory management, in a given period of time.

- Economic Production Quantity or EPQ, is similar to EOQ model with a slight difference. Instead of orders received in a single delivery, the units are received incrementally during production, which is, a constant production rate. This model is tailored for production situations in which when an order is placed, the production begins, a constant number of units is produced, replenishing the stock on daily basis until the production run has been completed.

The level of stock, on a time proportion basis, is given from the below formula:

$$G(t) = \int_0^t [p(t) - d(t)]dt \tag{2.1}$$

where p(t) represents the replenishment or refurbishment rate of the storage, d(t) represents demand and G(t) as the stock or level of stock, all on a time proportion basis.

2.1.6. Safety Stock

In a normal condition, consumer's demand and procurement lead time are both uncontrollable variables with constant fluctuation. The combination of the two uncertainties could lead to a stock-out situation. A stock-out situation is when the level of stock available is lower or barely covers consumers' demand. In financial terms, stock-out would in turn result in loss of revenue, gross profit, customer and, ultimately, market share.

On the other hand, too much inventory incurs extra holding and capital cost. The uncertainty of supply and demand makes it difficult to estimate the amount of stock needed to satisfy customers' needs while avoiding stock-outs. It is possible, however, to reduce this particular impact caused by the fluctuations, using the concept of Re-order Level and the Safety Stock. The safety stock is an extra inventory beyond expected demand, kept to avoid the risk of stock-out.

To determine the safety stock it is necessary to identify several variables which are:

1. **Demand** (**D**), the average quantity of goods consumed by the clients, on a given time.

2. **Procurement Lead Time** (**PLT**), which is the total time between the issue of the order (Re-order Level) and the reception the order. Depending on the vendor service used, lead times can be constant or variable. Reaching a stable lead time is almost impossible. More often the lead time is variable, meaning that products production or delivery time are not always the same.
3. Forecast Error is the estimation of the difference between the effective demand or the procurement lead time and the forecasted ones, which is expressed as a **standard deviation** (**σ**).
4. **Service Level** (**SL**), is the probability that the amount of inventory on hand during the lead time is sufficient to meet the expected demand. In other words, the probability that a stock-out will not occur. Deciding the correct service level for a certain product is essentially balancing inventory costs in contrast to the cost of a stock out.

It is necessary to keep in mind that increasing a products service level will in turn increases the amount of inventory held as safety stock. Consecutively, increasing cost associated with the particular product in discussion. Thus, it is advised to set a realistic service level which meets the business model needs. In order to convert the desired service level into a more concise value, it is required to use a normal distribution chart and find the **service factor** (**Z**), which corresponds to the service level established earlier.

It is suggested that safety stock and service level could be far more effective to be controlled through the use of standard deviation. The normal distribution describes a set of data where most values are close to the average value, fewer values exist at extreme distances from the average or the mean value and the total number of these values, above the average values, is close to those values occurring below the average value itself.

$$Standard\ Deviation\ (\sigma) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{2.2}$$

where x_i = demand on given period “i” and $\bar{x}$ = average demand. For a normal distribution equaling to 68.26% of the data falls under one standard deviation of the mean ($\bar{x}$ ± **σ**) 95.45% of the data falls under two standard deviation of the mean ($\bar{x}$ ± 2$\boldsymbol{\sigma}$) and 99.73% of the data falls under three standard deviation of the mean ($\bar{x}$ ± 3$\boldsymbol{\sigma}$).

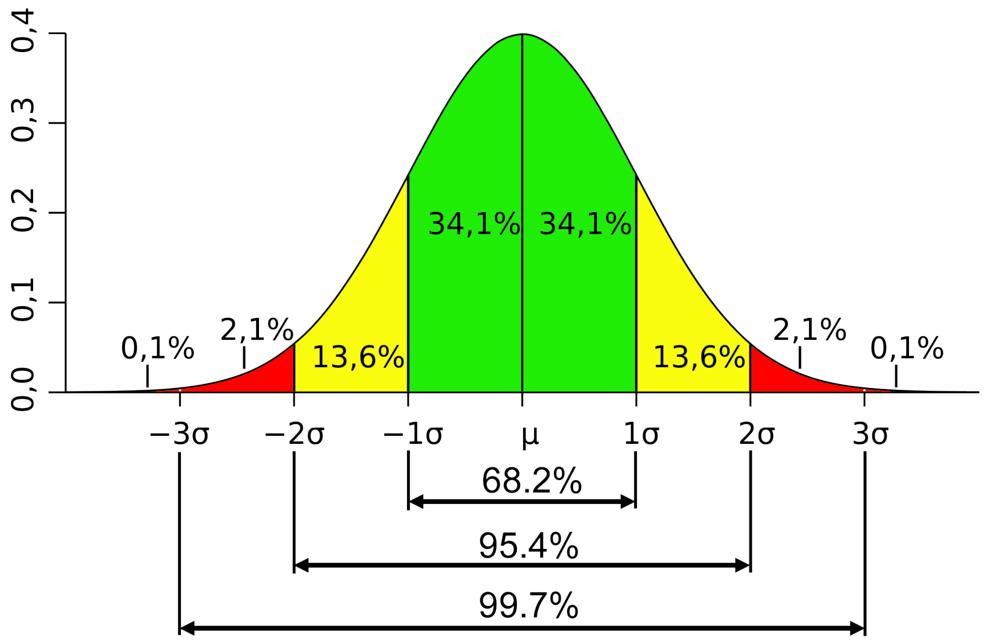


Figure 2-2: Normal (Gaussian) Distribution and Standard Deviation (Ivanov, 2014)

To calculate a specific quantity in order to meet the specific service level, the service factor is used as a multiplier along with the standard deviation. The relation between service level and service factor is non-linear, meaning that higher service level require higher service factor, thus resulting in higher safety stock level. As an example, if the desired level is 98% and the inventory reached reorder point, during lead time, the company expects to fill all customers' orders during lead time for 98% of the time. While 2% of the orders the company will expect to run out of stock.

Instead of using the same and fixed service factor for all products or components, different ones could be established for groups of products or components. The different service factor could be determined basing on strategic importance, profit margin or even contribution of sales. A product with greater value, as an example, will have more safety stock.

As stated before, when both demand variability and lead time variability are present, statistical calculations can be used together in order to give a lower total safety stock than the sum of the two individual calculations, using the following formula:

$$Safety\ Stock\ (SS) = Z\sqrt{(\overline{PLT}\ \cdot\ \sigma_D)^2 + (\overline{D}\ \cdot\ \sigma_{PLT})^2} \quad (2.3)$$

where, Z is the service factor, PLT is the Procurement Lead Time, D represents demand, σ_D is the standard deviation of the demand and σ_{PLT} is the standard deviation of the Procurement Lead Time.

Overall, this formula is suitable to forecast inventory and calculate variable changes in supply and demand. In summary, the company could estimate the frequency of out of stocks condition, without the exact nor estimated quantity or size of the unfulfilled orders. Safety stock solely calculates the amount of extra stock which should be added to overall inventory, other than indicating when to reorder. Once it has been established, inventory level should be monitored constantly over time to determine if the inventory profile is as expected or not.

2.2. WCM

World Class Manufacturing is an integrated manufacturing system which helps to control, manages, reduces, and to finally eliminate wastes and losses. It is done with as a continuous improvement and involvement of all levels and functions within the company, with a standardized methods and approaches.

Based on an advanced concepts or aspects of Toyota Production system, WCM allows the application of these concepts: Total Industrial Engineering, Total Quality Control, Total Productive Maintenance and Just In Time. WCM is also one of the most important production technique used across Europe. The WCM system is made up of ten technical and ten managerial pillars, illustrated on Figure 2-3 as a temple. The ten technical pillars are as follows:

1) Safety (Occupational safety)
2) Cost Deployment (Distribution of Costs)

3) Focused Improvement
4) Autonomous Maintenance and Workplace Organization
5) Professional maintenance
6) Quality Control
7) Logistics & Customer Service
8) Early equipment Management
9) People Development
10) Environment (and Energy)

Each of the technical pillar is applied in order to empower everyone within the team to be able to drive savings and to grow intangible assets. In other words, increasing autonomy, leadership behaviours and higher knowledge at all levels of the organization. The ten managerial pillars are:

1) Management Commitment
2) Clarity of Objectives
3) Route map to WCM
4) Allocation of Highly Qualified People to Model Areas
5) Commitment of the Organization
6) Competence of Organization towards Improvement
7) Time and Budget
8) Level of Detail
9) Level of Expansion
10) Motivation of Operators

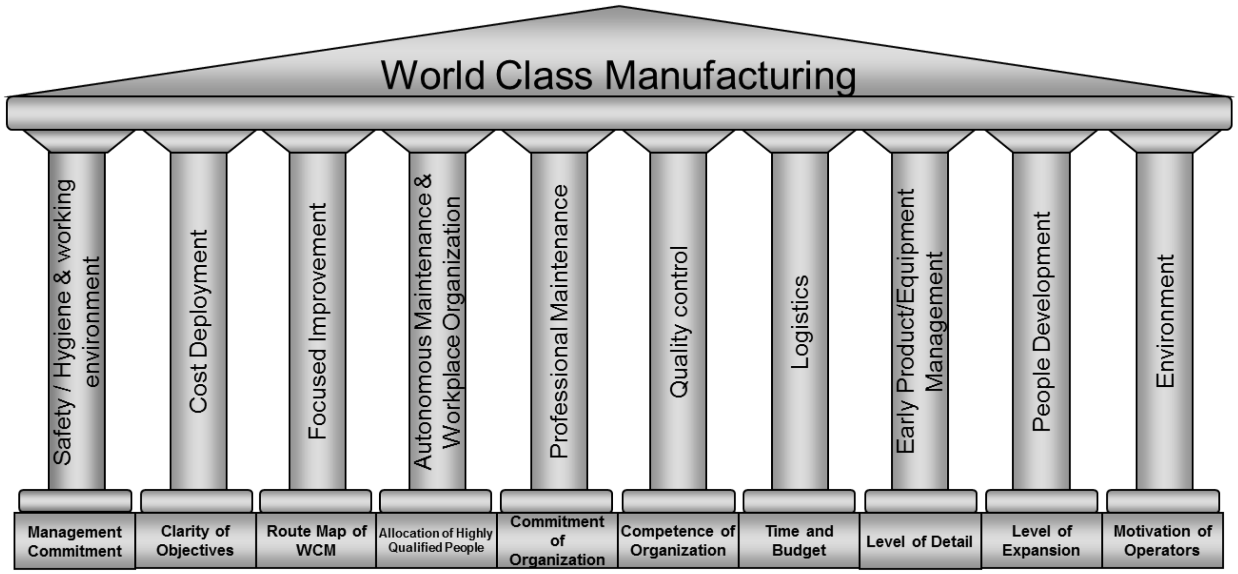


Figure 2-3: WCM Technical and Managerial Pillars

It is believed that to achieve and sustain the World Class level of manufacturing, a company must develop competent leaders throughout all levels of the organization. These leaders must be capable of supporting the needs of an ideal production system.

2.3. WCM in FCA

World Class Manufacturing (WCM) is a structured, rigorous and integrated production methodology adopted at FCA plants worldwide, which involves the entire organization, from safety to environment, maintenance, logistics and quality. It is the foundation of FCA's production processes and, first and foremost of, their industrial culture. The primary objective of WCM is continuous improvement in all areas of production in order to guarantee the quality of the final product and meet customer expectations. Projects developed under the WCM methodology – which rely on a high level of employee involvement – target the elimination of all forms of waste and loss with the ultimate objective of achieving zero accidents, zero waste, zero breakdowns and zero inventory.

The target of WCM is to meet the customer expectations by engaging and motivating all levels of our organization. Although technology is important, the investment in people is what really matters to achieve excellence within the manufacturing system. The core functions of the manufacturing system are outlined in each of the technical pillar methodologies covering safety, cost deployment, focused improvement, autonomous activities, professional maintenance, logistics, quality, early equipment management, early product management, environment and energy. The application of each technical pillar empowers the teams within FCA to drive savings and to grow intangible assets. This includes increased autonomy, leadership behaviours and higher knowledge at all levels of the organization.

In other words, WCM for FCA is a production system where:

- Safety is a basic value
- Customer expectations are heard within the plant
- Leaders apply standards with method
- Waste and loss are not accepted
- Methods are applied with rigor
- All anomalies are made visible
- People involvement is the engine of change

2.4. WCM Logistic & Customer Service Pillar

The scope of this pillar is to create a favourable condition of material flow within a company and towards supplier and client. The seventh pillar of World Class Manufacturing includes 3 basic fields in which any losses are systematically reduced:

- **Supply Logistics** deals with the organization of information flow and IT systems from and to suppliers, in search for more profitable routes and means of transport, and optimal management of materials and warehouses.
- **Production Logistics**, deals with planning and controlling production flow, cooperation with production system in order to satisfy the needs of the external and internal customers. These actions are performed based on the production flow, which is able to produce small batches, thus widening the production range and mix, shortening the

preparation time, at high quality processes, with adequate supply of materials and with strong motivation of workers and low absenteeism factor.

- **Distribution Logistics**, deals with disposal of distribution centres of final product, disposal of sales network, methods of choosing transportation, analysis of market demand and preparing a short-term sales plan and management and control of supplies. Distribution logistics is a field of organising logistics pillar in WCM in this case, since there is no separate pillar of customer service and is combined with logistics.

Logistics pillar is designed to fulfill the basic 3 tasks which are synchronising production and sales, introducing flow continuity that reduces warehouse balance and area, and reducing material reposition, storage and storage areas.

Logistics in WCM system aims to increase customer's satisfaction, especially with supply dates, reducing them if possible and strictly obeying the supply deadlines and quality. Also increasing productivity and effectiveness of the system and work positions by reducing disposal and over-storage, and finally minimising cost of material transportation and usage of space, thus contributing to general cost reduction.

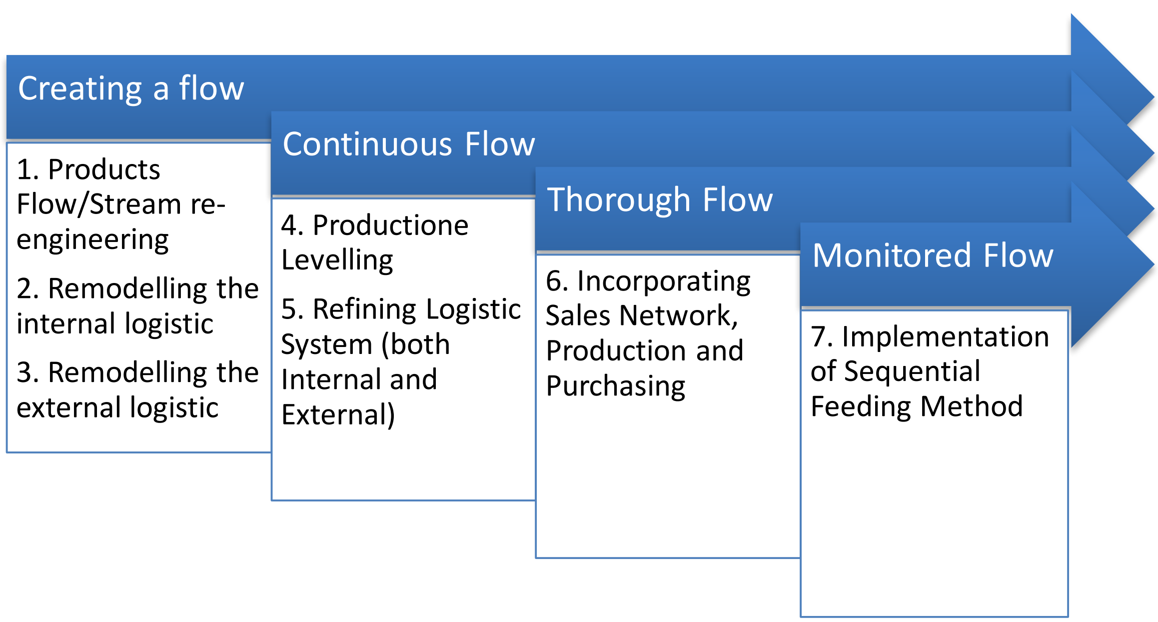


Figure 2-4: 7 Steps of Logistics and the Objectives

The way towards the realization of the logistic pillar is made up of seven steps which are enlisted on figure 2-4. Whereas the final objective of these steps is to create a thorough and monitored flow.

The creation of the flow could be done by reducing lead time, set up time, resizing of the batches, eliminating unnecessary movements of materials and other logistic wastes. The overall cleanliness and reorganisation of the working environment, along with FIFO materials management. The focal point of this particular step is to define and establish a thorough flow of each material class. This step also aims to reduce the Work In Progress (WIP) and material handling , while conforming to the Work Organization norms and adhering to the concept of Minimum Material Handling and the Golden Zone. Lastly, the Plan For Every Part is completed within the second step.

The internal Logistic deals with planning and control of material flow within the boundaries of the focal company. It is one of the most important sections within enterprises, especially in the large manufacturing companies. It manages, arranges, plans and delivers the finished products. It is an indispensable part of the supply chain and reflects the result of implementation company strategy. There are seven steps to be done to enhance/improve the internal logistic within a production plant:

1. Identification of the problem
2. Examination of material movements
3. The choice of method
4. Approach towards the objectives
5. Improvement spawn (Generation of ideas of improvement)
6. Choosing the “right” idea
7. Standardization and horizontal expansion (all over the plant)

2.5. Kaizen

Kaizen is a Japanese word meaning change (*kai*) for the good (*zen*). It is a philosophy which helps to ensure maximum quality, the elimination of waste, and improvements in efficiency, both in terms of equipment and work procedures. It stimulates continuous improvements in standardised work and help maximise productivity at every worksite. Standardised work to achieve regular and incremental improvements.

This concept helps humanises the workplace, empowering individual members to identify areas for improvement and suggest practical solutions. Kaizen begins in the early designs of a production line and continues through its lifetime. It is done by making it the responsibility of each member to adopt the improved standardised procedure and eliminate waste starting from the local working environment. It can be seen as a gentler and employee-friendly way to institute the changes that must occur as a business grows and adapts to its changing environment.

Kaizen aims for improvements in productivity, effectiveness, safety, and waste reduction, and when followed gives a whole lot more in return. Since this approach involves everybody within a company, when done correctly, people will feel the impact directly, thus giving a personal satisfaction. Moreover, it will improve employees commitment as they are the direct stakeholders of their own job. This type of engagement with everybody also improved retention level within a company. Under kaizen, all employees are responsible for identifying the gaps and inefficiencies and everyone, at every level in the organization, suggests where improvement can take place. Finally, it will help to reduce wastes and improve consumer satisfaction

2.6. Tools

This project is the application of the first step to continuously improving the Logistic Pillar of Mirafiori Powertrain Plant. The objective is to reduce the stock value of the finished products by re-establishing the basic condition of the facility (Plant). This is done by cleaning up, eliminating wastes, standardizing the approach and finally maintaining the ideal condition once it’s reached.

The specific tools used in order to achieve the objective are:

- 5S
- 5T
- Value Stream Map

The 5Ts method, along with 5S, represent the way to optimized, in way that it could be repeated, in a systematic way the work standard by improving the operational performance.

2.6.1. 5S

5S are the initials of the five Japanese words which nominate the phases to rearrange the work stations. The purpose of this method is to ensure a clean and organised work stations. This method is applied within the first step of Logistic. This method helps to shape the habit and custom to maintain an organised and clean workstation. As well as to do the continuous improvement of the work condition. The motto is "a place for each and every article and each article on its very own place".

5S method is usually done prior to every improvement activities. It is a very remote and controlled process which creates an organized workstation and facilitates workers to be able to notice immediately an abnormality, if one occurs. This type of visual management helps the workers to notice abnormalities immediately which in turn facilitates them to act immediately and resolve the problem.

1. Seiri → Separate and Sort

   This activity consist of separating the objects within the work station, dividing them into: most used, rarely used, old, new and other specification, decided accordingly beforehand.
2. Seiton → Systemize/Organize

   The second step is done to organize the previous articles(Objects) into a sensible (comfortable) and definitive position. This step allows to reduce time wasting/consuming activity of searching for the tools whilst also improve working security (safety).

3. Seiso → Clean

   A meticulous cleaning of the work station is required, which is essentially what the third step is. This approach is done with the objective of reinstating the basic condition of the station and to extend this very knowledge to the user, in this case, operator.

4. Seiketsu → Standardize (Defining the rules)

   What comes after the third step is the standardization and formalization of the cleaning and reorganising activities.

5. Shitsuke → Maintain

   Lastly, it is crucial to be able to maintain and obeying the rules, until it becomes a habit.

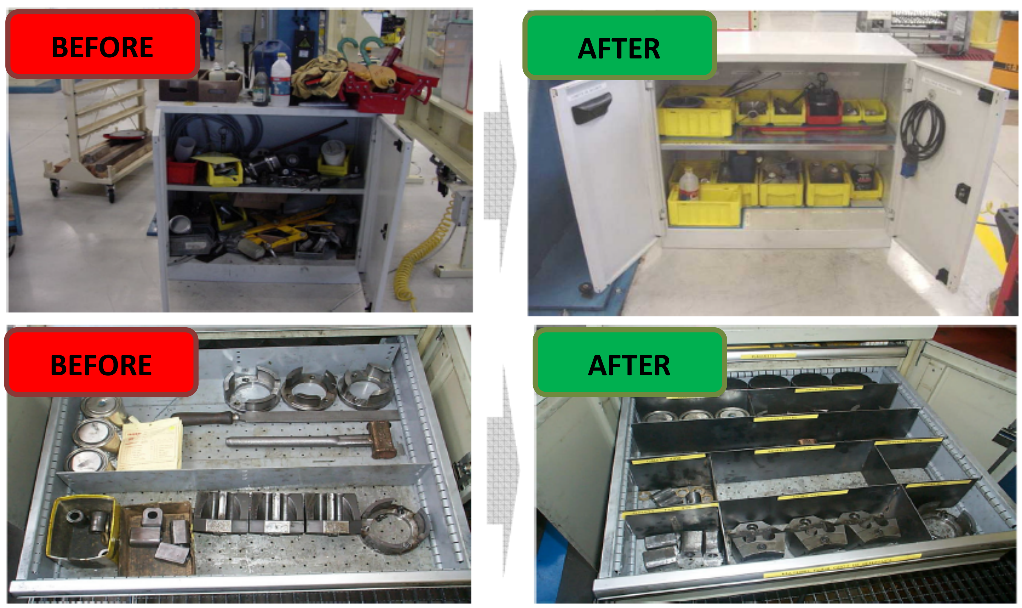


Figure 2-5: Application of 5S method (FCA, 2017)

2.6.2. 5T

1. Tei-Ji → Fixed Route

   In order to create a flow of products, information, equipment and/or people. The pathways need to be regular without any obstacles, one-way direction, shortest/quickest path, large/spacious U turn and with a good visibility. This applies for all pathways such as those for the AGVs and forklifts, and also for the personal pathways/ sidewalks.

2. Tei-Ichi → Fixed Place (or Allocation)

   The second step consists of designating a specific position for each tool or components, which facilitates user in noticing an incorrect operation, if one should take place. Furthermore, it is also used to minimise the required Non Value Adding Activites to search for the materials.

Figure 2-6: Example of Tei-Ichi Application Inside Plant (FCA, 2017)

3. Tei-Hyouji → Standardized Visual Management or Display

   This particular activity require standardized signage, such as labels or tags, to explain and indicate the correct position of each objects. This allows to reduce the time in explaining and showing the position of a tool to users and accelerate the main work/operation.

4. Tei-Ryou → Fixed Quantity

Within this step a limit is set out to easily control if the quantity of the objects ever exceeds the limit, in other words to control the quantity of each articles.

