# POLITECNICO DI TORINO

Corso di Laurea Magistrale in Ingegneria Gestionale

(Engineering and Management)

Tesi di Laurea Magistrale

# Applying Lean Manufacturing To Logistics Flows:

# The Dayco Europe Case Study

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# Introduction

The automotive industry has always been subject to high-complexity challenges. It is from this sector that Lean Manufacturing has its origins and expands both in manufacturing sites that diverge from automotive but also attests in public administration services, business administration or as in this case study in logistics. For a company looking to reduce waste, try to increase performance, thinking about applying Lean principles fairly straightforward. This thesis work is the result of an internship experience in Dayco Europe, in the Ivrea plant, where the notions gained from the university path were applied. Dayco is a global leader in the research, design, manufacture and distribution of essential engine drive systems and aftermarket services for automotive, truck, construction, agriculture and industrial applications.

The aim of this thesis is to identify the non-value-added activities that occur in the supply of assembly lines, thus analyze material flows from the component receiving area to the handling of the finished product, find the roots of critical issues, and propose improvements to curb the activities that do not contribute value to the product.

The first chapter of the thesis explains the philosophy of Lean Manufacturing, its history and the various tools used. At Dayco Europe, the lean philosophy was already applied, with a focus on assembly lines, such as the application of 5s. In addition, the notions of BPMN diagrams are introduced.
In the second chapter, the Dayco Global company is explained, its history focusing on innovation and various acquisitions, flagship products currently in production, and mission statement. The third chapter describes Dayco Europe's Ivrea plant. This is home to Dayco's largest R&D department, Sales and Administration offices, and production facility. Decouplers, idlers and tensioners are assembled in this plant. In chapter four, through the use of flow charts, the two assembly lines analyzed in this thesis work are described, manual line 32, where different types of timing belt tensioners are assembled, and semiautomatic line 42, which assembles accessory drive tensioners for light vehicles. In the latter section, through the use of BPMN diagrams, the tasks performed by the production worker and the production feeder are illustrated.
In chapter five, lean manufacturing tools are applied to various processes to supply assembly lines. Using Lean instruments, various critical issues are detected and the causes of them are analyzed through the 5whys.

In the concluding chapter, the various proposals for improvement associated with the detected critical issues are unfolded. Lastly, the limitations of this thesis work and suggestions for future study are outlined.

This thesis work enabled the identification of the various assignments of the resources employed in D4, which was beneficial in terms of understanding the current workload of the resources, and the interaction of the resources with the AGV. Understanding their interaction is crucial to developing better automation and thus reducing the workload on resources. In addition, the detection of several inefficiencies, in transportation and inventory in particular, highlighted the need for targeted investments to improve warehouse management and to reduce pallet handling to essentials.

# 1 Lean Manufacturing and Business Process Model Notation

In the first chapter, the theory of Lean Manufacturing and its tools used are explained in the first part of the chapter. In the second half, it concentrates in explaining the Business Process Model and Notation

## 1.1 Lean Manufacturing

Lean is the concept of efficient manufacturing/operations that grew out of the Toyota Production System in the middle of the 20th century. It is based on the philosophy of defining value from the customer's viewpoint, and continually improving the way in which value is delivered, by eliminating every use of resources that is wasteful, or that does not contribute to the value goal [1]. Lean production is "lean" because it uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products (Womack *et al*., 2017).

### 1.1.1 History

The Toyota production system was conceived and its implementation begun soon after World War II. But it did not begin to attract the attention of Japanese industry until the first oil crisis in the fall of 1973. Japanese managers, accustomed to inflation and a high growth rate, were suddenly confronted with zero growth and forced to handle production decreases. It was during this economic emergency that they first noticed the results Toyota was achieving with its relentless pursuit of the elimination of waste. They then began to tackle the problem of introducing the system into their own workplaces (Ohno, 1978). Toyota is often called the most Japanese of the Japanese auto companies, being located in insular Nagoya rather than cosmopolitan Tokyo. For many years its workforce was composed largely of former agricultural workers. In Tokyo, the firm was often derided as "a bunch of farmers". Yet today, Toyota is regarded by most industry observers as the most efficient and highest-quality producer of motor vehicles in the world. Toyota's chief production engineer, Taiichi Ohno, quickly realized that employing Detroit's tools – and Detroit's methods – was not suited to this strategy. Craft-production methods were a well-known alternative but seemed to lead nowhere for a company intent on producing mass-market products. Ohno knew he need a new approach, and he found it. Ohno, who visited Detroit repeatedly just after the war, thought this whole system was rife with Muda, the Japanese term for waste that encompasses wasted effort, materials, and time. He reasoned that none of the specialists beyond the assembly worker was actually adding any value to the car. What's more, Ohno thought that assembly workers could probably do most of the functions of the specialists beyond the assembly worker was actually adding any value to the car. Back at Toyota City, Ohno began to experiment. The first step was to group workers into teams with a team leader rather than a foreman. The second step, he gave the team the job of housekeeping, minor tool repair, and quality-checking. Finally, as the last step, after the teams were running smoothly, he set time aside periodically for the team to suggest ways collectively to improve the process. This continuous, incremental improvement process, kaizen in Japanese, took place on collaboration with the industrial engineers. A system for problem solving, called "the five whys", has been established (Womack *et al.*, 2017).

The preliminary step toward application of the Toyota production system is to identify wastes completely:

- Waste of overproduction
- Waste of time on hand (waiting)
- Waste in transportation
- Waste of processing itself
- Waste of stock on hand (inventory)
- Waste of movement
- Waste of making defective products

The TPS graphically can be represented by the House of Lean [1]. It is based on two basic pillars:

- Just-In-Time

  The JIT meaning describes a resource management strategy that directly matches the receipt and storage of raw materials with production schedules. A company that utilizes a JIT inventory only orders or purchases as many raw materials as needed to manufacture a set number of goods rather than ordering a bulk quantity of resources to last a long time. Just enough inventory is available to meet the demand for production, but not enough is present where the company must store an excess amount of goods. Just in time inventorying requires that producers forecast production schedules accurately so that costs can remain low and waste can be reduced. The ultimate goal of a JIT inventory is to improve a company's investment by reducing non-essential costs overall, which can be realized most significantly through the elimination of storage costs [4].As a supporting element to JIT, a scheduling system called Kanban, which means "billboards" in Japanese, is flanked. The kanban is a visual tool designed to manage workflows; it aims to define the quantities of material to be handled so as to avoid excess inventory and thus produce inefficiencies. Kanban cards are a key component of kanban and they signal the need to move materials within a production facility or to move materials from an outside supplier into the production facility. The kanban card is, in effect, a message that signals a depletion of product, parts, or inventory. When received, the kanban triggers replenishment of that product, part, or inventory. Consumption, therefore, drives demand for more production, and the kanban card signals demand for more product—so kanban cards help create a demand-driven system. In the last few years, systems sending kanban signals electronically have become more widespread.

- Jidoka

  Jidoka or Autonomation means "intelligent automation" or "humanized automation". In practice, it means that an automated process is sufficiently "aware" of itself so that it will:

1. Detect process malfunctions or product defects
2. Stop itself
3. Alert the operator

Concept is to authorize the machine operator and in any case if a problem occurs on flow line, operator can stop the flow line. Ultimately defective pieces will not move to the next station. This concept minimizes the production of wasted defects, over production and minimizes wastes. Also its focus is to understand the causes of problems and then taking preventive measures to reduce them. Now, human related judgment of component quality is minimized and worker will be only attentive, when machine will be stopped. This concept also helps in sequential inspection of components and ultimately good quality products are produced and also not much burden of final inspection is put on the shoulders of worker. Inspection is carried out by machine and when machine stops working, designated person or skilled person rush towards machine and try to resolve the problem. Jidoka focuses to investigate the root cause of that problem and make necessary arrangements so that this defect may not occur again. Defect prevention can be achieved by using Poka Yoke technique. When utilizing Jidoka philosophy, Taiichi Ohno had some specific goals of this tool in mind. But with the advancement in its scope, following goals are being achieved through its application:

1. Effective utilization of manpower
2. Product produced will be of top quality
3. Shorter delivery time of products
4. Reduction in equipment failure rate
5. Improve level of customer satisfaction
6. Increase quality of final product
7. Lower costs (Internal, External, and Appraisal cost etc.) [5]

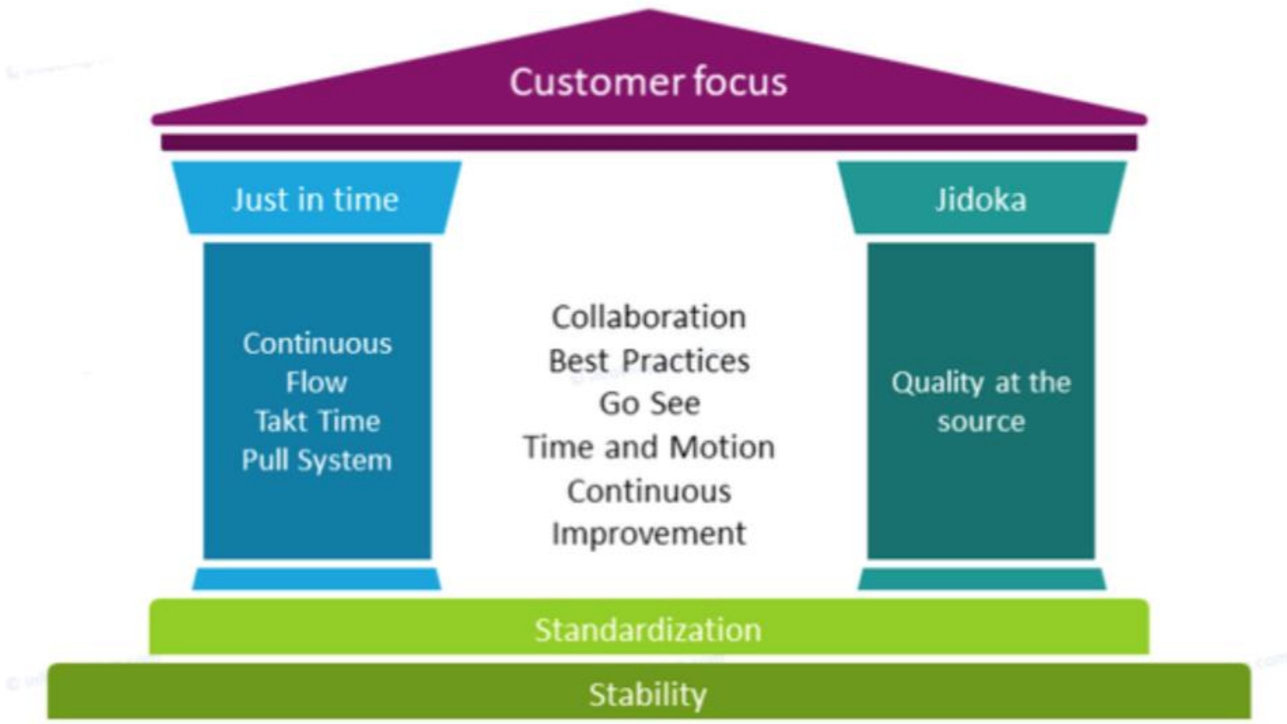


*Figure 1: House of Lean [6]*

In order to understand the flows, to improve them and bring value, there are various analyses and models that support the world of lean manufacturing. In this thesis work Spaghetti Chart, Gemba Walk, and 5whys will be explored.

### 1.1.2 Spaghetti Chart

A spaghetti diagram, also known as spaghetti chart, is a particular tool for determining the distance traveled by (usually) people or (in some cases) material. Hence, a spaghetti diagram can help reduce the distance traveled by either parts or people. Spaghetti diagrams are most useful for determining the route a person has traveled by either walking or driving (e.g., with a forklift). It even works for automated guided vehicles (AGVs). The necessary to perform the spaghetti chart is to have a layout, pen, someone observing, and someone observed [7].

Mapping spaghetti diagrams is simple and offers a starting point for numerous avenues of improvement to identify waste in production. Even so, it calls for either immediate evaluation or relatively elaborates further treatment in order to draw useful effects from an analysis. This is because the information content of the spaghetti diagram itself is rather minor compared to the additional input for analysis. The diagram shows only the paths of different means of transport in the widest sense. For material flow analyses, not to mention intensity analyses serving systematic layout optimization, the transport information must be enhanced with further pertinent details, e.g.

- exact distances (which requires a scaled representation of the layout);

- materials transported (type of container, filling level, contents, empty travel) (Rother and Shook, 1999).

*Figure 2: Spaghetti Chart example [9]*

### 1.1.3 Gemba Walk

A Gemba Walk is a workplace walkthrough which aims to observe employees, ask about their tasks, and identify productivity gains. Gemba Walk is derived from the Japanese word “Gemba” or “Gembutsu” which means “the real place”, so it is often literally defined as the act of seeing where the actual work happens. A gemba walk is a simple yet powerful lean method done by employers to promote continuous improvement. Gemba Walks are important because they enable managers and leaders to see what processes are like on an operational level. Gemba Walks help eliminate incorrect assumptions about the workforce and drive changes with a lasting positive impact. Gemba Walks can empower organizations to sustain continuous improvement efforts and help solve disconnects between leadership vision and implementation of processes in operations. Performing a Gemba Walk is the best opportunity to take note of good ideas, feedback, complaints, and issues in the workplace. Apart from going where the actual work happens and proactively engaging with employees, listed below are the top benefits of implementing and learning from Gemba Walks periodically:

- Demonstrate management commitment toward professional development
- Boost employee morale as you care about them and value their work
- Introduce changes that can be more easily embraced by workers
- Cultivate a culture of openness, collaboration, and teamwork
- Streamline operations across different levels in organizations, saving time and money

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After the Gemba Walk is done, follow up and share what has been learned from the activities, including the issues, struggles and gaps which needs immediate action and resolution. This is the phase to substantiate plans for process improvement. Decide which processes should remain and which ones to revamp [10].

### 1.1.4 Five Whys

The Five Whys technique is a simple but powerful way to troubleshoot problems by exploring cause-and-effect relationships. When looking to solve a problem, it helps to begin at the end result, reflect on what caused that, and question the answer five times. This elementary and often effective approach to problem solving promotes deep thinking through questioning, and can be adapted quickly and applied to most problems. Most obviously and directly, the Five Whys technique relates to the principle of systematic problem-solving: without the intent of the principle, the technique can only be a shell of the process (Serrat, 2017). Hence, there are three key elements to effective use of the Five Whys technique:

- accurate and complete statements of problems
- complete honesty in answering the questions
- the determination to get to the bottom of problems and resolve them.

The technique was developed by Sakichi Toyoda for the Toyota Industries Corporation

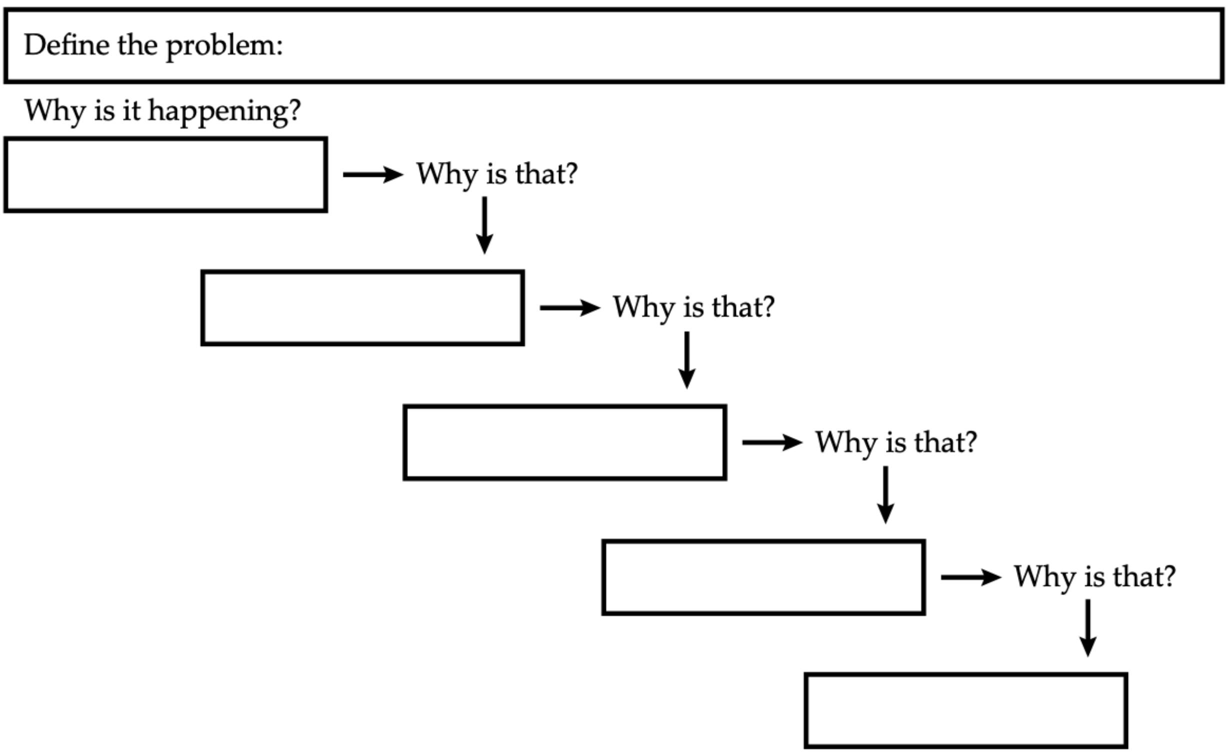



*Figure 3: Five Whys Technique (Serrat, 2017)*

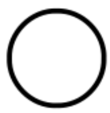
# 1.2 Business Process Model and Notation

Business Process Model and Notation (BPMN) is a graphical representation for specifying business processes in a business process. Originally developed by the Business Process Management Initiative (BPMI), BPMN has been maintained by the Object Management (OMG) since the two organizations merged in 2005. Version 2.0 of BPMN was released in January 2011, at which point the name was amended to Business Process Model and Notation to reflect the introduction of execution semantics, which were introduced alongside the existing notational and diagramming elements. [11] It should be emphasized that one of the drivers for the development of BPMN is to create a simple and understandable mechanism for creating Business Process models, while at the same time being able to handle the complexity inherent to Business Processes. The approach taken to handle these two conflicting requirements was to organize the graphical aspects of the notation into specific categories. This provides a small set of notation categories so that the reader of a BPMN diagram can easily recognize the basic types of elements and understand the diagram. Within the basic categories of elements, additional variation and information can be added to support the requirements for complexity without dramatically changing the basic look and feel of the diagram. The five basic categories of elements are:

1. Flow Objects
2. Data
3. Connecting Objects
4. Swimlanes
5. Artifacts

Flow Objects are the main graphical elements to define the behavior of a Business Process. There are three Flow Objects:

1. Events
2. Activities
3. Gateways

| **Element** | **Description** | **Notation** |
|---|---|---|
| Event | An Event is something that "happens" during the course of a Process. These Events affect the flow of the model and usually have a cause (*trigger*) or an impact (*result*). There are three types of Events, based on when they affect the flow: Start, Intermediate, and End. |  |

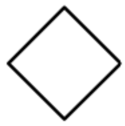
| | | |
|---|---|---|
| Activity | An Activity is a generic term for work that company performs in a Process. The types of Activities that are a part of a Process Model are: Sub-Process and Task, which are rounded rectangles. |  |
| Gateway | A Gateway is used to control the divergence and convergence of Sequence Flows in a Process. Thus, it will determine branching, forking, merging, and joining of paths. Internal markers will indicate the type of behavior control. |  |

Table 1: Flow Objects of BPMN [11]

Data is represented with the four elements:

1. Data Objects
2. Data Inputs
3. Data Outputs
4. Data Stores

There are four Connecting Objects:

1. Sequence Flows
2. Message Flows
3. Associations
4. Data Associations

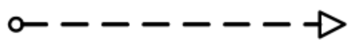
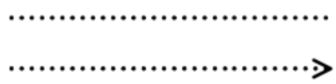
| **Element** | **Description** | **Notation** |
|---|---|---|
| Sequence Flow | A Sequence Flow is used to show the order that Activities will be performed in a Process. |  |
| Message Flow | A Message Flow is used to show the flow of Messages between two *Participants* that are prepared to send and receive them. |  |
| Association | An Association is used to link information and Artifacts with BPMN graphical elements. An arrowhead on the Association indicates a direction of flow (e.g., data), when appropriate. |  |

Table 2: Connecting Objects of BPMN [11]

There are two ways of grouping the primary modeling elements through “Swimlanes”:

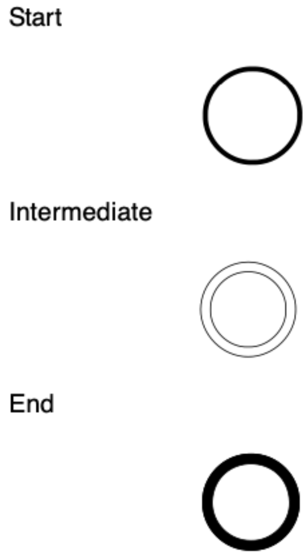
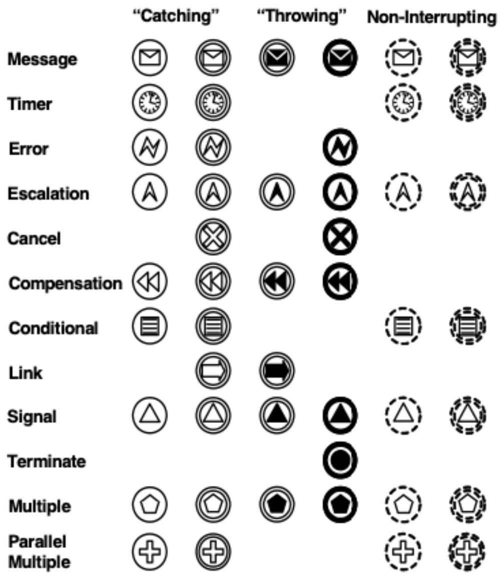
1. Pools
2. Lanes

| Element | Description | Notation |
|---|---|---|
| Pool | A Pool is the graphical representation of a *Participant* in a Collaboration |  |
| Lane | A Lane is a sub-partition within a Process, sometimes within a Pool, and will extend the entire length of the Process, either vertically or horizontally. |  |

Table 3: Swimlanes of BPMN [11]

Artifacts are used to provide additional information about the Process. There are two standardized, but modelers or modeling tools are to add as many Artifacts as necessary. There could be additional BPMN efforts to standardize a larger ser of Artifacts for general use or for vertical markets. Th current set of Artifacts includes:

- Group
- Text Annotation

| Element | Description | Notation |
|---|---|---|
| Event:<br><br>Start<br><br><br><br>Intermediate<br><br><br><br><br><br>End | <br><br>As the name implies, the Start Event indicates where a particular Process will start<br><br>Intermediate Event occur between a Start Event and an End Event. They will affect the flow of the Process, but will not start or (directly) terminate the Process<br><br>As the name implies, the End Event indicates where a Process will end. |  |
| Type Dimension | The Start and some Intermediate Events have "triggers" that define the cause for the Event. There are multiple ways that these events can be triggered. End Events may define a "result" that is a consequence of a Sequence Flow path ending. Start Events can only react to ("catch") a *trigger.* End Events can only create ("throw") a *result*. Intermediate Events can catch or throw *triggers*. For the Events, *triggers* that catch, the markers are unfilled, and for *triggers* and *results* that throw, the markers are filled. |  |
| Gateway Control Types | Icons within the diamond shape of the Gateway will indicate the type of flow control behavior. The types of control include:<br><br>• Exclusive decision and merging. Both Exclusive and Event- Based perform exclusive decisions and merging Exclusive can be shown with or without the "X" marker. | |

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- Event-Based and Parallel Event-based gateways can start a new instance of the Process.

- Inclusive Gateway decision and merging.
- Complex Gateway -- complex conditions and situations.
- Parallel Gateway forking and joining.

Each type of control affects both the incoming and outgoing flow.

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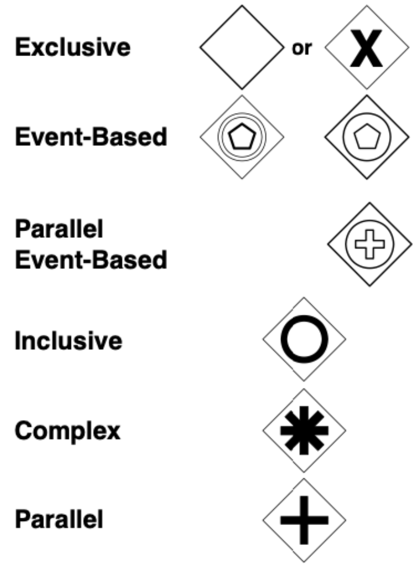

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Table 4: Flow Objects in Detail [11]

# 2 Dayco Global

In the present  chapter, the company's background, products currently on the market, and mission statements are described

## 2.1 History and locations

Dayco is a global leader in the research, design, manufacture and distribution of essential engine drive systems and aftermarket services for automotive, truck, construction, agriculture and industrial applications. Dayco's more than 115 years of experience in drive systems enables it to equip all customer applications worldwide with the most effective drive systems to meet customer-specific performance requirements. Dayco's world class global distribution network services the aftermarket industry with a full offering of kits and products to meet each local market's need. In 1905 the Dayco rubber manufacturing company was founded, in Dayton in the state of Ohio (USA). In 1960, the company's name was changed to "Dayco Corporation" to reflect the company's inclusion of a wide range of non-rubber technologies. These new technologies included plastics, aircraft and automotive seating, chemicals, wall coverings, silicone, luggage, Teflon coated fabrics, processed synthetic fibers, and hydraulic and cryogenic hoses. The decade of the 90s was one of acquisition and growth for Dayco, focused on automotive and rubber-based technologies. The most significant acquisitions made after the 1990s are summarized as follows: The Anchor Swan acquisition provided hose expertise and manufacturing capacity; Pirelli's belt division strengthened Dayco's timing belt offering with the "hyperbolic" tooth profile; Tecaflex in Italy and System Stecko in England were acquired as subsidiaries of Dayco Europe; U.S. Rubber Hose Co. of Vero Beach, FL produced large ID specialty hoses; Imperial Eastman added hydraulic hose and crimper capabilities; Lombardini, FM S.p.A. in Italy contributed expertise in small gasoline and diesel engines for Europe's fast-growing market; LPI in France and Nuova Eletta in Italy were combined into "System Moteurs", specializing in plastic injected molded air intake manifolds and cooling modules. In the new millennium, Dayco has continued to expand its product offerings and its customer base. Innovative product designs have given Dayco a competitive edge in the markets it serves. State-of-the-art support services such as electronic cataloging, EDI, and sales force automation have made Dayco a model for success in the ever-evolving, worldwide automotive marketplace. After a century in business, Dayco continues its legacy of innovation and the proactive ability to anticipate the market's needs into the next hundred years' of service to its customers [12]. Throughout the years, the Dayco Corporation was responsible for many industry firsts. Among some of the Dayco Corporation's company firsts were the first pneumatic tire and later the first tubeless pneumatic tire; the first "raw edge" automotive fan belt; the first industrial V- Belt, which has never been substantially modified, and the first successful V-Belt using a fastener (railroads); the first cog-belt [13].

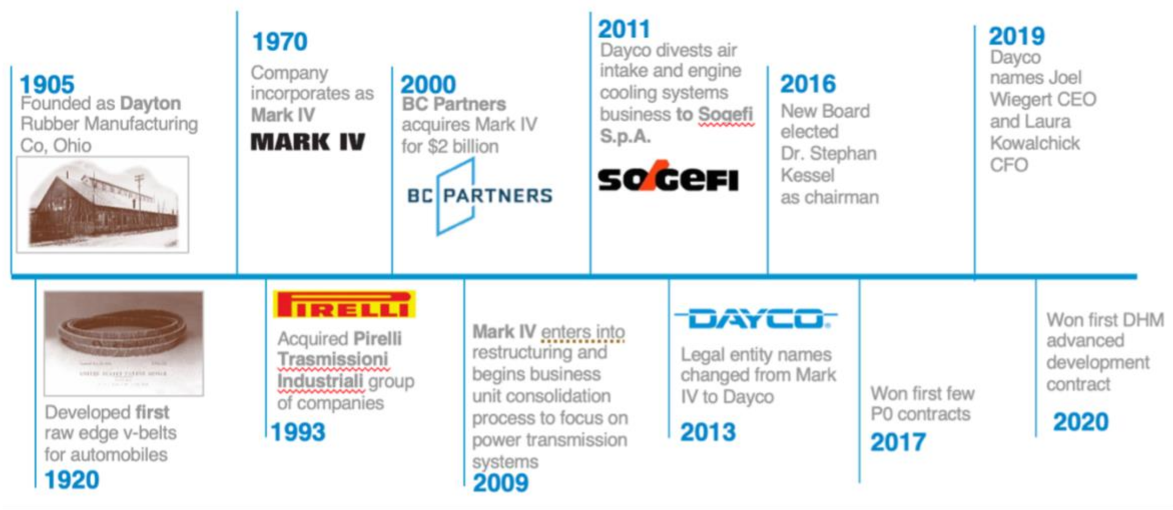


*Figure 4: Evolution of Dayco Company [14]*

Today, Dayco is operating in 22 countries with 16 production sites, 18 distribution centers and 6 technical centers with more than 4000 employees. The world headquarters is located in Michigan.


*Figure 5: Locations [14]*

# 2.2 Products

Dayco is a major global supplier to the leading light and heavy-duty vehicle manufacturers worldwide, delivering best-in-class powertrain solutions from design to delivery, with strong technical know-how and state-of-the-art manufacturing capabilities.

## 2.2.1 Belts

Since launching the first accessory drive belt application in the 1970s, Dayco has been a leader in belt technology and continues to develop highly engineered belts for a wide range of accessory drive designs and applications. Utilizing the latest and most advanced technologies, Dayco’s flexible design and manufacturing strategy matches materials to specific application needs [14].

- Accessory drive belts
- V-Belts
- Timing Belts

*Figure 6: Accessory drive belt & V-Belt [14]*

## 2.2.2 Tensioners

Dayco tensioners feature the original flat-wire spring design, engineered to provide more operating range and less tension variation. This innovative design reduces the risk of premature accessory bearing failure due to high tension and lessens the risk of belt noise, slippage and poor accessory performance caused by low tension as the belt begins to stretch and wear [14].

- Timing Belt Tensioners
- Accessory Drive Tensioners

*Figure 7: Timing Belt Tensioners & Accessory Drive Tensioners [14]*

### 2.2.3 Pulley & Idlers

As a complement to its accessory drive belts and tensioners, Dayco provides a wide range of pulleys and idlers in stamped and formed steel, plastic and powdered metal, with various bearing configurations to suit even the highest belt loading.

*Figure 8: Pulley [14]*

### 2.2.4 Timing Belt-In-Oil

In 2007, Dayco introduced the first Timing Belt-in-Oil system for automotive applications, a technological breakthrough that directly addresses customer focus on lower emissions, increased fuel efficiency and less tension on the drives. [14]

*Figure 9: Timing Belt-In-Oil [14]*

### 2.2.5 Dampers

Dayco has a long history of innovating, designing and manufacturing vibration dampers for automotive and drivetrain applications. Designed to reduce noise, vibration and harshness, these products maximize system stability, minimizes belt tension variation, improve system and component life and improve fuel economy. [14]

- Crankshaft Dampers
- Driveline Dampers

*Figure 10: Crankshaft Dampers [14]*

### 2.2.6 Crankshaft Decouplers

Dayco is the only brand that offers a premium package of complete FEAD (Front End Accessory Drive) system solutions for hybrid and ICE (Internal Combustion engine) vehicles with a wide range of decouplers, dampers, tensioners, idlers/pulleys, and belts with world-class global R&D capabilities and local manufacturing footprints and addresses the needs of leading premium and performance car manufacturers. [14]

*Figure 11: Crankshaft Decoupler [14]*

### 2.2.7 Electric Power Steering Belts

Dayco's unique belt characteristics lead to long-lasting performance in terms of high load capacity, resistance to tooth jump, extreme temperature variations, high resistance during severe environment conditions and reduced span vibration, all with a quiet-running belt thanks to advanced engineering.

*Figure 12: Electric Power Steering Belt*

### 2.2.8 ACTIVAT Vacuum Generation System

The Vacuum Generation System assembly, engineered for systems requiring vacuum such as vacuum brake assist, fuel vapor purge and crankcase ventilation, replaces costly, heavy and fuel-consuming mechanical and electrical vacuum pumps found on many of today's engines.

*Figure 13: ACTIVAT [14]*

### 2.2.9 Hybrid Solutions

To meet the new customer demand for high performance but low carbon emissions, Dayco provided components and subsystems for BSG mild hybrid solutions, for more than a decade. To continuously improve fuel-saving, durability of P0 Hybrid systems, and reduction in carbon footprints, Dayco is delivering fully integrated solutions for hybridization, optimizing the control logic of the electric machine performance, and pursuing a Smart System Management that reduces the CO2 emissions. This world-class propulsion technology and dedicated technical support positions Dayco as a system integrator that delivers high value to its customers and helps them achieve their low carbon emission objectives.

*Figure 14: P0 Architecture [14]*

## 2.3 Aftermarket

Quality requirements of maintenance activities on auxiliary and drive controls do not require single items anymore, rather complete systems allowing the installation technician to guarantee reliable replacement operations. Continuous research in cooperation with all automotive companies has made it possible to produce complete systems that meet all technical and application requirements [14]. The portfolio of products offered includes over 130 kits reaching a wide range of applications such as light vehicles, truck, industrial, motorcycles, power sports, lawn & garden, marine, and racing.

The aftermarket kit consists of:

- Genuine or OEM quality components
- Complete replacement of all wear parts (belts, metal parts)
- Continuous update of components according to the instructions of the car manufacturer
- Assembly instructions


*Figure 15: Types of Aftermarket Kits [14]*

# 2.4 Customers

Dayco is a leader in the Original Equipment Market, partnering with global automotive and industrial manufacturers to design, develop and produce high quality products for light duty, heavy duty, industrial, agricultural, off-highway and recreational vehicles. Original Equipment accounts for half of the customer base; the other half is represented by parts dealers supplied with aftermarket products.

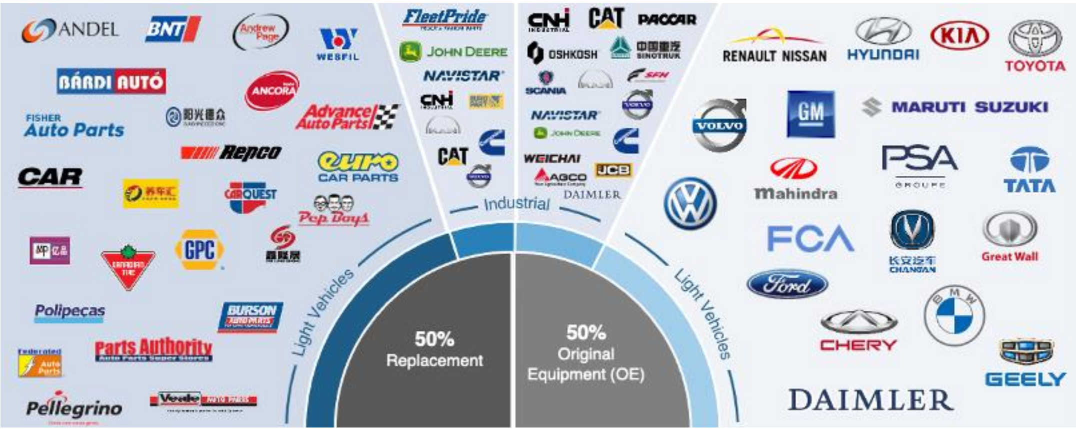


*Figure 16: Customer Base*

# 2.5 Principles & Strategies

Dayco's mission is to deliver innovative system solutions that move original equipment and aftermarket customers Forward, Always.

The principles and strategies are:

- Act like an owner
- Drive organic sales growth to outpace the market we serve by 8%
- Deliver industry leading financial performance
- Strive for an organization that represents our global business
- Build a Continuous Learning Environment
- Respect the team
- Stop doing some things and say no to other things

# 2.6 Awards & Certifications

Dayco has received many accolades for its resilient and committed approach towards supplying premium quality and innovative products, leading to high customer satisfaction. Its world-class global manufacturing facilities are equipped with highly advanced processes, strong R&D capabilities, and a proficient team, that consistently delivers excellent products to meet industry standards bringing the automotive revolution.

Awards and Certifications achieved:

- PSA Best Supplier Plant (Dayco Italy)
- Volvo Cars Quality Excellence (Dayco Italy)
- Ford Zero QR and Zero Warranty Claims in the year 2020 (Dayco Italy, India, China
- Cat Supplier Quality Excellence Silver (Dayco Italy) and Platinum (Dayco China, Spain and US)
- Cummins Most Improved Supplier of the Year 2019 (Dayco US)
- John Deere Excellent Quality Supplier Award (Dayco China)
- General Motors Supplier Quality Excellence Award (Dayco US, Mexico, India, Italy)
- Paccar Quality Gold Achievement (Dayco Italy)
- Weichai Special contribution award for co-development (Dayco China)

# 3 Dayco Europe S.r.l

In the third chapter, the Dayco plant located in San Bernardo d'Ivrea is explored. The case study under consideration was carried out in this plant, mainly in two locations: Dayco 4 and warehouse area.

## 3.1 Ivrea Plant, with Focus on Dayco 4

The Ivrea plant is located in the San Bernardo industrial area, where a historic Olivetti settlement once stood. The plant includes sales offices, manufacturing site and technical center. Operating since 1999, it covers an area of 19370 m$^2$; about 460 people currently work there. The plant is home to one of six R&D departments that Dayco has spread across EMEA, NA, SA, and APAC regions. R&D department assist the company drive innovations and be a technology leader, employing about 60 engineers in the Ivrea Plant. Production at the Ivrea plant focuses on rigid engine components, namely: decouplers, idlers, and tensioners. Production departments are arranged in 3 different areas called Dayco 1, 2 and 4. There are approximately 30 assembly lines, with predominantly manual lines but also the presence of semi-automatic lines. The warehouse is located in the middle of the production departments and consists of:

- Receiving Area
- Central Warehouse
- Kanban Warehouse
- Shipping Area

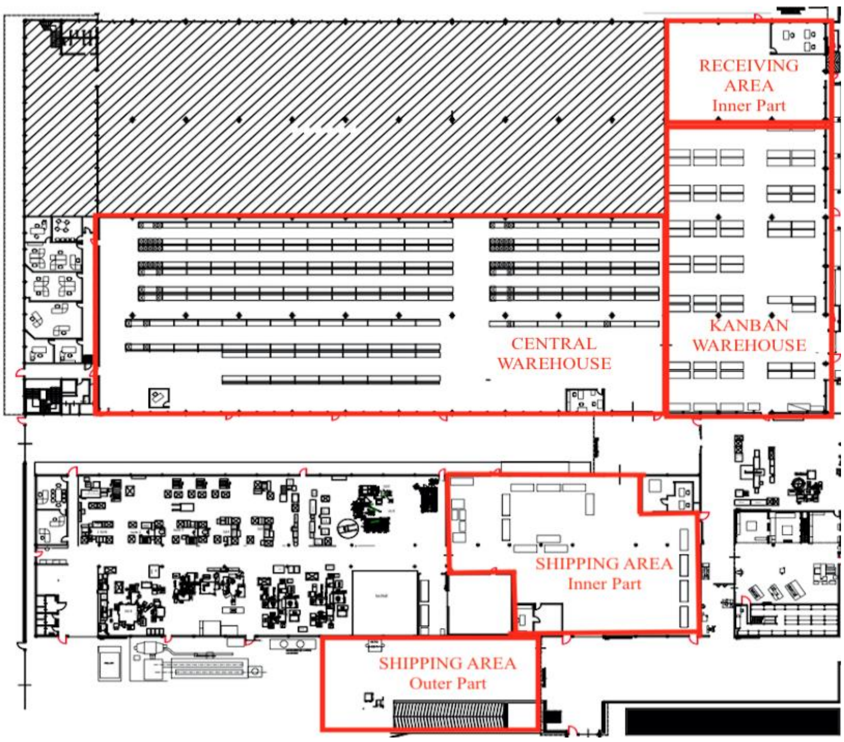


*Figure 17: Warehouse Description*

The warehouse staff consists of:

- Supervisor
- Forklift Drivers, licensed only for front or side forklift, or also for narrow aisle forklift.
- Warehouse worker, like those who handle the documentation, register incoming or outgoing goods, contact with customers or suppliers, and more.

The warehouse personnel are under the management of logistic department.

# 3.2 Receiving Area

The receiving area consists of an outer part, with a single unloading bay, and the inner part where there is an office and an area where the various pallets just unloaded from the trucks are temporarily placed. In this area there are 3 resources, in the daily shift, who are in charge of :

- Relations with truck drivers
- Unloading of pallets and possible loading of returnable packaging (pallets or odettes)
- Record the orders
- Print and apply Dayco label

When a truck arrives, the first step is the handing of the delivery note by the truck driver to the warehouse attendant. The delivery note containing information such as customer, item codes, quantity. After a visual inspection by the forklift driver, the pallets are unloaded and placed inside. Subsequently, the pallets will be registered in the information system, and then labeled. From there they will be taken over by a forklift driver who will store them in the central warehouse.

*Figure 18: Inner Part of Receiving Area*

# 3.3 Central Warehouse

The central warehouse stores:

- Components
- Finished products
- Semi-processed
- PPAPs

There are 3 aisles that extend the entire length of the warehouse, and they are operated exclusively with narrow aisle forklifts. Component pallets are usually stocked in these aisles, stored according to the first free location. In contrast, the outer aisle that spans the entire warehouse and the other aisles that only span half of it are accessible by front or side forklifts. Finished product pallets are stored in these aisles, in which they are divided by zones where each zone belongs to a customer.

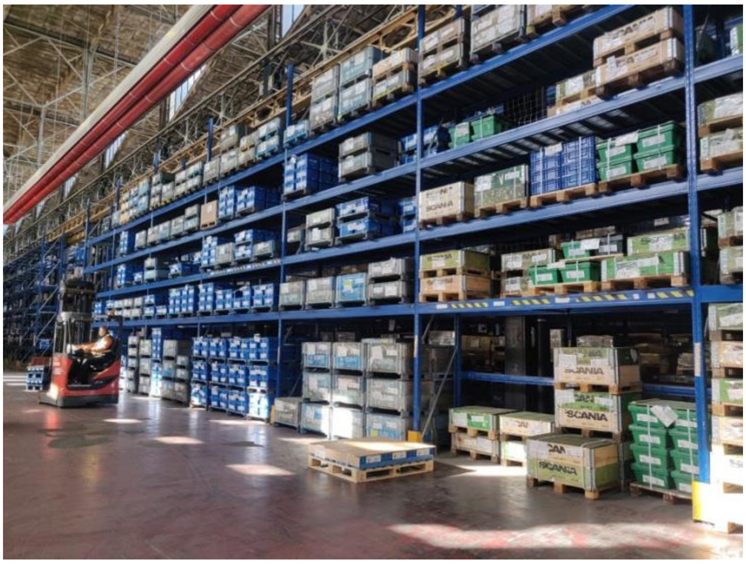


*Figure 19: External Shelving of the Central Warehouse*

# 3.4 Kanban Warehouse

The Kanban area exclusively houses component pallets, and is at the cost center of production. This warehouse is similar to a large line supermarket, and the component pallets station here after being picked up from the central warehouse. Each rack location is assigned to a component code. The locations of the various codes are displayed by the warehouse drivers using an excel sheet. Not all codes are present in the kanban warehouse, only those with high rotation. The rack has 7 floors, but only the first 4 belong to the Kanban warehouse, the other 3 floors are managed by central warehouse. In this area, pallets can be picked up by either the front or side forklift, for then brought to the line for assembly.

This area has been changed in recent years, in fact previously there was no distinction between the two warehouses, and it was created mainly to reduce the many returns made by the assembly lines directed to the central warehouse, which as explained in the next chapter is a time-consuming operation involving several resources.

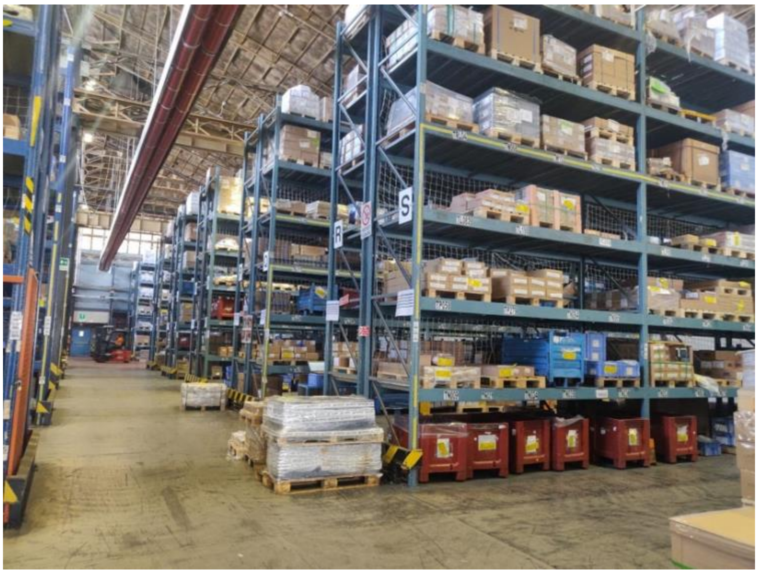

*Figure 20: Kanban Warehouse*

# 3.5 Shipping Area

This area is similar to the receiving area, in fact it consists of an inner part where the FPs pallet are placed before being loaded into trucks, and an outer part provided of loading bay and side loading are. The inner part is divided by zone, with each customer having its own predefined zone.

# 3.6 Dayco 4

Dayco 4 is the production area where the most advanced technologies for production and material servicing are located. There are currently 7 production lines, including 2 recently added. It is an unsaturated area where the next production lines will be added.

## 3.6.1 Assembly Lines

Lines 39 and 42 are semiautomatic, here the operator issues inputs to the production line by performing operations necessary for the continuation of the production phase, feeding the various inputs with raw material, has the control function for any downtime, the function of unloading finished products and their packing. Parallelism, offset, torque, and damping checks are done automatically by the machine. To fulfill the customer’s requirements, GP-12 is executed, quality control on 100% of finished product, external to the line aiming to inspect the torque screwing. In these two lines accessory drive tensioners are assembled, for light vehicles, with a production capacity of 120 pieces/h for line 42 and 200 pieces/h for line 39.

Lines 8, 19, and 32 are manual assembly lines, these are arranged with stations with presses, assembly, inspection and packaging. Different models of timing belt tensioners are assembled in these lines, with a production capacity of 130 pieces/h. Resources required for these lines depend on the type of finished product, and may be 4-5 production line workers.

Lines 41 and 45, are manual, recently implemented. They produce the last two products designed by the R&D team, the former producing side arm tensioner for MHEV and the latter accessory drive tensioners for heavy vehicles.

### 3.6.2 Resources

## Production Feeder

The production feeder is a figure that is only present in Dayco 4. Is at logistics cost center and there is only one resource per shift, for all three shifts. Its duties are:

- order the various component codes for production from warehouse
- arrange pallets from the warehouse in the supermarket of Dayco 4
- print and affix labels in the odettes or cardboard packages in order to register them in the Kanbanbox software
- feeding the racks of the assembly lines
- feeding the racks of AGVs
- bring the odettes or cardboard boxes for packaging the finished product
- pull out the FPs pallet and replace it with an empty pallet
- flank the production forklift driver when he is overworked or replace him when his figure is not present, for example, on the night shift.

## Production Forklift Driver

The main function of Production forklift driver is the handling of pallets from the warehouse to Dayco 4 and also to carry FPs to the warehouse, with front forklift.

Other duties:

- move the finished product to GP-12, outside Dayco 4
- flank the production feeder when he is overworked

The production forklift driver is at logistic cost center and there is only one resource for Dayco 4 and available for one daily shift. It works closely with the production feeder, often the two figures overlap, even exchanging their task.

## Production Line Worker

The duties of the production worker differ slightly for those working in the semi-automatic line and those in the manual line.

The main difference is in that in the semi-automatic process, the worker begins the assembly process by placing the first components in the platform. Then the assembly and control process is concluded by the robots.

Duties:

- Machine testing
- Scan the labels of the components for the KanbanBox
- Press fitting
- Assembling
- Final control
- Packaging
- Issue and stick label for any packages of finished product
- Control function for downtime
- Finished product positioning, in odette or cardboard box, on pallet
- Issue label when the pallet is complete

In Dayco 4, the production line worker does not have the task of replenishing the racks because it is done by production feeder. The production workers are available for the 3 shifts and are at production cost center.

### 3.6.3 Supermaket Dayco 4

A supermarket is an inventory where the parts are stored separately by type. It consists of multiple parallel FIFO lanes, one for each material type that is handled by the supermarket [15].

Shelves are filled by the production feeder on one side and picked from on the other side, in a way that the FIFO sequence is followed and that everyone involved can immediately see the state of things. The different items in a supermarket have a specific location and are organized in the exact quantity in which they are needed. This ensures the team has the right information on what materials were used and what weren’t, and therefore what materials need to be replenished and what don’t [16].

# Gravity Flow Rack

This type of supermarket is used for manual lines, where the finished product code changes almost daily. In fact, this supermarket is often reloaded when the code has been changed and component codes are advanced in the production line, this happens to avoid a movement to the warehouse returns.


*Figure 21: SM Gravity Flow rack L32*

# Traditional Shelves

This type is used for the 2 semiautomatic lines, Line 42 and 39, which share the same Finished Product codes. Only 2 types of finished product are produced in these two lines; in fact, this supermarket was implemented mainly because of the excessive distance of the production line with the warehouse and long delivery times.

*Figure 22: Traditional Shelves L39 and L42*

### 3.6.4 Softwares

## AS400

On June 21, 1988, IBM introduced the Application System/400 (AS/400), a new family of easy-to-use computers designed for small and intermediate-sized companies. The AS/400 quickly became one of the world's most popular business computing systems. By 1997, IBM had shipped nearly a half-million AS/400s. The AS/400 family was succeeded in 2000 by the IBM eServer iSeries — high-performance, integrated business servers for mid-market companies. AS/400 architecture is often used for ERP and other mission-critical tasks, particularly in industries that require extreme reliability, such as manufacturing.

## KanbanBOX

KanbanBOX is the web software designed for the companies that use kanban in order to manage their own internal production and that wish to maximize the efficiency of the physical kanban with a digital solution for the flow monitoring and the dimensioning update simplification. It allows the implementation of different templates for different kanban uses (production kanban, purchase kanban, sales kanban, handling kanban), by selecting the printing layout and the information to be displayed, adding company logo, pictures of components and colors for each department in a visual management perspective. [17]


*Figure 23: Kaban Label L42(on the left) and KanbanBOX software (on the right)*

Electronically tracing the filling up and the emptying of your kanbans means to have the opportunity to be aware of the Supply Chain in every moment, to promptly identify possible errors, for instance lost labels, and especially to collect valuable information for the improvement of all the system, such as the consumption trend in relation to the dimensioning data, the effective supply Lead time or the service level received by suppliers (Wiesse and Roser, 2017). This software is used exclusively in Dayco 4, for semiautomatic lines, so line 39 and 42. KanbanBOX allows to manage both supplier side, so supermarket D4 to flow rack, and customer side, so warehouse to D4. It is currently used only on the supplier side.

### 3.6.5 Material handling equipments

#### Forklift

Internal handling of pallets in the warehouse is done with electric front and side forklifts. Dayco 4 is assigned a single front forklift, with which the handling of component pallets from the warehouse to D4, and the handling of finished product pallets to the warehouse is performed.

#### AGV

Mobile industrial robots are pieces of machinery that are able to be programmed to perform tasks in an industrial setting. Mobile industrial robots introduce a new method for lean manufacturing. With advances in controls and robotics, current technology has been improved allowing for mobile tasks such as product delivery. This additional flexibility in manufacturing can save a company time and money during the manufacturing process, and therefore results in a cheaper end product (Estey, 1994).

Dayco 4 is equipped with:

2 MiR 250

The MiR250 has a footprint of 580 x 800 mm and a height of only 30 centimeters while still being able to move as much as 250 kg with a speed of 2 meters/second. This makes the AMR more agile than any other AMRs on the market and highly adaptable for challenging environments. Thanks to the small footprint, it can drive in spaces as narrow as 80 centimeters. They are used to supply assembly lines. They are equipped differently, one has a fixed gravity flow rack, while the other is equipped with the shelf carrier module. The shelf carrier is an anchoring device that enables the robot to pick up and deliver carts, racks, or similar items (Estey, 1994).

*Figure 24: MiR 250 with Fixed Gravity Flow Rack & MiR 250 Shelf Carrier Module*

Production feeder can launch different missions previously set, depend on the line to be serviced. With the help of a handheld the mission is launched, the AGV goes to the loading area adjacent to the supermarket, the operator loads the odettes directly into the AGV(fixed flow rack) or loads a cart which is then picked up by the AGV. When the loading operation is finished, the operator gives the command to start the delivery.