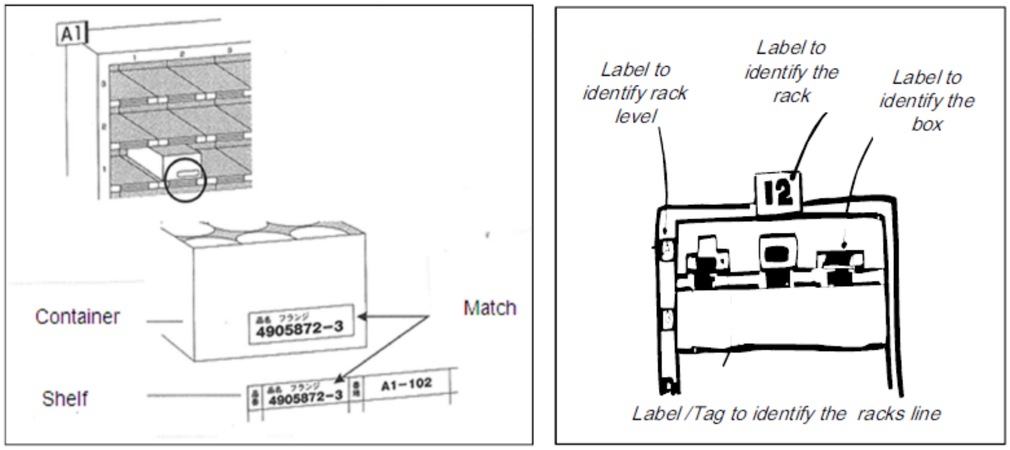


Figure 2-7: Tei-Hyouji Application (FCA, 2017)

5. Tei-Shoku → Standardized Colours

   The last step used the standardized colours which highlight anomalies, identify a specific working area and grant the logistic operators a better and easier visual management and control. This is done to prevent errors by using colours.

2.6.3. Value Stream Map

The Value Stream Map is a tool which used in order to highlight production wastes, the value stream map is used. It is considered as the most important tool in this pillar and used especially to analyse and plan, which in turn, helps to:

- Visualize the process flow and define what steps to take to make it better and to add (more) value
- Visualize where is the point which produces wastes and which are the causes
- Speculate a future situation (in which the current one tend towards)
- Develop the base for an implementation plan through a graphical representation which synthesize the operational decisions and its perks

It is a technic of/to achieve lean production, by analysing and projecting (planning) the flow of materials and information in order to bring the product/service to the consumer. It also gives an information about the Lead Time of a process.

2.7. World Class Logistics

It is the program used to define logistics processes at plants and warehouses. Through its extensive approach, World Class Logisitics helps to meet safety, ergonomics and eco-compatibility requirements as well as transport flow optimization. (Anon., 2018)

This method is used to identify and define how the world's leading firms achieve and maintain their logistical excellence. From a series on interrelated research initiatives, a comprehensive treatment of the topic is provided. These drivers identify the distinctive qualities and abilities of remarkable logistic performers. The initial assumptions show that the best practices could be generalized across all different industrial sectors as well as between firms at different levels in the channel of distribution. In other words, that the best practices are transferable.

There are ten characteristic behaviours of leading edge performers, they need to exhibit an overriding commitment to customers, placed a high premium on basic performance, developed sophisticated logistical solutions, emphasized planning, encompassed a significant span of functional control, had a highly formalized logistical process, committed to external alliance, invested in state-of-the-art information technology and employed comprehensive performance measurement.

The second initiatives generalized the capabilities of leading edge performers into a relational model which guides managers in the process of logistical renewal. The model portrays the integration, from initial internal operating processes followed by development and integration of external supply chain relationships. In order to achieve competitive advantage, all logistic aspects need to be as flexible as possible. This flexibility is achieved by a high state of internal and external integration. Based on this model, a new logistical competencies called the World Class Logistic was created. There are four competencies believed to be common among the performers of this concept:

1. Positioning – the selection of strategic and structural approaches to guide operations
2. Integration – the establishment of what to do and how to do it creatively
3. Agility – the achievement and retention of competitiveness and customer success

4. Measurement – the internal and external monitoring of operations.

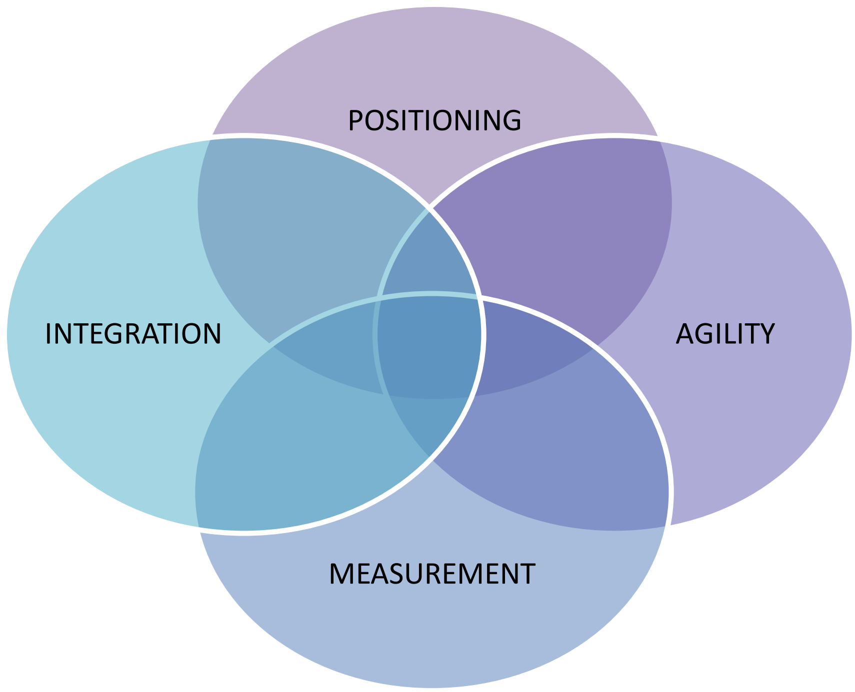


Figure 2-8: World Class Logistic Competency Model

Furthermore, the WCL advise that companies must embody the ability and willingness to identify changing customer needs and successfully respond to those needs. Finally, it is belief that in order to achieve and sustain World Class levels in every aspect of manufacturing, one must develop competent leaders throughout all levels of the organization who are capable of supporting the needs of an ideal production system.

3. Mirafiori Powertrain Plant's Internal Logistic

This project focal point is the first step of the Logistics Pillar: re-engineering the production lines in order to satisfy the clients. This step focuses on defining and creating a thorough flow of each and every class of materials by reducing the WIP and movements of materials and components between each processes. This could be achieve by reinstating the basic condition of the Plant, cleaning, organizing, eliminating excessive and unnecessary flow, followed by standardizing the method used to achieve the ideal condition, apply it to the other areas and maintain it.

As previously outlined, this Powertrain Plant main products are transmissions for FCA's cars with small to medium engine capacity, specifically those using the C514 Transmission. There are 4 different types of transmission produced within this Plant, they are the 5M, 6M, SELESPEED and 4x4. In this chapter, initial introduction and description about the components which forms the finished product is done, along with the production lines from which they are produced from.

3.1. C514 Transmission: Components and Production Lines

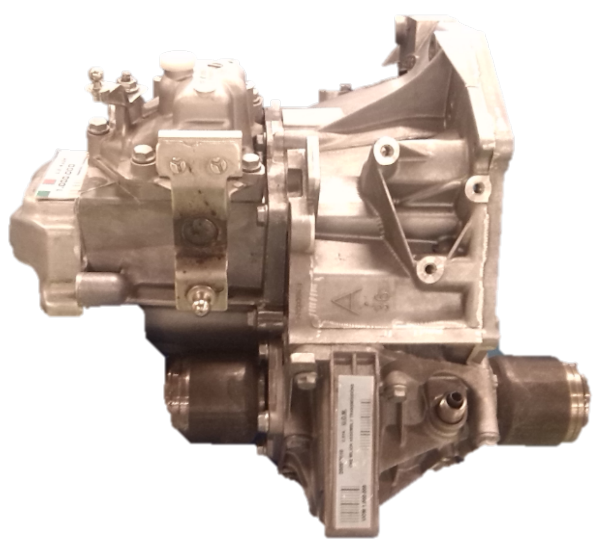


Figure 3-1: Transmission

There are approximately 250 components required to build one transmission. In Mirafiori Powertrain Plant, 50 of these components are produced on daily basis, whilst the remaining 200 are brought in from an external supplier, ready to be assembled. The components produced within the Plant are called “Make” components and the rest are also known as “Buy” components.

Since one finished products is composed out of 150 parts or so-called components and having 4 different product family (which in turn is divided into subsets, depending on the type of cars the transmission going to be mounted on), there are several hundred different types of components produced and bought into the plant. Approximately, there are 300 different designs Therefore, making the internal logistical management much more complicated.

The raw materials required, for the Make components, are ordered on weekly basis and brought in on daily basis, in order to keep a lower stock within the plant. This way, there are no excessive additional cost and space required. The raw materials arrive on the pier which is located right in the middle section of the Plant, which also divides the two main areas of the Plant, Production and Assembly. After that, these materials are stored within an area near the beginning of the lines of production. They came in a with a standardized packaging (appropriate size), in order for them to be easily handled, in other words, moved or transferred from one are to another, whenever and if needed, and also to control the quantity in order to adjust the consequent order. Each components has their own particular process to be transform from raw materials into finished components ready to be assemble with the others.

This project is focusing only the components which are produced within the Mirafiori Powertrain Plant, because every movement of these materials, since they arrived (under raw material forms) until assembled into finished product and ready to be sent to client, are under the internal logistic concern.

3.1.1. Technological Units: Group of Production Lines

There are 11 group of production lines in total within the Mirafiori Powertrain Plant. This project treats 8 out of 11 of these groups, especially those which required the Heat Treatment as part of the process, they are:

- Technological Unit 201: the components processes in this technological unit are made from aluminium and cast iron, which does not required the series of heat treatment processes.
- Technological Unit 202: the components processed here are crown gears which are made from steels, boxes made from cast iron, the assembled components which are gearboxes.
- Technological Unit 203: the components made from iron are processed here within this technological unit. The finished components are shafts, including both primary and secondary shafts.
- Technological Unit 204: from this technological unit, four different types of gears are produced.
- Technological Unit 205: This technological unit produces six different types of sleeves for the Plant.
- Technological Unit 211: five additional types of gears are produced from this technological unit.
- Technological Unit 223: one type of gears is produced within this production line. This production line is peculiar for its location. After the re-engineering of several lines of production this line could be found in the Assembly area, unlike the rest of the gears producing Technological Unit.
- Technological Unit 247: This specific Technological Unit produces several different types of components, including shafts, different types of gears and reverse gear bracket.

3.1.2. The Components

In order to become acquainted and comprehend better the complexity of the project, a table a table consisting the names of Technological Units, different types of components produced from each of them is provided below. The components enlisted below are the broader specifications of the components, later on, most of these components are going to be discussed in depth and the different types and/or ratios are going to be examined.

Table 3-1: Make Components

No	TU	Components Description
1	201	Gearbox
2	201	Select Unit Cover
3	201	Assembled Clutch Housing
4	202	Crown Gear
5	202	Differential Case
6	203	Primary/Input Shaft
7	203	Secondary/Output Shaft
8	204	Gears
9	211	Gears
10	205	Sleeves
11	223	Gears
12	247	Side Gear Shafts
13	247	Disengagement/ Release Shaft
14	247	Engagement Shaft
15	247	Reverse Gear Bracket

Gearbox

Sometimes the term Gearbox is confused with the term Transmission. Gearbox is a part of transmission, which contains the train of gears and to which the gear lever is connected.

Clutch Housing

In the manual transmission, the clutch can be linked to a valve which allows the system to control the timing to disconnect the flow of usable power from the engine to the gearbox.

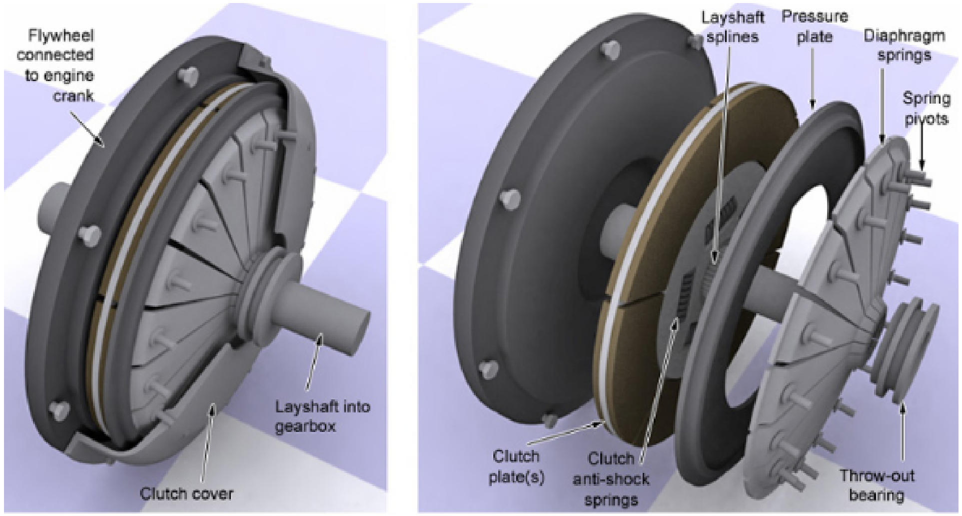


Figure 3-2: Clutch Mechanism (Collins, 2018)

Clutch is located between engine and gear box. When the clutch is engaged, the power flows from the engine to the rear wheels through the transmission system and the vehicle moves. When the clutch is disengaged, the power is not transmitted to the rear wheels and the vehicle stops, while the engine is still running. Clutch is engaged only when the vehicle is about to move and it is kept engaged when the vehicle is moving. It is disengaged when the engine starts, the gears are shifted and the engine is idled.

Differential Case and Side Gear Shafts

This component is what moves the wheels. It is designed to drive a pair of wheels, whilst allowing them to rotate at different speeds, thus giving the name Differential. It is connected to the transmission by a drive shaft. It also slows the rotational speed of the transmission. The location of differential varies according to the type of traction the car is. In a 2WD (2 Wheel Drive) front-wheel-drive car, differential its located in the front axle, while in a 2WD rear-wheel-drive car its located in the rear axle. Additionally, for other types of car traction such as the all-wheel-drive (AWD) and full-time four-wheel-drive car (full-time 4WD), one extra differential is needed to isolate the front and rear axles.

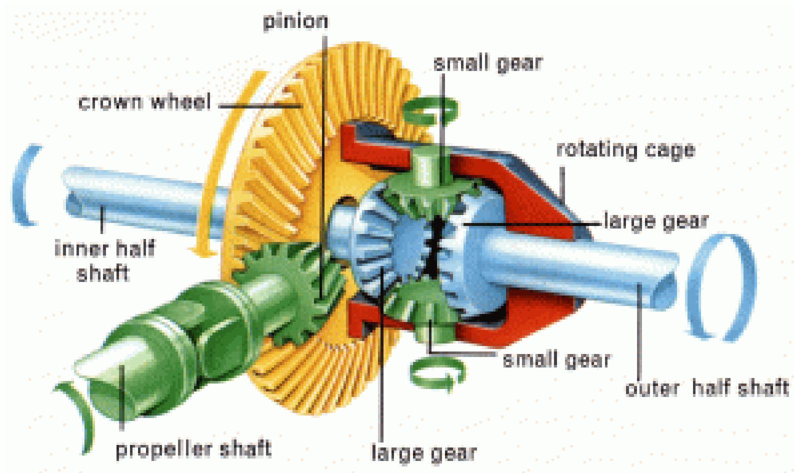


Figure 3-3: Differential (NA, NA)

Input Shafts

The input shafts connects the engine to the gearbox, thus carries the same power and speed of the crankshaft of the engine. On the other hand, the countershaft or the so-called lay shafts are the ones connecting the input shafts to the output shafts through a fixed speed gear. It contains the gears for the drive gears of the car including reverse gear.

Output Shafts

The output shafts runs parallel and directly above the countershaft. This shaft transmits the power of the engine to the rest of the drivetrain. The power and speed of this shaft depend on the gears engaged at the moment.

Drive and Reverse Gears

Within a car transmission, the gears are located on the output (secondary) shaft. They determine the 'gear' which the car is currently engaged in, as an example 1st gear, 2nd gear and so on.

Each gear is enmeshed with the gear directly underneath it, which is mounted on the countershaft. There are 6 different types of gears in total, the first drive being the largest, the fifth being the smallest and the reverse gear. The gears have different ratios, the bigger the ratio, the slower the spin. However, the larger ratio brings more usable power torque to the output shaft. As discussed previously/ initially, the highest the gear the lower the gear ratio until such time that the input and output shafts are transmitting the same amount of functional power and moving at the same speed.

Sleeves

The sleeves or synchronizer collars are the components which make the shifting gears phenomenon feasible, by making sure that only one gears at a time transmits the right amount of torque to the output shaft. The sleeves also assure a smooth transmission of power.

There are, in total, six different types of sleeves. All drive gears are mounted with ball bearings which permit them to spin without restriction while the crankshafts is spinning. In order to deliver power to the output shaft, the chosen gear must be clasped onto the secondary (output) shaft. This is done to enable the power transfer to the drivetrain. Drive gears are separated from one another by the sleeves.

3.2. Internal Logistic of Mirafiori Powertrain Plant

Internal logistic oversees in detail the flow of materials from one point to another within a Plant. It covers not only the movement of each components from the production area to the assembly area, but also in details, such as the transfer which occurs in between each machining processes. Not only that, it also oversees the information flow in relation to order management, incorporated within production planning and scheduling. There are different areas within the internal logistic, which could be improved and updated to have a better flow. In order to have a thorough flow of materials, in addition to the impossibility of obtaining a 100% reliability of the system, an organised and methodological approach is deemed necessary.

In generally, the logistic flow of Make components within Mirafiori Powertrain Plant could be described as the following:

1. Arrival of raw materials
2. Transfer to the beginning of the production(machining) line
3. The first series of processes and transformations
4. Transfer to the heat treatment area

5. Series of heat treatments
6. Re-transfer to the production(machining) area
7. The last series of treatment
8. Temporary storage (transfer to the inter-operational buffer)
9. Transfer to the Assembly area
10. Assembly
11. Testing
12. Packaging for shipping
13. Shipping

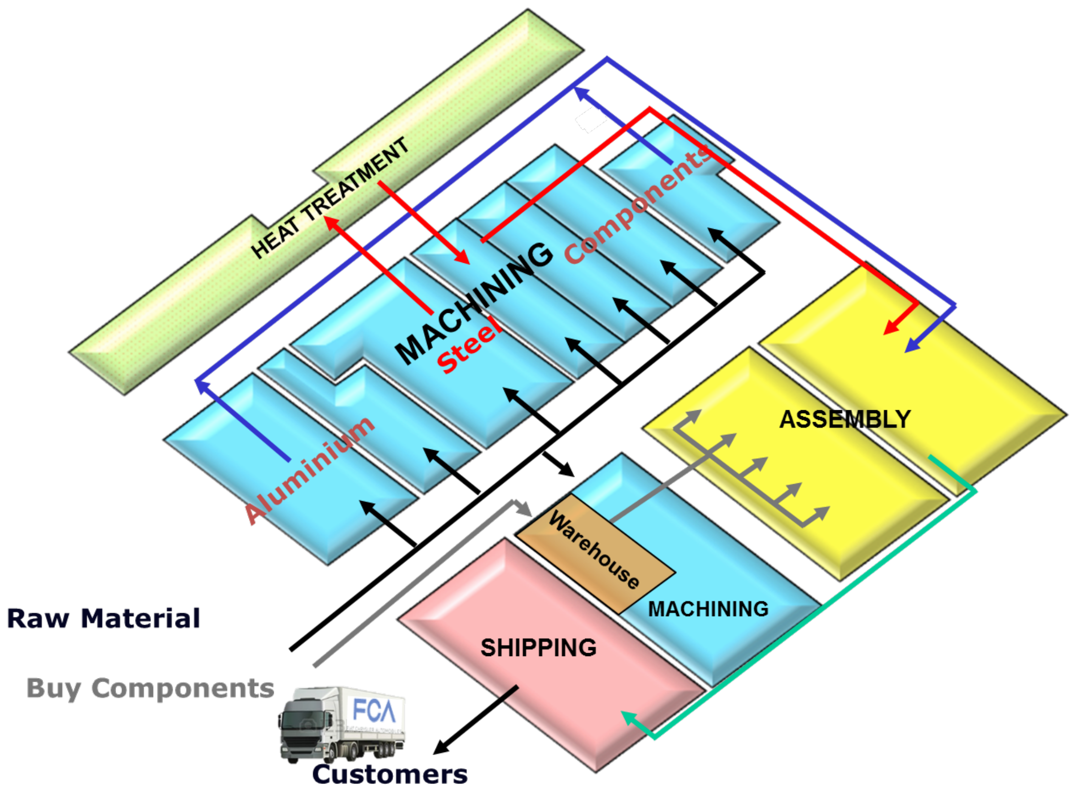


Figure 3-4: Internal Logistic of Mirafiori Powertrain Plant (FCA, 2017)

The total lead time (including cycle time and various other consideration) is equal to more or less 10 days. The TAKT time is equal to 2,9 minutes/ transmission. The average amount of daily production to fulfil clients' request is equal to 2,400 transmissions per day. There are 4 types of transmission produced in the Mirafiori plant: 5M, 6M, MTA and AWD.

Each transmission consists of 150 different components. 100 of which are bought from and external supplier (finished form and ready to assemble) and the rest, 50 types of components, are processed and transformed within Mirafiori Powertrain Plant.

The raw materials are brought in through the arrival or so-called unloading piers on daily basis, according to the plan done earlier or usually ahead of the week. These raw materials then enters the production line and had the first part of the process. After, from the middle section of the production area, these components, known as WIP components are transferred to the Heat Treatment area. This phase lasts, on average, for 24 hours. Thus, making this part the bottleneck of the whole production process. This, though, did not apply to the components which is part of 201 and 202 technological units, for their materials did not require such process.

Before arriving at and within the perimeter of Heat Treatment Area, the components which came from the same technological unit are stored and transferred on a specific type of tray. The trays are made from material resistant to a very high temperature of the heat treatment processes. Unlike the processes within the machining lines, here in the heat treatment processes, these components are stored and handled with a different approach.

After the heat treatment, the components are transferred to back into each line to undergo the last set of processes. Finally, the components will be transferred to the other side of the plant, the assembly part or stored momentarily until a robot or an operator could "pick them up" and transfer them to the assembly area.

3.2.1. Problem and Criticality

Between each processes, more often than not, the finished component needs to "wait" in order to be picked up by an AGV or the forklift or so-called dolly operator and transferred to the next area of process or eventually to the assembly part. This waiting line sometimes are done intentionally, in this case this stock is called buffer. This type of stock comes in handy at times, as an example, when one production line is under maintenance thus unable to process a particular component, the assembly line could continue to perform using the stock available of that particular component. This buffer usually located at the end of the line or somewhere near this area for various reasons, one of them being facilitating the operators to store them within reach, possibly within the golden zone.

Initially, before the project was proposed and officially initiated, the designated areas were already established, but the components were not managed or kept adequately and there was lack of inventory. Additionally, the standardize packaging was often not used for their limited number, no particular order or sequence on storing the different type of components, no defined area or spaces to store different types of component, lack of cleanliness and clear visual display to identify and distinguish different component. Finally, producing powertrains entails handling several hundreds of components and simultaneous transfer between lines and parts of the plant on daily basis. For these reasons, remodelling the area of stocks or buffer for the production of the various components is deemed necessary and fundamental.