*Figure 25: MiRFleet software*

- 1 MiR 1350

  MiR1350 has, with specially designed pallet lifters from MiR, the ability to pick-up, transport and deliver pallets automatically, with a payload of 1350 kg.
  This AGV is being implemented and will be used for handling finished product. The pallet of FP will be taken from the production line and then unloaded into a dedicated area in Dayco 4, which will then be picked up by the forklift driver to take it to the warehouse.


*Figure 26: MiR 1350 for Handling FPs*

Other equipments used, in Dayco 4, are Hand truck fourwheel and Electric foot transpallet.

# 4 Logistic Process Representation to Feed Lines 32 and 42 (As Is Process)

In the fourth chapter, the processes of the production operator performed in the manual line, L32, and the semi-automatic line, L42, are described. To then focus on the production feeder processes to feed the assembly lines. The implementation of the BPMN tool is used to graphically represent the processes.

## 4.1Assembly Line 32

It is a manual assembly line, where different models of timing belt tensioners are produced. These are products designed for the light duty OE category and for the aftermarket. The line consists of 4 presses, an assembling and calking station, an upsetting station, and a bench. It requires 3-4 resources (production worker), which depends on the type of code being processed.

FP codes processed by the line are:

T0L0413, T0L238, T0L239, T0L250, T0L0419 , T0L0462, T0L160, T0L184, T0L22, T0L120, T0L219, T0L0452, T0L0465, T0L408, T0L290,T0L01, T0L0591, T0L111, T0L0666, T0L0591, TWL82, T0L332.

Depending on the type of FP code being processed, the number of resources and machinery involved changes. For example, the processing cycle of T0L238/T0L239 requires 4 production workers and all the machinery used.

1st Production worker: Pulley press and arm press
2nd Production worker: Arm press and pivot bushing press
3rd Production worker: Assembling/calking station and upsetting station
4th Production worker: Testing station and bench

Instead, the assembly process of T0L0413 is composed as follows:
1st Production worker: Arm and pivot bushing press
2nd Production worker: Assembling/calking station
3rd Production worker: Testing station and bench

The hourly throughput of the line is also affected by the type of code being produced. It can go to a maximum of 130 pieces/h for code T0L0413, 125 pieces/h for T0L219, and 103 pieces/h for T0L0452 and T0L0465.

All presses and stations are equipped with gravity flow racks, plus there are two Supermarkets (32/A and 32/B) at the beginning of the line that are supplied by the production feeder. SM 32/B comes direct the line, so the production worker picks up the material directly from the workstation, whereas for 32/A it is outside the line. The two supermarkets are programmed to be supplied by the AGV with the fixed gravity flow rack.

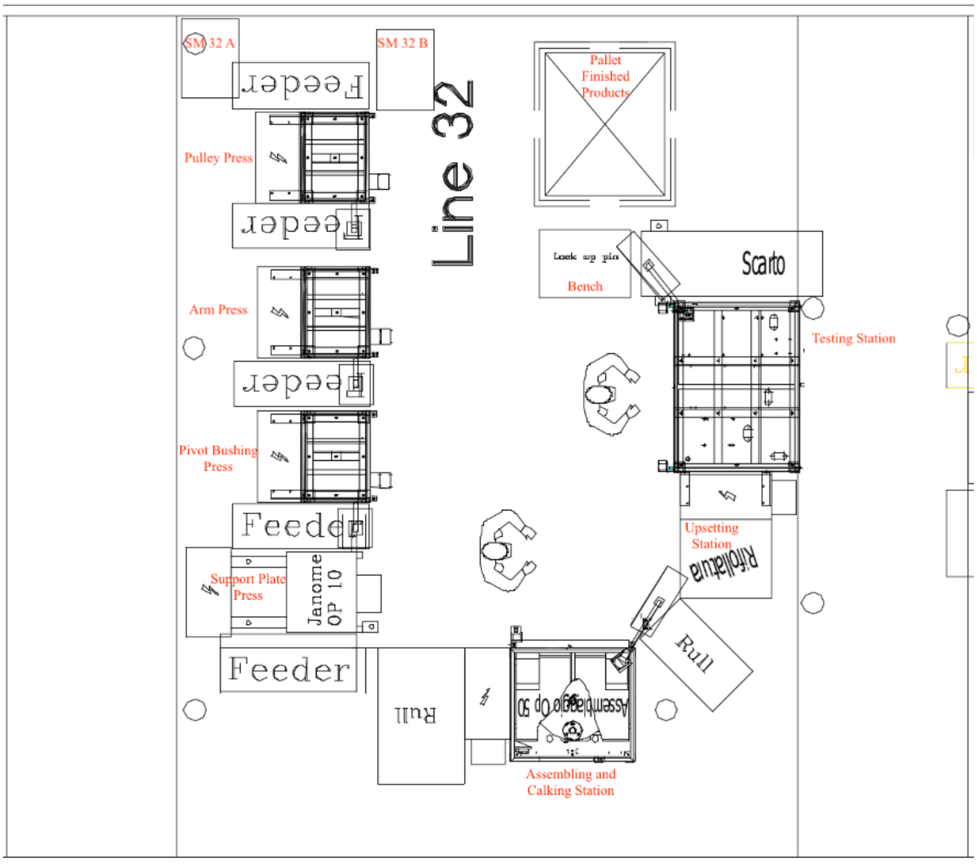


*Figure 27: Layout L32*

## 4.1.1 Flow Chart Production L32

The first operation involves washing a specific component, the pivot, and is an operation performed off-line. In fact, the pivots before being taken to the assembly line, from the warehouse go to the washing area, outside D4, and then once washed go to the line. The washing does not involve line resources instead the handling is done either by the D4 forklift driver or the production feeder.

Step 10.1 represents the preparation of the subgroups that are carried out in line by the 4 presses. The subgroups vary as the FP code changes.

10.2 and 10.3 provides for the inclusion of additional components in subassemblies.

In the oiling stage, the arm with the pulley is picked up and they are placed in the laying. The oiling cycle is carried out, when finished it is picked up and laid down for the next position. The oiling phase is performed only for the TAL290/TAL0591/TAL0666.

Step 20.1/20.2 involves upsetting. The pivot bushing inserted into the posing is picked up

and then the subassembly is inserted, finally the end cap and then the machine cycle is started. The checks are performed and then it is laid down for the next operation.
In step 30, the assembly of the end cap, pivot, and main spring with the subassemblies from step 10 takes place.
At the end of machine cycle, the assembled part is unloaded, performed checks as per ISQ, and laid down for next operation.
Step 40.1 performed offset and parallelism checks.
Step 40.2 performed checks on torque and static damping.
Step 40.3 the FP is marked.
Step 40.4 control on pivot/pulley with free rotation.
In step 50, the lock up pin is inserted and immediately checked for correct insertion (50.2).
Step 60 is the last step performed by the line operator, where components are arranged in boxes following guidelines that change by customer type.
Step 70, when the pallet is complete, it is picked up by the production feeder or Forklift driver D4 and stored in PF area warehouse.

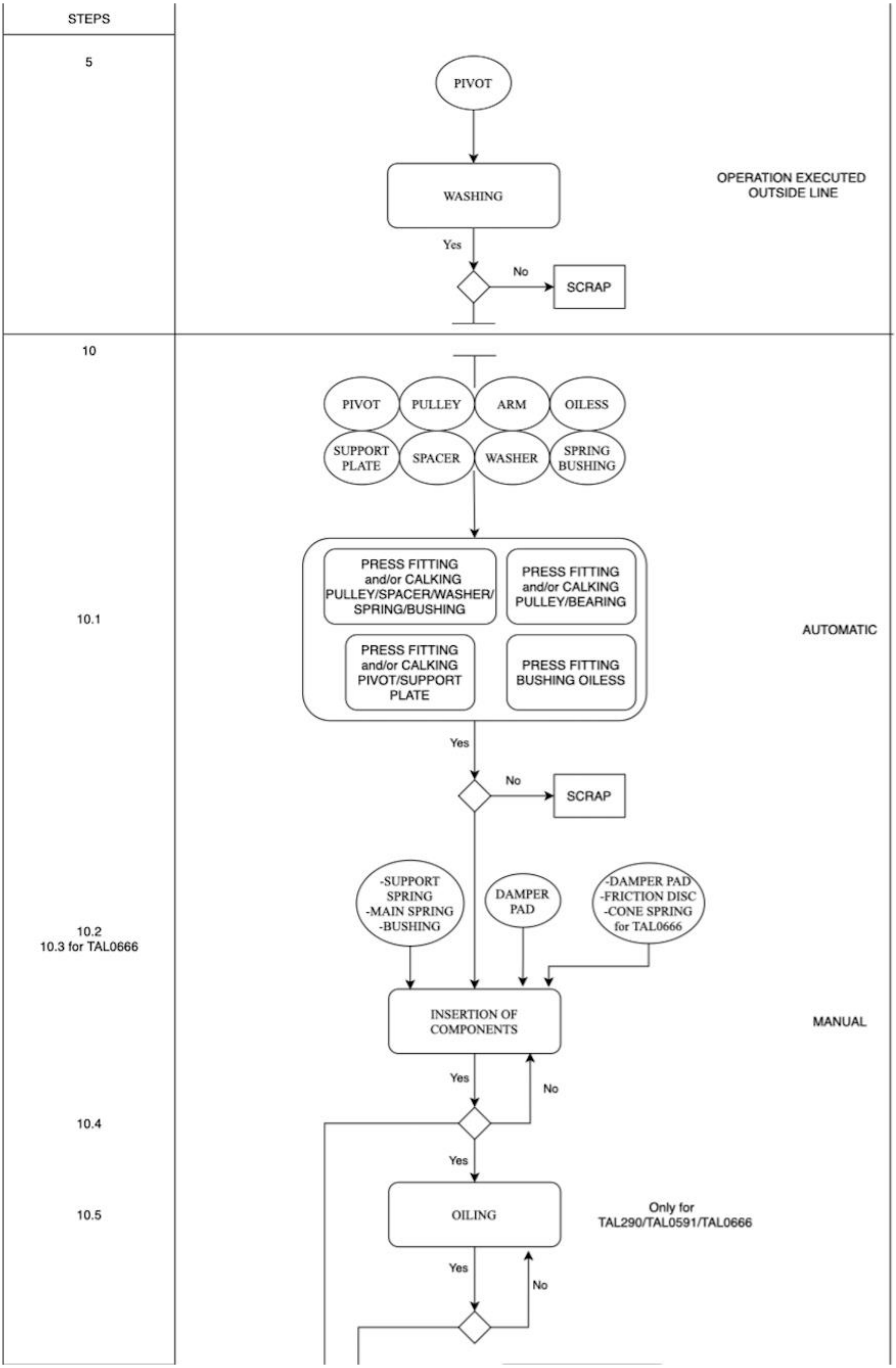


*Figure 28: Flow Chart L32 1st part*

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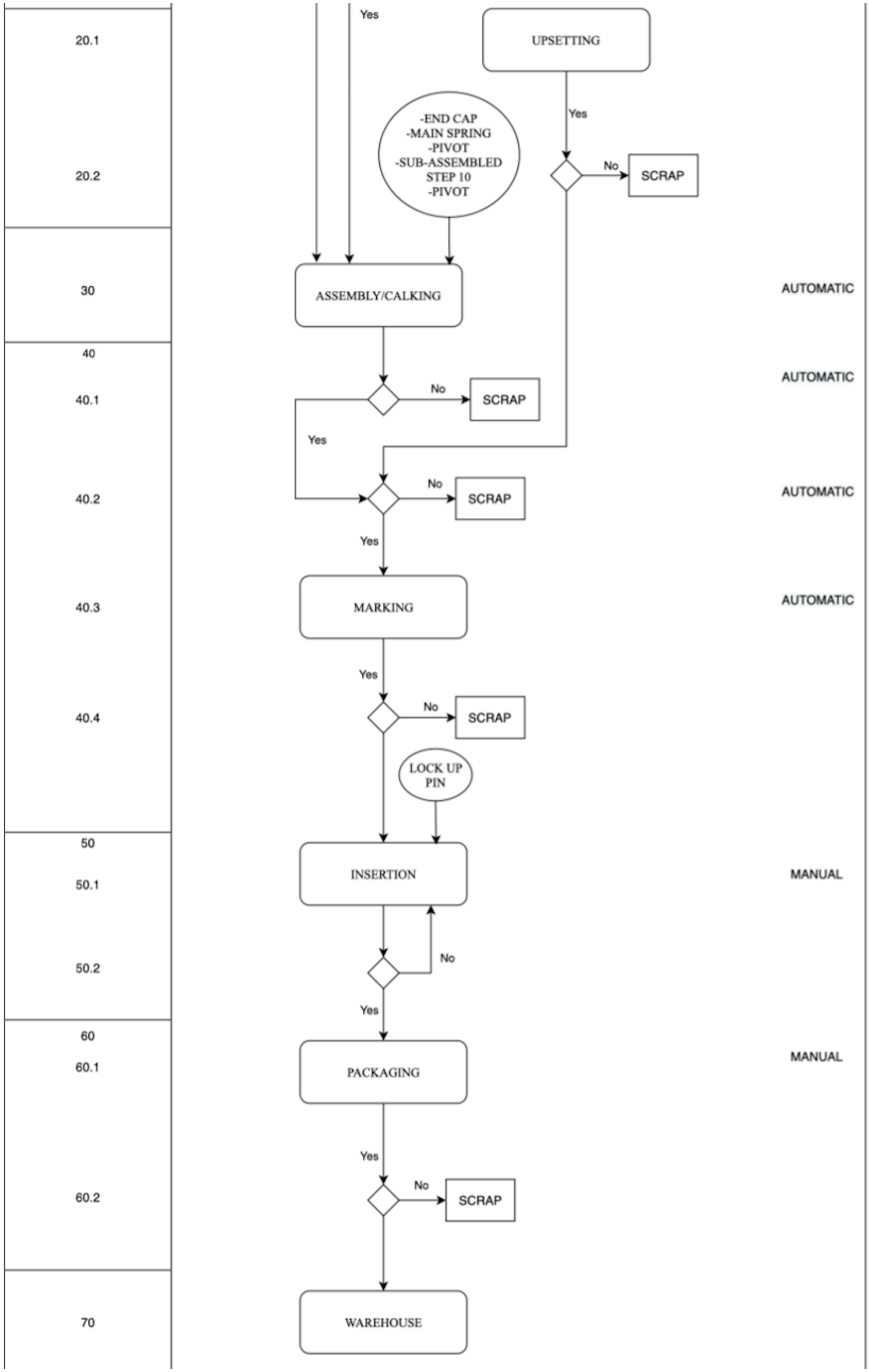



*Figure 29: Flow Chart L32 2nd part*

# 4.2 Assembly Line 42

This line assembles accessory drive tensioners for light vehicles. Dayco tensioners feature the original flat-wire spring design, engineered to provide more operating range and less tension variation. This innovative design reduces the risk of premature accessory bearing failure due to high tension and lessens the risk of belt noise, slippage and poor accessory performance caused by low tension as the belt begins to stretch and wear [14, 2]. Line 42 is programmed to assemble 2 finished products, T01507 and T01585.They consist of 11 components, and the distinction between the two finished products lies only in the difference of one component, TF312 for the former and TF336 for the latter. It is a semiautomatic line, which requires the presence of a single production line worker. It can assemble up to 138 pieces/hour, but it averages an throughput of 100 pieces/hour.

| T01507 | T01585 | |
|---|---|---|
| TC144 | TC144 | SPRING BUSHING |
| TE287 | TE287 | PIVOT BUSHING |
| TL1098 | TL1098 | PULLEY |
| TB540 | TB540 | ARM |
| TF312 | TF336 | SPRING CASE |
| TK181 | TK181 | END CAP |
| TD179 | TD179 | MAIN SPRING |
| TN049 | TN049 | DUST COVER |
| TP351 | TP351 | BIHEXAGONAL HEAD BOLT |
| TQ380 | TQ380 | GREASE BALDOTOX |
| TQ862 | TQ862 | LOCK UP PIN |

*Table 5: Component List of FPs T01507 and T01585*

Adjacent to the operator's workstation are positioned:

- Gravity Flow Rack
- Pallet for Odettes or Cardboard boxes of FPs
- Pallet with Odettes or Cardboard boxes to contain the FPs

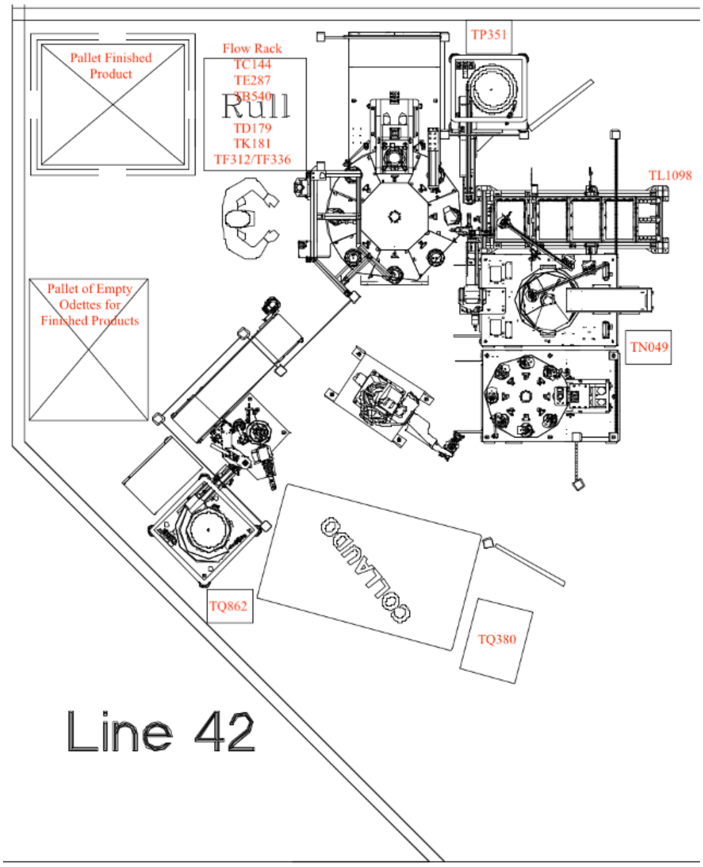



*Figure 30: Layout L42*

The assembly line has 6 different loading points and are arranged as follows:

- Gravity flow rack:
  Made up of 4 floors, and each floor houses 2 different component codes. Locations in the flow rack for cardboard boxes or odettes of components are fixed and can be replenished manually by the production feeder or through the AGV with fixed gravity flow rack.

| Floor | Left | Right |
|---|---|---|
| 0 | Empty | Empty |
| 1 | TD179 | TF312/TF336 |
| 2 | TE287 | TB540 |
| 3 | TC144 | TK181 |

*Table 6: Component Code Arrangement in the Line Gravity Flow Rack*

Component boxes differ in size and in the type of container.

| | Left | | Right | |
|---|---|---|---|---|
| Floor | Container type | Amount of boxes in the flow rack | Container type | Amount of boxes in the flow rack |
| 1 | Cardboard box | 4 | Cardboard box | 3 |
| 2 | Odette | 4 | Cardboard box | 4 |
| 3 | Cardboard box | 2 | Odette | 2 |

Table 7: Size and Type of Boxes

- Load Floors for TP351, TN049, and TQ862.
  These components are manually placed by the production feeder on its own load floor. A maximum of two component boxes can be placed. It will be the task of the production line worker to transfer items inside the box to the hopper.
- Belt Conveyor: Here the odettes containing the pulleys are placed, T01098. The Production feeder will be responsible for loading the roller conveyor manually or by launching the specific mission with the AGV. It will also be responsible for unloading the empty odettes and taking them to the collection point .
- Load Floors for the grease, TQ380. This is the product where replenishment occurs the least, about once every two weeks.

### 4.2.1 Flow Chart Assembly Line 42

The flow chart in Figure 25 represents the entire processing cycle performed on the assembly line. The processing cycle of the production line worker, which initiates the assembly process is as follows:

- Phase 10: Inserts the spring case,TF312 or TF336, on the empty posing in front of it.
- Phase 20: Greases the spring bushing TC144 at the dedicated point.
- Phase 30: Inserts spring bushing on the previous component and adds the main spring.
- Phase 40: Inserts the arm by directing it as suggested in the note, inserts the pivot bushing, the end cap and proceed with assembly.

Manual stages are arranged with anti-error systems, also called poka yoke. They check: greasing of the spring bushing, presence and orientation of the arm/main spring, and presence of the pivot bushing/spring case/end cap. After the operator has achieved the previously announced steps, the rotary table rotates so as to give a new free position for the assembly of a new part. From step 50, the pre-assembled part enters the automated processing cycle.

- Phase 50: A robotic arm picks up the pulley, TL1098, and dust cover, TN049, and bolt, TP351, and are added in that order to the pre-assembled component and then a pre-screwing. The last task of this robot is to transfer the assembled component to a second rotary table.
- Phase 60: Once the screwing operation is completed, the offset and parallelism of the component is tested. If the value is not in tolerance, it goes to the scrap section, otherwise it goes to the next step.

After these operations are completed, the component is transferred by a robotic arm from the rotary table to the testing station.

- Phase 70: At the testing station, torque and damping are checked.
- Phase 80: Here a third robotic arm inserts the lock up pin
- Phase 90: Before being placed in the conveyor belt for later pickup by the operator, the finished product is marked.
- After marking, the operator picks up the PF and places it on an odette, which in turn will go

on a pallet. This is not the final packaging because by agreements made with customers, finished products must pass an additional 100% check on the screwing torque (Phase 100). This control is external to the line, and is called GP12. Visually any cracks, blowholes, and incorrect positioning of the lock up pin are also evaluated.

- Phase 110: the last stage involves the packing of the FPs, it is done by the same operators who perform GP-12, they must follow the packing sheet to do the proper packing.

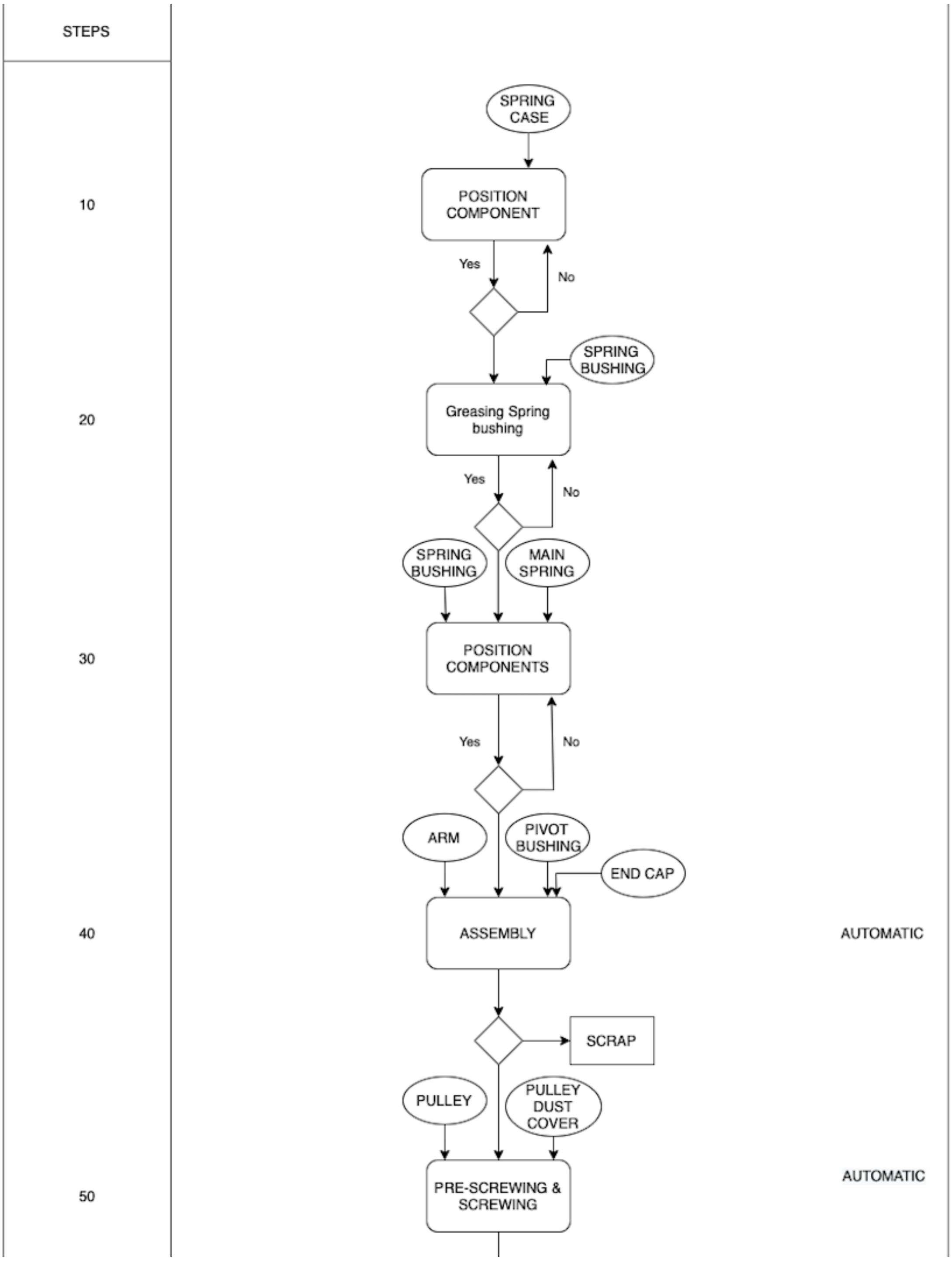



*Figure 31: Flow Chart L42 1st part*

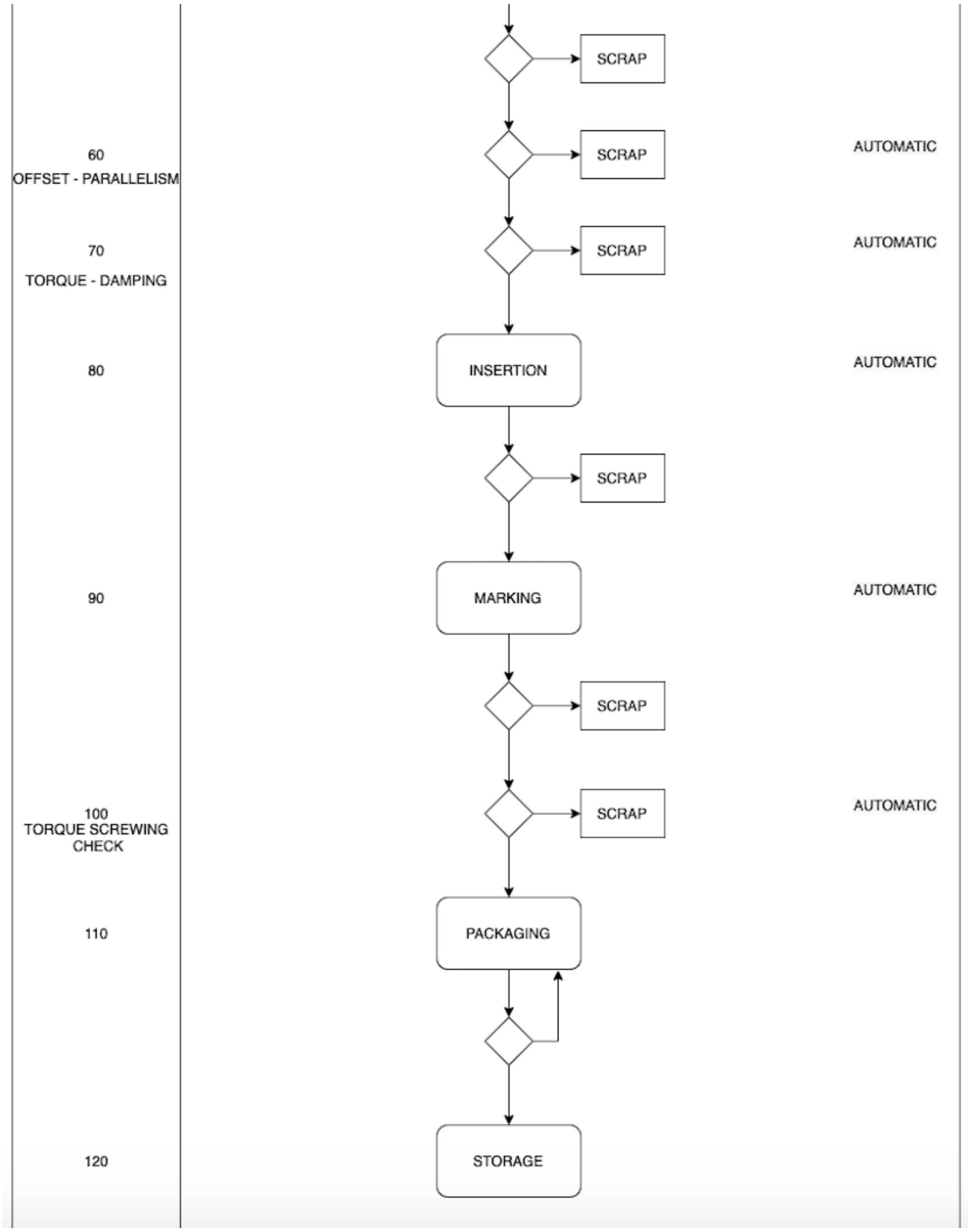



*Figure 32: Flow Chart L42 2nd part*

## 4.2.2 BPMN Line Worker L42

### *Sub-process Production Start-up checks*

Production start up check is the sub-process, which every production worker on line 42 must implement when:

- Operator starts the shift
- The line after a downtime is restored
- FP code change takes place

This sub-process is part of the work instructions issued by the company, the operator after having been successful from the 4 types of verification and then obtaining approval can move on to the next step. The time spent to carry out the changeover procedures is 600 s (C/O=600 s).