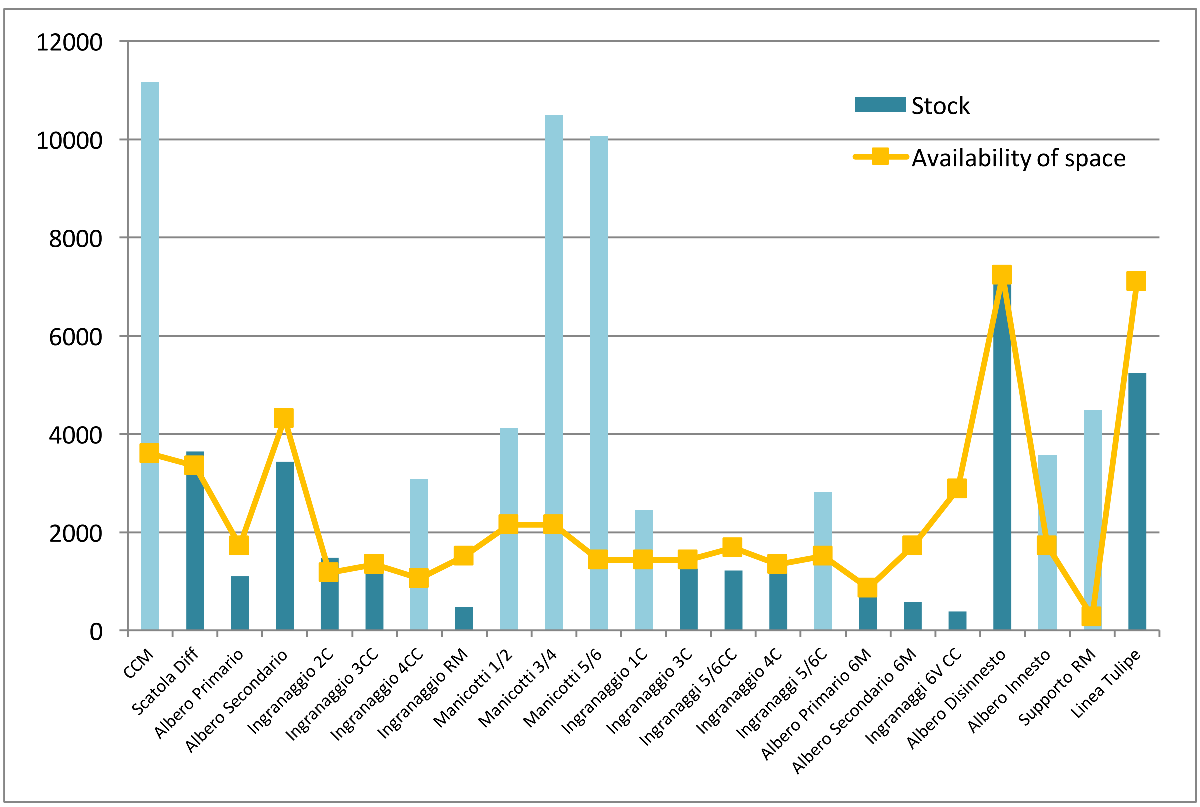


Chart 3-1: Buffer Stock Management before the project

The lack of management of these components did not only brought disadvantages on small scale, but also on the bigger scale. It is believed that the flow of materials affect costs and thus also the company's profit. Incorrect material handling method or approach could cause major negative implication in social-economical, financial and manufacturing aspects. From diagram 2-5, the lack of management is highlighted especially with how the spaces available seemed "not enough" to store the finished components.

On a relatively smaller scale, so called smaller since it is not evident externally, the lack of management and inefficiencies of material handling could cause issues ranging from those with minor impact to major ones. The lack of inventory of the components when they are within machining processes, or in other words the Work In Progress components, is causing the intractability of components. Which could result in difficulties to allocate the components when needed and worse of all, an over production.

Another problem faced in an absence of management, especially for the buffer stocks is the waste of space. The probability of incorrect used of the spaces available is high in this case. Moreover, when the components are very similar to one another and due to the lack of clear instruction on how to store and keep them, they are often kept next to each other or even together in one pallet. This could cause confusion especially for the logistic operator or anyone else who are not familiar and could not distinguished between one type of components to another. There are more or less 60 different components produced within the plant and more often than not, it is not very easy to distinguish one from another, for their difference might only be from the total number of teeth of the gears, differing from one ratio to another.

Altogether, these problems could cost the company a big loss. The lack of management could lead to the wrong components being delivered to the area of assembly and could cause the assembling of those wrong components onto the finished product. When this mistake is detected, it might have been too late. Not only this means additional cost, to disassembled and reassembled but this also means waste of time by producing defect products. Clearly, the lack of management is the critical point, especially for a World-Class Automotive company such as FCA.

3.2.2. KPI & KAI

In these past decades, Japanese manufacturers have been recognized for their strength over the world through their strategy based on development and application of Kaizen scheme. For instance, strength points of manufacturing workers' ability in Japan are higher compared to other manufacturers. Under the existing conditions, it is necessary to develop more systematic approach of Kaizen activity than ever.

One relevant way to realize effective Kaizen activity is clarification of relationship between a result of improvement project and a process for achieving purpose of improvement project. An indicator of the former is called Key Performance Indicator (KPI) and the latter is called Key Activity Indicator (KAI) within Total Productive Maintenance (TPM) that is regarded as one of the most relevant improvement management systems.

KPI: The inventory of each finished components ready to be assembled (WIP)

The downside of keeping stock are not only that the occupy space but also, they stretch the production's lead time. They also generate additional needs of transportation, meaning the transfer from one point to another, and storing. Finally, they tie up the working capital of the company. This stock could come in many forms, but the ones which has the most impact in the manufacturing world are those of the finished products and work in progress, especially those which could be found production area or within the warehouse which does not add additional values to the products. Quite the contrary, they could deteriorate and could become obsolete from one day to another, especially when the market changes it's direction and the competitors start selling new and improved products.

It is impossible, though, to have zero stock for several reasons, such as the unpredictability of the market, the various setup time and processing time of each machine for each and every particular type of components, accountability and reliability of the machine and that of the system as a whole, along with other various reasons. Thus, limiting the stock or keeping the correct amount of finished products and work in progress components is deemed essential.

The WIP (Work In Process) indicates the number of pieces that are currently under processed. It is used to evaluate the performance of the system. Under equal production quantity, the solution with the lowest WIP is preferred. This means that the company can reduce the costs due to the immobilization of stocks of raw materials and semi-finished products. Production waste can be determined by various factors, such as incorrect materials and incorrect tolerances. It is essential to monitor the waste in order to analyse costs and understand their sources.

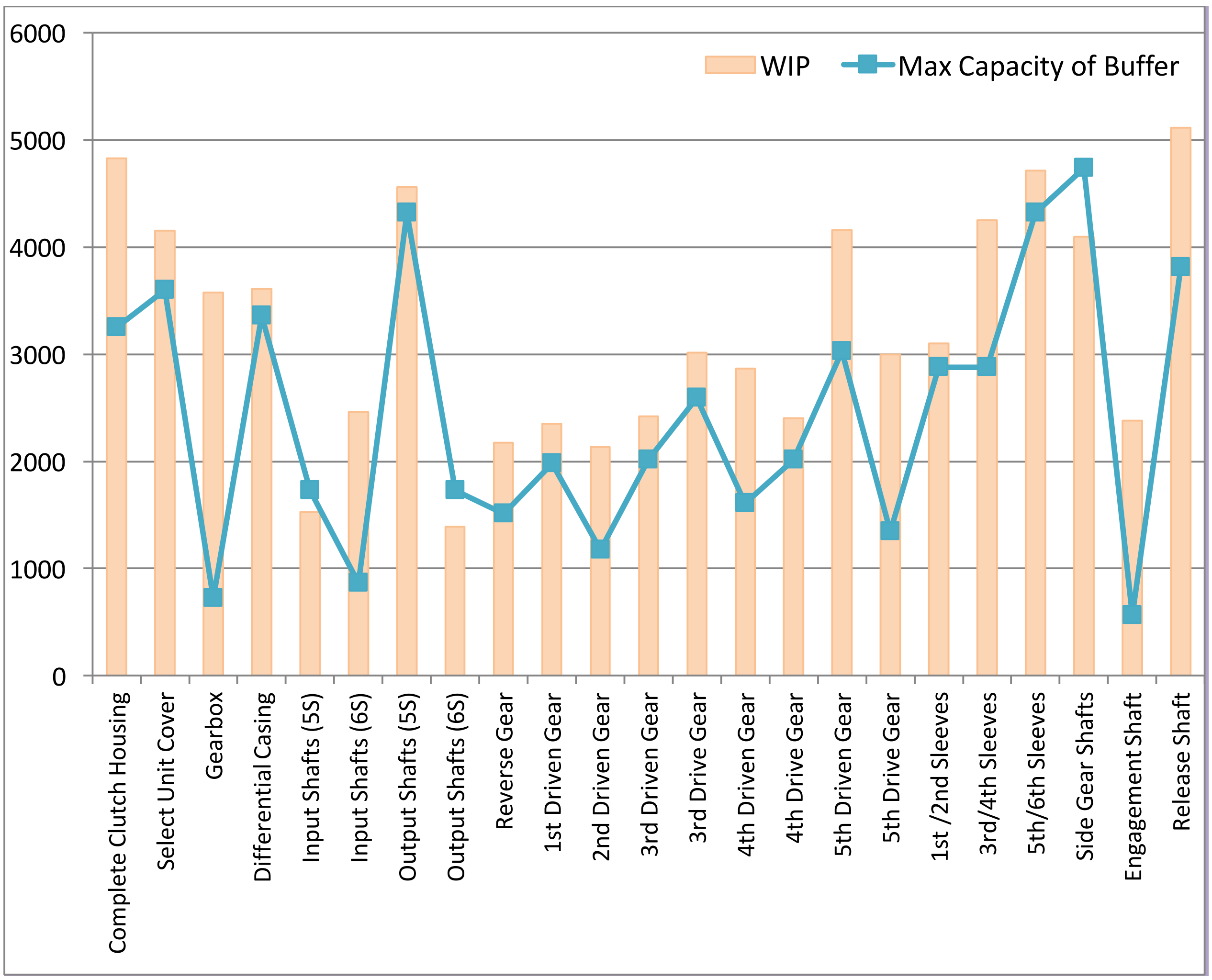


Chart 3-5: Initial WIP Inventory as Project's KPI

The orange bars on chart 2-6 represent WIP values for all components, which are taken from the Plant's value stream map. These values are in turn based on the inventory recorded on the plant, both manually and automatically. On the other hand, the teal line with teal squares depicts the maximum availability of spaces or in other words the maximum capacity of buffers for respective component. The maximum capacity of each buffers are calculated using the safety stock formula and taking into consideration several constraints, including the availability of space and packaging used to store the components.

KAI: Number of buffer completed over the total number of buffers planned to be created

Followed by the Key Activity Indicator being the number of buffer area completed for each type of Technological Unit. The image below enlist the areas needed to be created and managed. After each area is completed, the percentage of KAI will increase until finally reaching 100%, when all of the areas are done.

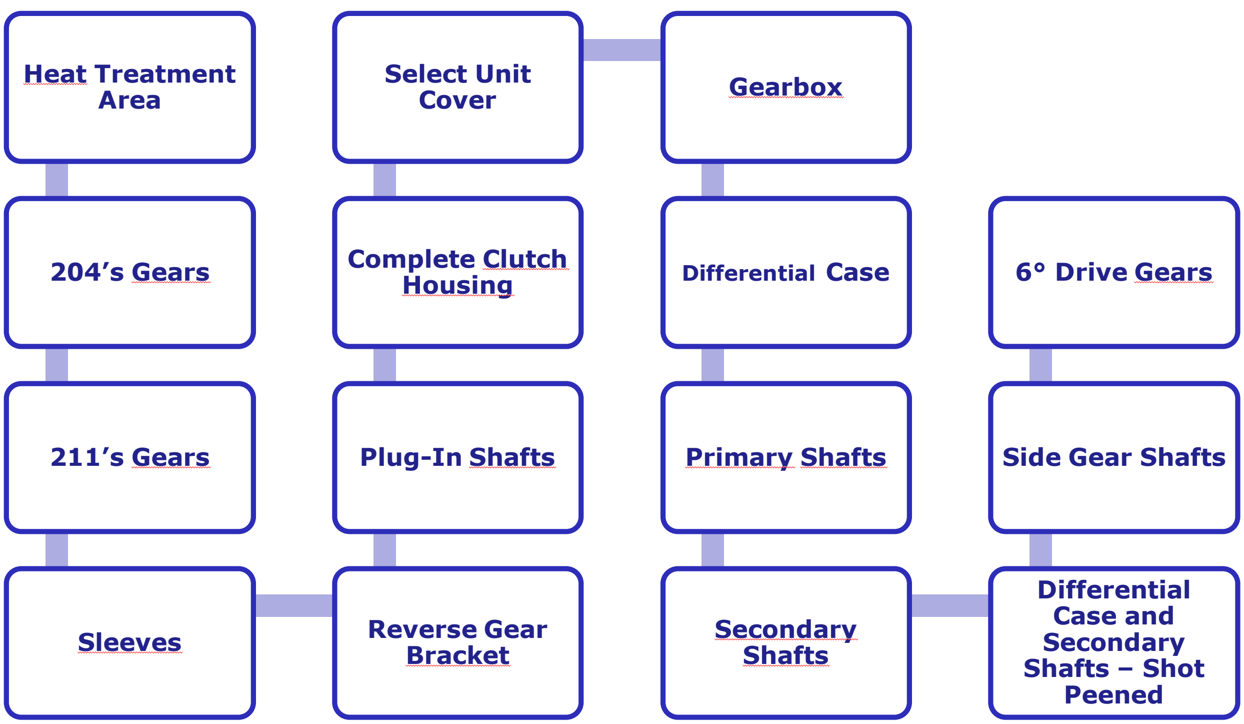


Figure 3-6: Project's KAI

3.2.3. Methodology

The methodology used in the grand scheme on this project is the nested PDCA cycle with the incorporation of several WCM tools in order to achieve the ideal result.

PDCA

The model is implemented to improve the quality and effectiveness of processes within product lifecycle management, project management, human resource management, supply chain management and many other areas of business.

Founded in 1950's by W. Edwards Deming, he suggested that in order to identify the sources of variations which cause products to stray away from customer requirements, the business processes should be analysed and measured accordingly. In order to do so, he recommended that business processes should be placed in a continuous evaluation loop, to a degree that managers can identify and change the parts which require improvements. Thus, Deming established a diagram to illustrate this continuous process, commonly known as the PDCA cycle, which stands for:

Figure 3-7: Deming's Cycle (Lean Value Solutions, 2018)

PLAN: Design or revise business process components to improve results and searching for the root cause, identifying the countermeasure , defining the indicators and planning the steps to achieve that by asking the questions (using the method of) 5W-2H and also by using the 5S and 5T methods.

DO: Implement the plan and measure its performance. Perform/execute the activities coherently to the action plan, which is achieved in the earlier phase.

CHECK: Assess the measurements and report the results to decision makers and verifying whether the activities are inherent to the plan and the objectives are reached.

ACT: Decide on changes needed to improve the process and standardizing the new method and apply it to the processes.

Deming focuses on industrial production processes and sets the level of production as the main focus of improvements. These kinds of improvements are still desired in the modern post-industrial company, but the real drivers of performance more often than not occur on the business strategy level. For a large company such as FCA, as a longer-term variation, a strategic deployment could also be taken into consideration. It is considered as a longer-term because the change in large company could not be done as rapidly compared to a smaller business units. Nevertheless, strategic initiatives should be placed in a feedback loop, complete with measurements and planning linked within a PDCA cycle. Hence, a nested PDCA cycle could be formed.

4. Mapping, Dimensioning and Implementation of Buffer

The ultimate aim of the project is to improve internal logistic stream. In order to achieve the goal, each component needs to have their own plan. This project is focusing especially in improving the flow of components from the production part of the plant to the assembly part and within this chapter, every single detail will be laid out and discussed, from planning phase, execution, monitoring and adjustment, if needed any.

The main focus is the transfer of the finished components to the assembly line. Special exception was the management of the components after heat treatment processes. The transfer between the heat treatment area, back to the machining area, is considered crucial since the heat treatment process altogether is considered as the bottleneck of the entire operation. This chapter is going to breakdown the project using the approach explained in the previous chapter; nested PDCA along with several WCM tools, especially 5S and 5T methods.

4.1. Plan

In this first part, the lines of production were analysed, especially those with which a buffer supposed to be improved or created. This phase is done to prepare the activities to organize each area, using 5S and 5T methods. The steps taken to systemize and regulate the work are explain within the diagram 4-1 below provided.

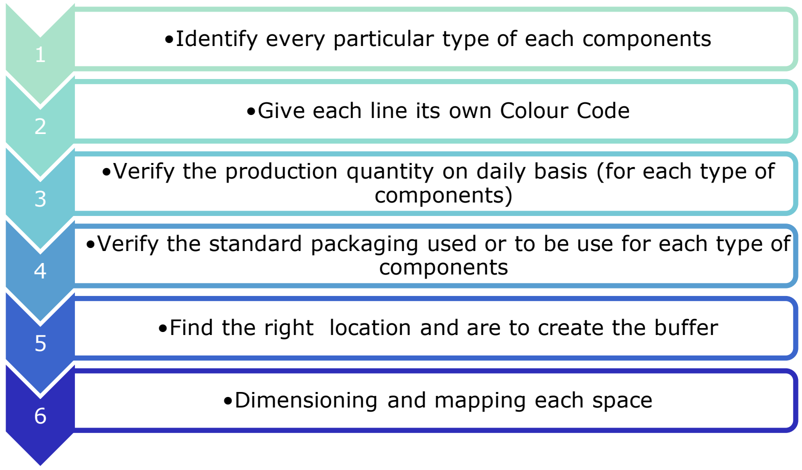


Figure 4-1: Planning steps by step

4.1.1. Mapping: Component Analysis, Packaging and Area Research

The table below lists every components produced within the line of production of interest, divided into groups and colour coded to simplify and to identify each different line of production. It also includes the average quantity needed/ required (of each components) daily. Finally, the last row of the table demonstrate the rate of daily production, which was given by comparing the quantity of the particular type of component with the total quantity of the component's family. As an example: the Differential Case with 57/16 ratio has 50% rate of production daily because the quantity of daily production is equal to 1,200 which is 50% of the total daily production of all types of differential cases, 2,400 pieces. The average production taken into consideration is equal to 2,400 pieces daily, in order to simplify all other considerations such as demand fluctuation and other factors to which variates the daily production plan/demand.

Table 4-1: Make Components of Mirafiori Powertrain Plant

TU	Components	Type/ Ratio	Daily Production	DP Rate
201	CCM	CCM DX	2400	100%
201	Complete/assembled clutch housing	FIRE	2000	83%
201	Complete/assembled clutch housing	SGE	400	17%
201	Gearbox	Normal	2160	90%
201	Gearbox	SELESPEED	160	10%
202	Differential Case	55/16	360	15%
202	Differential Case	56/15	160	7%
202	Differential Case	57/14	180	8%
202	Differential Case	57/16	1200	50%
202	Differential Case	58/15	160	7%
202	Differential Case	63/14	100	4%
202	Differential Case	64/13	240	10%
203	5 Speed Primary/Input Shaft	10/41	1800	75%
203	5 Speed Primary/Input Shaft	11/43	200	8%
203	5 Speed Secondary/Output Shaft	13/64	80	3%
203	5 Speed Secondary/Output Shaft	14/57	80	3%
203	5 Speed Secondary/Output Shaft	14/63	400	17%
203	5 Speed Secondary/Output Shaft	15/56	80	3%
203	5 Speed Secondary/Output Shaft	15/58	80	3%
203	5 Speed Secondary/Output Shaft	16/55	80	3%
203	5 Speed Secondary/Output Shaft	16/57	1200	50%
203	6 Speed Primary/Input Shaft	11/39		
203	6 Speed Primary/Input Shaft	10/41	160	7%
203	6 Speed Primary/Input Shaft	11/43	240	10%
203	6 Speed Secondary/Output Shaft	MAT.17 13/64	330	14%
203	6 Speed Secondary/Output Shaft	MAT.17 13/69	40	2%
203	6 Speed Secondary/Output Shaft	MAT.17 14/57	30	1%
204	2nd Driven Gear	4252	2400	100%

204	3rd Drive Gear	A	840	35%
204	3rd Drive Gear	B	1560	65%
204	4th Drive Gear	A	840	35%
204	4th Drive Gear	B	1560	65%
204	Reverse Gear	9631	2400	100%
205	1st/2nd Gear Hub Sleeve	9601	2400	100%
205	3rd/4th Gear Hub Sleeve	9618	2400	100%
205	5th Gear Hub Sleeve	9628	2000	100%
205	5th/6th Gear Hub Sleeve	9638	400	100%
211	1st Driven Gear	39/11	24	1%
211	1st Driven Gear	43/11	700	29%
211	1st Driven Gear	MAT.17 41/10	1676	70%
211	3rd Driven Gear	Type A	840	35%
211	3rd Driven Gear	Type B	1560	65%
211	4th Driven Gear	Type A	840	35%
211	4th Driven Gear	Type B	1560	65%
211	5th Drive Gear	34/41	200	8%
211	5th Drive Gear	36/47	566	24%
211	5th Drive Gear	38/35	200	8%
211	5th Drive Gear	39/35	1440	60%
211	5th Driven Gear	34/41	200	8%
211	5th Driven Gear	35/38	200	8%
211	5th Driven Gear	35/39	1440	60%
211	5th Driven Gear	36/47	566	24%
223	6th Drive Gear	47/36	50	2%
223	6th Drive Gear	48/31	2350	98%
247	Disengagement/Release Shaft		2400	100%
247	Engagement Shaft / Select Lever Shaft	FIRE	2130	89%

247	Engagement Shaft / Select Lever Shaft	SGE	270	11%
247	Reverse Gear Bracket		2400	100%
247	Side Gear Shaft	Large	1920	80%
247	Side Gear Shaft	Small	2880	120%

In total, there are 60 different components produced within the plant. This quantity is more than the one introduce initially, because it was stated initially that 150 components constitute one finished product, and that 50 of them are produced within the plant. Since, the plant produced not only one but four different types of finished products, these different type of transmissions are distinguished by some constituents. Therefore, almost 80% of the components are distinguished into particular types and/or ratios, as an example the Side Gear Shafts. Depending on which final car the transmission would installed into, a different size of shaft would be mounted on the transmission, a smaller car with smaller tires would most likely used the transmission with the Small sized Side Gear Shafts mounted on it.

As for the packaging, there are specific packaging used to store each components. These packaging are enlisted below within the table with description of components held within each, maximum holding or storing capacity, widths and lengths.

Table 4-2: Packaging Data

No	Components	Maximum Capacity	Dimension (cm)	
			W	L
1	Primary/Input Shaft	6	52	26,5
2	Secondary/Output Shaft	6	52	26,5
3	Reverse Gear	12	51	27,5
4	2nd Driven Gear	12	51	27,5
5	3rd Driven Gear	24	51	27,5
6	4th Drive Gear	12	51	27,5
7	1st Driven Gear	10	51	27,5
8	3rd Drive Gear	24	51	27,5
9	4th Driven Gear	24	51	27,5
10	5th Driven Gear	12	48,5	38,5
11	5th Drive Gear	12	48,5	38,5
12	6th Drive Gear	12	51	27,5
13	1st/2nd Gear Hub Sleeve	12	52	27,8
14	3rd/4th Gear Hub Sleeve	12	52	27,8
15	5th/6th Gear Hub Sleeve	24	52	27,8
16	Complete clutch housing	50	150	110
17	Gearbox	120		
18	Differential Case - Bigger Pallet	80	145	110
19	Differential Case - Plastic Pallet	132	145	110
20	Side gear shaft - large	450	95,5	77
21	Side gear shaft - small	550	95,5	77
22	Reverse Gear Bracket	10	51	27,5
23	Engage Shaft (Select Lever Shaft)	6	109	71
24	Disengagement/Release Shaft	NA	109	71

The aim of this analysis is to identify the correct method to divide, position and arrange adequately the stock of components at the end of each line. This analysis helped not only to rearrange the stock keeping but also ease up the inventory keeping and other inventory purposes. This data analysis is completed with the identification of area for each line of production. The areas are situated near to or directly at the end of each line of production. Below are the some pictures to depict the situation with which the project is based upon.

The plan for all areas could not be standardise. However, by adapting the 5S and 5T methods to reorganize these stocks, a more systemized and repeatable approach could be implemented. Every lines of production has their own particularities which varies from set up time to the availability of the space to hold the stock/create the buffer. By analysing the needs, recognising constraints and resolving particular problems of each and every lines, the appropriate buffer could be established. Schemes are established in the next part for each Technological Unit. The project's KAI established earlier, is used to guide which area should be done first and which comes next.

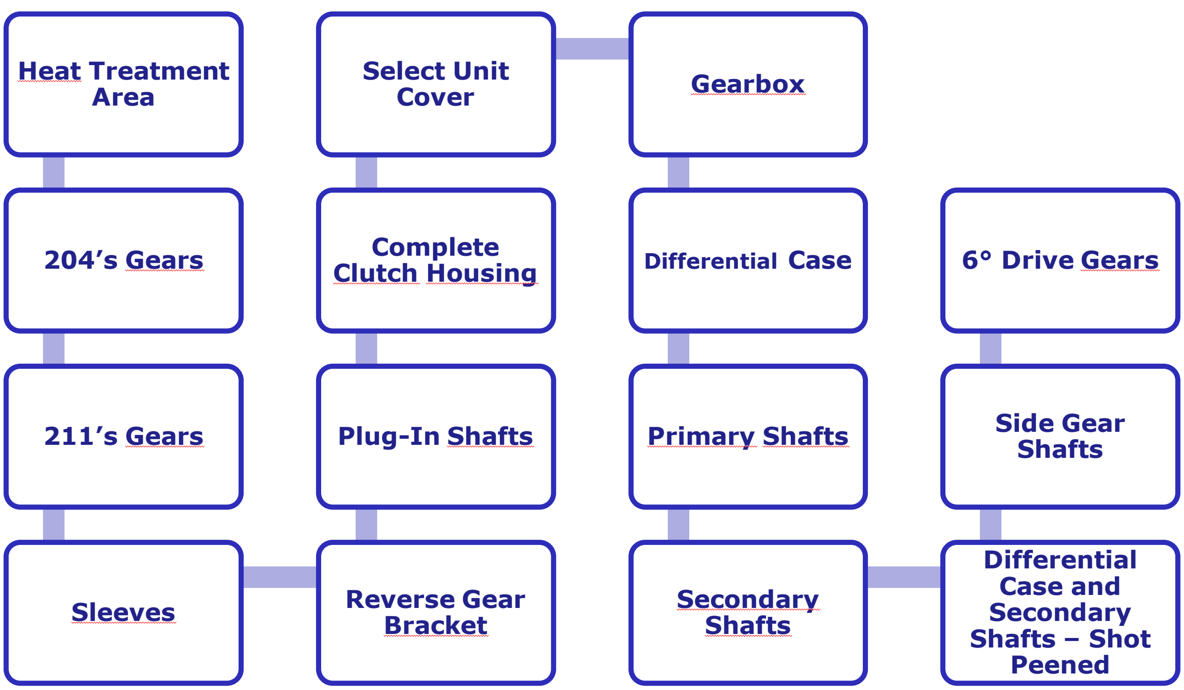


Figure 4-2: Projects KAI used as advancement indicator and guide

Most of the areas and spaces to create a buffer are already established. They are usually located near to the end of the production line. The figures below show the specific areas in which the buffer will be created.

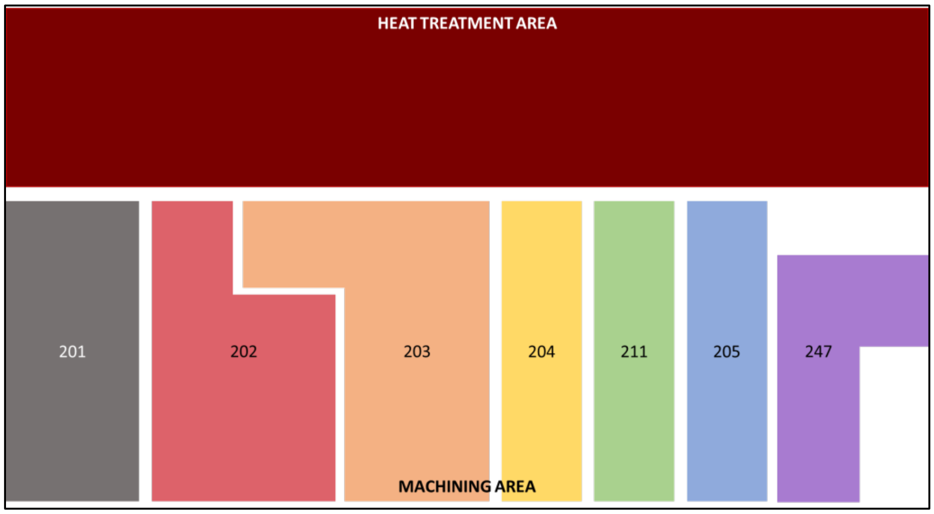


Figure 4-3: Machining and Heat Treatment Area within Mirafiori Powertrain Plant

4.1.1.1. Heat Treatment Area

This space is located in the middle section within the heat treatment area. As shown on Figure 4-4. It is considered as one of, if not, the largest space covered in the project. The dimension of the area is equal more or less to 21 x 7,5 m^2. The actual space is already divided, into several different lines, where the components are stored after the heat treatment process, before being transported back to the middle section of the production area, and continue their individual processes.

4.1.1.2. 201 Technological Unit

The whole area of this technological unit is represented in grey within figure 4-3. As previously described, the components made out of aluminium are processed in this unit, including the Gearbox, Clutch house, Differential case and several others. There are several spots/ spaces which are free and could be used to store the buffer stock of this unit. These spaces are not very spacious and all of the finished components from this unit are stored in a container with the minimum dimension of 1 x 0,8 m^2, thus resulting a very limited capacity and dimension of buffer.

4.1.1.3. *202 Technological Unit – Crown Gears and Differential Cases*

The final differential casing/ cases are stored onto trays which then are stacked one upon another on a tailored pallet. An open space which is already dedicated to store them is already established and can be found close to the end of the Crown Gears' production line.

4.1.1.4. *203 Technological Unit – Shafts*

Initially/ Originally, the input shafts are kept in an area available on the corner (seen from the figure noted as the first circle). The storage system and location were already established but there were no fixed position and visual display which helps indicating different types of shaft.

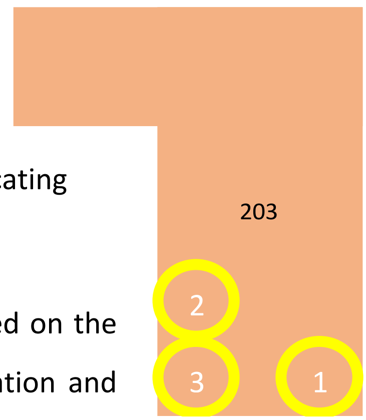


Figure 4-4: 203 TU's Area

As for the output shafts, they were stored within the area marked on the second circle on the figure beside. Here too, lack of standardization and management were found. Moreover, there isn't enough space to store all of the particular ratios of the shafts. Thus, an expansion or eventual reallocation is required.

The third circle represents the area where the old office of 204's Technological Unit was located. Eventually, before the project started the office was moved to another side, thus leaving this area empty. This area is situated just next to the area where the line stored the output shafts, making it the perfect solution to the problem mentioned above. This specific area is surrounded by cardboard walls. To be able to exploit the whole area and more, it is proposed to dismantle the walls surrounding the area and merge the two areas.

Another major adjustments and modification is required in the creation of the buffer meant for the shafts. Other than requesting for the rearrangement of the area where the office used to be, which requires a couple weeks, some adjustments to the original plant are required. This adjustments are necessary as a result of the reallocation of several machines required to process the shafts. The machine used to test the gears was located within the assembly area and planned to be moved to the machining area, within the area of 203 technological unit itself. Specifically, these machines are to be reallocated within the buffer area.

4.1.1.5. 204 and 211 Technological Unit – Gears

Within the machining part of the plant there are 7 different technological units, two from which produces the gears, 204 and 211. These lines ended on the far side of the plant, opposite to the assembly part.

Figure 4-5: Blue Structures

At the end of these lines, exactly across the hallway, the blue structures are used to store the buffer stock of the finished components and sometimes returning components too. By returning components meaning those components that require re-integration or re-calibration or any reparation in order for them to function at their full capacity.

The blue structures or so-called racks are tailored to fit the packaging used to store the gears and for the AGV to be able to pick up the packaging directly, without any intervention from the operator. Whereas, if an operator needs to manually load the finished components, the height of these racks is appropriate and comply to the ergonomic rules. This also means that when there is no AGV available to pick up the components from the racks, a forklift or so-called dolly operator could easily pick them up, load and deliver the components to the assembly area. Lastly, in total there are 71 blue structures available along the corridors and additional spaces, which could be filled with pallets or other structure if required.

4.1.1.6. 205 Technological Unit – Synchronizer Sleeves

Similar to the area meant for the gears, the buffer stocks/ finished components are stored in the area available across the hallway from the end of the 205's technological unit, which produces the sleeves. This area is located also on the far part of the plant, far from the assembly line. However, the sleeves are stored in trays which are more similar looking to a basket, and in turn, are piled upon each other on a pallet. Each pallet holds up to 60 trays, 6 trays on each level with maximum heights of 10 levels.

4.1.1.7. 247 Technological Unit

Several different components are produced here, including the side gear shafts, the select lever shafts, reverse gear brackets and the disengagement shafts. Most of the transformation done within the Plant are those considered to be simpler thus making these lines of production shorter in terms of processes compared to others. Shorter processes result in a more restrictive area or spaces available to store the buffer stock anywhere near the lines.

4.1.1.8. 223 Technological Unit

This area is located within the Assembly part of the Plant, thus non represented in figure 4-3. The technological unit produce two types of 6th Drive gears used in the finished product, whilst the driven gears are the only gears bought from a supplier. This area was recently modified and considered to be spacious to hold the buffer stocks. Additionally, thanks to the recent modification, a new standardized trays are used to store the finished components and to enter the assembly line.

4.1.2. Dimensioning

In this part each particular area is discussed in detail, including the identification of existing buffer areas, calculation of the dimension, taking into account the safety stock and physical constraints, and finally the arrangement. After these analyses and basing on the arrangements, the materials and tools needed to create for the buffer will be listed. This will include the visual display, packaging and transfer or transportation method.

4.1.2.1. Heat Treatment Area

The first area to be treated as planned is the Heat Treatment area. This process could be found between the first series of machining processes and the second series of processes most components must undergo. Particularly, the management for the components that has undergone a series of heat treatment processes is deemed necessary. The total process time of the series of processes grouped under this area is the longest compared to other processes. Thus, making this part the bottleneck of the entire processes.

The components which undergoes the heat treatment processes are steel based components. Being the bottleneck of the entire processes within the plant, the safety stock for this type of components are set to be higher.

This particular area also has a couple of different rules from the rest of the production processes. Here, the different types and/or ratios of the gears are mixed and disregarded. Meaning that in one pallet, different types or ratio of each components, as an example both 5th drive gears and driven gears could be stored together, but such rule do not apply for the 6^{th} Drive type of gear and bushes. This exception is applied on the grounds of the destination area, which are located within the assembly line, whilst the rest of the components are transferred back to the middle section of the production part of the plant, to continue with the remaining processes on each lines. Another additional, rule is that within this area the standardized packaging or so called “inserts” are piled up on pallets. Therefore, the organization of the space is deemed simpler, thanks to the standardised packaging. The inserts used within this process is made of Nichrome, which are resistant to the high temperature use in the series of processes. The packaging could be seen as the following three images:

Figure 4-6: Trays or the so-called Inserts used in Heat Treatment Processes

Table 4-3: Shafts, Crowns, Gears and Sleeves Pallets Receptivity

N° PACKAGING / PALLET	SHAFTS
No of Trays / Level	6
Maximum Allowable Level	1
Total No of Trays / Pallet	6

N° PACKAGING / PALLET	CROWNS
No of Trays / Level	4
Maximum Allowable Level	16
Total No of Trays / Pallet	64

N° PACKAGING / PALLET	GEARS & SLEEVES
No of Trays / Level	4
Maximum Allowable Level	15
Total No of Trays / Pallet	60

As pointed out before, another method used is 5S, thus the first thing to do is to separate and sort out the components. On table 4-3, every type or ratio for each components are classified, and then the first step is done by configuring how much of the space available are dedicated for each type of gears, bearing in mind the various set up time and the daily absorption divided by holding capacity of each packaging used.

Shafts

The insert for the shafts is design to positioned the components vertically and each inserts hold 35 shafts. Positioned vertically, these tray or known as inserts could not be stacked one upon another. Thus, 6 total inserts could be stored on each pallet, resulting in maximum capacity of 210 shafts on each pallet.

Crown Gear

Each tray, used to store the crown gears, could hold 9 pieces. On each pallet, 4 trays could be stored on each level and the maximum allowable levels equal to 16. Thus, each pallet could contain the maximum quantity of 64 trays containing 9 pieces of crown gears each, resulting in total 567 pieces of crown gears.

Gears and Sleeves

A similar rules apply for the saturation of the pallets for these components. 4 trays on each levels with the maximum allowable level of 15, resulting in 60 trays on each pallet. However, the holding capacity of each type of gears and sleeves varies. This variation is noticeable from the table 4-4 below provided.

Table 4-4: Data of Components Subjected to Heat Treatment Processes

TU	Components	Type/ Ratio	Daily Production	DP Rate	Holding Capacity (Pcs/ Pack)	Space Requ ested	Spaces Assigned	Total Buffer Capacity	BC %
202	Crown Gear	57/16	1440	60%	9	3	6	3456	100%
202	Crown Gear	55/16	160	7%	9	1	1	576	100%
202	Crown Gear	56/15	160	7%	9	1	1	576	100%
202	Crown Gear	58/15	160	7%	9	1	1	576	100%
202	Crown Gear	57/14	160	7%	9	1	1	576	100%
202	Crown Gear	64/13	160	7%	9	1	1	576	100%
202	Crown Gear	63/14	160	7%	9	1	1	576	100%
203	Input Shafts	5M	2000	83%	35	10	12	2520	100%
203	Input Shafts	6M	400	17%	35	2	6	1260	100%
203	Output Shafts	5M	2000	83%	35	10	12	2520	100%
203	Output Shafts	6M	400	17%	35	2	6	1260	100%
204	Reverse Gear		2400	100%	26	2	1	1560	65%
204	3rd Drive Gear		2400	100%	26	2	1	1560	65%
204	4th Drive Gear		2400	100%	26	2	1	1560	65%
204	2nd Driven Gear		2400	100%	26	2	1	1560	65%
211	1st Driven Gear		2400	100%	26	2	1	1560	65%
211	5th Drive Gear		2400	100%	26	2	1	1560	65%
211	5th Driven Gear		2400	100%	26	2	1	1560	65%
211	4th Driven Gear		2400	100%	26	2	1	1560	65%
211	3rd Driven Gear		2400	100%	26	2	1	1560	65%
223	6th Drive Gear		2400	100%	24	2	3	4320	100%
205	1st/2nd Sleeves	1/2	2400	100%	24	2	2	2880	100%
205	3rd/4th Sleeves	3/4	2400	100%	34	1	2	4080	100%
205	5th Sleeves	5	2000	83%	34	1	1	2040	100%
205	6th Sleeves	6	400	17%	34	1	1	2040	100%

The second column lists the families of the components whilst the following one classify the ratios and type of each components. The average daily production considered is equal to 2,400 pieces, it is decided to hold at least a quantity of safety stock equalling to 50% of the daily production based on the calculation using the safety stock formula.

The physical area of storage could be seen on figure 4-7. Some additional constraints were found when after the first meeting with the team speaker of the whole area. Some parts of this area is covered with an aluminium sheet, which later found out that this sheets are covering the hollow parts underneath. This implied that, over these metal pieces no overweighed objects should be stored. This particular constrain impede or prevent the use the whole area, meaning that actually the extensive area could not be exploited.

Figure 4-7: Area of Stock - Components after Heat Treatment

Finally to systemise and organize this area, which is the second step of the 5S method together with a series of consideration, the configuration of the buffer could be seen from the following image. The boxes represents each pallet and they differed in colours, as seen on the previous table, to make it easier to distinguish the components family. The grey coloured areas represent the hollow spaces covered with metal sheets and are completely forbidden to be bestowed upon with pallets, whilst the light orange boxes is also an area covered with metal sheets but is available/it is permitted to store the shafts' pallet. This exception is made basing on the fact that on each pallet used to store both primary and secondary shafts, there is just one level of inserts, unlike the others which could be piled up until 15 level of inserts on each pallet. Thus making the shafts' pallets lighter compared to the others.

This allocation proposal are done to conclude the first two steps of 5T, which are fixed route and location. The division between lanes are going to be highlighted by painting yellow lines and highlighting the delicate areas with black and yellow adhesive. The fourth step, which is fixed quantity is done previously, on the calculation of maximum capacity of the buffer. The configuration below shows also that on each lane, the maximum number of pallet is equal to 6. Finally, to adhere the third step of 5T method, standard visual management displaying the name and picture of the components are to be provided and placed both at the beginning of each and at the end of each lanes.

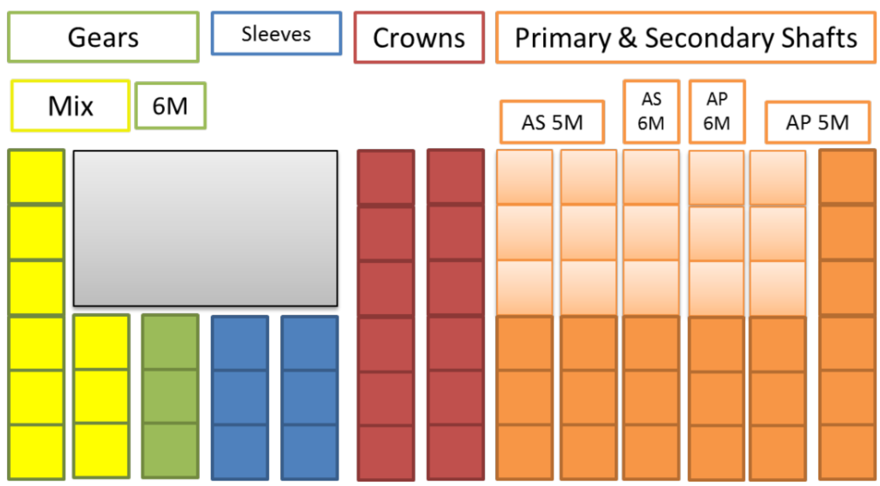


Figure 4-8: Heat Treatment Proposal Configuration

4.1.2.2. Drive and Reverse Gears

The analysis begins with data collection by identifying the components produced by this production line, the general flow, the safety stock decided in advanced and followed by details such as, the packaging used and the availability of it, and finally the original buffer area and management.

There are 6 different types of gears produced in total with various set up time which amount to an average of 65 minutes. The standard packaging used is made of plastic and tailored to be picked up by a mobile robot, AGV, immediately from the end of the production line.

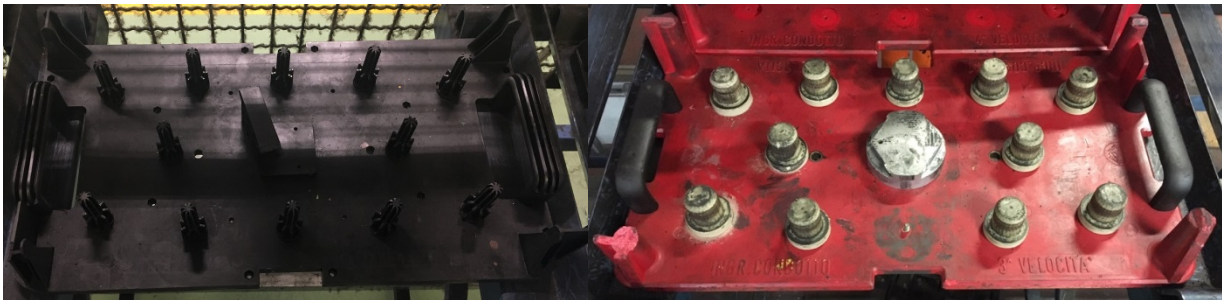


Figure 4-9: Trays used for reverse and drive gears

Blue structures or so-called racks are used to store the buffer for this line of production. These racks are tailored to fit the packaging and for the AGV to be able to pick up the packaging directly, without any intervention from the operator. Whereas, if an operator needs to manually load the finished components, the height of these racks is appropriate and comply to the ergonomic rules. This also means that when there is no AGV available to pick up the components from the racks, a forklift operator could easily pick them up, load and deliver the components to the assembly area.

Initially, when a set of gear is produced, the mobile robot AGV is supposed to pick it up and deliver it to the assembly line. When there isn't enough AGV around, the line operator needs to transfer the set of components to the buffer area in order to continue the production flow by not blocking it with the finished components at the end of the line. The operator will go across the hallway where the blue racks are and load the components in the first one available, or in other words randomly. To indicate the type of components, a piece of paper indicating the name, ratio and status, either deliberated or need to be checked, is usually attached to the packaging. This method is unfit and inefficient, for several reasons:

- The mobile robot would not know where to go and pick up the specific components requested, thus creating the necessity of manual intervention of the line's operator
- The dolly operator will need some time to allocate the specific components requested and crosscheck with the line operator for the specific type, considering the similarities of the gears which results in difficulties in distinguishing the different ratios

In order to resolve these issues and attain a proper division and allocation for each components, the adaptation of the 5S method is deemed suitable. The first step of the method is to separate and sort. Beforehand, every type or ratio for each gears is classified, and then the first method is done by configuring how many slots are dedicated for each type of gears, bearing in mind the safety stock that must be kept, various set up time, the daily absorption divided by holding capacity of each packaging used, and finally the availability of the racks.

The other tool used is the 5T. The first two steps are to standardized the route and location of the buffer area. In this particular part this means continuing to use the blue racks across the hallway, at end of the line, as the buffer area.

The table 4-5 shows, the data so far mentioned, along with the daily absorption of each one of the gears, followed by a column which enlist the holding capacity of each packaging used. it is decided that the level of safety stock of these components must be at least equal to 50% of the respective daily absorption. The sixth column disclose the number of slots available immediately across the end of production line. The Empties column gives the number/quantity of racks meant to store the empty packaging. This is done to point out that the assembly part supposedly need more supply of that particular type of gear. The columns belong to the Allocation group is the second step of the 5S, which is systemizing and organizing. The total numbers indicates how many postages are meant for each type of components and thus, how many signage required.

Table 4-5: Gears from 204 Line of Production

Components	Type	Daily Prod Rate	Absorption	Holding Capacity	Availability	Allocation			Total	Total Pkg.	Receptivity (Buffer capacity)	
		2400				Blue Slots	Pallet	Empties	signage needed	Permitted	Qty	%
Reverse Gears		100%	2400	12	7	9		2	11	14	1512	63%
3rd Drive Gear	B	65%	1560	24	15	4		1	5	14	1344	86%
3rd Drive Gear	A	35%	840	24		2		1	3	14	672	80%
4th Drive Gear	B	65%	1560	12		1	1	1	3	60	888	57%
4th Drive Gear	A	35%	840	12			1	1	2	60	720	86%
2nd Driven Gear		100%	2400	12	8	7		1	8	14	1176	49%

The maximum allowable level of packaging stacked on each rack (or pallet) is indicated on the 11th column. The last two columns give the information of total receptivity or storing capacity of the buffer, in other words, the maximum number of components permitted to be kept on the buffer. This number is given by the holding capacity of each tray multiplied by the number of racks available and dedicated for that particular component, multiplied by the total number of trays or packaging each racks permitted. Lastly, the last column represents the relation between the total quantity which could be stored over the daily production (or the daily absorption) of each components, which gives the buffer's receptivity in other words, its maximum capacity. Below is the graphical representation of the buffer proposal.

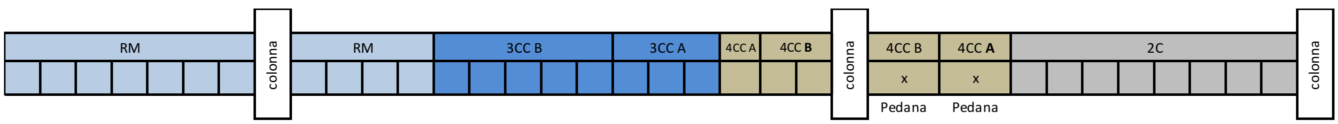


Figure 4-10: Gears' Buffer Layout Proposal

4.1.2.3. Drive Gears and Synchronizer Sleeves

Continuing with the KAI's plan, the 3rd area under observation is the 205 and 211 production lines. Here, a similar approach as the previous production line is adopted to analyse both production lines. These lines produce gears and sleeves, respectively.

The two lines operates analogously to 204 production line. The standard packaging used for the gears and sleeves are made of plastic and tailored to be picked up by a mobile robot, AGV, immediately from the end of the production line.