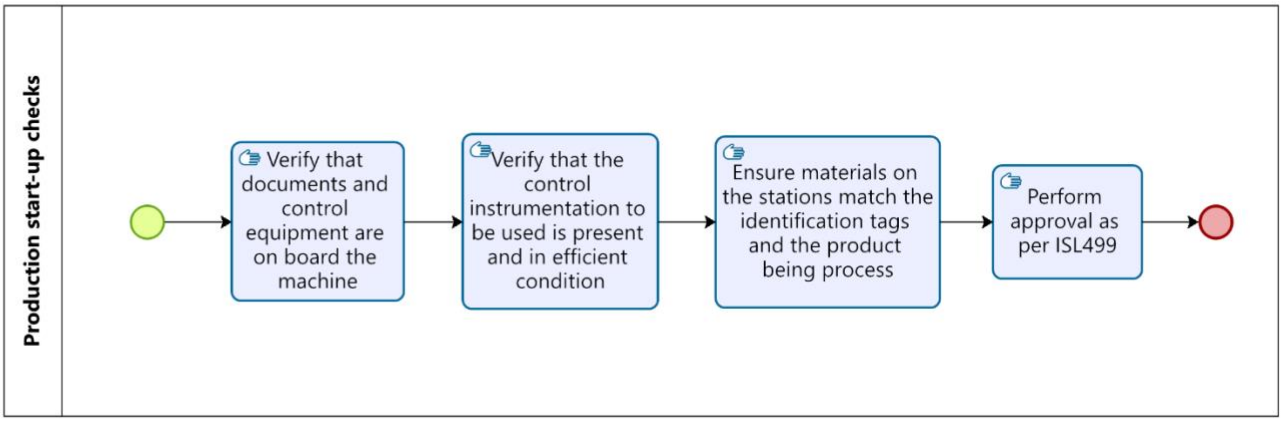



*Figure 33: Production Start-Up Checks*

### Sub-Process Assembly T01507

The second sub-process that will be analyzed describes the cyclic operation of the line operator depicting the first 4 steps of Flow chart L42. All components that are picked up by the operator in this subprocess are taken from the gravity flow rack that is managed through the KanbanBox application. Line 42 along with 39, are the only two lines in the entire plant that are managed by this software from October 2021. For the Kanbanbox software, the line gravity flow rack is seen as the customer instead the Dayco 4 supermarket is the supplier. When running out of components in the box, the operator, using a handheld and the KanbanBox software, must scan the Kanban label previously affixed to the box by the production feeder. In this way, the production feeder, can see via PC or handheld, that the gravity flow rack needs replenishment. Hence, the only extra task in charge of the production line worker, compared to the other assembly lines in the plant, is to scan the kanban label. The cycle time of the assembly process is 30 seconds, (C/T=30 s), assuming no empty component boxes. The graphs show the assembly process of the T01507 code. Changing component TF312 to T336 provides the assembly of T01585.

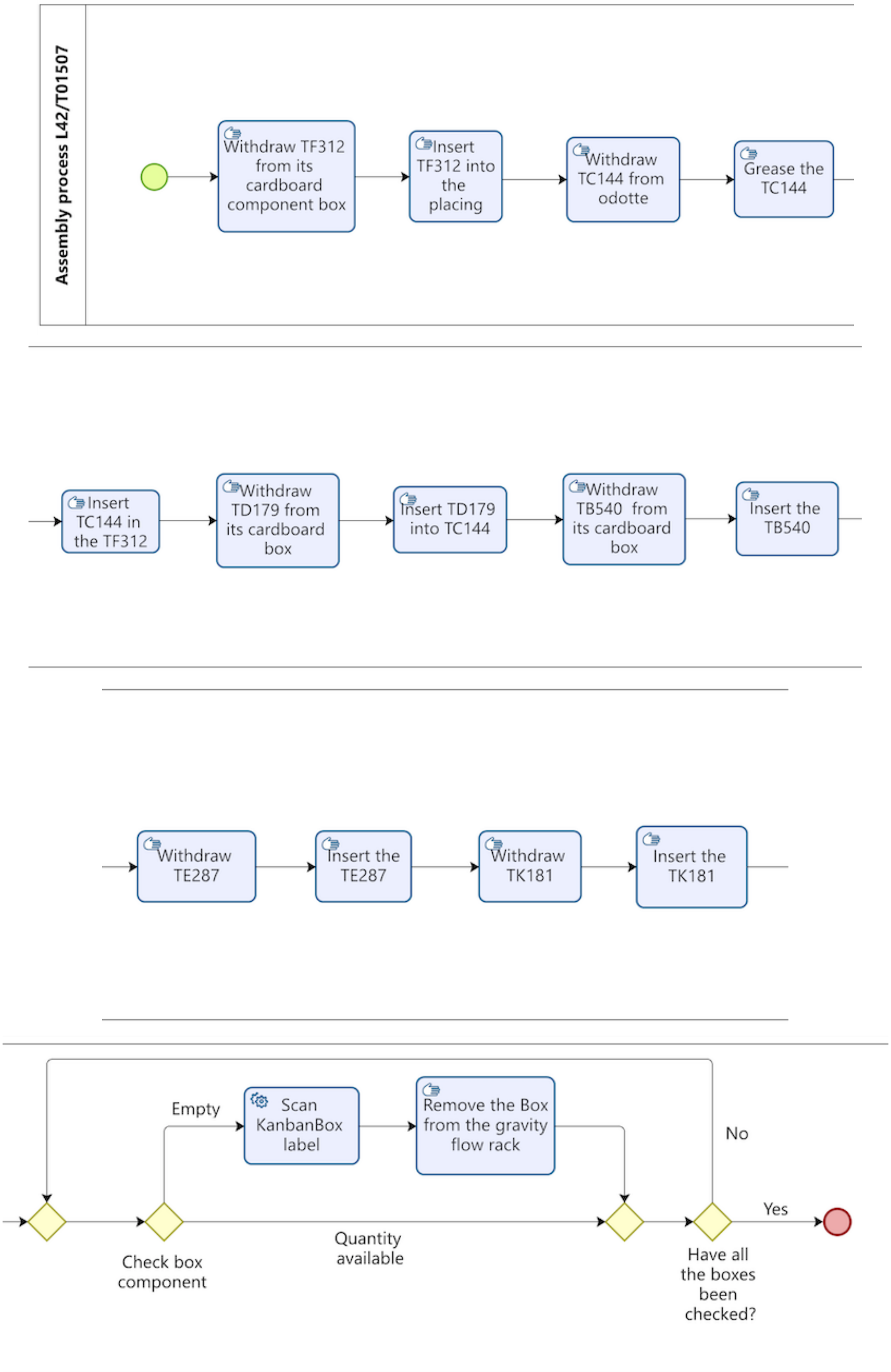



*Figure 34: Assembly Manual Process*

## 4.2.3 Assembly Process L42

The figure below depicts the various processes performed by the operator during the shift in assembly line L42, valid for the two codes T01507 and T01585. After performing the set up phase, the operator as needed must deal with the assembly phase resulting in the handling of finished products, deal with the handling of empty boxes, and feed the different hoppers. The last two operations are acyclic operations performed by the operator. The management of empty boxes consists, in the case of odettes to place them in the appropriate area for odettes to be returned, while for cardboard to dispose of it in the appropriate area. Feeding the hoppers involves detaching from the workstation and checking the level of each hopper and if it is below, feeding it.

Since this line involves a single operator, it must also take care of the pickup of the finished product and its placement. On the right side of the workstation, there is the output of finished products carried by a conveyor belt. The operator should fill the odette and FP pallet according to the work instructions, when the pallet is complete, it should take care of printing the FP label of the pallet and ask, the production feeder, to unload the PF pallet and replenish it with an empty pallet.

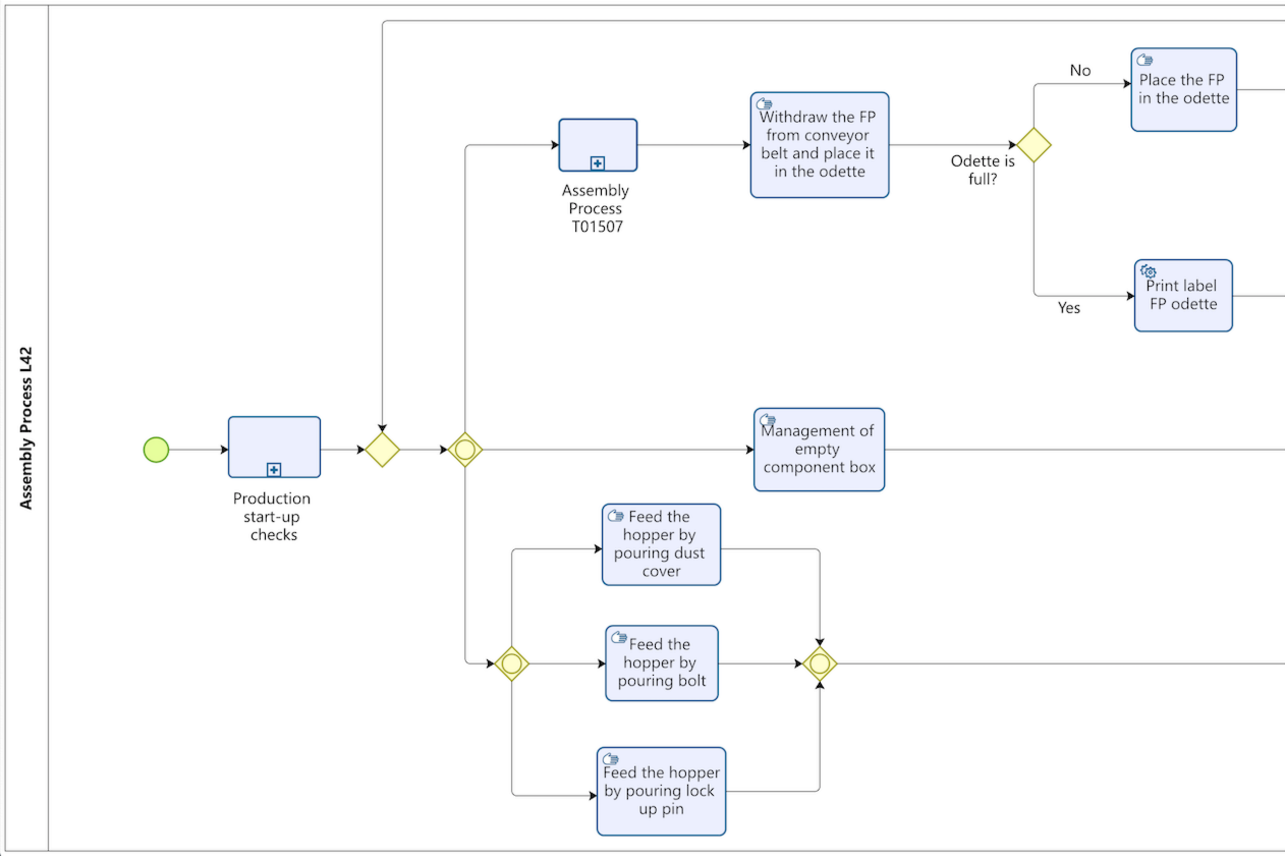



*Figure 35: Assembly Process L42 1st part*

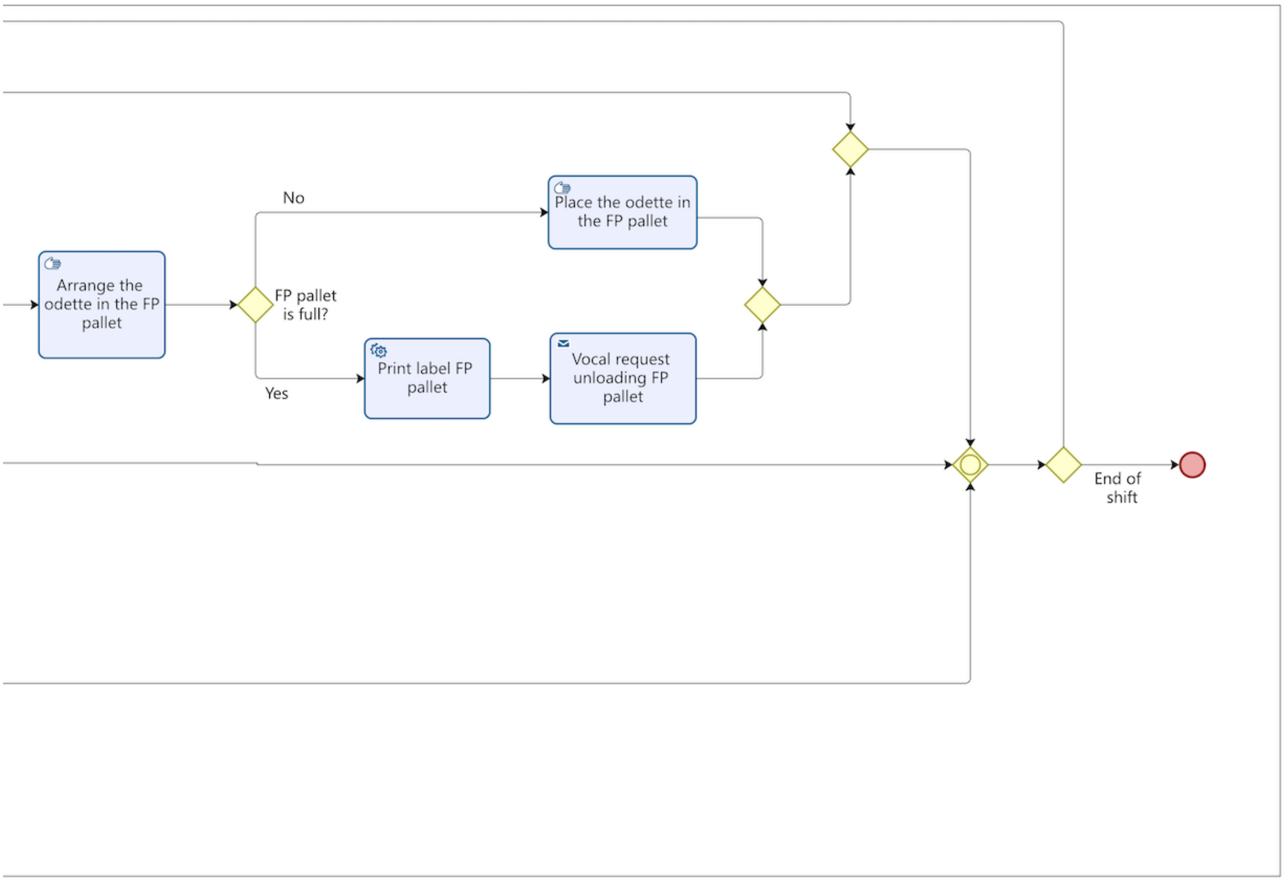



*Figure 36: Assembly Process L42 2nd part*

# 4.3 Logistical Process of the Production Feeder

## 4.3.1 1st Task Production Feeder

The production feeder figure is exclusively present in Dayco 4. In the other 2 production departments, the warehouse worker brings pallets of required material near the line, and then it is up to the line workers to unpack and feed their flow racks. In order to optimize this process and reduce material at the edge of the line, the choice fell to having supermarkets near the line and a resource to unpack and replenish the material. Start of shift begins by inquiring about the lines currently working in D4. Each shift change, an exchange of information takes place between the resource that is ending their shift with those about to replace them. Lines currently working, material ordered from the warehouse, material to be ordered, and other useful information are communicated. The operator goes to the assembly lines under his management, and verifies the FP code currently in assembly by checking the “Primo pezzo prodotto e benestariato”.


*Figure 37: Label of "Primo pezzo prodotto e benestariato"*

Obtained the information about assembly lines(FPs in progress, any code changes, or start/stop of one or more lines), the resource prints itself the finished product code info with each component code. In this way, he can take care of the feasibility study of components that need to go into production.

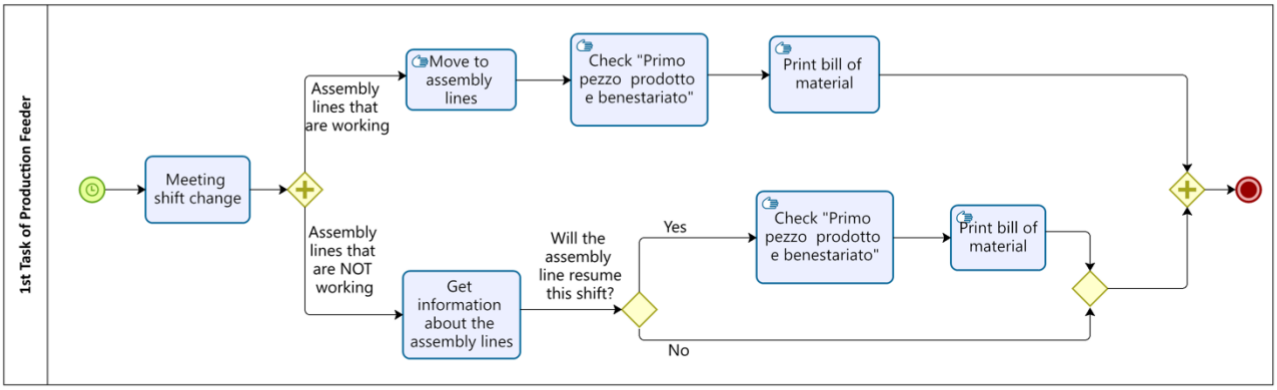



*Figure 38: 1st Task Production Feeder*

## 4.3.2 Feed Line 32

The production feeder cyclically provides visual inspection of the line SMs (32/A and 32/B) and the various gravity flow racks for the presses and the various stations. This can cause incorrect evaluations or missed checks due to excessive workload. In fact, if it happens the production worker can prompt the production feeder by requesting material supply. The line has not yet been programmed to be managed with KanbanBox software.

Line 32 is a more complicated line to supply than line 42, it is mainly due to:

- High number of FP codes
- Each FP consists of at least 12 component codes
- Difficulty in establishing the correct flow rack dimensions of presses and stations
- Set the AGV gravity flow rack for all component codes.

The operator can choose whether to feed the line with the AGV or manually. The AGV can feed one SM at a time, this implies that if both SMs have to be fed, the AGV has to go the round trip route 2 times.

Since it is not handled by the Kanban Box, component loading operations in the AGV or hand truck fourwheels are faster because two steps are skipped, label printing and label application in the boxes.