Blue structures are used to store the gears and the pallets are used for the sleeves instead. Like before, these are tailored for the AGV, whilst the pallets aren't. When there isn't enough AGV around, the line operator needs to transfer the set of gears to the buffer area in order to continue the production flow. The operator will go across the hallway where the blue racks and the pallets are and load the components in the first one available, or in other words randomly. To indicate the type of gears, a piece of paper indicating the name, ratio and status, is usually attached to the packaging. The same procedure is done for the sleeves.

Albeit the similarities with the previous production line, the creation of buffer meant for the two production lines could be considered as the most challenging, this is due to several additional reasons, other than the ones mentioned previously. These reasons are:

1. Many subsets exist under the gears family thus ratios of the gears, some more than five different ratios.
2. Lack of standardized packaging which are adequate for/ transferable using the AGV.

These additional constraints added some serious complication to the buffer management and configuration, especially the packaging shortages. This entails the need to use a temporary packaging to store the components. The non-standardized packaging used in this case could be seen from below figures.

Figure 4-11: Gears's Packaging

Figure 4-12: Sleeves' Packaging

The black trays are used to store the gears whilst the orange baskets are used to store the sleeves. However, these packaging could not go through the line, meaning that at some point the components would be transferred manually from the standardized packaging onto these ones by the line operator, for them to be transferred to the buffer area, across the hallway. The holding capacities of the two packaging are higher than the standardized ones, being 20 gears on each black tray and 24 sleeves per basket.

Table 4-6: Gears data

Components	Type	Daily Prod Rate 2400	Absorption	Storing Capacity	Availability	Allocation			Total	Total Pkg,	Receptivity (Buffer capacity)	
						Blue Racks	Pallets	Empties		Permitted	Qty	%
1st Driven Gear	41/10	70%	1680	10	11	2	2	1	5	14	1480	88%
1st Driven Gear	43/11	29%	696	10		3		1	4	14	420	60%
1st Driven Gear	39/11	1%	24	10		2			2	4	80	100%
5th Drive Gear	39/35	60%	1440	12	18	2		1	3	14	336	23%
5th Drive Gear	38/35	8 %	192	12		2			2	14	336	100%
5th Drive Gear	34/41	8%	192	12		2			2	14	336	100%
5th Drive Gear	36/47	24%	576	12		2		1	3	14	336	58%
5th Driven Gear	35/39	60%	1440	12		6		1	7	14	1008	70%
5th Driven Gear	35/38	8%	192	12		2			2	14	336	100%
5th Driven Gear	34/41	8%	192	12		2			2	14	336	100%
5th Driven Gear	36/47	24%	576	12		8		1	9	14	1344	100%
4th Driven Gear	B	65%	1560	24	12	4		1	5	14	1344	86%
4th Driven Gear	A	35%	840	24		2		1	3	14	672	80%
3rd Driven Gear	B	65%	1560	24			1	1	2	60	1440	92%
3rd Driven Gear	A	35%	840	24			1	1	2	48	1152	100%

Table 4-7: Synchronizer Sleeves data

Components	Absorption	%	Trays	Allocation of Pallets			Buffer Capacity	
		2400	Holding Capacity	Emptie s	Area 1	Area 2	in pcs	%
1st/2nd Sleeves	2400	100%	12	1	3		2880	100%
3rd/4th Sleeves	2400	100%	12	1	3		2880	100%
5th Sleeves	2000	83%	24	1		3	5760	100%
6th Sleeves	400	17%	24	1		1	2880	100%

With the 5S method a proper division and allocation for each type of gears and sleeves could be obtained. The first step of the method is to separate and sort. On table 4-7 and 4-8 every type or ratio for each gears and sleeves are classified, then continued by configuring how many slots and pallets are dedicated for each of these components, bearing in mind the standard variables, which are the safety stock level, various set up time, the daily absorption divided by holding capacity of each packaging used, and finally the racks availability.

Both tables also show, the data so far mentioned along with the daily absorption of each one of the components, followed by a column which enlist the holding capacity of the packaging used. The packaging taken into consideration in this phase are the standardized ones, not the additional ones.

The sixth column disclose the number of slots available immediately across the end of production line. The columns belong to the Allocation group is the second step of the 5S, which is systemizing and organizing. Under the blue racks and pallets column, the total number of space dedicated to store the buffer is provided. The Empties column gives the quantity of racks or pallets meant to store the empty packaging. This is done to point out that the assembly part supposedly need more supply of that particular type of components. The total numbers, listed under the eleventh column, indicates how many postages are meant for each type of components and thus, how many signage planned to be provided – standard visual management and fixed quantity, respectively third and fourth steps of the 5T method.

The maximum allowable level of packaging stacked on each rack, or pallet, is indicated on the eleventh column, under Total Packaging (permitted). The last two columns give the information of total receptivity or storing capacity of the buffer, in other words, the maximum number of components allowed to be kept on the buffer. This number is given by the holding capacity of each tray multiplied by the number of racks available and dedicated for that particular component, multiplied by the total number of trays or packaging each racks permitted. Lastly, the last column represents the relation between the total quantity which could be stored over the daily production, or the daily absorption, of each components, which gives the buffer's receptivity or in other words its maximum capacity. The maximum capacity represents also the stock level chosen to be maintained for each components. Below is provided the graphical representation of the layout proposal.

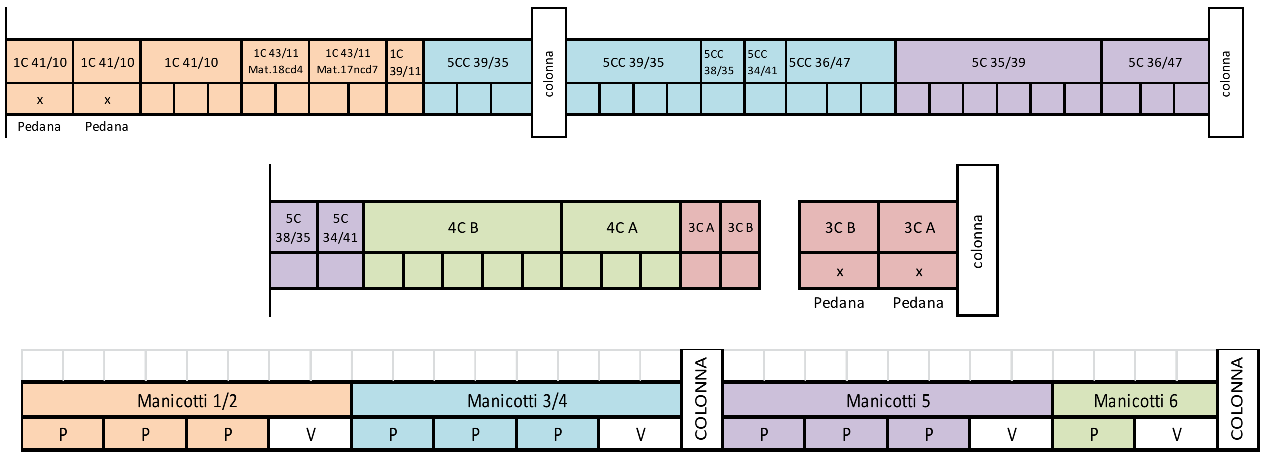


Figure 4-13: Gears and Sleeves Buffer Organization Proposal

4.1.2.4. Reverse Gear Bracket

The reverse gear brackets are one of the components originated from the 247 group of production lines. This group of production lines is distinguished by various components produced from it and also by the area arrangement and configuration of the different lines.

There is only a single type of bracket which is used in all different models of transmission. Thus, the average daily production is considered equal to 2,400 components, with 100% rate of absorption. The raw materials arrived on daily basis, on the arrival dock, unloaded and brought to the beginning of the line in a standardized container. This container is provided directly from the supplier and the brackets are then place manually onto the inserts, or in other words trays, which are attached to the conveyor belt. The trays will then circulates on the conveyor belt, advancing, to be welded. Finally, the finished components will then be transferred onto another tray, within which these components will be transferred onto the assembly line.

The finished components are places into a standardized packaging, trays, which could hold up until 14 components. These trays are then allocated onto blue racks. Both the trays and racks used are identical to the ones used to store the gears, for both 204 and 211 groups. Below is given the information of how many trays are needed for the buffer and the allocation of the components within it, managed accordingly established upon the availability of the blue racks.

There are 4 blue racks available at the end of the line, used to keep buffer and store finished components, and also store the empty trays, ready to be filled again.

Fundamentally, the first step of 5S of separating and sorting could be skipped, considering the low level of complexity of this particular technological unit and its product. The proposal of systemization/ arrangement and organisation for the buffer, is as shown in the figure below.

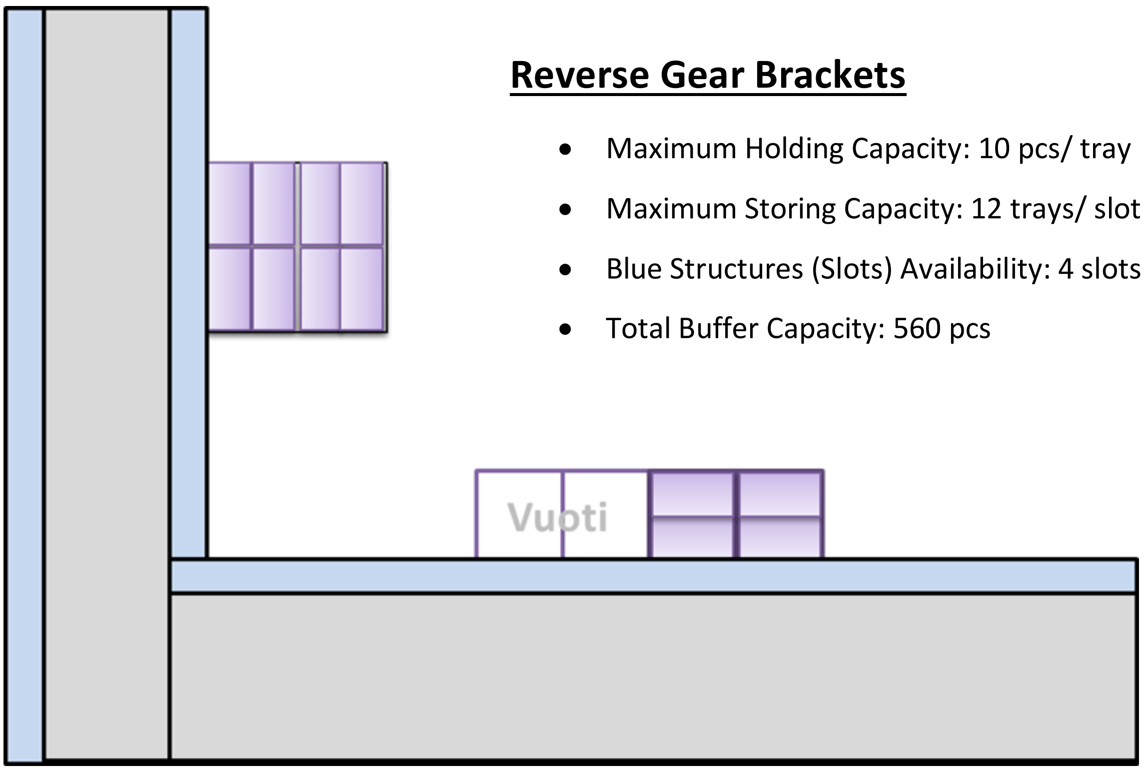


Figure 4-14: Reverse Gear Bracket - Layout Proposal

4.1.2.5. Select Lever Shaft

The Select Lever Shaft's, or so-called engagement shafts, production fell under the same group of lines as the brackets, the 247. Initially, the separation is done based on the two different types of shaft produced, FIRE and SGE. Unlike the brackets, all of the processes from raw materials until the finished components are done within the plant.

The average cycle time of the initial processes inside the plant is equal to 1,76 minutes. After enduring the processes within the plant, these shafts are then transferred to an external company for the nitration process and then transferred back to Mirafiori plant after 1,440 minutes or equal to 24 hours. Afterwards, they will undergo several others processes with 0,7 minutes of cycle time.

A further analysis of the storing method is deemed necessary in consideration of the two different packaging used to store the shafts, container and smaller tray. The container could hold up until 300 components, while the smaller trays could store six components per tray. The trays are usually stored on a pallet, which could accommodate in total 24 trays, six levels of trays with four trays on each level. In total, each pallet consists of 144 components. From this analysis, the use of container to store the components are preferred. The tables below show the different types of shafts produced and each absorption rate, and a clearer comparison between the two methods of storing.

Table 4-8: Select Lever Shafts Data

Components	Type / Ratio	Daily Production	DP %
Select Lever Shaft	FIRE	2130	89%
Select Lever Shaft	SGE	270	11%

Storing Method	Holding Capacity	Allocation		Total Buffer Capacity	%
		FIRE	SGE		2400
Container	450	18	12	13500	100%
Trays on Pallet	144	10	2	1728	72%

From the comparison above and bearing in mind the space available to create the buffer, the use of container is opted to store the components within the buffer area. The proposed layout of the area is provided in the figure below. The area is going to be divided into five different lanes. To adhere with the first two steps of the 5T method, the division between lanes are going to be highlighted by putting adhesive yellow tapes and providing a visual signage on the wall at the back of the area. These steps adhere to the completion of the third step.

On each lane, three containers with maximum level of two, can be stored, meaning that each lane can store six containers in total. The figure 4-14 below shows the buffer proposal for these components. Two lanes are dedicated for the SGE type of shafts and the remaining three are meant for FIREs, since the absorption rate of FIRE is higher than SGE. Thus, resulting in a higher quantity of safety stock required.

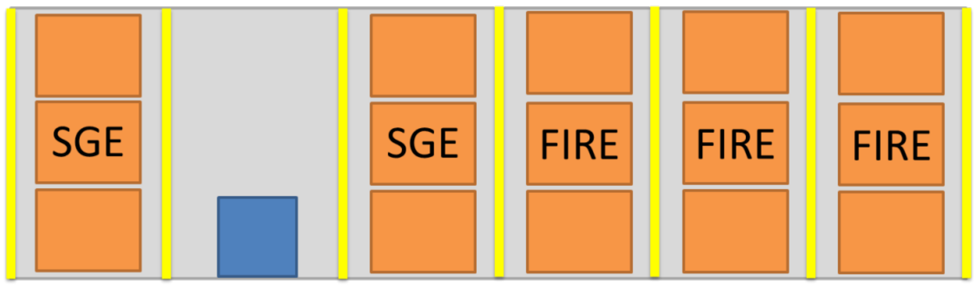


Figure 4-15: Select Lever Shafts Buffer Configuration

4.1.2.6. Shafts

A couple of shafts goes on each transmission, input and output. The shafts are produced from the 203 Technological Unit within the Mirafiori Plant. Beginning immediately with the first step of 5S method, separating and sorting out the components, below provided table 4-10 which includes all the necessary data for the initial analysis and planning.

Table 4-9: Shafts – Different type and ratio

Components	Type/ Ratio	Daily Production	DP %
5S Primary	10/41	1800	75%
5S Primary	11/43	200	8%
6S Primary	10/41	160	7%
6S Primary	11/39	-	-
6S Primary	11/43	240	10%
5S Secondary	13/64	80	3%
5S Secondary	14/57	80	3%
5S Secondary	14/63	400	17%
5S Secondary	15/56	80	3%
5S Secondary	15/58	80	3%
5S Secondary	16/55	80	3%
5S Secondary	16/57	1200	50%
6S Secondary	13/64	330	14%
6S Secondary	13/69	40	2%
6S Secondary	14/57	30	1%

In total there are 15 different types of shaft, contrasting ratios from one another, five different ratios for primary shafts and ten for the secondary shafts. For this particular group of components, a thorough analysis of the processes is deemed essential. The process begins with the arrival of the raw material on the arrival dock, the shafts arrived in a container provided by the supplier, brought to the initial part of the line and loaded automatically onto the production line. For the first set of processes, the phase before the heat treatment, each group of shafts have their own production sequences, consisting a set of machines. There are two different lines, one line for the primary shafts and another one for the secondary.

For the secondary shafts, the first process is milling and followed by turning. After turning process, the shafts move towards the upcoming process, advancing on a conveyor belt singularly, going through calibre, hobber, skiver, three different thread rollers, milling machine or grinder, washer, calibre, shaver, and another washer before being unloaded onto insert trays and transported automatically, and sometimes also manually, to the heat treatment area. The buffer management for the shafts in the heat treatment area is already discussed previously.

Returning from heat treatment area, these shafts are transported and unloaded automatically to re-enter the line and continuing with the third phase of processing. After a series of machining, final calibre and control, these components are finally ready to be transferred to the assembly part to enter the assembly line. This part of process, after the heat treatment, are shared between the two bigger schemes of shafts, unlike the processes before the heat treatment. Meaning that, both primary and secondary shafts go through the same processes on the same machines.

Unlike the previous components which are transported automatically and seldom manually by an operator and the forklift, the shafts are transferred manually regardless in this case. They are loaded manually after each calibre by the line operator to a standardized tray and which are stored and stacked on a pallet. Each tray stores six shafts and each pallet the total of 72 trays could be placed, which gives the total capacity of 432 shafts per pallet.

Table 4-10: Shafts Data - Finished Components

Components	Type/ Ratio	Daily Production	DP %	Storing Capacity (Pcs/Pack)	Total pallet	Buffer Capacity	BC %
5S Primary	10/41	1800	75%	6	3	1296	72%
5S Primary	11/43	200	8%	6	1	432	100%
6S Primary	10/41	160	7%	6	1	432	100%
6S Primary	11/39	-	-	6	-	-	-
6S Primary	11/43	240	10%	6	1	432	100%
5S Secondary	13/64	80	3%	6	1	432	100%
5S Secondary	14/57	80	3%	6	1	432	100%
5S Secondary	14/63	400	17%	6	1	432	100%
5S Secondary	15/56	80	3%	6	1	432	100%
5S Secondary	15/58	80	3%	6	1	432	100%
5S Secondary	16/55	80	3%	6	1	432	100%
5S Secondary	16/57	1200	50%	6	4	1728	100%
6S Secondary	13/64	330	14%	6	2	864	100%
6S Secondary	13/69	40	2%	6	1	432	100%
6S Secondary	14/57	30	1%	6	1	432	100%

Table 4-11 provides all the necessary information to plan the organization of the buffer and allocation of each type and or ratio of shafts. The Total daily absorption for both primary and secondary shafts is equal to 2,400 components. The safety stock of these components is calculated and set to be equal to the daily absorption quantity. The division of the total between each ratio are given on the third column, with the percentage on the following column. The sixth column provides the total number of pallets proposed to store that particular type or ratio of shafts. The last two columns provide the total holding capacity and the percentage, relative to the daily production, of each component.

A particular attention must be paid onto 6 Speed primary shafts with 11/39 ratio. As can be seen from table 4-11, there are no information given regarding the daily absorption rate, number of pallet dedicated for them and neither about the holding capacity nor the buffer capacity meant for this particular type of primary shafts. This is due to the fact that the 11/39 type of shafts are rarely produced as they are meant to be assembled to a particular type of transmission which then goes to a specific type of car. Since this particular type of transmission is a Make to Order type of product, the production of its constituent parts is based on the same logical approach. Thus, there are no specific safety stock calculated and neither allocation given to these shafts.

Continuing with the 5S method, the second step is to systemise and organize, below are divided the plans and proposal for each particular buffer.

Primary/ Input Shafts

This area is located at the end of primary shaft's production line. Being closer to the calibre and gear inspector machines, a reasonable approach is to create the buffer for primary shafts in this particular area.

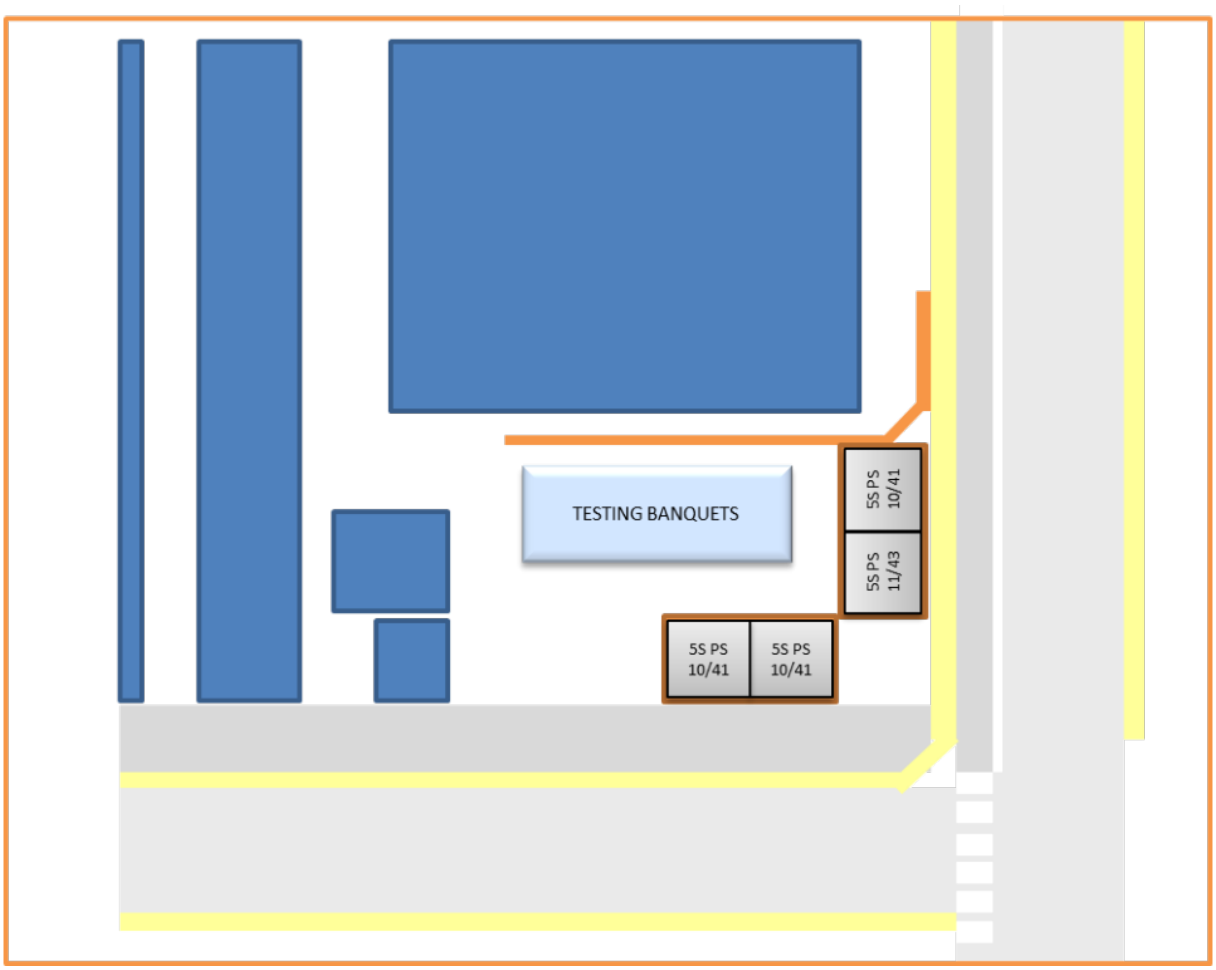


Figure 4-16: Buffer Configuration - 5 Speeds Primary Shafts

The grey boxes represent the pallets on which the trays are going to be stacked, with the type and ratio written on each. To comply with the fourth step of the 5S method, standardising, the 5T method is chosen. Starting with the first two steps of this method, defining fixed route and location, below proposed configuration will be established by placing two pallet holders. These pallet holders are represented on the image below by the orange bases under the pallets. By limiting the number of pallets that can be put/ parked within the area, the maximum capacity of buffer can be established/ figured out. This implies the fulfilment of the fourth step of the 5T method, fixed quantity. Finally, to comply with the third and fifth steps, standard visual management, headboards with colour coded signage will be placed upon the pallet holder.