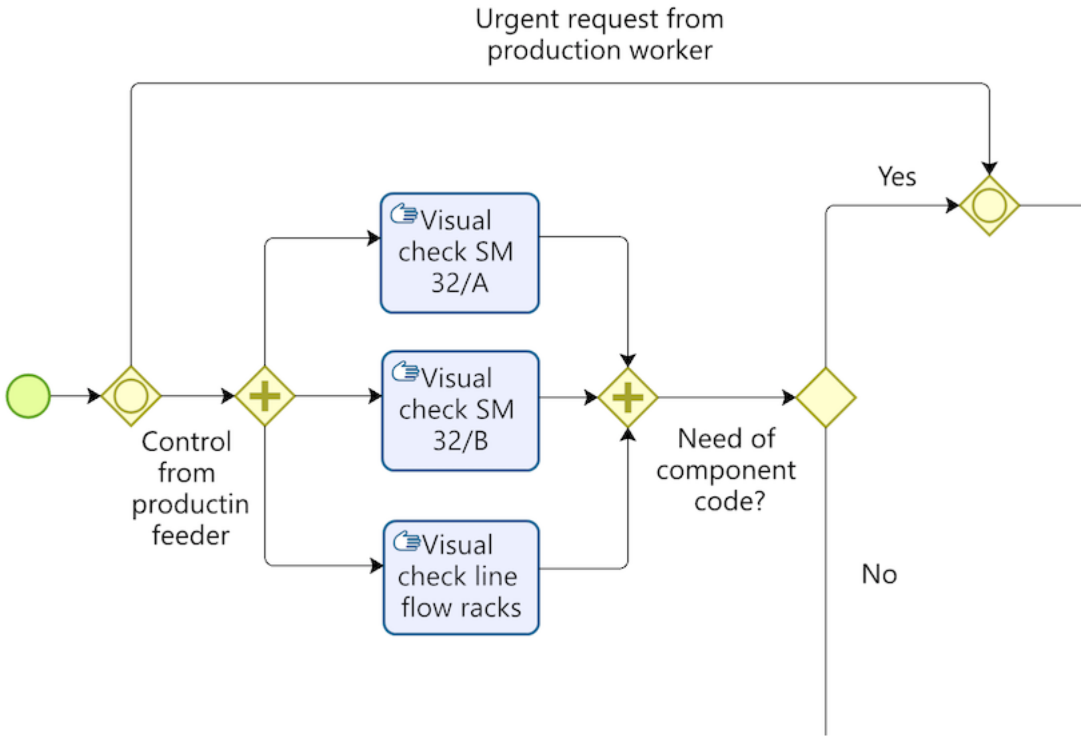



*Figure 39: Feed Line 32 Start*

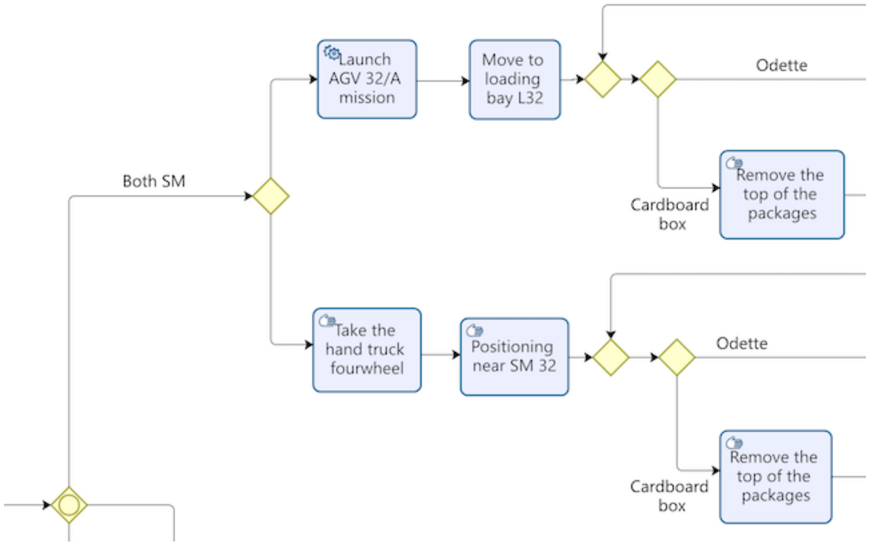



*Figure 40: Feed only SM 32 A/B 1st part*

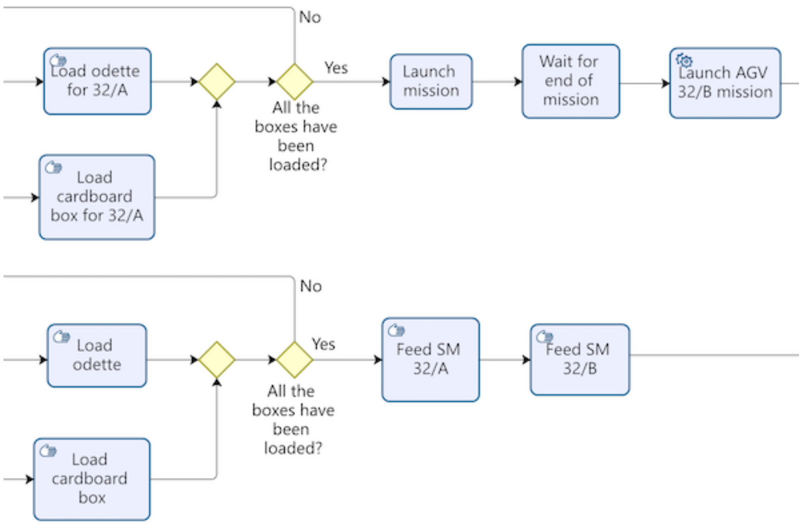



*Figure 41: Feed only SM 32 A/B 2nd part*

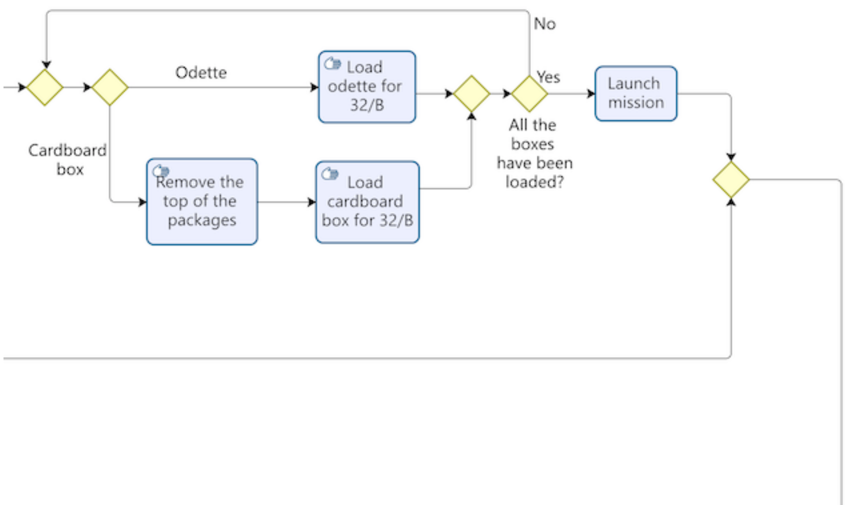



*Figure 42: Feed both SM A/B 3rd part*

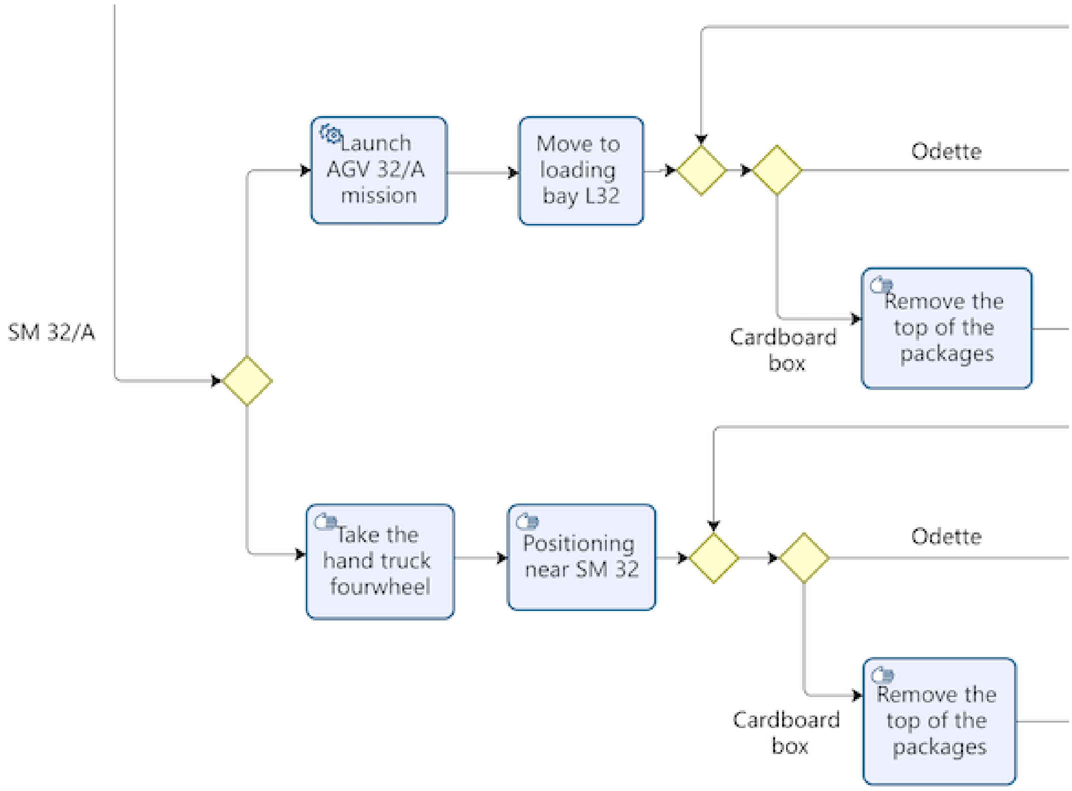



*Figure 43: Feed both SM A 1st part*

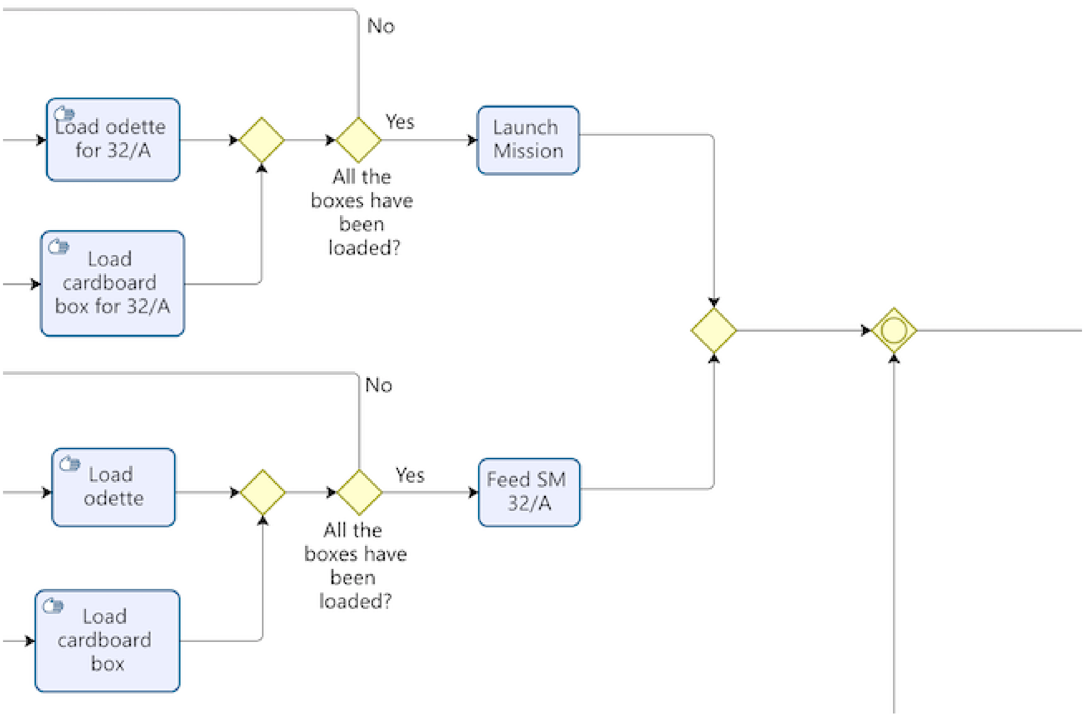



*Figure 44: Feed both SM A 2nd part*

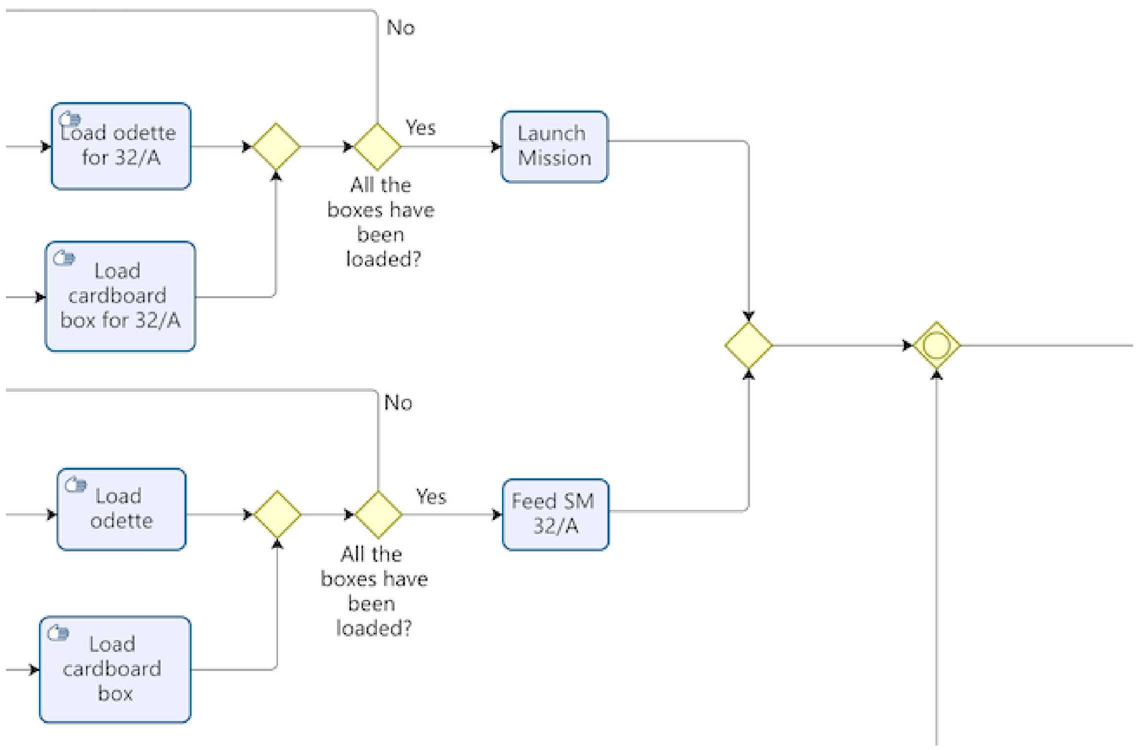



*Figure 45: Feed only SM 32/B 1st part*

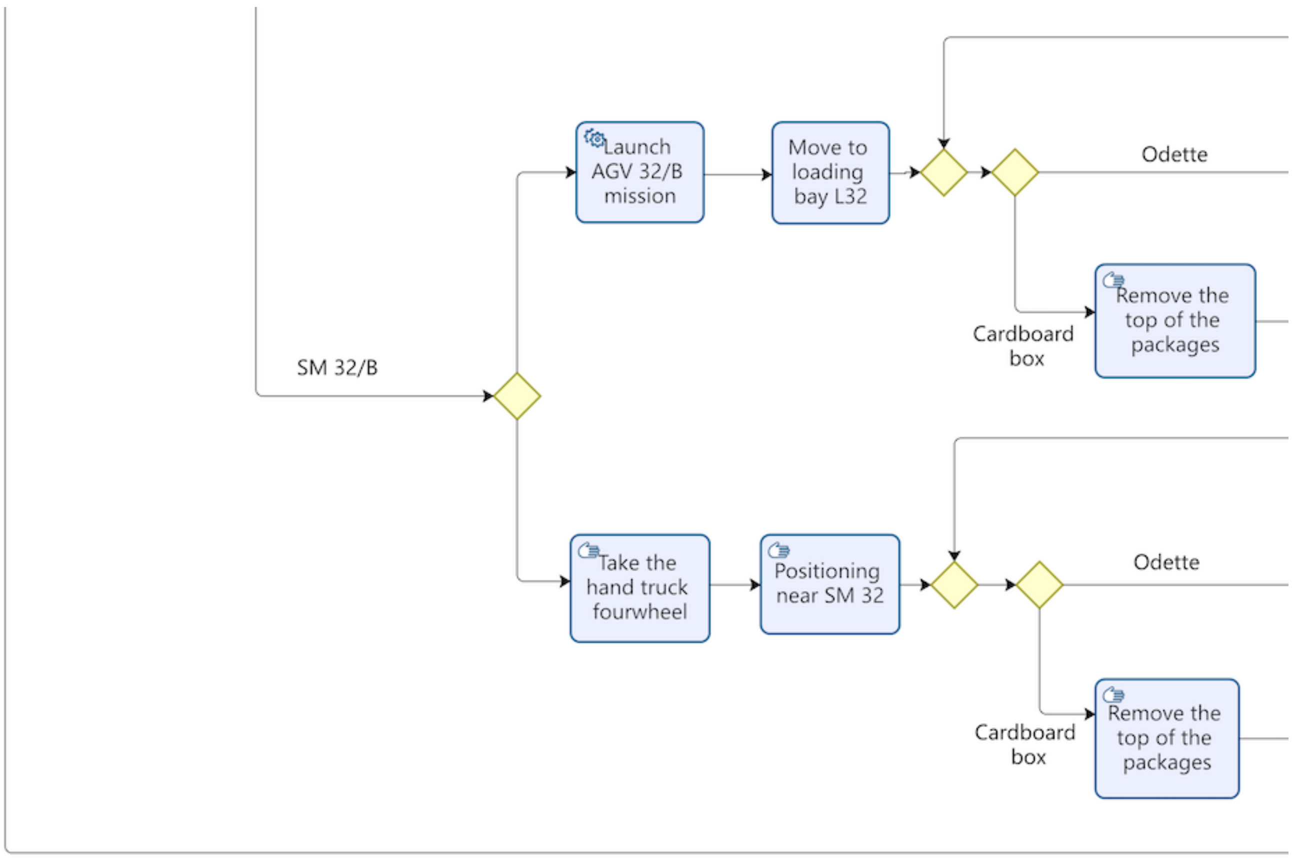



*Figure 46: Feed only SM 32/B 2nd part*

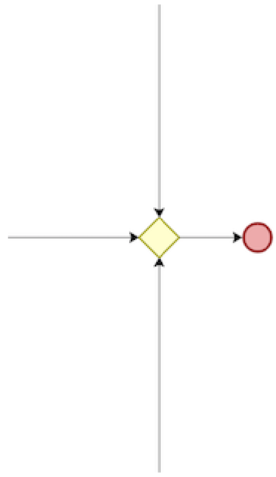


*Figure 47: Feed Line End*

### 4.3.3 Feed Line 42

Line flow  rack feeding is handled by the production feeder. He is responsible for monitoring the level of stock in the flow rack. Monitoring can be done visually, i.e., by going to the line and checking the current quantities or by consulting the KanbanBox software. By selecting the line to be monitored, the application, in green, gives information regarding the quantities of boxes currently in charge of the line and in red instead the component boxes to be restocked.

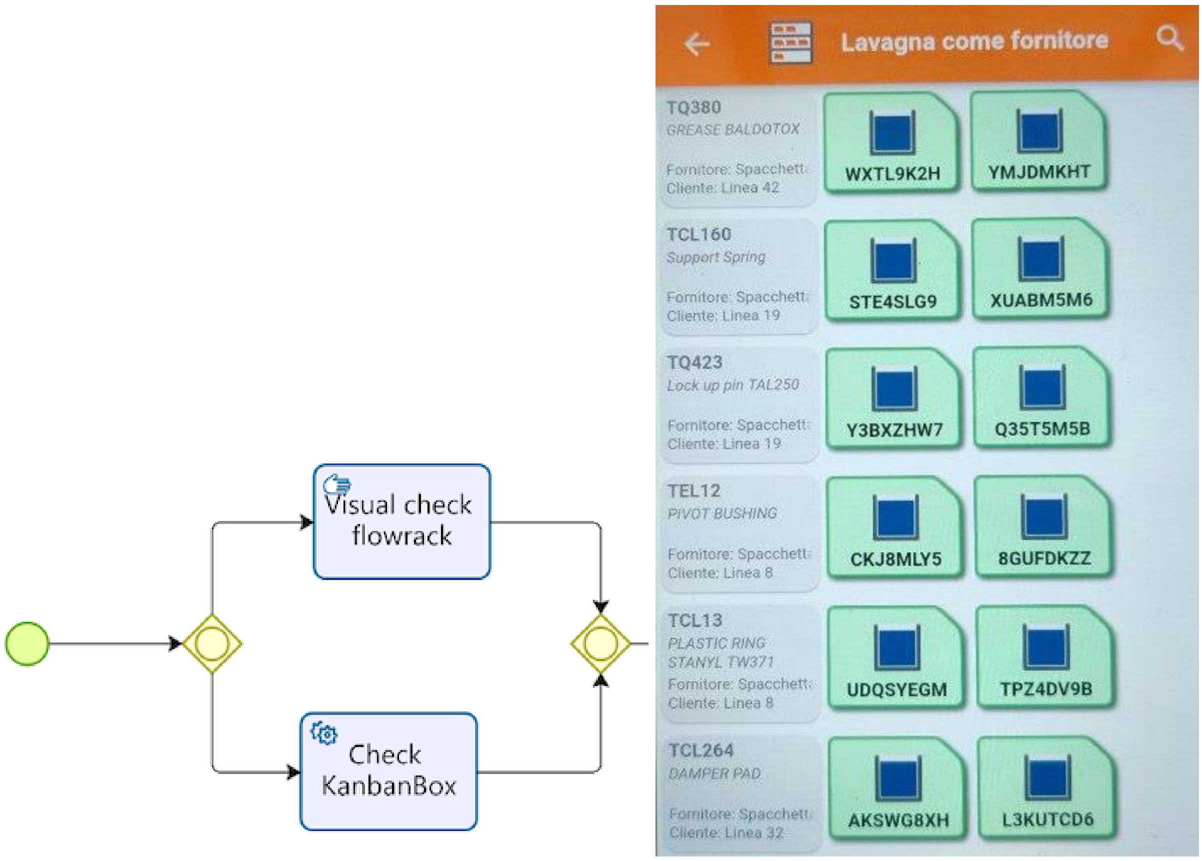



*Figure 48: Component Quantity Control*

When the line needs to be fed, labels that will be applied to each box are printed via the kanbanbox. Once the labels are printed, the software already updates the line flow rack quantities even though the material is still stored in the supermarket. If the station to be fed is programmed with AGVs, the operator can choose how to feed it, giving priority to feeding with AGVs.The mission can be launched by going to the PC station or with the handheld, by launching one mission at a time.

For line 42, 2 missions are currently programmed:

- Line flow rack code servicing with AGV fixed flow rack

| | |
|---|---|
| TD179 | TF312/TF336 |
| TE287 | TB540 |
| TC144 | TK181 |

Table 8: Codes in the AGV Flow Rack

- Belt Conveyor for T01098 with AGV fixed flow rack


*Figure 49: Example of AGV Missions and Kanban Label of T01098*

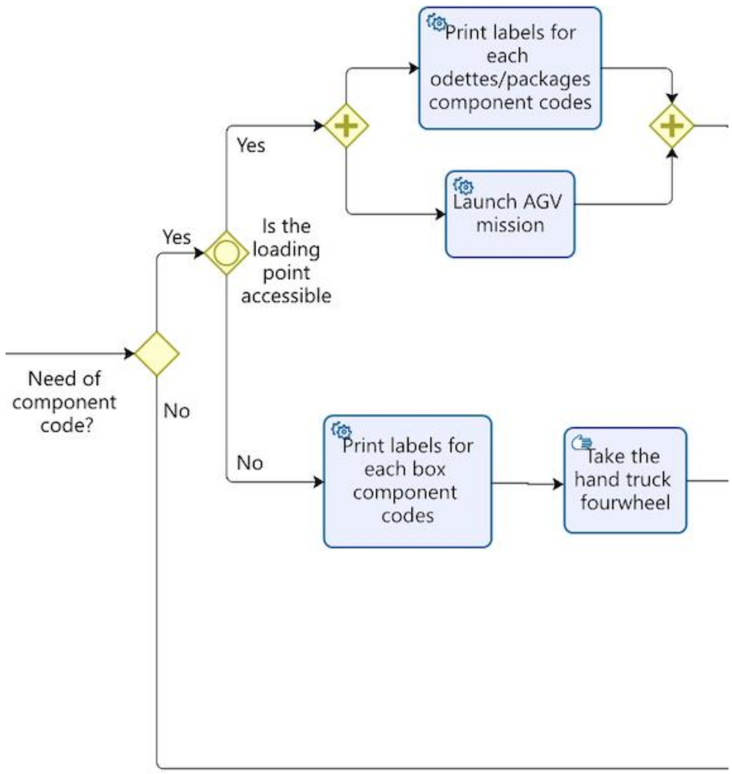



*Figure 50: Feed Line 42 2nd Part*

If the box is made of cardboard, the production feeder should take care of removing the top, so that when the box arrives at the line, it does not need to be handled by the line operator. If, instead, they are concerned with odettes, no further work is needed. A single label is then applied to each box for line management with the KanbanBox, and finally it is loaded onto the AGV or hand truck fourwheel.

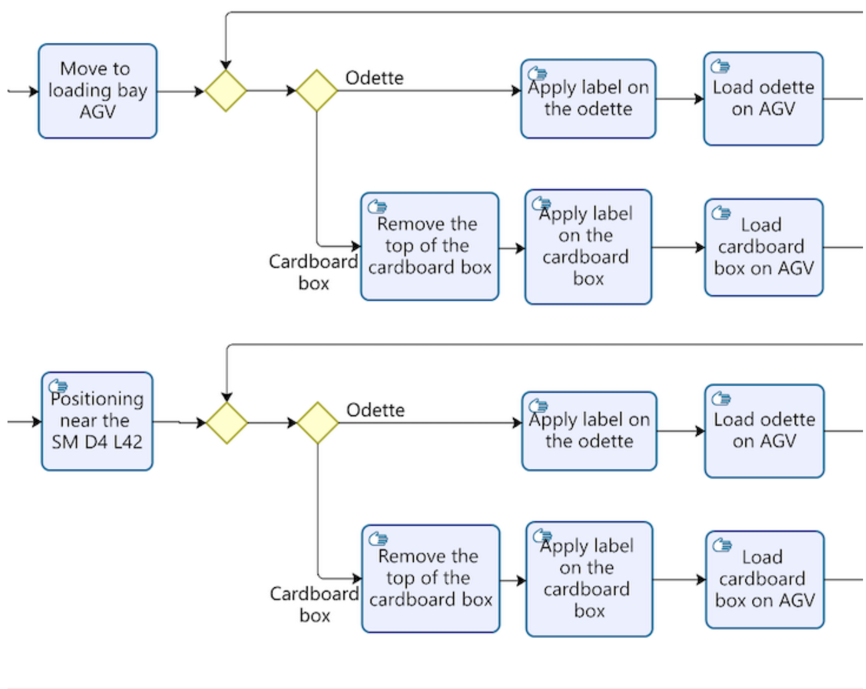



*Figure 51: Feed Line42 3rd Part*

After the loading operations are finished, through an operator input in the AGV can initiate the loading phase for the line flow rack. From this stage onward, the operator should visually attend to the fact that there are no problems in the transition from AGV to line flow rack. These problems, may be caused mainly by even slightly damaged cardboard boxes that may find it difficult to pass or light boxes, in flow racks with little inclination, that cannot descend smoothly.

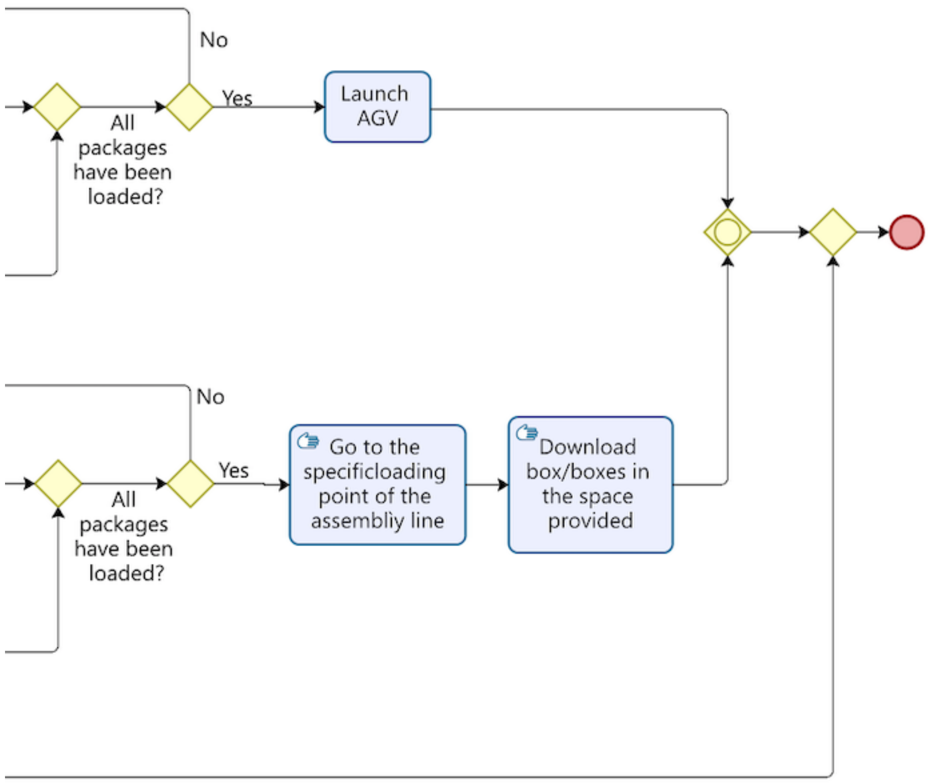



*Figure 52: Feed Line 42 4th Part*

### 4.3.4 Place Order

The way material is ordered varies according to assembly lines. Semi-automatic lines 39, 42 process FPs handled exclusively by these lines. The component codes that compose the FPs of these two lines do not have a location in the kanban warehouse, but it is replaced by the supermarket, with tradition shelves, found in Dayco 4. With this setup, managing component pallet supplies for the production feeder is simple. The operator with the help of AS400, performs material ordering operations. Although the operator can choose material quantities, usually the entire component pallet is brought into SM D4. The path from Warehouse to D4, is carried out by the Forklift driver D4. This is a figure that is present exclusively on the daily shift. it is mainly in charge of transporting the components from the warehouse to D4, and the finished product from D4 into the warehouse. At the time of ordering, the operator can request pallet delivery from warehouse forklift drivers, usually on the night shift, by requesting it in the order notes, or instruct the D4 Forklift driver or he can just go himself.