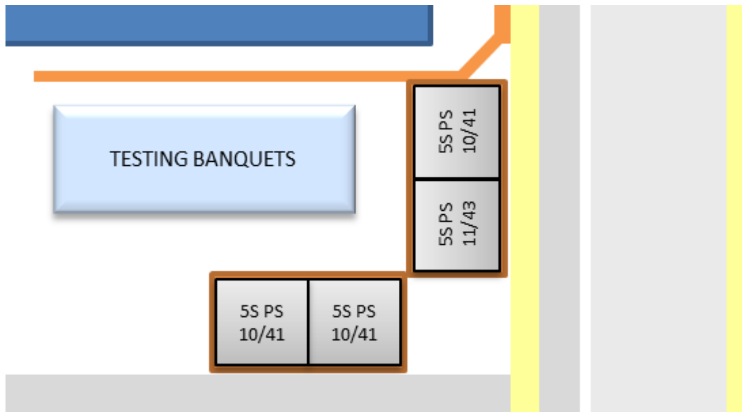


Figure 4-17: Details of the Primary Shafts Area

Secondary/ Output Shafts (Without & before Shot Peening)

This area is located within 203 Technological Unit. The left side area which could be seen from the figure below, is a free space which was already used to keep the finished components, especially the secondary shafts. The right-side area, on the other hand, used to be the office for 204 Technological Unit until it was recently moved to another side and emptied. This specific area is surrounded by cardboard walls. To be able to exploit the whole area and more, it is proposed to dismantle the walls surrounding the area. Figure 5-6 below is the graphical proposal of the buffer configuration.

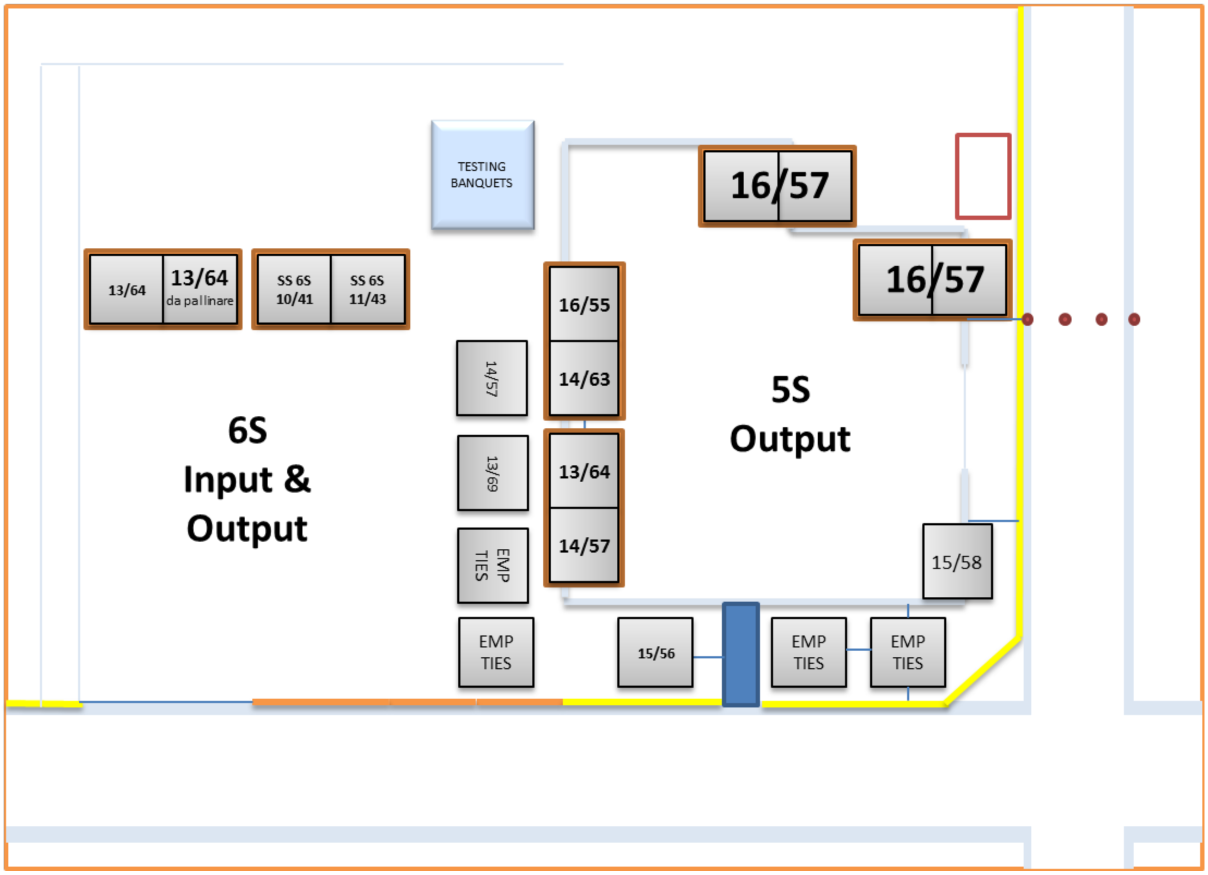


Figure 4-18:Buffer Configuration - Primary and Secondary Shafts

The grey boxes represent the pallets on which the trays are going to be stacked, with the type and ratio written on each. To comply with the fourth step of the 5S method, standardising, the 5T method is chosen. Starting with the first two steps of this method, defining fixed route and location, below proposed configuration will be established by placing two pallet holders. These pallet holders are represented on the image below by the orange bases under the pallets. By limiting the number of pallets that can be put/ parked within the area, the maximum capacity of buffer can be established/ figured out. This implies the fulfilment of the fourth step of the 5T method, fixed quantity. Finally, to comply with the third and fifth steps, standard visual management, headboards with colour coded signage will be placed upon the pallet holder.

4.1.2.7. Gearbox, CCM & Clutch Housing

Following the 5S method, the first step is separating and sorting out the components, below provided the table 4-12 which contains all the necessary data for the initial analysis and proposal for the buffer management of the 201 Technological Unit's area.

Table 4-11: 201 Technological Unit's Products

Components	Type/ Ratio	Daily Production	DP %	Storing Capacity (Pcs/Pack)	Allocation	Storage Method	Holding Capacity	HC %
Complete clutch housing	FIRE	2000	83%	50	4	CONTAINER	2800	100%
Complete clutch housing	SGE	400	17%	50	1	CONTAINER	450	100%
Select Unit Cover	CCM DX	2400	100%	300	1	CONTAINER	3600	100%
Gearbox	Normal	2160	90%	120	1	CONTAINER	360	**17%**
Gearbox	SELESPEED	160	10%	120	1	CONTAINER	360	100%

The three different components are grouped under the 201 Technological Unit, for they are made out of aluminium. These components are stored in standardized containers, tailored to fit each one of them. From the table 4-12 could be seen that there are two types of Completed Clutch Housings produced within this Plant, FIRE and SGE. Each Complete Clutch Houses are composed of dowels, bolts, clutch housing and differential cover. Within the Mirafiori Plant, the clutch housing and differential cover are produced, whilst the other components are bought from external suppliers. These components have their own automatic transportation system which connects the machining area and the assembly area directly, passing through overhead, right below the ceiling level.

The select unit cover (referred to as CCM) has only one type which goes to all final products, thus its daily production (absorption) is equal to the average daily production of the finished products. The safety stock for this particular component is calculated and resulting to equal to

80% of the daily production. From the table provided the buffer proposed offer to hold more than requested. As for the gearbox, there are two different types of gearboxes produced, Normal and SELESPEED, with 90% of the finished products requiring the Normal ones and the rest, 10%, requiring the SELESPEED type. While there are no problem of storing capacity for the SELESPEED type, since the production is significantly lower thus mirrors in the safety stock level, major problem is encountered for the Normal type. Since the production rate is higher, the safety stock level reflects the same pattern.

The fifth column lists the maximum holding capacity of the standard containers used to store these components, followed by the allocation proposal (management) for each component. The Gearboxes have their own storing space near the loading dock. An additional, smaller space, at the end of the production line was made available to store just a minor amount of buffer stock.

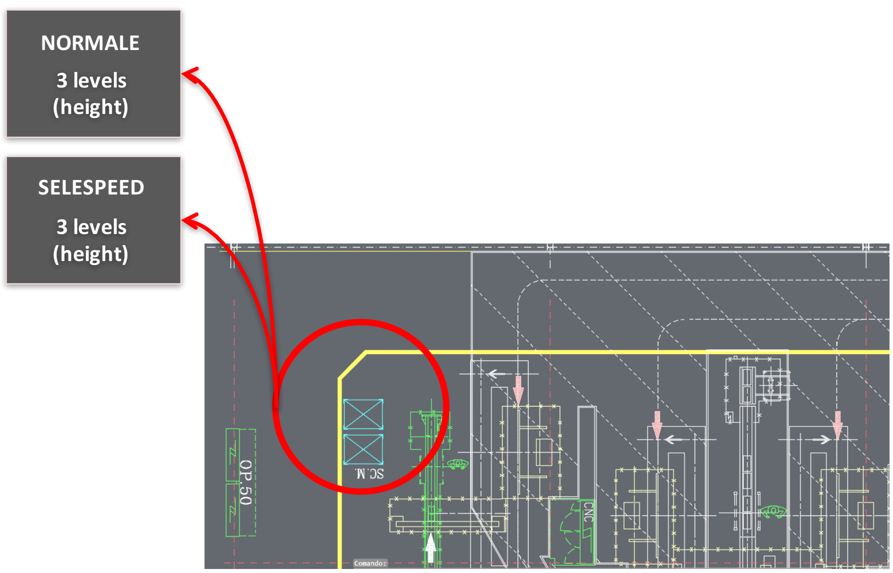


Figure 4-19: Gearboxes' Additional Space for Buffer Stock

The select unit cover containers are going to be stored on one lane made from 2 levels of six containers lined one after another, resulting the maximum buffer capacity of 12 containers. As for the Complete Clutch Housings, one lane of each type is created. Four containers are planned and proposed to be lined with maximum level of 2 in height for FIRE type of clutch housings. While for SGE clutch housings', one lane which allows the total of 9 containers is proposed. The allocation proposal can be viewed from figure 4-19.

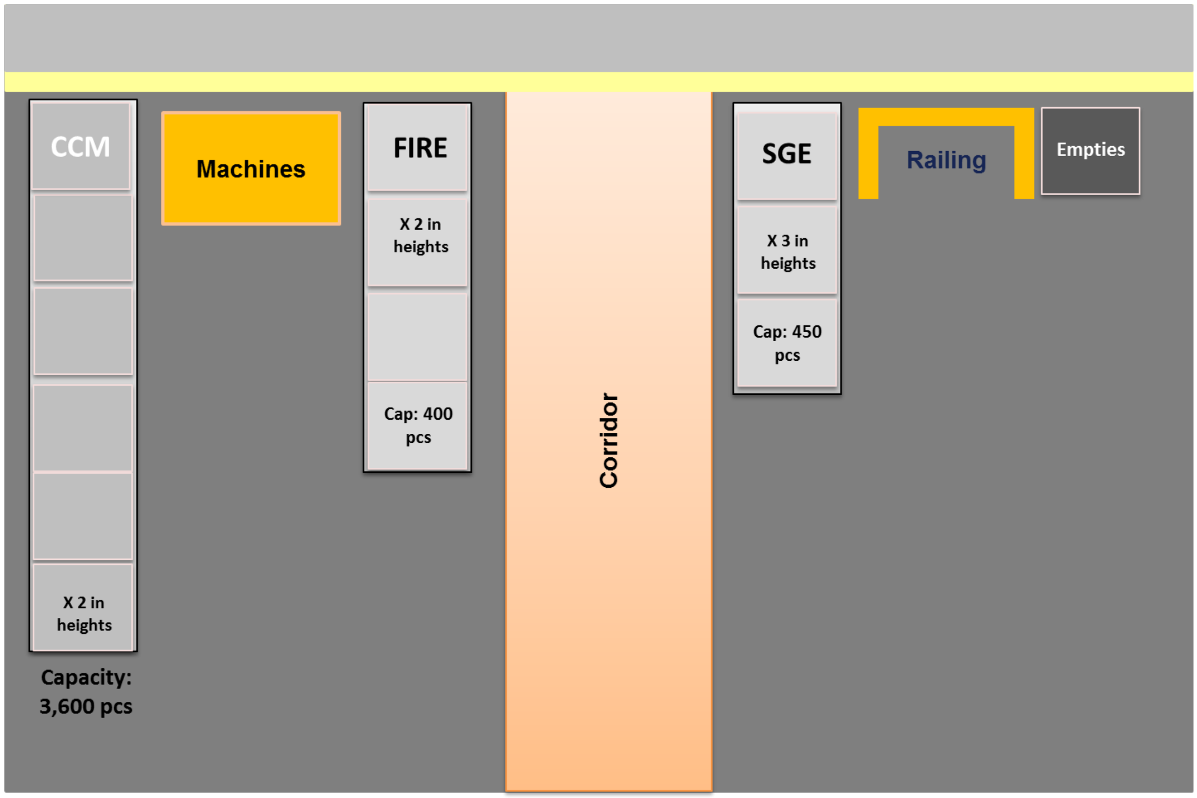


Figure 4-20: 201 Technological Unit's Buffer Layout

4.1.2.8. Differential Case

Table 4-12: 202 Technological Unit's Products

Components	Type/ Ratio	Daily Production	DP %	Storing Capacity (Pcs/Pack)	Allocation		Buffer Capacity	
					Storage	Empties	In pcs	%
Differential Case	57/16	1200	50%	80	2	1	1440	100%
Differential Case	55/16	360	15%	80	1		320	89%
Differential Case	56/15	160	7%	80	1		320	100%
Differential Case	58/15	160	7%	80	1		320	100%
Differential Case	57/14	180	8%	80	1		320	100%
Differential Case	64/13	240	10%	80	1		320	100%
Differential Case	63/14	100	4%	80	1	1	320	100%

From 202 Technological units the crown gears are transformed and assembled into differential cases with different ratios. There are seven different ratios of differential cases produced in Mirafiori Powertrain Plant which goes to different type of transmissions. As provided on the table above, 50% of the total are those with 57/16 ratio. When these differential cases are assembled, they are loaded onto trays which then stacked one upon another on a tailored pallet made out of iron. As seen initially, there are several different pallets available to store this particular component, but for the purpose of standardization and uniformity of this project, the first type of tray, with capacity equalling to 80 differential cases, is taken into consideration to project the allocation proposal. The safety stock for this particular component is calculated and determined to be equal to 80% of the daily production. From the table provided the buffer proposed offer to hold more than requested.

As previously outlined, in the mapping phase, a space alongside the 202 technological unit is available and already been used to keep the buffer stock for this particular component. The configuration below shows how the area is planned to be arrange. Each lane could line up to 3 containers with the standard dimension of 1,45 x 1,1 m^2, and the maximum heights equalling to the total heights of 4 containers stacked one upon another.

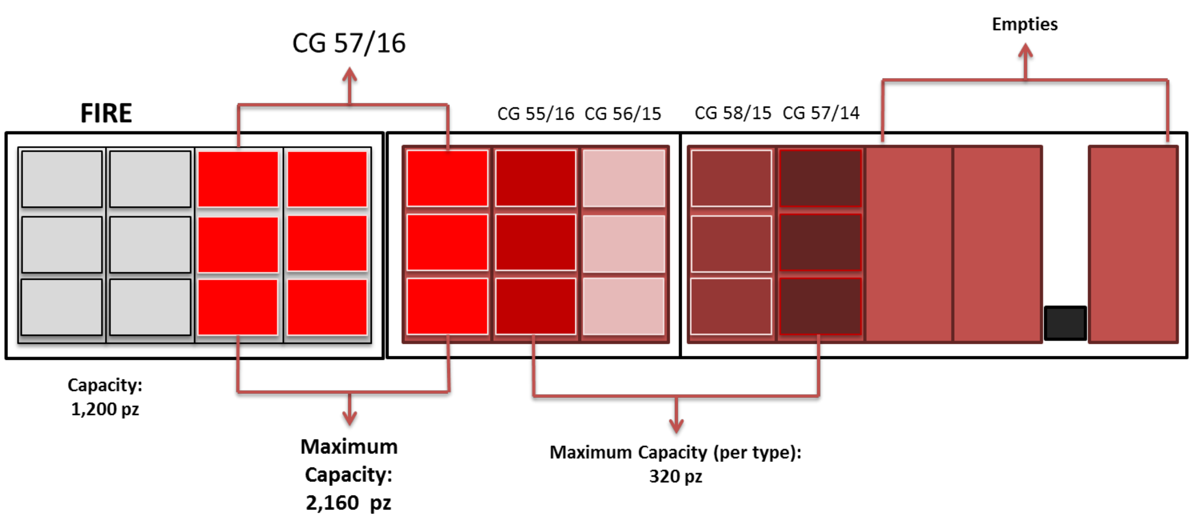


Figure 4-21: Differential Cases Buffer Layout Proposal

4.1.2.9. *Differential Case & Secondary Shafts (after Shot Peening)*

Some of the components required a final shot peening process before continuing their path to enter the assembly line. These components are several types of differential cases and output shafts. Below is a table providing the initial analysis, taking into consideration the same safety stock calculated for respective type of components before and the first step of 5S method.

Table 4-13: Components After Shot Peening Process Data

TU	Components	Type/ Ratio	% of Total 2400	Absorption	Stock			Storage (Containers)		Storage (Pallets)		Buffer Capacity	
					days	Total	Div.	Storing Capacity	Allocation	No of trays	Allocation	Qty	%
202	Differential Case	64/13	20%	480	2	960	320	80	4	-	-	320	100%
		63/14					320	80	4	-	-	320	100%
203	6S Output Shafts	13/64	17%	400	2	800	100	6	-	72	1	432	100%
		13/69					100	6	-	72	1	432	100%

These components went through one additional process before continuing to the assembly line. The Shot Peening process is a cold working process used to produce a compressive residual stress layer and modify mechanical properties of metals and composites. It entails impacting a surface with shot (round metallic, glass, or ceramic particles) with force sufficient to create plastic deformation. In machining, shot peening is used to strengthen and relieve stress in components like steel automobile crankshafts and connecting rods. In architecture it provides a muted finish to metal.

The shot peening machine is located near to the 247 Technological Unit, thus, the differential cases with 64/13 ratio and 63/14 ratio, and also the two output shafts, need to be transferred along the perimeter to be able to be processed. In front of the shot peening machine there is a space available, below on figure 4-22 a layout proposal of the buffer can be observed. The orange boxes represent the pallets, on which the trays used to store the shafts are stacked upon. Meanwhile the pink boxes represent the containers used to store the differential cases.

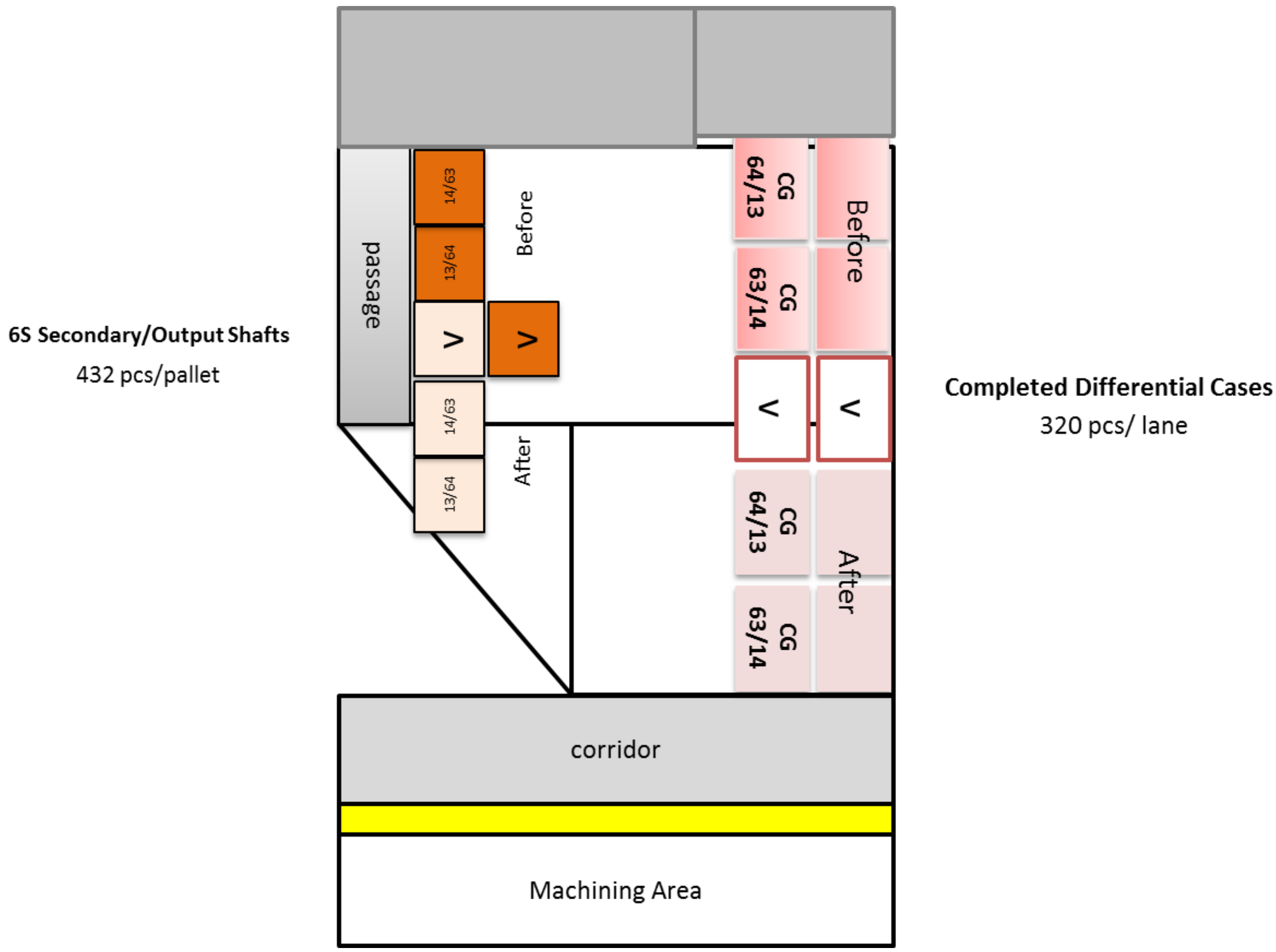


Figure 4-22: Shot Peening Process' Buffer Layout Proposal

4.1.2.10. *Side Gear Shafts*

The side gear shafts are also produced in the 247 Technological Unit. The space available are not spacious, but the below proposal, table 4-14 and figure 4-23, shows an ideal buffer capacity. There are two different shafts produced here. A couple of side gear shafts are assembled on each transmission, connecting the differential to a pair of wheels.

After a series or transformation and processes, these shafts are unloaded manually from the production line, by an operator, and store into a standardized containers. Each container accommodates exactly 550 pieces of the smaller sized shafts and 450 pieces of bigger sized shafts. The orange boxes, on figure 4-23 represent the containers. "B" meaning containers which store the bigger shafts' and "S" for the smaller ones.

Table 4-14: Side Gear Shafts Data

Type/ Ratio	DP %	Absorption	Stock		Container				Buffer Capacity	
			days	Total	Holding Capacity	Requested	Availability	Final Division	In pcs	% stock
Small	60%	2760	1,5	4140	550	8	14	8	4400	100%
Big	40%	1840	1,5	2760	450	7		6	2700	98%

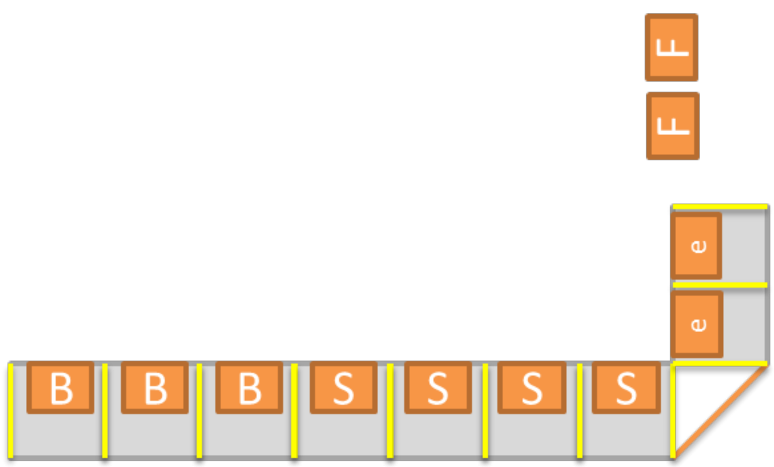


Figure 4-23: Side Gear Shafts' Buffer Layout Proposal

4.1.2.11. *6th Drive Gear*

This area has recently got renovated, thus resulting a well-organized area. The finished components are stored in blue trays which could hold up to 12 gears. These trays are then stacked one upon another on an Euro pallet with standard dimension of 1,2 x 0,8 m^2. 6 trays can be stored on each level, for the maximum level allowable of 10 on each pallet. Thus, the maximum capacity of each pallet is equal to 720 gears.

Figure 4-24: Packaging used to store 6th gears

To adhere with the ergonomic rule and to facilitate the transfer of these components, each pallet is placed on a structure called Rorò, which is a structure tailored perfectly to accommodate a pallet. This structure comes with 4 wheels in rhombus form. The figure below shows the allocation proposal of the buffer for this technological unit.

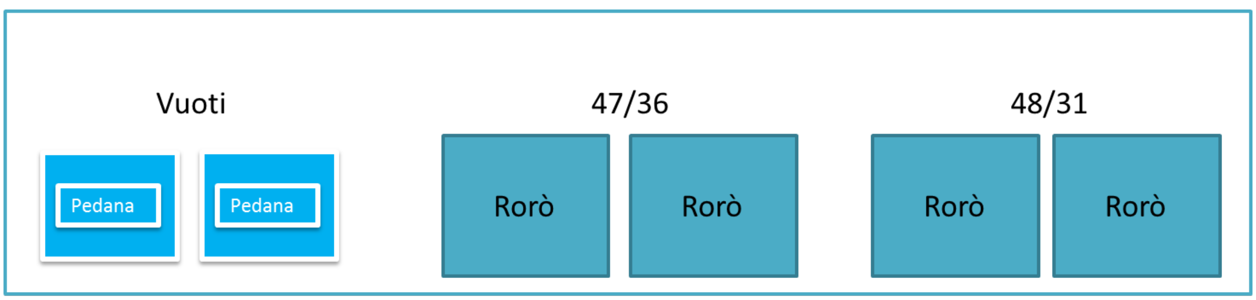


Figure 4-25: 203 Technological Unit's Buffer Management Proposal

4.1.3. Equipment Analysis

The fourth approach explained in 5T tool is create a standardized display or a visual management. In order to do this the next essential step is to list the necessary tools for the creation of the headboards and other type of signage to be used, along with other additional equipment to highlight the areas. To comply with the lean and WCM standards, the principal equipment deemed necessary/fundamental include:

- **Colour coded signage or signboards**: each signage will display the name of the component, the specific type and or ratio, the picture of the component highlighting their particularities and also the description of the particularities (if available). In order to comply with the last step of the 5T method, thus concluding the implementation once and for all, this signage will be colour coded, in other words they will be framed with different colours, depending on which state the components are in. As for example, the signage for the gears to be stored within the heat treatment area and the gear indicator/ displayer within the production area will have different frame colour. The figures below show the example mentioned.

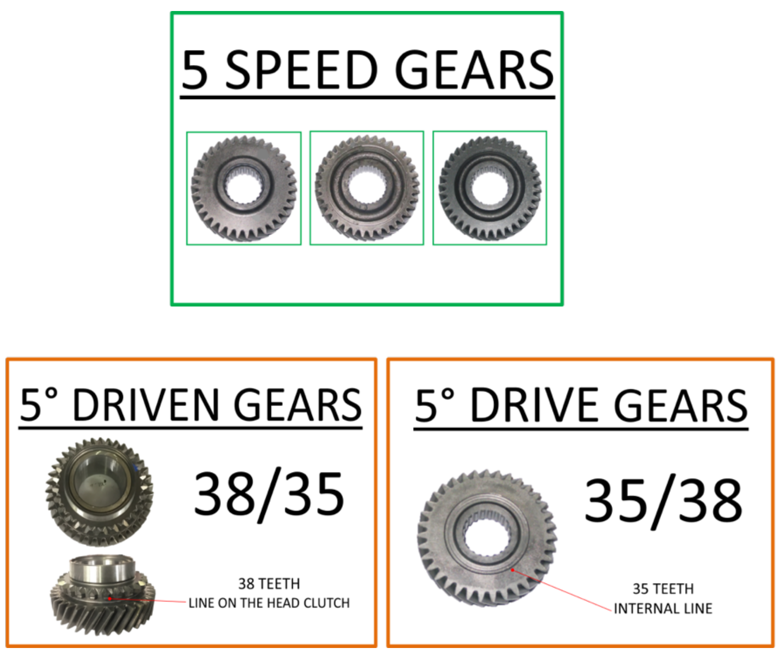


Figure 4-26: Signage Layout Proposal

These signage are to be print and laminated, then to be set on the headboards and on the lower part of the blue racks (if using these to store the stock) or on the floor (if using pallets instead).

Table 4-15: Colour Codes for Signage

COLOUR CODES FOR THE FRAME
AFTER HEAT TREATMENT
FINISHED COMPONENTS

The colours used on the table are those that will be used on the signage (visual management) and are selected for the purpose of standardizing the visual management, adhering to the last step of 5T method.

- **Headboards**: are made out of plastic board and to which the laminated signage will be glued onto. In the case of using pallet holder and the blue racks will be put on the grid, attached to the structure itself. Otherwise, these are to be installed on the poles and put accordingly to identify the component which goes into that specific space/lane.
- **Poles**: the poles are made out of plastic coated tubes which is light but sturdy, suitable and appropriate to be used for the purpose of visual display management inside the Plant. The completed signboards, made from the laminated signage attached to a headboard, are going to be mounted on top of these poles. The heights are adjusted, depending on which area the poles are meant to be placed in. For the heat treatment area the poles are designed to be higher (140 cm in heights) in comparison to those meant for the pallets in 205 technological unit area (120 cm).
- **Adhesive Sign Protector**: this adhesive displayer are designed to be glued on to the ground, to protect the signage from coming off from the floor, caused by friction from the passing forklift and other reasons.

Figure 4-27: Visual Display Equipment

These materials are used to indicate what components goes on which specific space. On the other hand, to highlight the areas, according to the configuration proposed as it is the correct approach according to WCM standard. The other additional equipment are yellow adhesive tape, yellow paint, black and yellow band, red and white band, scotch tape, scissors and cutter. The distinction for each specific area, depending on what type of storage used:

- **Blue racks**

  The structure of the blue racks is tailored to served (work together) with the AGV, but in case the need to be used manually, to store the buffer stocks by an operator, the height of the plane (structure) adhere with the ergonomic rules. The structure has a steel grid on the back side and a flat structure to store the trays. On this particular structure the headboard with the signage, or the visual signboards, are planned to be installed on the grid. This particular positioning serves also to point out the maximum height of the stacks of trays. If at some point the pile of trays covers the signage, it means that the maximum allowable level has been exceeded. Along with the headboards, which is perfectly on the eye level, an extra/supplementary signage is set/ installed on the lower part of the structure.

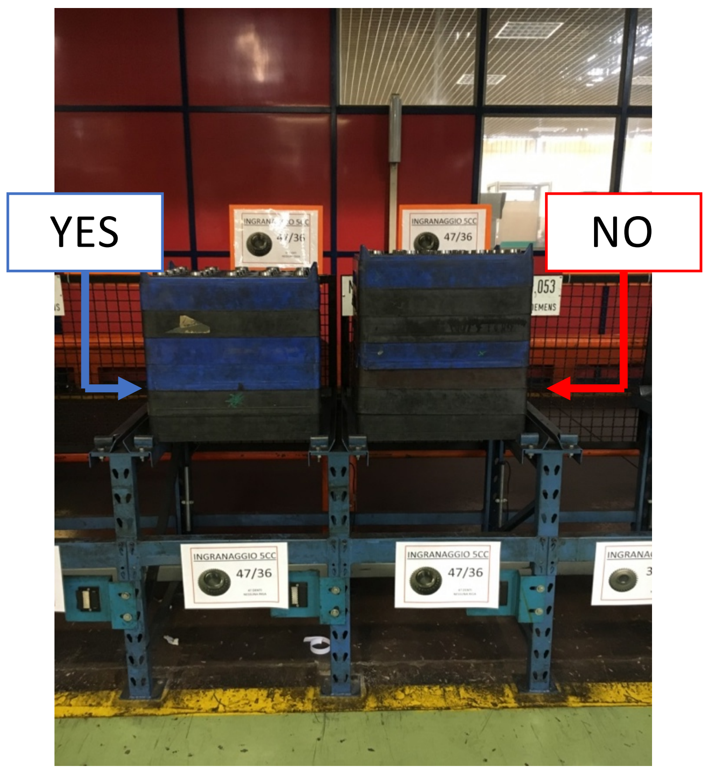


Figure 4-28: Blue Structures' Visual Display Setup

- **Pallets on the floor**

  The pallets used are the Euro-pallet with 120 cm x 80 cm standard measurement. This type of pallet is suitable to store different types of trays used to keep various finished components. For this type of storage, the poles with the signboards installed on it are used as the visual display. More often than not also the adhesive frame which protects the signage installed on the ground, which are usually positioned outside the lines or bands used to highlight the buffer areas.

Figure 4-29: Visual Display Proposal

- **<u>Pallet Holder</u>**

  As the name suggest, the structure is tailored to fit two pallets, lifting it to a height which adhere/comply with the ergonomic rules. Thus, making the used of this holder as the acceptable storing method whenever the pallets are used as the storing base. Other than this particularity of the structure, a grid is available at the backside of the it, similar to the one at the backside of the blue structure or so-called the racks, making it easier to set up the visual display. This last type of storage has so far only been proposed to be used to store the shafts.

Figure 4-30: Pallets Holder

The next step is to verify the visual display proposal, decide on which method is appropriate for each buffer, present the proposal to the team speakers and shift managers, before moving on to the implementation stage and further onto next phase of the cycle and thus the project.

4.2. Do

The second step of the PDCA cycle is Do, which for this project is divided into several stages:

- Presentation, consultation and agreement with team speakers and shift managers
- Adjustments to the plan (accordingly and if needed)
- Equipment research, purchase and construction
- Implementation

4.2.1. Presentation, Consultation, Agreement

Before continuing to the implementation phase, it is appropriate to share this proposal to the stakeholders of the project, especially the team speakers, shift managers, the line operators and the logistic operators (including dolly operators). This is done to communicate and share the intention and the idea of improving, not only the production but also the overall logistical process, while in some ways facilitating their tasks. Several adjustments made initially are considered as part of Do, not as part of check because it happened early and before the implementation phase. There are several adjustments to be made for several areas, but there are no major ones required. These adjustments are shown in the following part.

4.2.2. Adjustments

For the heat treatment area, after having further discussion with the person in charge of the area, known also as team speakers, an additional space to store the bushes and miscellaneous items were requested. The miscellaneous items are stored in wooden containers which occupies space and are heavy, including new trays or inserts to be used in the processes for various components. Recalculation and addition of one other line was done. As for the bushes, they have always been kept and stored near the machinery. Luckily, no further analysis was required and an adequate space to store these components was found immediately, near the principal area, in front of what used to be the team speaker’s box.

Figure 4-31: Updated Heat Treatment's Buffer Layout Proposal

The meeting was also conducted with the shift manager and team speakers of 203 Technological Unit, which produces the input and output shafts. As mentioned on the previous part, the plan was to take advantage of the available and unused space that is available within the perimeter of this Technological Unit. After several meetings and consultation with the stakeholders of this particular area, an agreement was reached and finalised. The new layout (figure 4-31) was created and the initial phase of reconstruction of the area began in May 2018. It is estimated that the area will be liberated and ready at the beginning of the month of July, 2018.

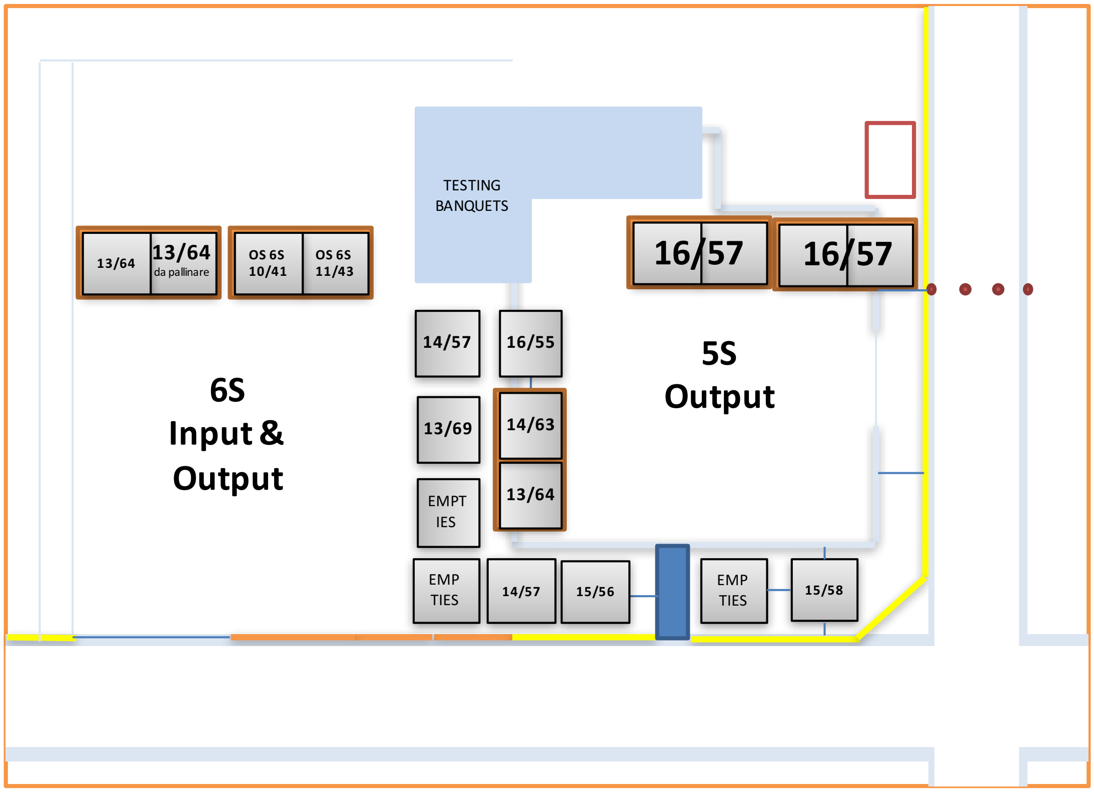


Figure 4-32: Updated/ Latest Layout Proposal for Shafts' Buffer

Other meetings were also conducted with the stakeholders of each particular area or technological unit and resulting in no adjustments required for the other areas at this stage.

4.2.3. Equipment Research, Purchase and Construction

According to the equipment analysis within chapter 4.1.3. and bearing in mind the adjustment the necessary equipment are listed in the tables below.

Table 4-16: Signage Requirement

No	Areas	Quantity
1	Heat Treatment	32
2	Gears (204)	58
3	Gears (211)	102
4	Sleeves	14
5	Reverse Gear Brackets	8
6	Input Shafts	6
7	Output Shafts	17
TOTAL	**SIGNAGE**	**237**

As previously discussed in chapter 4.1.3. Equipment Analysis, adhering to the method adapted, 5T method, especially the third and fifth steps, these signage are colour coded basing on their steps within the production process. After being printed on A4 format paper, they are then laminated, plastic-coated, to prevent them being from being torn and damaged.

Table 4-17: Headboards Requirement

No	Areas	Quantity
1	Heat Treatment	16
2	Gears (204)	30
3	Gears (211)	53
4	Sleeves	14
5	Reverse Gear Brackets	4
6	Input Shafts	6
7	Output Shafts	17
TOTAL	**HEADBOARDS**	**140**

These headboards have standardized measurement, 25x30 cm^2. The laminated signage, which goes onto the poles and to the grids, are glued to the headboards making complete signboards as the standardized display.

Table 4-18: Poles Requirement

No	Areas	Quantity
1	Heat Treatment	16
2	Gears (204)	30
3	Gears (211)	53
4	Sleeves	14
5	Reverse Gear Brackets	4
6	Input Shafts	6
7	Output Shafts	17
TOTAL	**POLES**	**140**

There are two types of poles used. The first one, used within the Heat Treatment area are design to be 140 cm in heights. This is done under the circumstances that the vision range is further in this area than others, for the length of area covered. The others are designed to be lower, with heights of 120 cm, considering the shorter vision range required.

Table 4-19: Adhesive Sign Protector Requirement

No	Areas	Quantity
1	Heat Treatment	16
2	Gears (204)	28
3	Gears (211)	50
4	Sleeves	0
5	Reverse Gear Brackets	0
6	Input Shafts	6
7	Output Shafts	17
TOTAL	**ADHESIVE SIGN PROTECTOR**	**117**

While half of the total signage are glued to the headboards to be the eye-level visual display, the remaining laminated signage are designed to be placed on the ground. Since there are much more exposure to damaging factors such as oil spillage and other damaging actions, an extra measure is taken to prevent these events, by placing an adhesive sign protector on the floor signage.

4.2.4. Implementation

The final stage of the second phase of the cycle is the implementation of the proposed buffer management. This stage consists of clearing, cleaning and highlighting each of the area, following the layout proposed and using the additional equipment such as yellow adhesive band, yellow paint, black and yellow band, red and white band, scotch tape, scissors and cutter. On a less oily, or less likely to get oil spillages surfaces or areas, the yellow band is opted, for it is easier and quicker to be done. On the other cases, the use of yellow paint to accentuate the lanes and or the buffer perimeter is preferable. After defining the perimeters, the visual displays management are positioned in two location on each station. The figures below are the finished buffers.

Figure 4-33: Heat Treatment Area and Gears' Buffer - 204

Figure 4-34: Sleeves' Buffer - 205 Technological Unit and Gears' Buffer - 211 Technological Unit

Figure 4-35: 247 TU - Reverse Gear Brackets' Buffer Management and Plug-in/Select Lever Shaft's Buffer

The creation and establishment of the remaining areas were still under progress up until the fourth month after the project was initiated. Thus, the completion of the whole project is foreseen in the near future. As for the completed buffers, they proceed to the next stage or phase of the cycle, which is Check.

5. Analysis of the Results – Check

The main objective of this particular phase is to observe and monitor the area after implementation, and making adjustments where necessary. First, the monitoring activity is done on daily basis for the first two weeks after implementation, in order to be able to monitor and observe the real-time fluctuation of the buffer stock, in other words the quantity of finished components. Another PDCA cycle is used in order to have a continuous improvement of the buffer areas. Afterwards, a consistent monitoring is done to maintain the buffer management established, until it becomes the standard way, in other words a habit, of the entire process. This represents the conclusion of the 5S method adapted.

The areas discussed below are those which are created and completed within the initial period of the project. The timeframe required to complete these areas is equal to 10 weeks. The creation and establishment of the remaining areas will be continued by the Logistic Pillar Leader within the Mirafiori Plant.

5.1. Check and Control

Each specific area constructed are under observation and constant control. The control is done twice a day, at the end of the first operator's working shift and in the middle or sometimes at the beginning of the second shift of the day. The method adapted is by simply going around the area recently established and examine whether on a specific space, the component stored correspond with the one shown on the signage (visual display). If yes then the system has been obeyed and adhered to, otherwise it is necessary to search for the cause of this anomaly. After discovering the root cause of the problems and figuring out the solution, some adjustments is required to be done. In order to have a reliable outcome, the adaptation of another PDCA cycle is deemed appropriate. Meaning, planning these adjustments, implementing them to the affected area and checking the outcome of the improved area.

5.1.1. Heat Treatment Buffer

The first buffer created, within the heat treatment area, did not encountered any problem. No modification was required for this specific area. However, some changes were required especially for buffers created for 211 Technological Unit, which produces five types of gears, with at least two different ratios for each.

Figure 5-1: Heat Treatment - Final Buffer

5.1.2. Gears - 204 Technological Unit Buffer

The area for this group of gears was completed the week after the heat treatment area. The original proposal was implemented directly without any modification. Three weeks after implementation of the layout proposed, the proposed method of organization was still complied with, although it seems to be always empty. Which could be a benefit but also a warning. It is seen beneficial, because it imply that the production flows smoothly without anything that could cause a blockage or anything which could cause a peak in the production of the gears which in turn, would have caused a problem for the spaces available or dedicated for each of them. On the other hand, it could and should also be a warning, since this presumably indicates that there are low to no safety stock for these types of gears. If something happens, increase in production request as an example, they would have to produce more in a limited amount of time.

Figure 5-2: 204 TU Gears - Final Buffer Management

5.1.3. Gears – 211 Technological Unit Buffer

This buffer area is located right next to the area of 204 and it also have the same concept. The implementation, however, didn't began immediately. It was delayed for a whole week, due to shortage of equipment problem. Materials such as the plastic headboard and the poles, took longer to be constructed due to the high quantity requested particularly for this area.

When it came to the time of implementation, it was noticed immediately that a series of adjustments needed to be done to the proposed plan. The major problems were the lack of space available to store the 5th driven gears, particularly those with ratio 35/39 and 36/47. The problems occurred to this specific area were caused mainly by the minimum availability of the suitable/appropriate packaging, especially for the 5th driven gears. Additionally, the various set up time, as an example, some ratio requires more set up time than the others and fluctuation of production requests, were not helping the situation.

The standard packaging, the red trays which could store up to twelve gears on each one, are very difficult to be found around the machining area for its limited number. Most of them could be found on the initial phase of the assembly line where the 5th Driven gears are loaded onto, while the remaining others could be found within the last part of the machining process.

This is due to the fact that the last part of machining consists of the loading operation by a robotic arm, which is programmed on default. The operators could not interrupt this last part, they could only unload manually from this standard packaging onto the black ones, after the robot arm finished filling out the red trays and the trays come to edge of the machine on the conveyor belt. The same mechanism applies to the beginning of the assembly line, there is a robot arm programmed on default, which could only pick up the gears and place them onto the red trays, thus programmed with specific coordinates. Along with this, the dimension of the black tray is not suitable for the conveyer belt and the machines, both for production and assembly lines, thus resulting in incapability to use these trays instead.

Due to these limitations, it is decided to use the black trays to store the buffer stock. In order to do this, the operator needs to transfer the gears manually from the red trays, which are used at the end of the machining line and stay there, to re-enter and store other finished gears, to the black trays. This decision was seen plausible and beneficial, since the black trays have greater holding capacity than the red ones, it can hold up to twenty components per tray. Thus, the initial plan needed some adjustments. This emphasis and amplify the importance of the third phase and also the concept of continuous improvement by adapting the Deming cycle, thus making the approach as the nested PDCA cycle. Below is the specification of the reallocation. The initial proposal:

Table 5-1: Initial Allocation Proposal Data

No	Type of Gears	Ratio	Pallets	Blue Slots
1	1^{st} Driven	41/10	2	3
2	1^{st} Driven	43/11		4
3	1^{st} Driven	39/11		1
4	5^{th} Drive	39/35		7
5	5^{th} Drive	38/35		1
6	5^{th} Drive	34/41		1
7	5^{th} Drive	36/47		3
8	5^{th} Driven	35/39		6
9	5^{th} Driven	35/38		1
10	5^{th} Driven	34/41		1
11	5^{th} Driven	36/47		3
12	4^{th} Driven	B		5
13	4^{th} Driven	A		3
14	3^{rd} Driven	B	1	1
15	3^{rd} Driven	A	1	1

From then on, the configuration, or in other words the allocation of each particular gear ratios, was changed until it reached the final one which is provided on the table below.

Table 5-2: Final Allocation Proposal Data

No	Type of Gears	Ratio	Pallets	Blue Slots
1	1st Driven	41/10	2	2
2	1st Driven	43/11		3
3	1st Driven	39/11		2
4	5th Drive	39/35		2
5	5th Drive	38/35		2
6	5th Drive	34/41		2
7	5th Drive	36/47		2
8	5th Driven	35/39	1	6
9	5th Driven	35/38		2
10	5th Driven	34/41		2
11	5th Driven	36/47		8
12	4th Driven	B		4
13	4th Driven	A		2
14	3rd Driven	B	1	1
15	3rd Driven	A	1	1

This decision was made under several considerations, discussions with the line managers, with the operators, for they know exactly what happens on daily basis, along with the production planner. Finally, it can be concluded that the fluctuation of production is the key element which impacts the quantity of components held in the buffer, along with the various setup times and method of storage or the holding capacity of the tray in use. Below is provided the various modification of the layout.