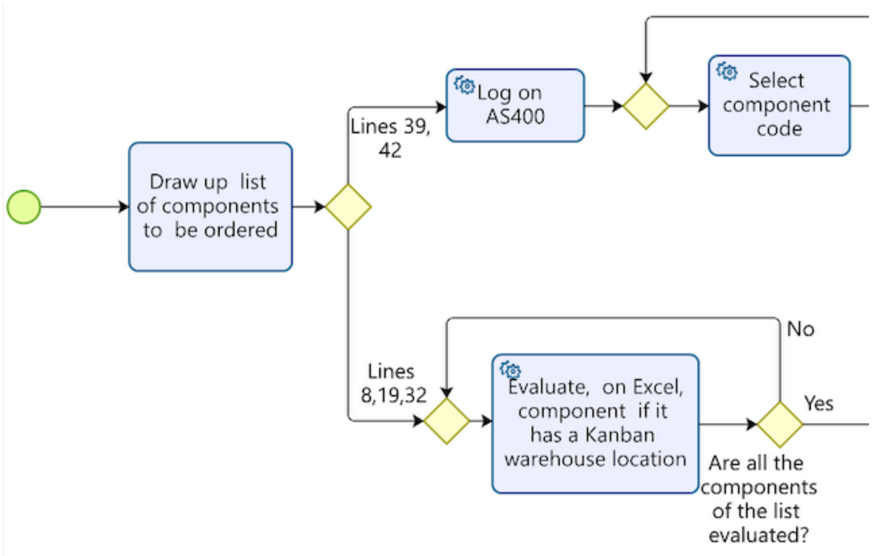



*Figure 53: Place Order Production feeder 1st part*

In contrast, lines 8, 19, 32 are lines that assemble different FPs that are also interchangeable with other manual lines in the Ivrea plant.

Before placing the order, it is checked on excel whether certain codes have a location in the kanban warehouse.

The code to be checked is entered, if it is present as output the row, floor and location is displayed.

Having a place in the kanban warehouse does not ensure that the pallet is always there. For example, the location might be empty because just earlier the same codes were requested from another assembly line and still need to be replenished, or because of forgetfulness, or because the component pallet was placed in the wrong location, or because the code is finished as well in the central warehouse. If successful on the presence of the location in the kanban excel file, the production feeder can instruct the forklift driver D4 or go himself, to go and pick up the component pallets. For codes that are not present in the excel file, material ordering is done through AS400. As mentioned earlier, the operator may not find the component pallet in the Kanban warehouse, causing excessive time loss and place an additional order on AS400.

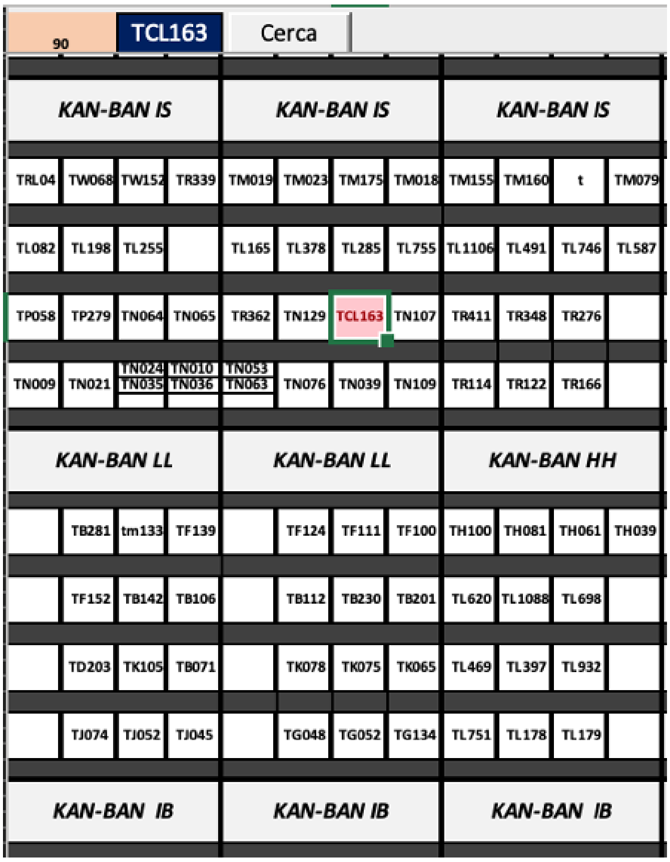



*Figure 54: Kanban's Location*

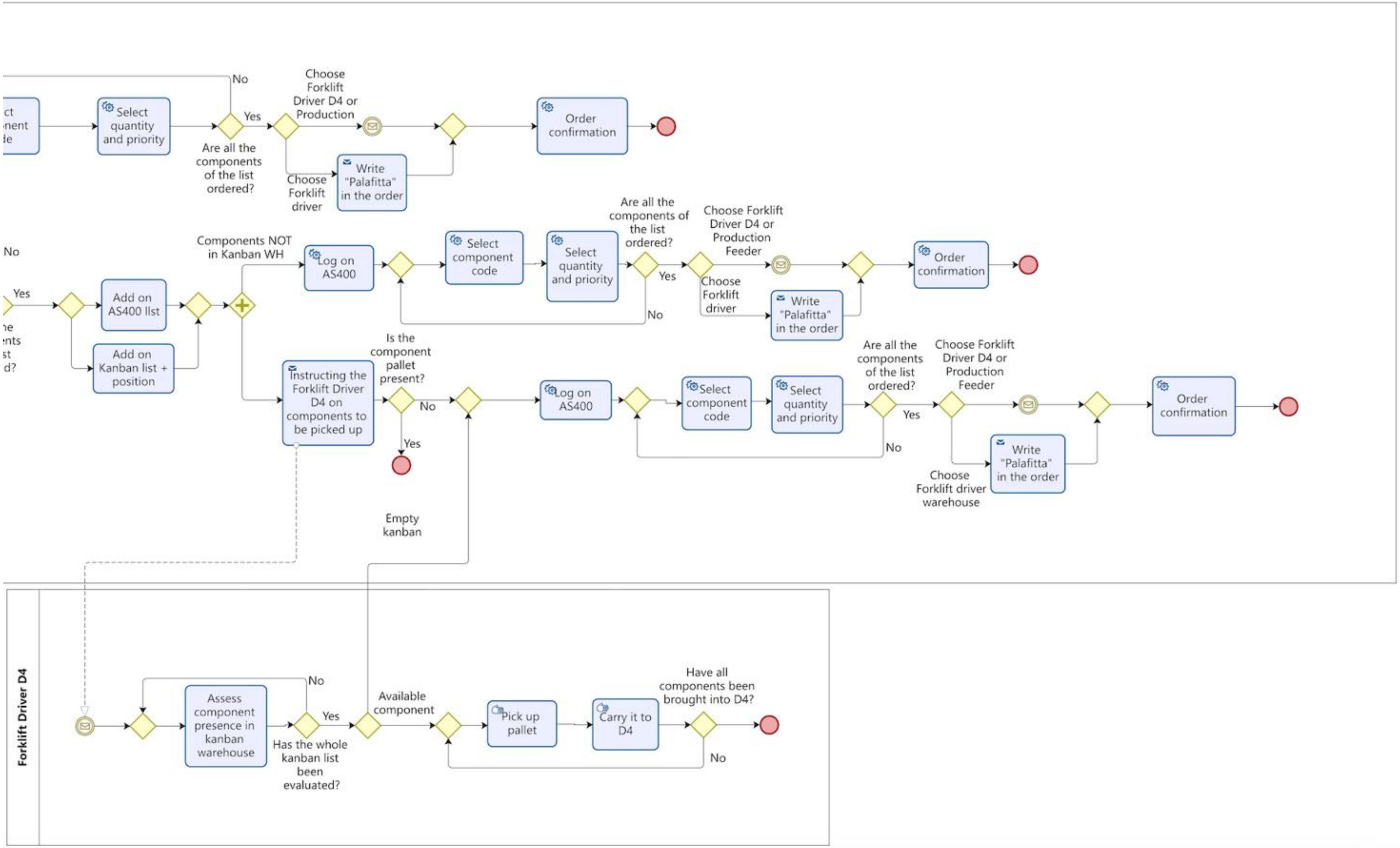



*Figure 55: Place Order Production feeder 2nd part*

### 4.3.5 Picking up Components from Warehouse

This phase can involve up to 4 different resources. The order placed by the production feeder. Order receiving, picking, and label management by the Warehouse forklift driver. If the pallet is stored in the narrow aisles reachable by the appropriate forklift driver, then picking by him is required. Lastly, transport from the warehouse to D4, and then be made available to the production feeder.

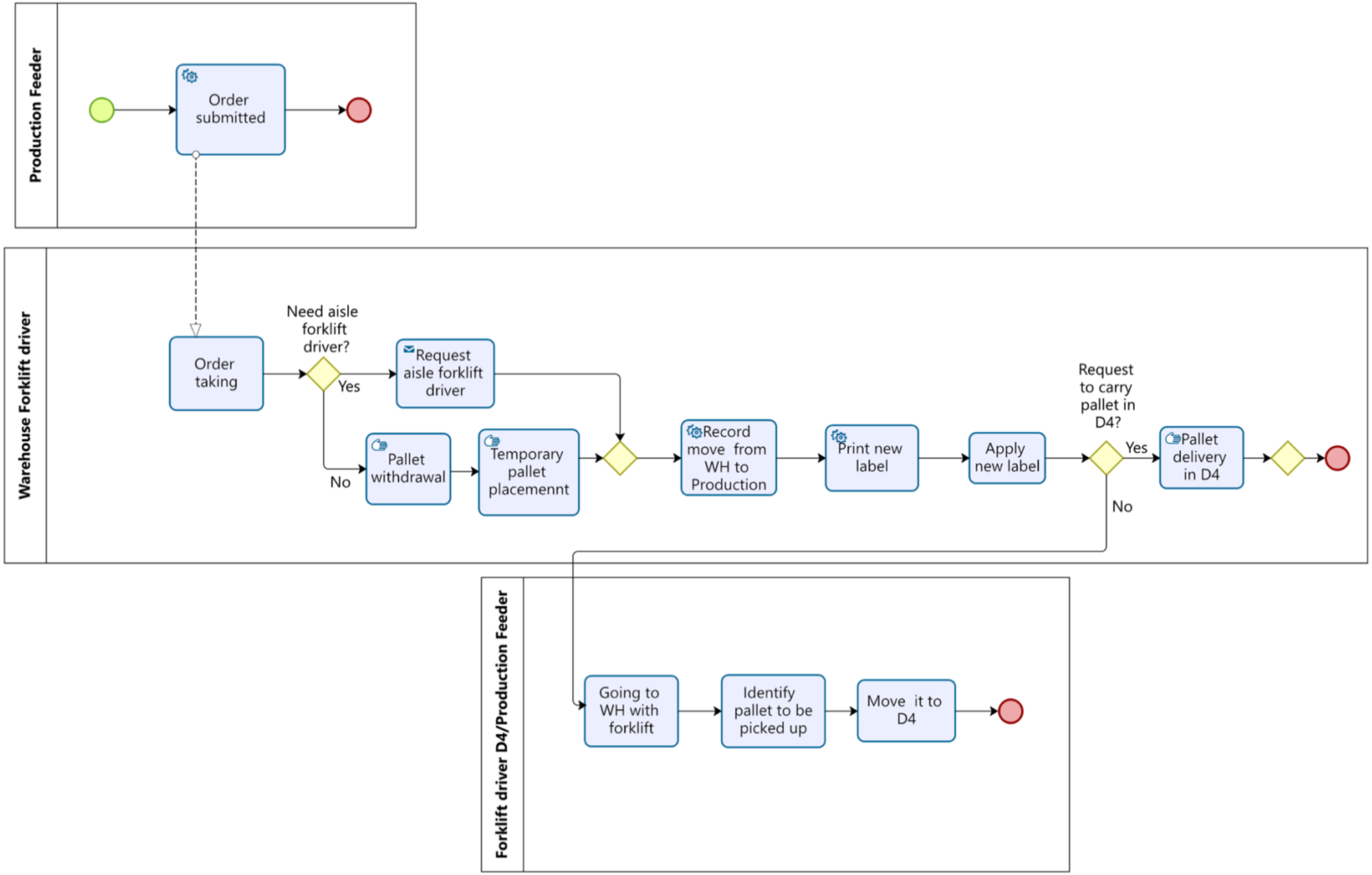



*Figure 56: Picking Up Components from WH to D4*

### 4.3.6 FP Code Change in Assembly Line

FP code change is occurrence that can happen even several times a day. In addition to involving a set-up change of the line operated by production operators, thus a downtime, it is one of the most challenging events facing the production feeder. From the point of view of material handling, semi-automatic lines in D4 are easier to handle. Line 42 is programmed to assemble two FPs (T01507/T01585), which then consist of the same components except for a single code (TF312/TF336). In fact, in the D4 supermarket there are 12 positions per pallet, 11 for the code currently being assembled and one position for the code corresponding to the other FP. Thus, returns to the warehouse are zeroed out.

| AUX | | lunedì 4 aprile 2022 | | martedì 5 aprile 2022 | |
|---|---|---|---|---|---|
| Orario 8x5 | | CODICE | QUANTITA' | CODICE | QUANTITA' |
| LINEA 42 (20342) | | T11585BB | 540 | T11585BB | 2160 |
| | | | | T11585BB | 540 |
| | | T11585BB | 2160 | | |
| prod./h | 120 | q.tà progr. | 2.700 | q.tà progr. | 2.700 |
| add. | 1 | h macch.progr. | 26 | h macch.progr. | 26 |
| eff. | 85% | h manodop. | 26 | h manodop. | 26 |

WK 14

| mercoledì 6 aprile 2022 | | giovedì 7 aprile 2022 | | venerdì 8 aprile 2022 | |
|---|---|---|---|---|---|
| CODICE | QUANTITA' | CODICE | QUANTITA' | CODICE | QUANTITA' |
| T11585BB | 2160 | T11585BB | 2160 | T11585BB | 2160 |
| T11585BB | 540 | T11585BB | 540 | T11585BB | 540 |
| q.tà progr. | 2.700 | q.tà progr. | 2.700 | q.tà progr. | 2.700 |
| h macch.progr. | 26 | h macch.progr. | 26 | h macch.progr. | 26 |
| h manodop. | 26 | h manodop. | 26 | h manodop. | 26 |

*Figure 57: Example of Production Scheduling of Line 42*

Manual lines can assemble tens of different FP codes, and can change FP codes even several times during working hours, so material handling is more delicate. In fact, comparing the two production schedules of line 42 and 32, from week 14, the difference in assembly line types is highlighted with line 42 maintaining the same FP(T01585) in 5 days and instead line 32 assembling 5 different FPs (T0L239, T0L238, T0L219, T0L408, T0L413) in 4 days.

| Distribuzione | | | | | |
|---|---|---|---|---|---|
| Orario 3x8 | | lunedì 4 aprile 2022 | | martedì 5 aprile 2022 | |
| | | CODICE | QUANTITA' | CODICE | QUANTITA' |
| LINEA32 | | T0L239EA | 2400 | T0L238EA | 1600 |
| | | | | T0L219NA | 600 |
| prod./h | 130 | q.tà progr. | 2.400 | q.tà progr. | 2.200 |
| add. | 4 | h macch.progr. | 22,2 | h macch.progr. | 20,4 |
| eff. | 83% | h manodop. | 89,0 | h manodop. | 81,6 |
| | | q.tà rita.progr. | | q.tà rita.progr. | |

**WEEK 14**

| mercoledì 6 aprile 2022 | | giovedì 7 aprile 2022 | | venerdì 8 aprile 2022 | |
|---|---|---|---|---|---|
| CODICE | QUANTITA' | CODICE | QUANTITA' | CODICE | QUANTITA' |
| T0L219NA | 525 | T0L408DA | 490 | | |
| T0L408DA | 1700 | $T0L408DA | 500 | | |
| | | T0L0413DA | 1200 | | |
| q.tà progr. | 2.225 | q.tà progr. | 2.190 | q.tà progr. | 0 |
| h macch.progr. | 20,6 | h macch.progr. | 20,3 | h macch.progr. | 0,0 |
| h manodop. | 82,5 | h manodop. | 81,2 | h manodop. | 0,0 |
| q.tà rita.progr. | | q.tà rita.progr. | | q.tà rita.progr. | |

*Figure 58: Example of Production Scheduling of Line 32*

For line 42, in the code change then you evaluate the different component if it is in the supermarket and eventually order it. Instead, the other component that previously went into production is removed from the line flow rack and repositioned in SM D4. In this way, the return, which is an expensive operation in terms of number of movements, will be avoided and the component will be available for the next code change. The diagram was represented with the line change from T01507 to T01585, obviously the reverse change applies with the difference that the presence of T0312 in SM D4 is evaluated.

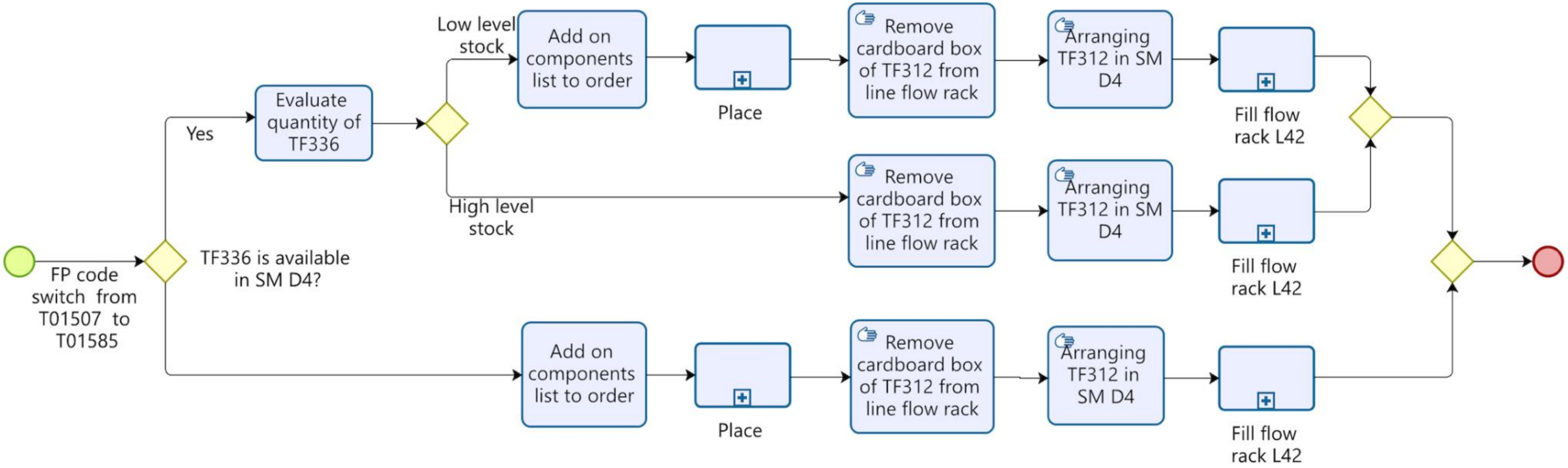



*Figure 59: FP Code Change in L42*

The FP code change of line 32 is a more delicate operation than line 42. If handled improperly, it can cause several inefficiencies. The first task performed is to print BoM of the new FP code and compared with the previous BoM, act to evaluate any codes in common. If there are components in common, the presence in both the line flow rack and SM D4 gravity is evaluated, and if found positive, the quantities in overall that resides in Dayco 4 are evaluated. On the other hand, if there are no components in common, a visual check in SM D4 is carried out because they may be residual component codes from the previous days' assembly codes. Once any codes in common and quantities have been evaluated, a list is compiled with component codes not in common along with codes in common but with low or no stock levels in D4, to then be ordered and supplied to the assembly line.

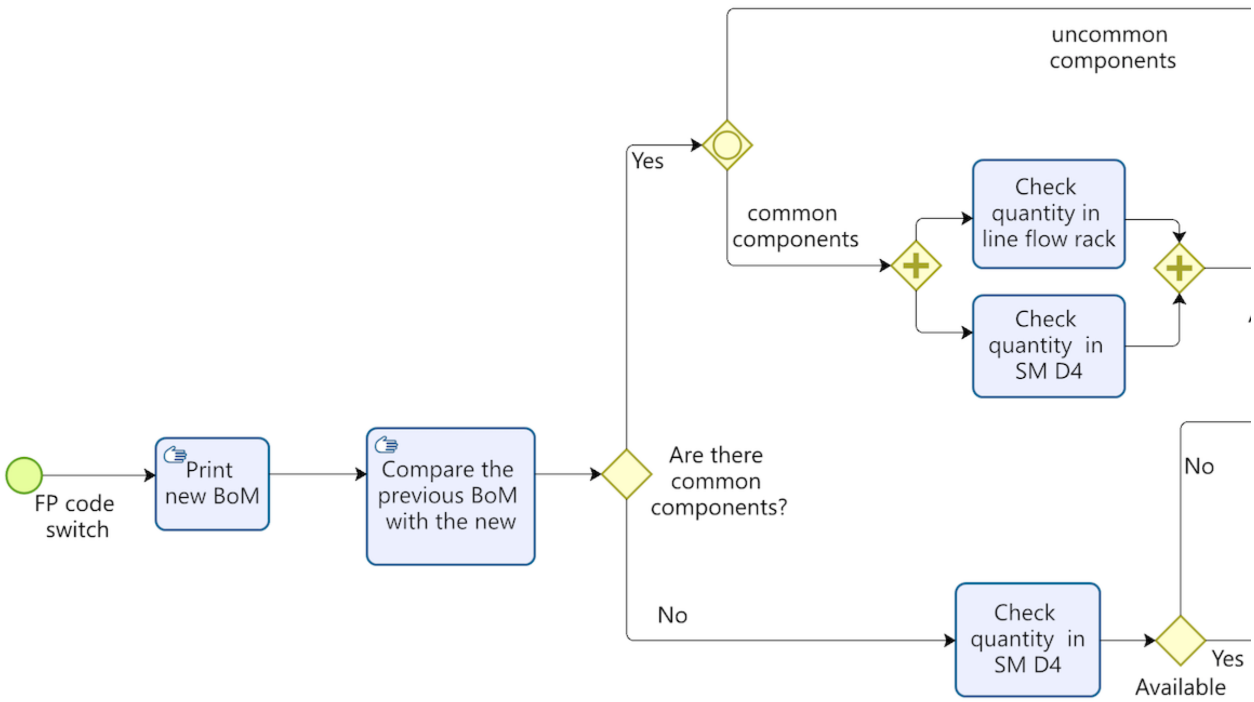



*Figure 60: FP Code Change in L32 1st part*

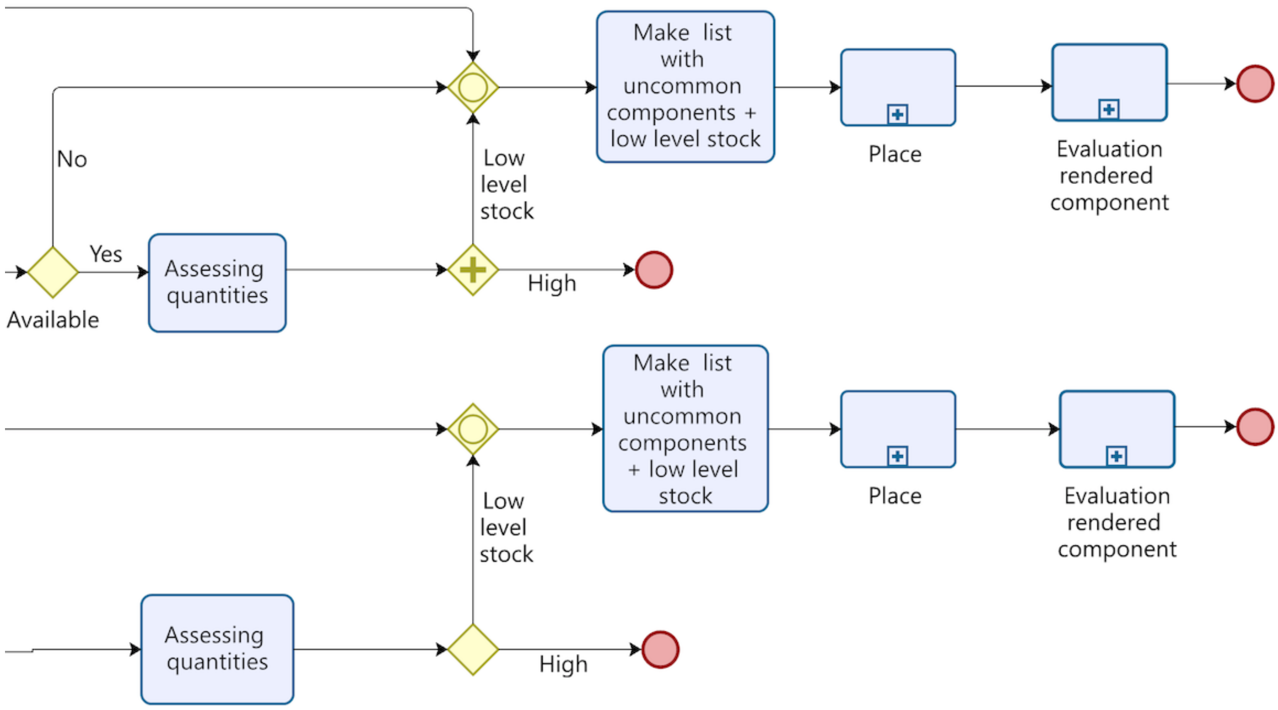
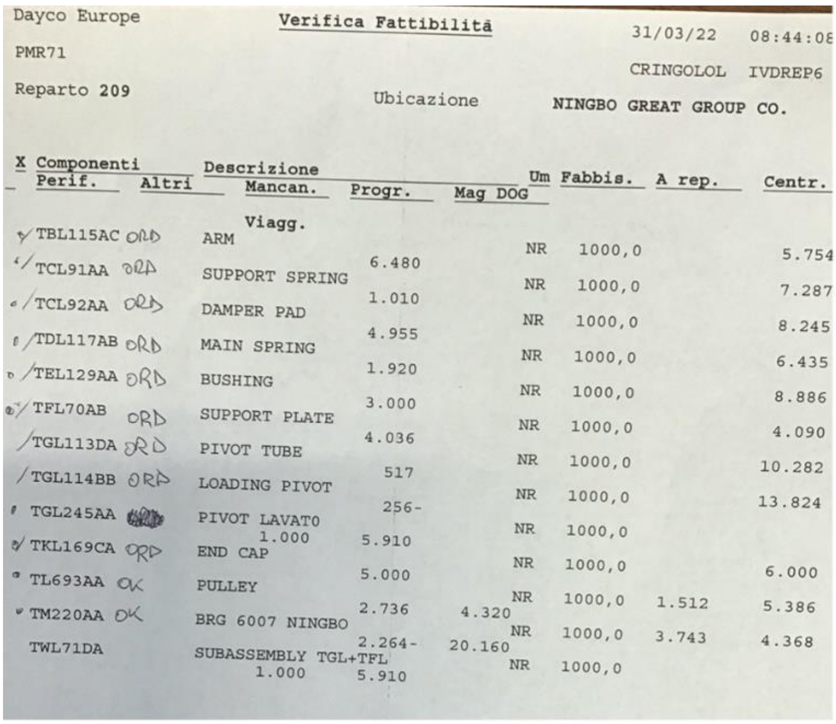



*Figure 61: FP Code Change in L32 2nd part*

The photo below shows the order executed by the production feeder, in an FP code change from T0L465 to T0L239.The two FPs have no component code in common. After performing checks in SM D4, and finding that two component codes were available, the operator proceeded with ordering the other 10 missing components.