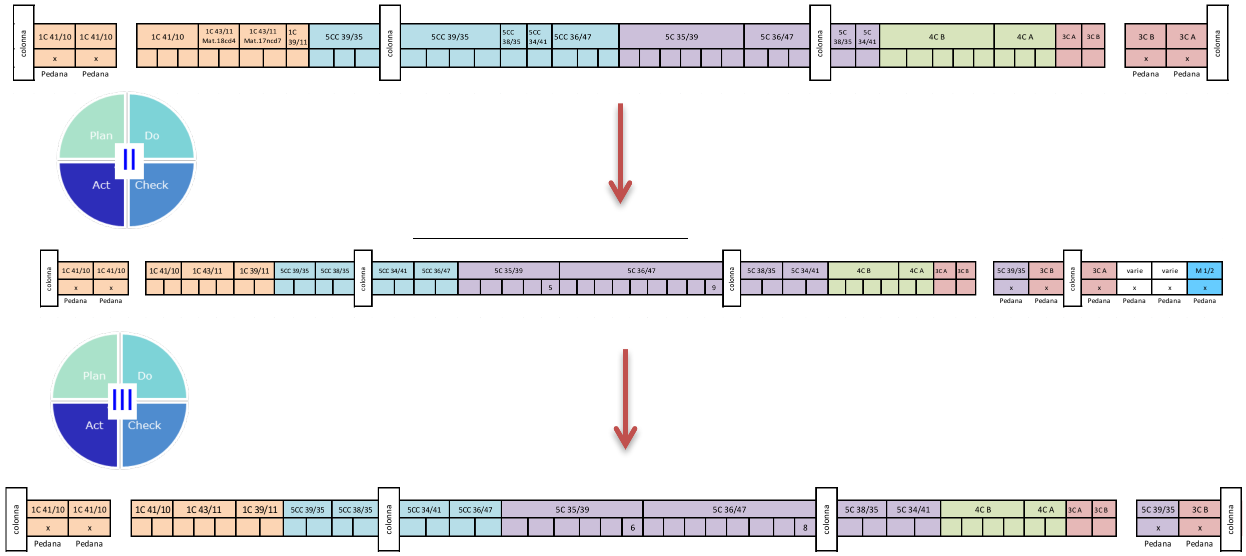


Figure 5-3: Nested PDCA for 211 TU's Buffer

5.1.4. Sleeves – 205 Technological Unit Buffer

The location of the sleeves' buffer is situated next to the gears'. In order to increase the capacity to stock the 211 gears, a series of modification needed to be done, as stated previously, this modification did not only affect the area itself, of 211 Technological Unit, but also the sleeves' area. Initially, there are fourteen slots divided accordingly to the necessity of each sleeves' ratio. However, three slots need to be reallocated to 211. This reallocation does not mean a change of physical positioning, instead it means that three slots will be reduced from the total number of spots meant initially for the sleeves and therefore given to 211's gears. These additional slots are deduced by considering which particular ratio of the sleeves requires fewer space. At the end, it was decided that each one slot from each ratio would be reallocated for 211's gears.

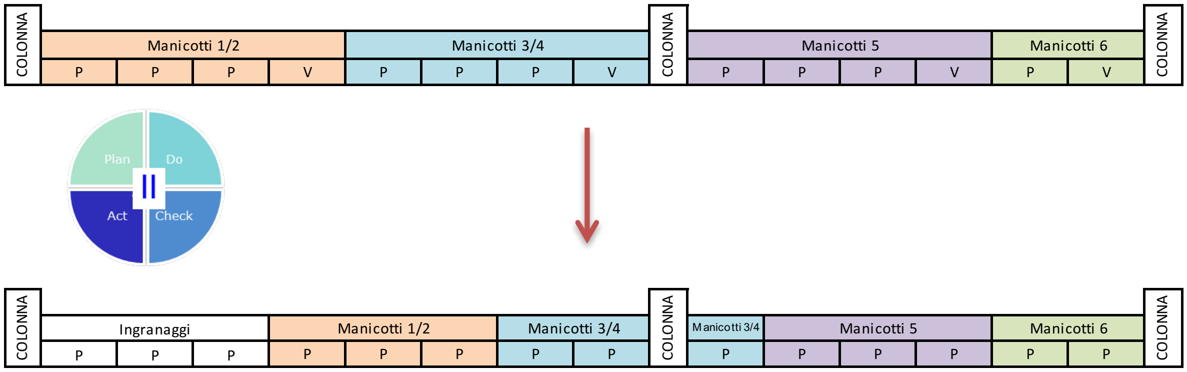


Figure 5-4: Nested PDCA for 205 TU's Buffer

5.1.5. Reverse Gear Bracket and Plug-in/Select Lever Shaft

No further adjustments were required for the two buffers created. The layout implemented helped the inventorial and management of the buffer stock stored within it.

6. Extension – Act

The last step of the PDCA cycle is Act. This step was already done within the phase where adjustments and direct implementation of the new plan were done previously. Additionally, as explained before, the new method needs to be standardized and applied to the whole process in order to achieve a thorough improvement. In order to attain such improvement, the method applied to the establishment and management of the previously discussed buffer is proposed to be implemented to the remaining Technological Units within the Mirafiori Powertrain Plant. The areas enlisted below are the pilot areas proposed as the extension of the project:

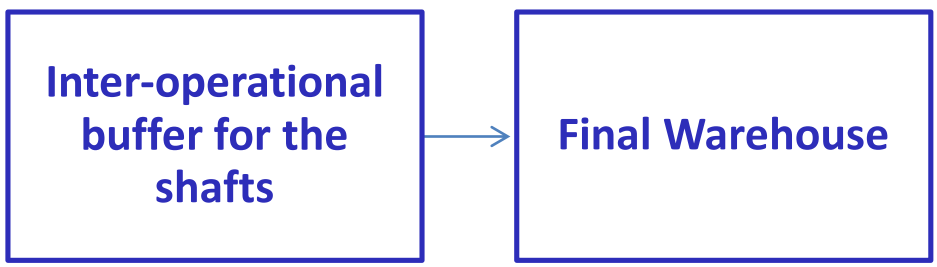


Figure 6-1: Project's Extension

The initial planning part are already established for both areas mentioned above, including the initial proposal of the configuration of each area. Particular attention needs to be paid to the inter-operational shafts' area. The next step which comes after is Do. On this project however, this step is going to show only the initial stages which include finding the area or space to create the buffer followed by the presentation, consultation and agreement with team speakers and shift managers, and finally adjustments to the plan, accordingly and if needed. The last two stages, which are the research on all the necessary equipment and the implementation, are not discussed within this project.

6.1. Secondary Shafts - Turned

The first extension was planned to be done in the 203 Technological Unit. More specifically, the plan was to create a buffer between the process. Starting from the milling process and then continued to turning process. After these two initial machining processes, the secondary shafts are often unloaded from the line and loaded again afterwards, manually by the line operator. The reason varies from the availability of the milling machine and the turning machine to the availability of the other processing machines afterwards. As for example, the roller machine is under maintenance thus blocking the processes, the other WIP shafts will need to be unloaded manually from the line until the maintenance is over and the process could continue. For these reasons, an inter-operational buffer is required between the two initial processes.

After turning, the shafts are loaded into different containers, based on its ratio. The maximum holding capacity of each container is equal to 450 pieces. On table 6-1, the division of each type and ratio for this particular buffer is provided. The total daily production or absorption considered remains the same, which equals to 2,400 pieces in total for all types and ratios of secondary shafts, as for one output shaft goes on each transmission. Thus, it is decided that the safety stock level should be at least equal to 100% of the daily production rate.

The fourth column demonstrate the daily production of each ratios, with each respective percentage, given by comparing the daily production to the total daily production, on the following column. The number of containers needed are provided in the sixth column and the total holding capacity is given on the following column. The last column represents the maximum capacity of the buffer.

Table 6-1: Secondary Shafts Data - Turned Components

No	Components	Type/ Ratio	Daily Production	DP %	No of Containers	Total Holding Capacity	Buffer Cap.
1	5S Secondary	15/56	80	3%	1	450	100%
2	5S Secondary	15/58	80	3%	1	450	100%
3	5S Secondary	16/55	80	3%	1	450	100%
4	5S Secondary	14/57	80	3%	1	450	100%
5	5S Secondary	13/64	80	3%	1	450	100%
6	5S Secondary	14/63	400	17%	1	450	100%
7	5S Secondary	16/57	1200	50%	3	1350	100%
8	6S Secondary	13/64	330	14%	1	450	100%
9	6S Secondary	13/69	40	2%	1	450	100%
10	6S Secondary	14/57	30	1%	1	450	100%

This space is meant to store the secondary shafts, which goes to two different car transmissions, after the turning process. The orange boxes represent the containers with the type and ratio explained. To define a fixed route and location, which are the first two steps of 5T method, this configuration will be translated onto the space by painting yellow lines on the ground, indicating each space. Additionally, a pole with a headboard describing each particular design and ratio, as a visual management is going to be places behind each yellow box. These steps are done to adhere with the third step of the 5T method, and were discussed in depth within chapter 4.1.3. Equipment Analysis.

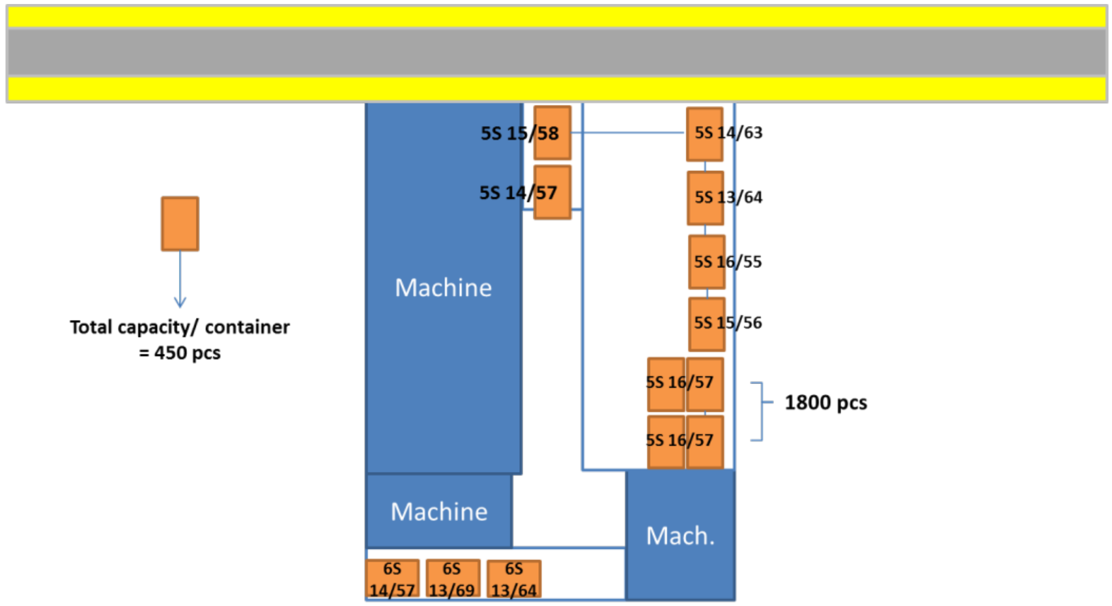


Figure 6-2:Inter-operational Buffer for Secondary Shafts - After Turning

6.2. Final Warehouse

After the assembly line, the finished products are transferred to the final warehouse. This warehouse is located at the back of the plant, to make it easier for them to be load into the trucks and sent to their final destinations, in other words, the clients. The finished products are stored in a pallet, with trays on top of these iron based pallets. The trays are used to hold the products properly and avoiding any accidental damage. The maximum holding capacity of the pallet is six transmissions. They are positioned with some distance between each other, to avoid any accidental external damages. The height of the pallet's frame is also tailored to allow them to be pilled one upon another, without going anywhere near the transmissions.

Once transferred to this area, several check and registration in done initially by several operators before the packaging phase. The controls and checks are done both manually, by an operator and using an electronical device, to diagnose any anomalies not predicted beforehand. After the initial check, the finished products which are already sorted on one pallet are planned to be stored within the dedicated areas, based on the type of transmission. In case of a mix of several types of transmission on one pallet, which sometimes happen due to the limited amount of packaging to store and high frequency of movement inside and outside the plant using the pallet, this pallet will be placed in the corner for them to be sorted. The sorting is done by an operator using a hoist, transferring the same type of transmission into one pallet and so on.

Afterwards, depending on the destination, the transmission are moved towards the dedicated packaging areas and then to the temporary storage space on the other side of the warehouse. This area will be divided basing on the destination of the transmission and in turn divided based on the type of transmission. Appendix A shows the proposal layout with the graphical representation of the division explained above.

7. Conclusion

Four months after the initial launch of the project, several buffer areas were successfully completed. Most of them were smoothly established/ created following the proposed plan without any major disruptions and thus no adjustments needed initially and neither after the implementation phase, while others have had some modifications in order to achieve the ideal management and the desired final outcome. Overall, the application of the management proposal of each particular buffer had brought a positive result. The figure below shows the advancement of the project, resulting in the completion of 40% of the project's KAI.

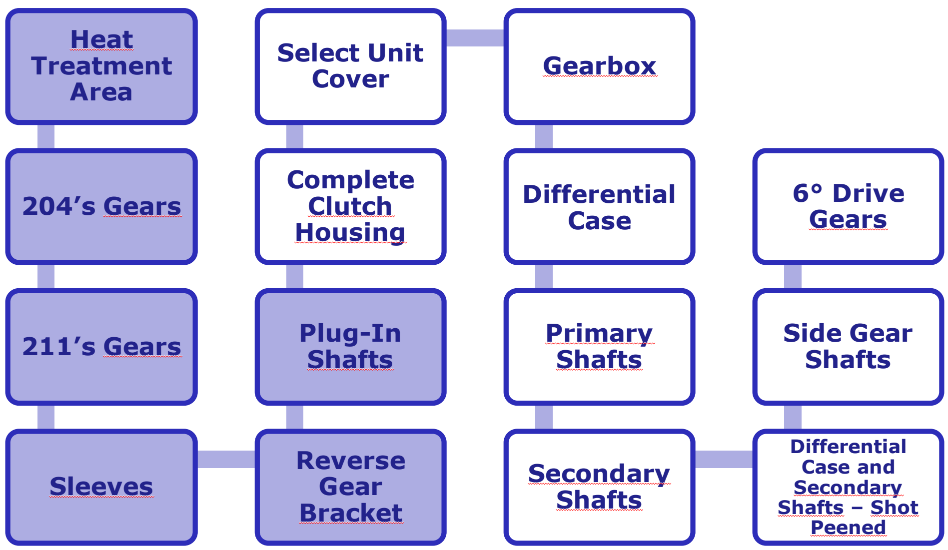


Figure 7-1: Project's KAI - Final

The initial analysis and layout proposal of the remaining areas were already done. The project will be carried out and supervised by the Logistic Pillar Leader of the Plant. Special attention would be required for all areas, especially in the Check stage.

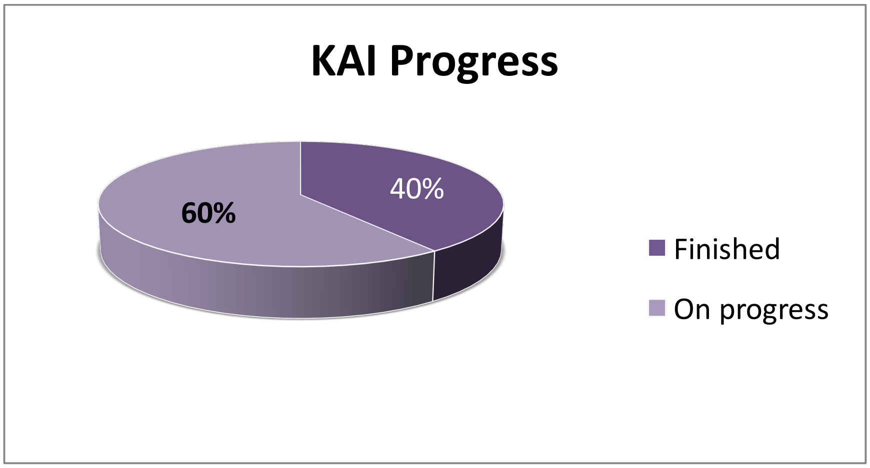


Chart 7-1: Project's Final KAI

As for the KPI given initially, from the chart below, it is noticeable that the number of stocks are significantly lower, especially for the gears and sleeves. This reduction could be seen as a concrete result of the management proposed. Particular attention should be given to the gears, as the quantity is significantly lowered after the implementation of the project. This results were attained from an appropriate method applied which compromise the level of safety stock, the availability of spaces along with other constraints, such as lead time and system reliability, resulting in tailored organization and management along with clear visual display.

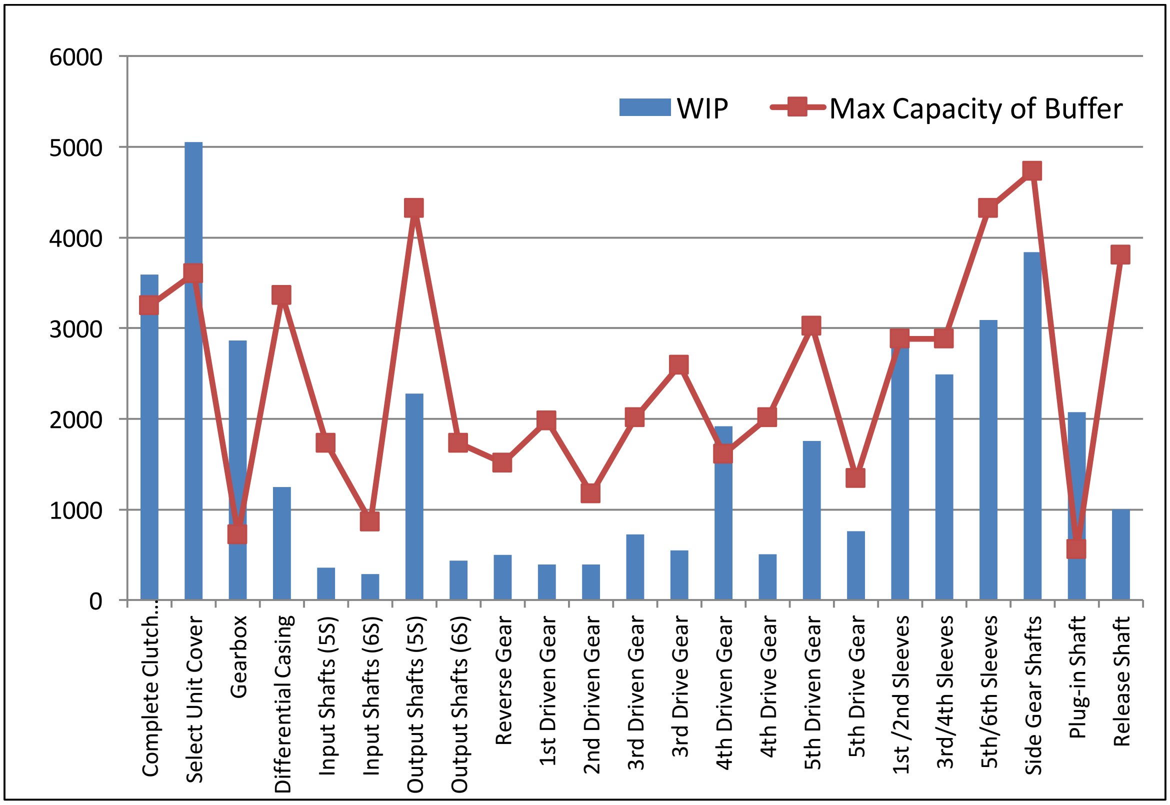
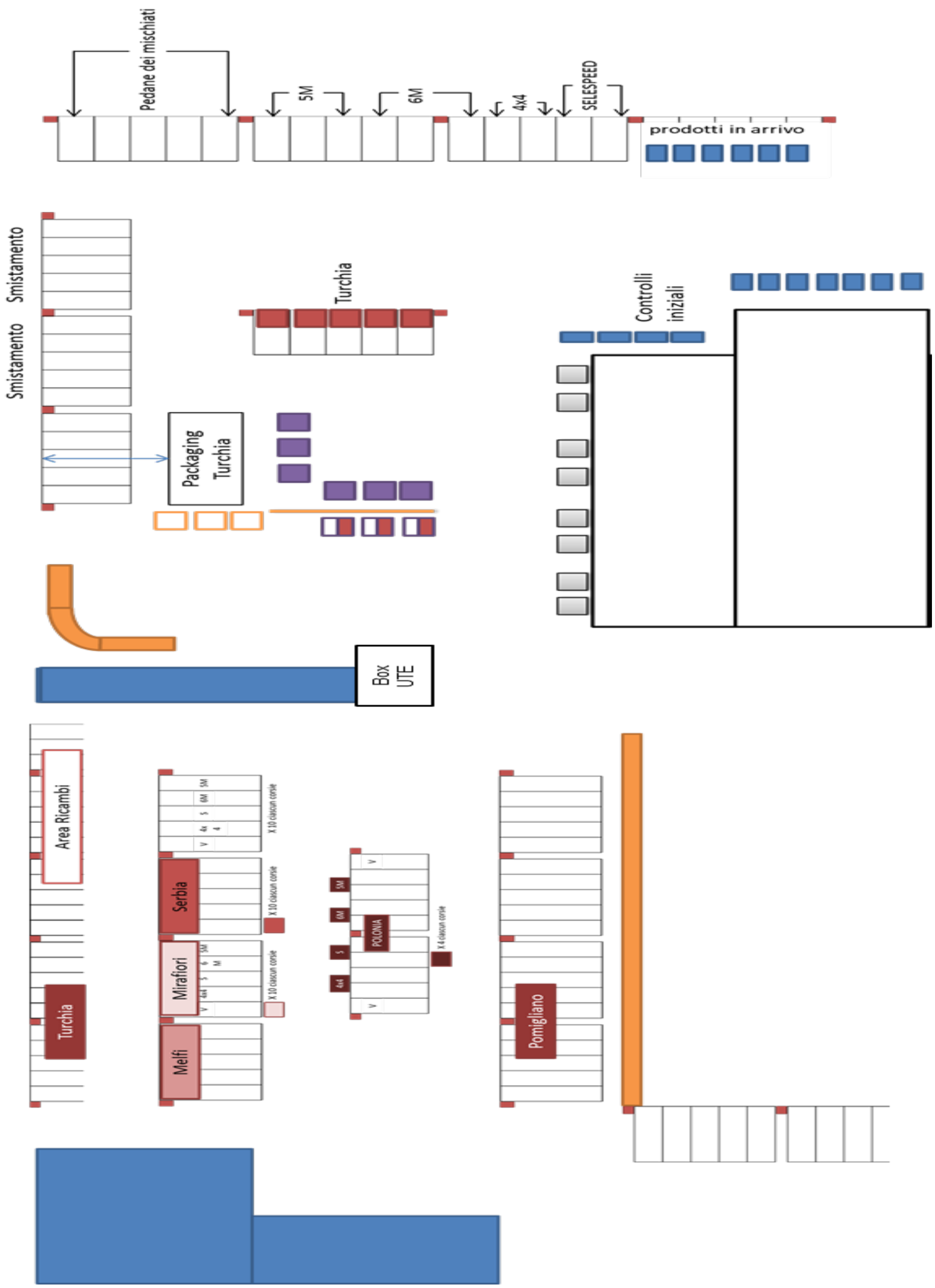


Chart 7-2: KPI improvement

Finally, along with the extension to the two pilot areas, a further extension could be done. As seen on the previous chapter, the model areas have been designed and planned. When the KAI's will reach 100%, thus meaning the completion of the project, the execution and implementation of the extension can be initiated. Conclusively the extension could also be proceeded along with other inter-operational areas within each technological units, by formulating a tailored proposal of management with the standardized approach established and used in this project.

8. Appendices

Appendix A: Finished Products' Warehouse Proposal



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