Dayco Europe Verifica Fattibilità 31/03/22 08:44:08
PMR71 CRINGOLOL IVDREP6
Reparto 209 Ubicazione NINGBO GREAT GROUP CO.

| Componenti Perif. | Altri | Descrizione | Mancan. Viagg. | Progr. | Mag DOG | Um | Fabbis. | A rep. | Centr. |
|---|---|---|---|---|---|---|---|---|---|
| TBL115AC | ORD | ARM | | 6.480 | | NR | 1000,0 | | 5.754 |
| TCL91AA | ORD | SUPPORT SPRING | | 1.010 | | NR | 1000,0 | | 7.287 |
| TCL92AA | ORD | DAMPER PAD | | 4.955 | | NR | 1000,0 | | 8.245 |
| TDL117AB | ORD | MAIN SPRING | | 1.920 | | NR | 1000,0 | | 6.435 |
| TEL129AA | ORD | BUSHING | | 3.000 | | NR | 1000,0 | | 8.886 |
| TFL70AB | ORD | SUPPORT PLATE | | 4.036 | | NR | 1000,0 | | 4.090 |
| TGL113DA | ORD | PIVOT TUBE | | 517 | | NR | 1000,0 | | 10.282 |
| TGL114BB | ORD | LOADING PIVOT | | 256- | | NR | 1000,0 | | 13.824 |
| TGL245AA | [illegible] | PIVOT LAVATO | 1.000 | 5.910 | | NR | 1000,0 | | |
| TKL169CA | ORD | END CAP | | 5.000 | | NR | 1000,0 | | 6.000 |
| TL693AA | OK | PULLEY | | 2.736 | 4.320 | NR | 1000,0 | 1.512 | 5.386 |
| TM220AA | OK | BRG 6007 NINGBO | | 2.264- | 20.160 | NR | 1000,0 | 3.743 | 4.368 |
| TWL71DA | | SUBASSEMBLY TGL+TFL | 1.000 | 5.910 | | NR | 1000,0 | | |

*Figure 62: Order Executed by AS400 for L32*

| FP-T0L405 | FP-T0L239 |
| --- | --- |
| TCL163 | TGL114 |
| TCL168 | TWL165 |
| TDL188 | TBL115 |
| TGL209 | TCL91 |
| TWL103 | TCL92 |
| TL751 | TDL117 |
| TM071 | TEL129 |
| TM276 | TK169 |
| TM339 | TL693 |
| TWL104 | TM220 |
| TFL119 | TFL70 |
| TGL204 | TGL245 |

Table 9: Component Codes of T0L405 and T0L239

### 4.3.7 Evaluate Rendered components

When an FP code change takes place, given the large number of components to assemble an FP, it is inevitable that some code will not be leftover. Removed from the assembly line to make room for the new components, the production feeder must consider whether to initiate return or store them in SM D4. This process does not affect line 42 where the difference between FP code and the other is only one component which is then stored in SM D4. Therefore, when an FP code change occurs in line 32, the production plan is checked and evaluated whether the code in the following days will resume assembly, if affirmative then the code is from the line is put back into SM D4, otherwise it is evaluated based on the quantities in both the line and SM whether to make the return or not.

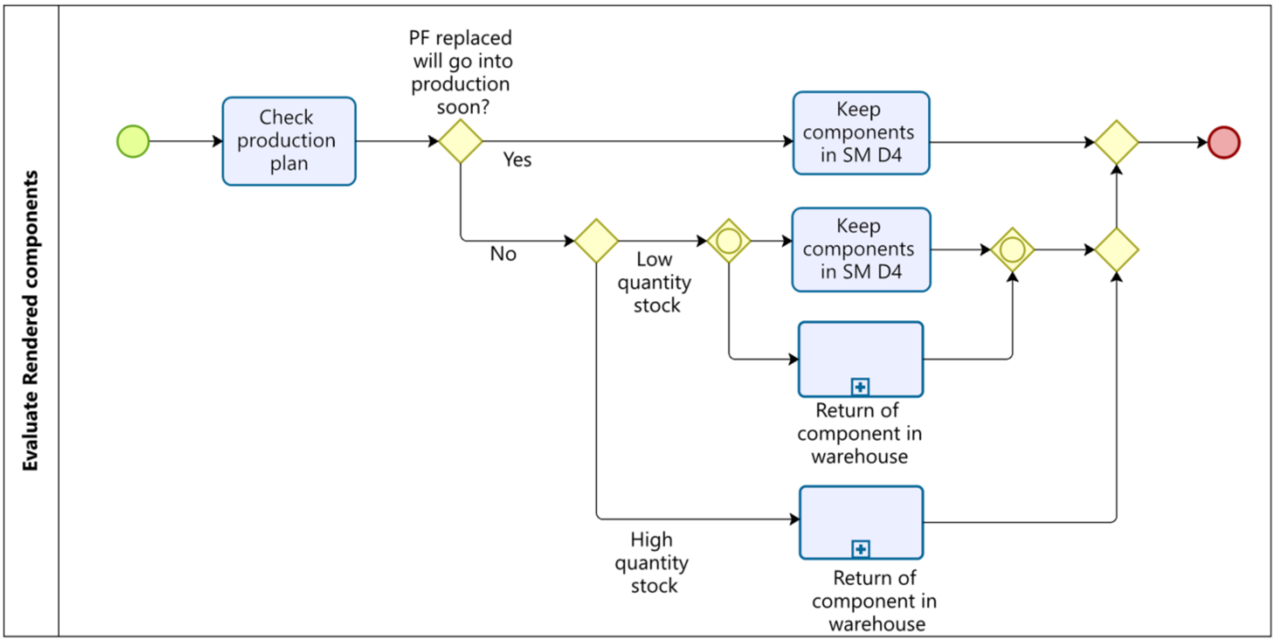



*Figure 63: Evaluated Return Component*

### 4.3.8 Return Component

The process of returning components in warehouse takes significant effort and time and involves at least 3 different resources to bring the material back to the warehouse. Once the production feeder has decided to render the components, it unloads the line flow racks and the SM D4 gravity flow rack, to place the boxes into one or more pallets. After performing this step, it alerts the D4 forklift driver to continue with the return operations. It is checked whether the code has a location in the Kanban warehouse. If it has a location and it is empty the pallet is placed there, this avoids passing through the returns area. Otherwise the pallet is left in the returns area and given to the warehouse worker in responsibility for returns. The return WH worker when the pallet arrives has the task of identifying the component being rendered, weighing the pallet and counting the components and then recording them on AS400. After these steps are done, a film is applied to the pallet because it needs to be repositioned in the warehouse and thus prevent boxes from falling from high heights. Finally, the pallet is left in a specific warehouse area where it will be picked up by the forklift driver and placed in the shelves.

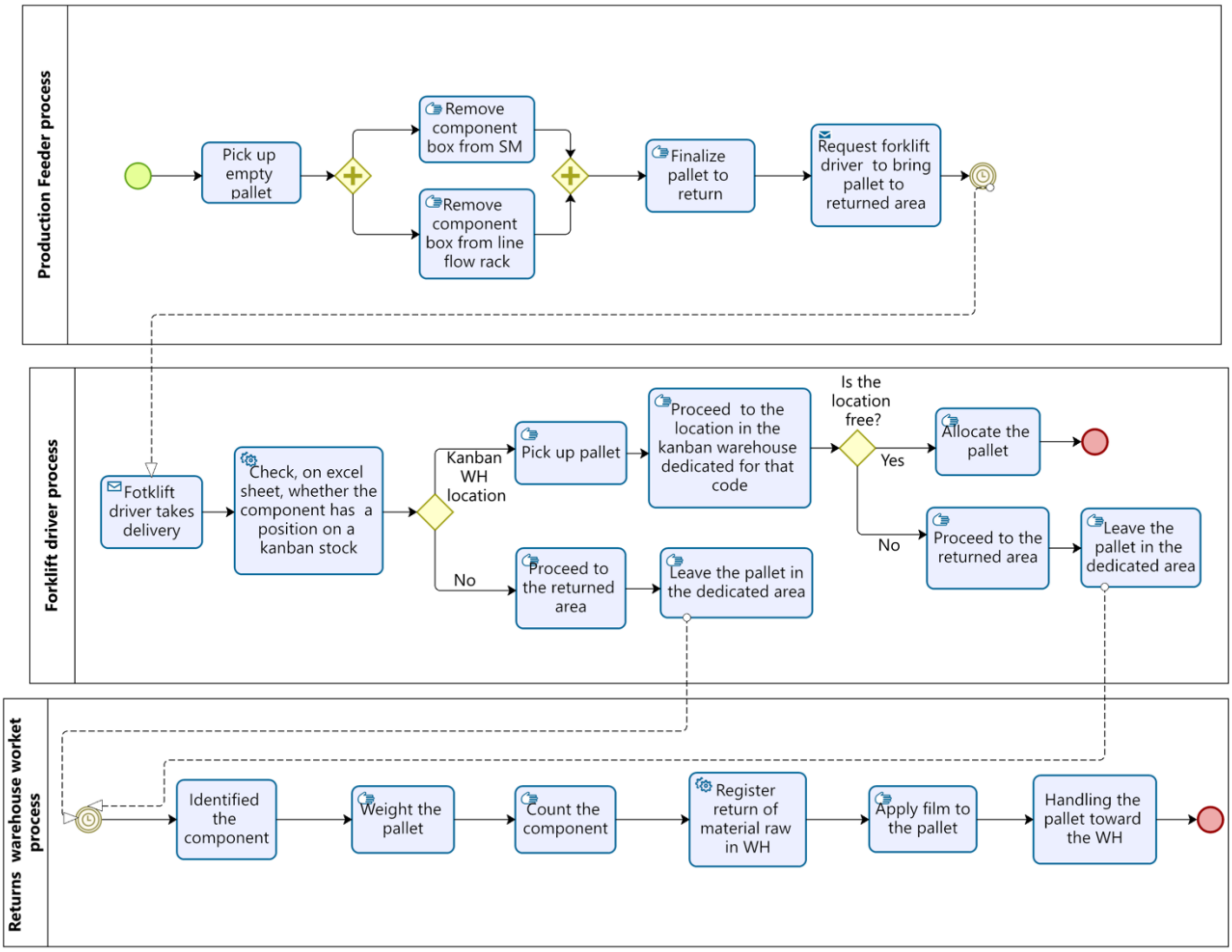



*Figure 64: Return Component*

## 4.3.9 Fill Supermarkets D4

Pallets arrived at D4, are temporarily allocated near the entrance and then sorted by the production feeder. Pallets from the warehouse to D4 are moved by:

- forklift driver D4 (this resource is only present in the 8 a.m. to 4 p.m. shift)
- forklift driver warehouse
- or, by the production feeder itself (especially when it is an urgency)

When a pallet of a component arrives, and the assembly line needs that component, it is obviously not stored in the supermarket but goes directly to the line. Otherwise, if the pallet is addressed to lines 39 and 42, it is placed in the SM traditional shelves, whereas if for lines 8, 19, and 32 they are placed in the SM gravity flow rack. If the line is run with the KanbanBox, then the packages are labeled first, otherwise they go directly into the flow racks on the line.

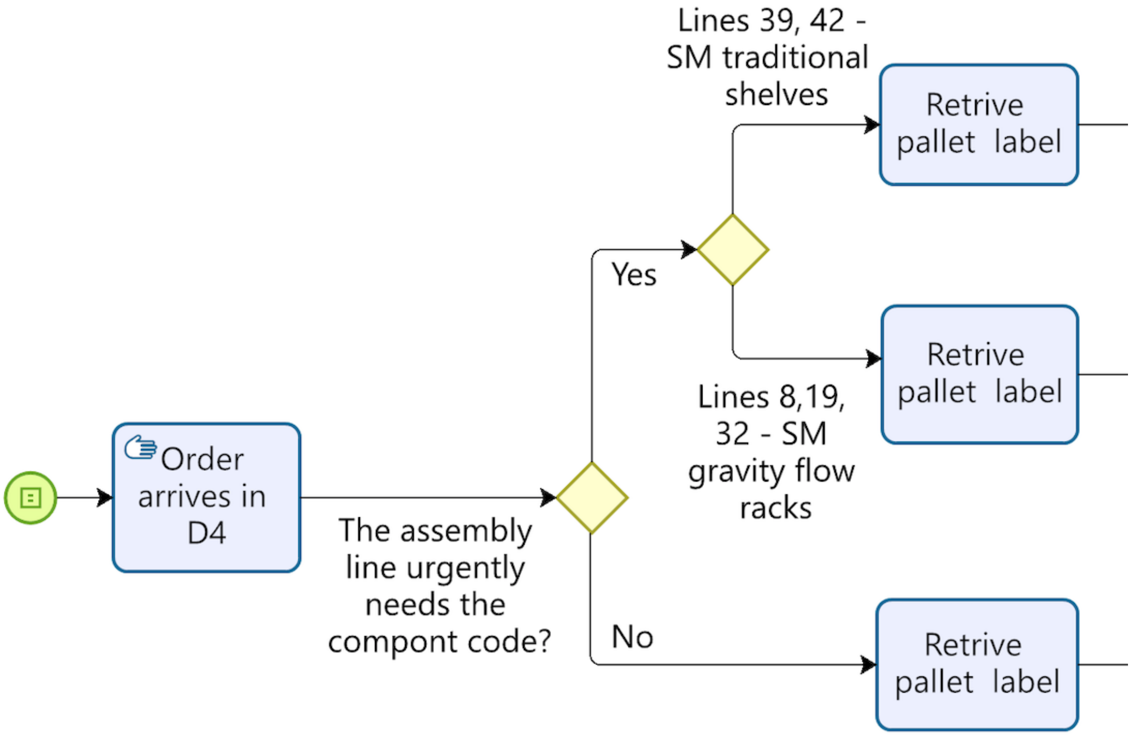



*Figure 65: Fill Supermarket D4 1st part*

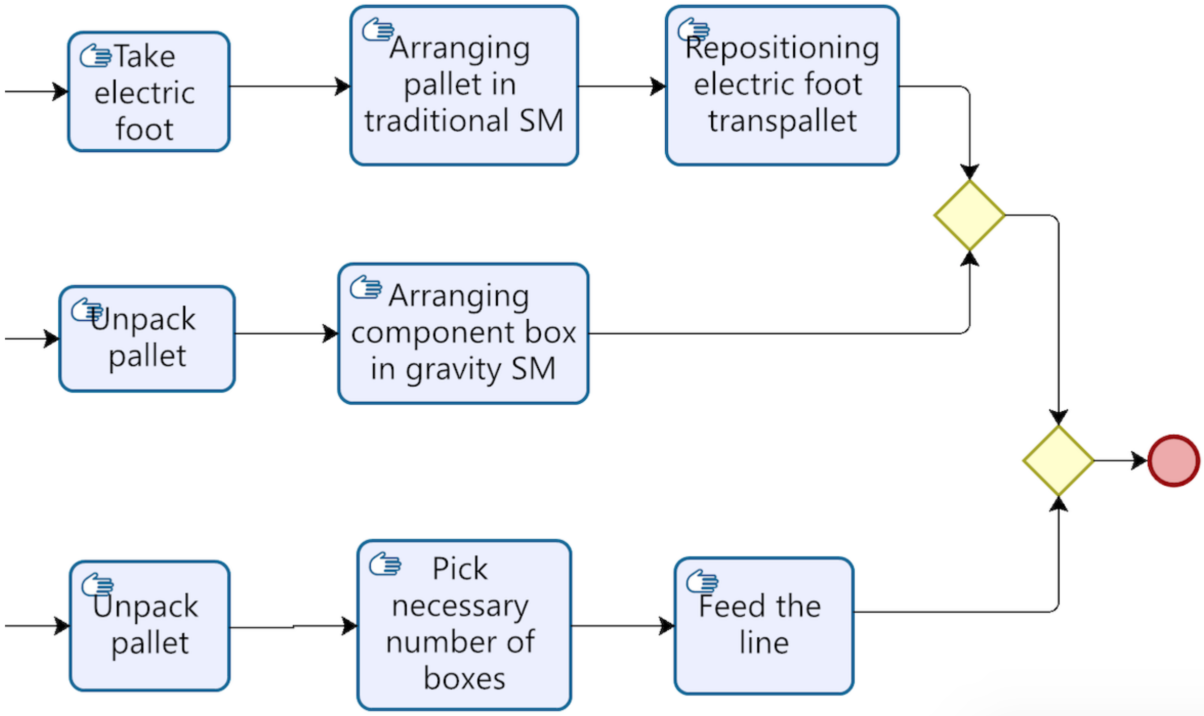



*Figure 66: Fill Supermarket D4 2nd part*

# 4.3.10 Current Kanban Rack and SM Capacity

The KanbanBox software enable the management of material procurement in supplier-side (SM D4) and customer-side (Flow rack line). At the time of implementation, October 2021, the software was programmed to manage both the supplier and customer side. After a short period of time, supplier-side management was eliminated; this occurred for a number of reasons:

- Prior to placement in the supermarket, all boxes had to be labeled
- The production feeder did not use this feature because SM is located in D4 near the line and thus visually can estimate the quantities of pallets present.

SM D4 is shared between line 39 and 42, which produce the same FPs. Line 39 has an average throughput of 200 parts/hour, so the two shared lines consume an average of 300 parts/hour. And since each code component has a single pallet position, there is a lot of difference as station times in the SM between pallets. For example, with average 300 parts/hour and working all three shifts, TB540 needs 4 daily pallets, while TQ862 needs 8 working days to be consumed.

| T01585/ T01507 | Pallet | Box | pcs/box | pcs/pallet | | Length [cm] | Width [cm] | Height [cm] |
|---|---|---|---|---|---|---|---|---|
| TC144 | 1 | 24 | 300 | 7200 | Cardboard | 40 | 30 | 20 |
| TE827 | 1 | 24 | 240 | 5770 | Odette | 40 | 30 | 21.5 |
| TL1098 | 1 | 32 | 75 | 2400 | Odette | 40 | 30 | 17 |
| TB540 | 1 | 32 | 60 | 1920 | Cardboard | 40 | 30 | 17 |
| TF336/TF312 | 1 | 32 | 120 | 3840 | Cardboard | 40 | 30 | 17 |
| TK181 | 1 | 25 | 600 | 14870 | Odette | 40 | 30 | 21,5 |
| TD179 | 1 | 48 | 70 | 3360 | Cardboard | 30 | 20 | 18 |
| TN049 | 1 | 12 | 800 | 9600 | Cardboard | 40 | 30 | 17 |
| TP351 | 1 | 48 | 250 | 12000 | Cardboard | 28 | 20 | 9 |
| TQ362 | 1 | 30 | 2000 | 60000 | Cardboard | 24 | 22 | 14 |
| TQ380 | | 1 | 25 kg | | | | | |

Table 10: Supermarket D4 L39/42 Capacity

The loading of full pallet and unloading of empty pallet is done by electric foot pallet truck, and it takes place in the aisle side D4. In contrast, the unloading of the boxes from the SM with subsequent loading of the AGV takes place in the opposite side (as pictured). Picking up the boxes in the upper floor of D4 must be done with the help of electric foot pallet truck, bringing the pallet back to a lower height, because the boxes are above the worker's shoulder height.
This brings a difference in timing for box picking between the lower and upper floors.


*Figure 67: Supermarket D4 L39/42*

The design of the client-side KanbanBox was constrained greatly by the size of the gravity flow rack in L42. In fact, there is no real uniformity in the total number of components in the line flow rack and when it is replenished with all components, it has no room for more boxes. The problem of the difference in quantities in the rack is due to the:

- difference in the number of components in the boxes between one code and another.
- Difference in box sizes
- Small size of the Gravity flow rack

For example, comparing the box of the TE287, which holds 240 pcs, with the TB540, which holds 60 pcs, but the gravity flow rack provides 4 slots for both codes. So there is a significant divergence in the number of components in the line.

In contrast, the TQ862 that for each box involves the presence of 2,000 pieces, and thus have a runtime of about 20 hours of production, involves the continuous presence of 2 boxes due to the fact that the production worker scans the label only when the box is finished and thus avoids the risk of blocking the line for this code.

| | | | | Throughput [pcs/h] | 100 | 138 |
|---|---|---|---|---|---|---|
| | Number of box | Pcs/box | Rack quantity | Position | Lifetime[h] without replenishment | Lifetime[h] without replenishment |
| TC144 | 2 | 300 | 600 | Rack | 6,0 | 4,3 |
| TE287 | 4 | 240 | 960 | Rack | 9,6 | 7,0 |
| TL1098 | 4 | 75 | 300 | Belt Conveyor | 3,0 | 2,2 |
| TB540 | 4 | 60 | 240 | Rack | 2,4 | 1,7 |
| TF336/TF312 | 3 | 120 | 360 | Rack | 3,6 | 2,6 |
| TK181 | 2 | 600 | 1200 | Rack | 12,0 | 8,7 |
| TD179 | 4 | 70 | 280 | Rack | 2,8 | 2,0 |
| TN049 | 2 | 800 | 1600 | Load Floors | 16,0 | 11,6 |
| TP351 | 3 | 250 | 750 | Load Floors | 7,5 | 5,4 |
| TQ362 | 2 | 2000 | 4000 | Load Floors | 40,0 | 29,0 |

Table 11: Material Consumption L42

The photos show the flow rack of line 42 just after loading operations are completed. It consists of 4 floors and 2 rows on each floor. In floor 1, two codes are arranged that have boxes available at the assembly station to prevent the operator from picking up components at the bottom with each assembled part. Floors 2 and 3 are arranged with favorable heights for the operator, so the operator picks up directly from the rack. Unlike floor 1, there is no space for additional boxes on these two floors. Instead, floor 4 is unused because with the addition of the boxes, the height to pick up components is high.


*Figure 68: Front and Side View Gravity Flow Rack L42*

# 5 Application of Lean Manufacturing Concepts

In the present  chapter, the Lean Manufacturing tools previously described are applied. Through the use of Spaghetti charts and Gemba walks, various critical issues will be detected in the feeding of assembly lines. Lastly, to identify the root causes of the problems, the 5whys technique is applied.

## 5.1 Spaghetti Chart L32

The spaghetti chart in Figure 69  represents the analysis of FP code T0L120.

- The first 3 phases correspond to the handling of incoming goods to warehouse storage and corresponds to the spaghetti chart of line 42.
- Phase 4 can be divided into 3 different types of Warehouse forklift driver movements:
    1. Unloading and temporary placement in WH where then the various pallets will be picked up by WH Driver D4.
    2. Pallet placement in Kanban warehouse.
    3. Transporting pallets to the washing area. Code T0L120 stipulates that the pivot (TGL66) before going to the assembly line needs a piece washing step (TGL67).
    In addition to pallet handling, computer-level processing takes place on AS400. In fact, components are transferred from the warehouse department to production.
- Phase 5, the D4 warehouse driver in central warehouse picks up the various pallets and transports them to D4, instead for the components arranged in the kanban warehouse provides kitting by making the rounds in the kanban warehouse and picking up specific quantities of the various components. If the quantities to be picked up are not large, arrange to prepare the kit on a single pallet and then take it to D4.
- Phase 6 involves the production feeder, which is responsible for unpacking the various pallets to store the boxes in SM 32 and then later is either AGV replenished or is manually replenished, replenishing from SM 32.
- Phase 7, represents the route performed by the AGV.  It depicts the route from the recharging station, where the AGV is stationed when it needs to be recharged or there are no missions to be performed, to the AGV loading bay near SM 32, and then perform replenishment and eventually return to the recharging station.
- Phase 8, unloading from L32 of the FP pallet to entry aisle D4 where it is temporarily placed. Step carried out by the production feeder performed by electric foot transpallet because entry by forklift is prohibited in the assembly line aisle.
- The last 4 phases correspond to those of line 42 and the other D4 lines.

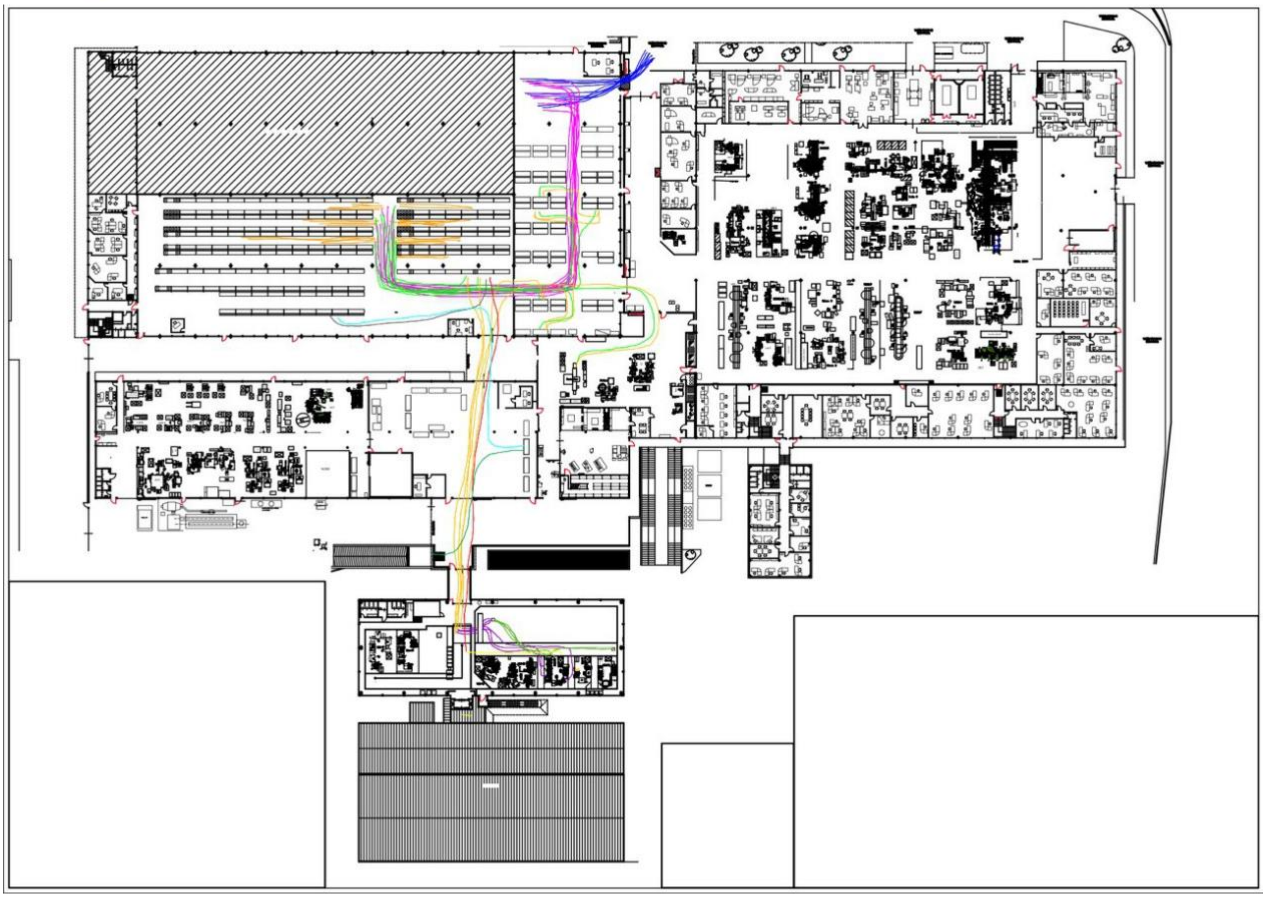


*Figure 69: Spaghetti Chart L32*

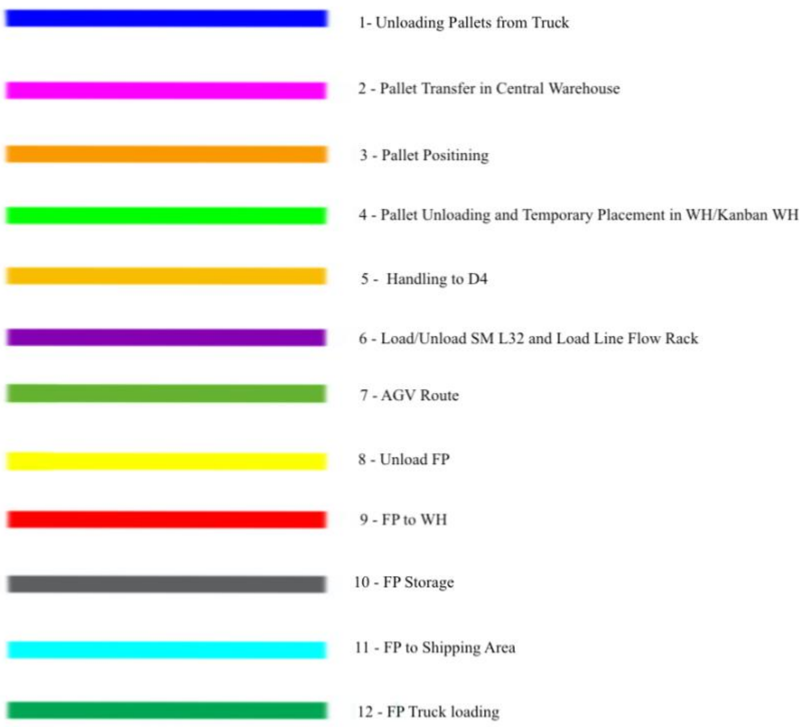



*Figure 70: Legend Spaghetti Chart L32*

Criticalities detected:

1. High distance between receiving area and assembly line.
2. The pallets unloaded from the central warehouse do not have a defined area where they can be temporarily placed while waiting to be taken over by the forklift driver. Therefore, they are positioned where they find free space between the central warehouse and the kanban warehouse.
3. Traffic jam between central warehouse and the kanban warehouse
4. The many codes that compose the FP, are transported up to the supermarket of Dayco 4, involves high movements covering long distances and also returning unloaded
5. AGV route not optimized, long distances between charging station and material pickup.
6. Many small movements involving different resources.

# 5.2 Gemba Walk L32

Gemba walks which indicates the action of going to see the actual process, understanding the work, asking questions and learning from those doing the work. It is an opportunity for management and support staff to break away from their daily tasks to walk the floor of their workplace and identify wasteful activities. The goal is to understand the value stream and its problems [20]. Through this approach, criticalities were derived as listed below:

1. Component quantity management on the line is handled manually, so the production feeder must go to the line and check the quantities available in the various gravity flow racks. Not yet programmed with KanbanBOX software. If there is urgency of one or more part numbers, it may happen that before the production feeder notices the lack of material, it is requested vocally by the production line worker to the production feeder.
2. L32 has 2 supermarkets that are located in the assembly line. Both can be replenished through AGVs, however, only one feeds one station directly, the other is used as an additional SM storing boxes for later transfer to the gravity flow rack at the various stations.
3. AS400 order: the production feeder orders the material with a symbolic 1000 pieces. From the warehouse comes both whole pallets with quantities greater than one thousand pieces and unpacked pallets with quantities less than 1000 pieces.
4. Arrival goods from the warehouse without priority. The times change according to who takes in charge and from the workload that has in that moment. It happens that goods ordered to beginning shift arrives after hours and other goods ordered after arrives before
5. This line of production changes code at least once to the day, when it comes ordered the goods the line feeder does not look at the quantities to produce. This involves that or boxes of the members will be rendered, therefore ulterior movements, or allocated in the supermarket waiting that in the next few days that code comes used
6. It may happen that the production schedule changes and does not correspond to the logistics program. If the Production Feeder is not updated, there is a risk of a line stop.
7. The kit in the Kanban warehouse is run with unsuitable tools, the forklift driver prepares the kit on a pallet that he transports during the tour in the warehouse. For the boxes that he has to pick up from a pallet, the operator must place the pallet kit on the ground, unload the

component pallet, load the necessary boxes into the pallet kit, reposition the component pallet, and finally pick up the pallet kit to move on to the next operation.

8. Line 32 is powered by the line feeder through to 2 floor racks on board the line and a multi-storey cart moved with the AGV. Only one floor rack is next to the work station, to supply the other work stations the production worker must go and get the material from the floor rack adjacent to the line and from the multi-storey cart and supply his own line feeding floor rack.
9. Occasionally, the production program undergoes changes and does not correspond to the logistics program. if the line feeder is not updated, there is a risk of a line stop.
10. The production feeder cannot assess the availability on the software of codes in Kanban warehouses, only if that code has a defined location.

## 5.3 Spaghetti Chart L42

A spaghetti diagram is defined as a visual representation using a continuous flow line tracing the path of an item or activity through a process. As a process analysis tool, the continuous flow line enables process teams to identify redundancies in the work flow and opportunities to expedite process flow [19]. The diagram in figure 71 shows the required handling of the numerous components to obtain a finished product and its shipment.

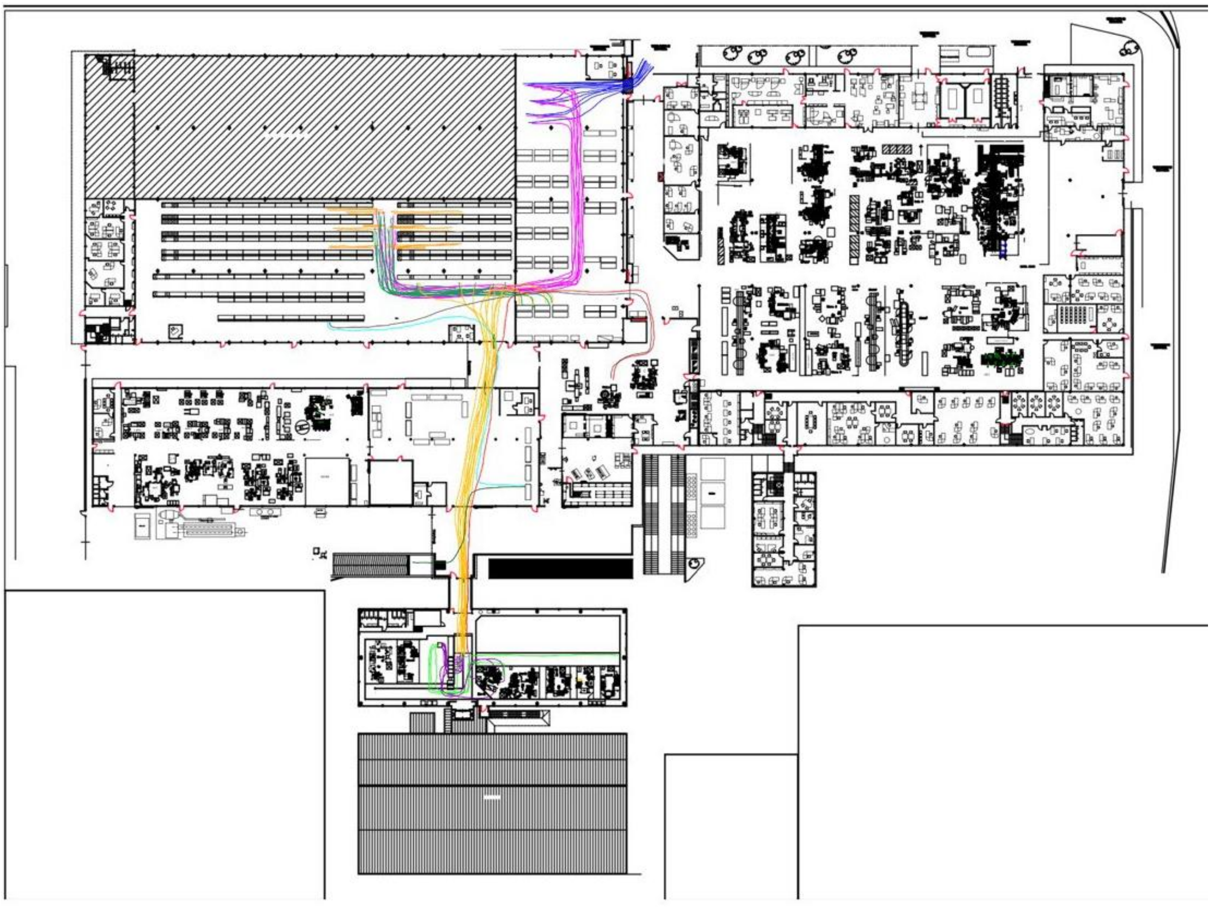


*Figure 71: Spaghetti Chart L42*

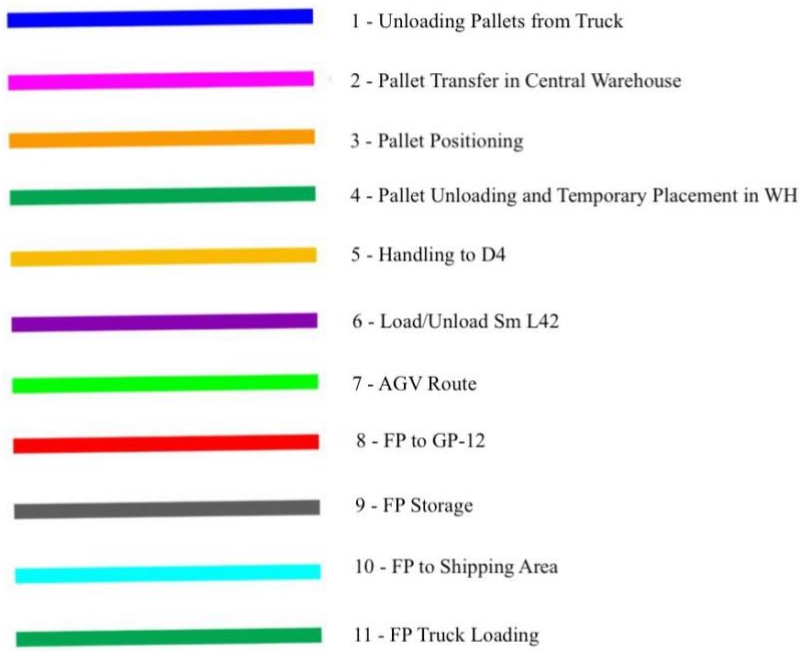



*Figure 72: Legend Spaghetti Chart L42*

The first 3 phases represented in the spaghetti chart are in common for all codes arriving in the plant.

- Phase 1, concerns the receiving area, where pallets are unloaded from the outside loading bay and then temporarily allocated inside. The resource involved is a warehouse forklift driver assigned in unloading pallets in the receiving area.
- Phase 2, after registration in the information system and subsequent placement of labels in the pallets, the pallets are transferred to the central warehouse. They are released in the proximity of forklifts for narrow aisles.
- Phase 3, involves placing the pallets in the warehouse racks. There is no predefined position for the various pallet codes, but they are placed at the first free position. Once the allocation has been chosen, the operator must scan the barcode of the pallet and the barcode of the location in the rack in order to assign a location for the pallet in the computer system.

From phase 4, the processes of supplying the Dayco 4 lines changes from the other lines in the plant.

- Phase 4, input is given through the order on AS400. In fact, the warehouse operator once the order is displayed provides the unloading operations from the rack. Once the pallet is unloaded, there is no specific area to temporarily place it, but it is usually placed close between the central warehouse and The Kanban warehouse.
- Phase 5, pallet handling from Central Warehouse to D4. Handling is done with the help of the front forklift mainly by the D4 forklift driver, but it can also be done by the warehouse forklift driver or the production feeder. Once the pallet arrives at D4, it is released to the entry area near the D4 SMs.

- Phase 6, involves the production feeder, which is in charge of loading SM D4. Line 42, is set on an SM traditional shelves, then with the use of an electric foot transpallet the operator arranges the pallets in it.
- Phase 7, concerns the supply of line 42. The gravity flow rack and belt conveyor are fed by the AGV instead the other loading points are done manually by the operator using the hand trolleys.
- Phase 8, Finished Product is withdrawn from the line and taken to the specific area GP-12 to perform 100% control of FPs leaving line 42. The pallet is handled by Forklift driver D4, but if necessary it can be performed by other resources.
- Phase 9, once the pallet passes quality control, it is stored in the warehouse in the customer-specific area.

From this stage, processes begin to align with the other lines again.

- Phase 10, on the day of shipment, the pallet is transferred from the warehouse to the shipping area by the forklift drive warehouse.
- Phase 11, the last step, where pallets are loaded into the truck via the outside loading bay with the shipping warehouse worker

Criticalities detected:

1. High distance between the receiving area and the assembly line
2. The pallets unloaded from the central warehouse do not have a defined area where they can be temporarily placed while waiting to be taken over by the forklift driver. Therefore, they are positioned where they find free space between the central warehouse and the kanban warehouse.
3. Traffic jam between central warehouse and the kanban warehouse
4. The many codes that compose the FP, are transported up to the supermarket of Dayco 4, involves high movements covering long distances and also returning unloaded
5. AGV route not optimized, long distances between charging station and material pickup.
6. The SM D4 and L42 are very close together however, the loading area of the agv and manual servicing of the SM D4 is on the opposite side from the line. This provides for a longer route for the AGV or production feeder to run.
7. The FPs of the L42 undergo 100% inspection. High distance between the assembly line and GP12.

# 5.4 Gemba Walk L42

Gemba walks indicates the action of going to see the actual process, understanding the work, asking questions and learning from those doing the work. It is an opportunity for management and support staff to break away from their daily tasks to walk the floor of their workplace and identify wasteful activities. The goal is to understand the value stream and its problems [20].Through this approach, criticalities were derived as listed below:

1. The kanban labels that define the number of boxes that must fit in the rack, are calculated according to the available space of the floor rack instead of the quantities of the individual boxes.
   For example:

| | Number of box | Pcs/box | Rack Quantity |
|---|---|---|---|
| TE287 | 4 | 240 | 960 |
| TL1098 | 4 | 75 | 300 |
| TB540 | 4 | 60 | 240 |

*Table 12: L42 Rack Quantity, Data Extracted From Table 11*

2. L42 has not been optimally designed for supplying with AGV, in fact the loading points of the line are 5, excluding the grease, and only 2 you can feed with the AGV.
3. High line loading times. The SM D4 is composed of two floors. When an odette/box has to be picked up from the $2^{nd}$ floor, the pallet truck has to be used to bring the pallet under shoulder height and only afterwards the Odette/box can be picked up.
4. There is no location for empty odettes/boxes when they are to be removed from the floor rack.
5. The KanbanBOX is used exclusively as a supplier of the production line, the quantities of pallets available in the supermarket are not implemented so the production feeder can evaluate the availability only visually.
6. If production feeder is workloaded, , it feeds the line without proceeding with the kanban labels and therefore the availabilities on the screen do not correspond with those in the floor rack.
7. Pallets from warehouse to D4 arrive without priority, timelines change depending on the workload of operators.

## 5.5 Five Whys

Five whys (5 whys) is a problem-solving method that explores the underlying cause-and-effect of particular problems. The primary goal is to determine the root cause of a defect or a problem by successively asking the question "Why?". The number '5' here comes from the anecdotal observation that five iterations of asking why is usually sufficient enough to reveal the root cause. In some cases, it may take more or fewer whys, depending on the depth of the root cause.

The Benefits of Five Whys:

- Helps identify the root cause of a problem
- Understand how one process can cause a chain of problems
- Determine the relationship between different root causes
- Highly effective without complicated evaluation techniques [21]

| **Inefficiencies** | **Waste classification** |
|---|---|
| Traffic jam between central warehouse and the kanban warehouse | Transport |
| Amount of the number of components in the flow rack at full load diverged between the various codes that make up the FP | Inventory |
| High movements between WH and D4 | Transport |
| Partial supply of components for L32 through the use of AGVs | Transport |
| Returned pallet in WH | Overprocessing, Transport |
| KanbanBOX not implemented in L32 | Inventory |
| Null withdrawal in Kanban of the WH driver D4. | Inventory |

*Table 13: Waste Classification*

| | |
|---|---|
| Inefficiency | Traffic jam between central warehouse and the kanban warehouse |
| Why is there traffic jam? | The pallets unloaded from the central warehouse are positioned where they find free space between the central warehouse and the kanban warehouse. |
| Why is there traffic jam? | The corridor between the two warehouses is the central part for the plant, where all the forklifts go to the production area. |
| Why the pallets are positioned between the two WHs? | Because there is not a defined area where they can be temporarily place. |
| Why is there an undefined area? | Because most of the warehouse area is dedicated to the storage of pallets and a dedicated area has not been designed. |

*Table 14: 1st Inefficiency Analyzed*

| | |
|---|---|
| Inefficiency | Amount of the number of components in the flow rack at full load diverged between the various codes that make up the FP. |
| Why is there not a similar full-load quantity? | Because each component box differs in size and quantity of components between part numbers. |
| Why not target a similar amount among the various components so that there is a well-defined range? | Because they are calculated according to the available space of the flow rack instead of the quantities of the individual boxes. |
| Why are calculated about the available space? | Because the space available for a bigger flow rack is not easy to obtaining |
| Why is not easy to obtain? | Because the flow rack cannot be developed in height and also sideways |
| Why cannot be developed in height? | Because the last level of the SM should not be higher than the shoulder of the line operator where he has to pick up the components |
| Why can't it be developed sideways? | Because there is no space available |

*Table 15: 2nd Inefficiency Analyzed*

| | |
|---|---|
| Inefficiency | High movements between WH and D4 |
| Why? | Because each FP consists of more than 10 component codes, and of each component the entire pallet is handled. |
| Why is the whole pallet being moved? | Because there is no kitting area. |
| Why? | Because there is no space available near the warehouse for a kitting area. |
| Why? | Because the WH area is saturated and changing the layout requires high investment. |
| Why? | Because in addition to a new layout, it requires a change of internal transportation means, staff training, and new software for kit management. |

*Table 16: 3rd Inefficiency Analyzed*

| | |
|---|---|
| Inefficiency | Partial supply of components for L32 through the use of AGVs |
| Why? | Because AGVs has not yet been programmed to supply all the flow racks on the line |
| Why? | Because flow racks are not adequate to be fed by AGVs |
| Why? | Because AGVs were introduced recently and the flow rack were thought to a manual supply |
| Why are they not settled? | Because line feeding via AGVs was first implemented in semiautomatic lines, and will soon be extended to manual lines such as the L32. |

*Table 17: 4th Inefficiency Analyzed*

| | |
|---|---|
| Inefficiency | Returned pallet in WH |
| Why? | Because it was brought into lines more components than necessary |
| Why brought more material in line than necessary? | Because the production feeder does not know exactly the exact amount of material that needs to go into production |
| Why? | Because he consults the logistics schedule, which may differ from the production schedule |
| Why? | Because the production schedule may have been changed at the last minute and the production feeder has not been updated |
| Why brought more material in line than necessary? | Because WH drivers bring a whole pallet or even an already started pallet that has fewer components because it has already been returned |
| Why? | Because it is not planned to unpack the pallets but to bring the whole pallet directly |
| Why? | Because there is no unpacking area where the right amount is taken from the pallet |

*Table 18: 5th Inefficiency Analyzed*

| | |
|---|---|
| Inefficiency | KanbanBOX not implemented in L32 |
| Why? | Because it is a software recently adopted by the company and was implemented first on the two automatic lines |
| Why was it initially implemented in automatic lines? | Because they are easier to manage by having exclusively two types of PF code |
| Why is it not also implemented in line 32? | Because the programming of this line is more complicated. |
| Why? | Because it is a line with more than 10 FPs and each FP has different types of components |
| Why is not implemented? | Because for production feeders it is a useful tool, however, it is more time consuming in terms of line feeding |
| Why? | Because KanbanBOX management requires the printing and affixing of labels for each box |
| Why do additional labels need to be applied? | Because the system is not compatible with the labels with which the boxes arrive |

*Table 19: 6th Inefficiency Analyzed*

| | |
|---|---|
| Inefficiency | Null withdrawal in Kanban of the WH driver D4. |
| Why? | Empty pallet location |
| Why? | Because the pallet was picked up and taken to another line or finished and then not reloaded with the new pallet |
| Why was the new pallet not placed in the Kanban WH? | The pallet was taken temporarily to the assembly line, WH driver with high workload, absence of the pallet also in the central WH |
| Why doesn't the WH driver D4 know about the availability in Kanban WH? | Because there is no software that manages the actual availability in the Kanban WH, and code location is managed by excel file. |
| Why is there no software? | Kanban Warehouse was recently converted, additional software, additional costs. |

*Table 20: 7$^{th}$ Inefficiency Analyzed*

# 6 Conclusions

This thesis work focused on the analysis of the internal material flows of Dayco's Ivrea plant, mainly, however, the focus was on the flows from the warehouse to the D4 assembly lines. Once the various pallets of components are delivered to the entrance of D4, they are picked up by the production feeder from this point. The figure of the production feeder has been deepened for various reasons such as:

- Identification of task performed
- Understanding its workload
- Understand whether software such as KanbanBOX facilitates his work.
- Understand how much AGVs help with rack replenishment.

The production feeder is at the cost center of logistics, in the other two departments the tasks performed by the production feeder are divided between the forklift driver and the production worker. In fact, in those departments, the warehouse driver brings the material close to the line, then the production worker breaks away from production to replenish the racks. The production worker on the line is also in charge of reordering components from WH. In contrast, the new philosophy present in D4, the production worker never comes off from replenishing the line and reordering components, these tasks are all left to the production feeder. The reason for this choice due to the presence of the two semiautomatic lines, L39 and L42, where there is a single operator on the line with a high throughput value. Currently, there are 7 assembly lines in D4, with the supply of components in charge of the production feeder. If the lines are all working at the same time, the production feeder cannot handle them and must be supported by warehouse personnel. The greatest workload is required by the two semiautomatic lines, L39 and L42.
With the help of Lean Manufacturing tools, several critical issues were derived, some of which belong to D4 that negatively affect the work of the production feeder.

- Small flow rack of L42 and L39. For certain component codes, the production feeder is required to replenish the lines at least once every two hours. A larger flow rack, would allow more boxes of the bulky components such as part number TB540 to be held, and one could conceivably have a fully loaded flow rack with the number of component part numbers similar to each other.
- Partial supply of components for L32 through the use of AGVs. They in D4 are used to partially supply assembly lines. In fact, line 32 is not replenished in the flow racks of the assembly machines, but in SM near the line. This forces the line operator to fetch material a few meters from the line, interrupting the assembly process. This problem is given by the lack of adequate flow racks that can be replenished directly from the AGV, which would eliminate additional component handling. In addition to line 32, line 42 is also not fully powered by the AGV. In fact, it consists of 6 loading points, and it is able to feed the line flow rack and pulley loading point. The other loading points for reasons of feeding type, such as

hoppers, must be compulsorily supplied by the production feeder.

- KanbanBOX not implemented in manual lines, such as 32. This software is a tool that can be very helpful to both the production feeder and the line worker. It has been noticed that when one of them is loaded with work, one of the first tasks to be partially abandoned is the management of the KanbanBOX. For the production feeder, it is especially time-consuming to manage the labels for optimal management the software. In fact, it has to deal with printing and subsequent affixing in the boxes. As for the line staff it only has the task of scanning the label when the box of a certain code is finished. This way of line management is prone to errors, either due to abandonment by workload or forgetfulness of resources. To defeat these kinds of errors, the adoption of RFID technology could be considered. It would enable process automation and zero out staff errors.

The critical issues just listed belong to the department of D4 and resources there, and that if resolved could reduce their workload. The other critical issues found through Lean, concern the internal logistics of the WH so they involve the feeding of all lines in the plant. Excessive pallet handling is one of the most pronounced critical issues. This definition includes high movements between WH and D4 and vice versa and returned pallets in WH. High movements are given by the multiple codes that each FP comprises and that each code is transported one code at a time by forklift. In addition to this, the quantities brought to the line do not match the quantities needed but the entire pallet is transported. This type of manual line feeding can be time-consuming and costly. They daily change FP code and thus implies a high rate of returned material. To solve this type of criticality requires a considerable effort compared to the criticalities found in D4.

The proposed improvements are:

- Kitting area, located close to the warehouse to send the desired quantity to the assembly line.
- Implement milkrun trains, in order to transport the entire kit for each line and possibility that more lines are supplied with a single trip.
- A new management software to replace AS400, especially for managing kits to be transported to the assembly line.

The last critical issue noted is in the use of the Kanban WH. This area facilitates the retrieval of the codes stored there. It was created to decrease picking times in the warehouse and especially to reduce returns in the general warehouse, however, it carries with it several critical issues.

The most notable critical issues are:

- Increased pallet handling, because the pallet is unloaded from the WH, brought to WH Kanban area, and then subsequently in line
- Does not include all codes
- No software exists to manage this area
- Null pickup given by the empty and unstocked location.

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Currently, the benefits of this area outweigh the criticalities derived, however, if the improvement proposals listed earlier were implemented this area could be considered for disposal. As a result of the Lean Manufacturing approach, several critical issues were found in this case study, and various proposals for improvement were presented to attempt to solve them.

Clearly, this study exhibits limitations such as not having quantified in monetary losses by continuing to work without making changes and an estimate with proposed improvements. Another limitation due to the number of assembly lines analyzed, taking a larger sample of the other production departments as well would improve the analysis.

In a future study, additional Lean tools could be employed. Last limitation, analyze and propose improvements for outbound activities.

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# Figures

# Tables