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Manufacturing Warehouse Analysis by Lean Production Methodologies

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Alla mia Famiglia e a chi per me c'è stato.

A mia madre che mi ha insegnato a essere forte.

A mio padre che mi ha spinta a inseguire i miei sogni.

A Lorenzo che ha deciso di condividere il cammino con me.

A mia sorella che non mi ha mai lasciata sola.

Summary

Introduction

In a world where interconnectivity and smart automation are every day increasing, business intelligence and process mining are becoming more and more important to connect the high amount of data generated to the real processes of the companies. Moreover, when adaptability and responsiveness are as fundamental as today, the supply chain plays a primary role in the optimization of the company operations and so its processes deserve higher attention to be managed.

With its history of industry-leading first through innovative and efficient solutions, Dayco cannot avoid innovating its supply chain processes. Dayco is the case study company of this thesis and it is a global leader in the research, design, manufacturing and distribution of engine drive systems and aftermarket services for the automotive sector.

To start a business project management analysis, a traditional business process map could be useful to have a better idea of how the processes flow and to identify the inefficiencies that must be avoided.

Since Dayco adopts the Lean Production principles to manage each aspect of the company, the analysis of the process is developed through Lean Production tools such as 5W and 5S analysis.

The first chapter of the thesis analyses the main principles of Business Process Management and of Business Process Modelling (BPM) as well as the tools of Lean Production that will be employed in the thesis.

The second chapter introduces Dayco company describing its products as well as its mission and strategies which are fundamental to understanding why an innovative and challenging project such as process mining could be implemented.

In the third chapter of the thesis, a traditional formal process model of the Dayco warehouse is developed. Each area of the warehouse is mapped through the Business Process Model and Notation (BPMN) to investigate how the material flows in the plant.

The fourth and last chapter analyses the process model of the incoming area of the warehouse. From this analysis, the inefficiencies of the procedure are identified and analyzed through the 5W and 5S methods of Lean philosophy. A possible solution to increase the quality of data logs and to solve the process inefficiencies is proposed. Using the BPMN language and the Bizagi software a low code application is developed.

To conclude, the advantages of the application are analyzed together with the limits. Thanks to this study, it is possible to see how the new software application cannot substitute the in-use information system but it could be a powerful tool to keep the process under control and to optimize it.

1 Business Process Modelling and Lean Production

In this first chapter of the thesis, the main principles of the Business Process Modeling and Business Process Model and Notation are introduced. Then the focus is moved on Lean Production methods and tools such as 5S and 5W. Finally, the concept of process mining is presented as a possible method to analyze business processes in the future.

1.2 Business Process Modelling (BPM)

Business process management is based on the idea that each product provided to the market is the outcome of many activities that take one or more inputs to create an output valuable for the customer (Weske, 2012). Starting from this assumption it is possible to give to business process management the following definition.

Business process management includes concepts, methods, and techniques to support the design, administration, configuration, enactment, and analysis of business processes (Weske, 2012).

To analyze and manage a business process, this one must first of all be clarified with an explicit representation of its activities. Traditionally, the business process representations are manually depicted by the company's personnel, but to achieve a better result it is possible to employ business process management systems.

A business process management system is a generic software system that is driven by explicit process representations to coordinate the enactment of business processes. (Weske, 2012)

For the representation of a business process through a Business Process Management system, a graphical notation must be adopted. Even if there are many graphical notations, they are quite similar. To the scope, the Business Process Model and Notation (BPMN) is introduced as the current the facto standard of process modeling (Patig & Casanova-Brito 2011).

1.2.1 Business Process Model and Notation (BPMN)

The Business Process Model and Notation (BPMN) aims to represent a process diagram through the use of flow charts for the description of business operations. BPMN is designed to be machine-readable for the execution environment of the process, but at the same time is easy to understand (Campos & Oliveira, 2011) as can be seen in Figure 1. BPMN was developed under the coordination of Object Management Group and it is in its version 2.0 (OMG, 2010).

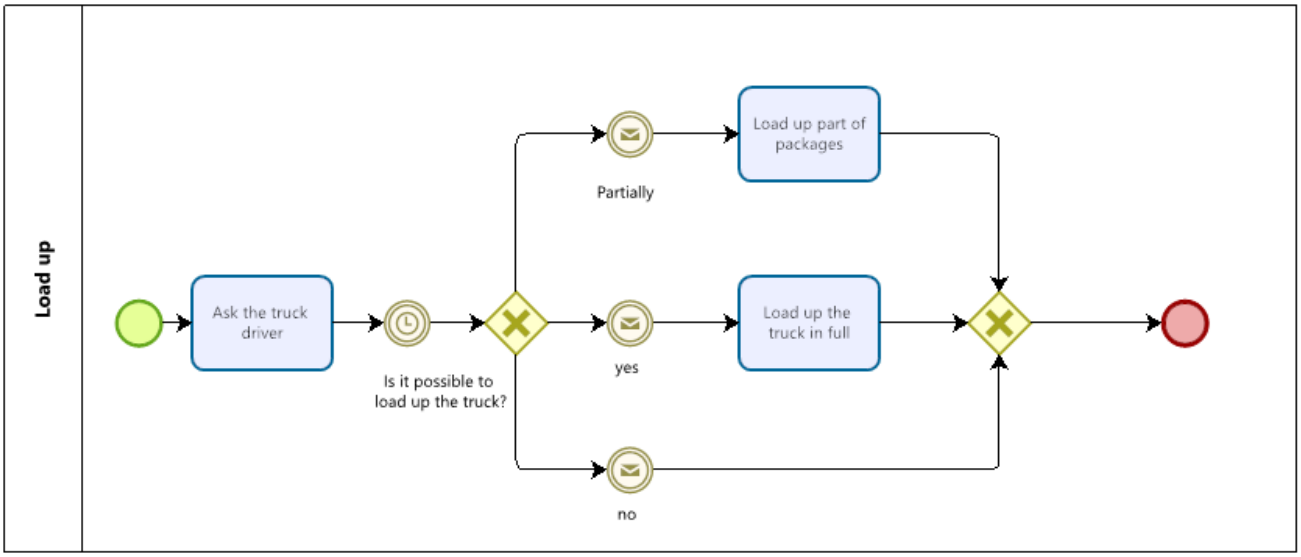

Figure 1: Example of business process mapping with BPMN

The BPMN notation is based on four object categories as illustrated in Figure 2 (Weske, 2012):

- Flow objects
- Artefacts
- Connecting objects
- Swimlanes

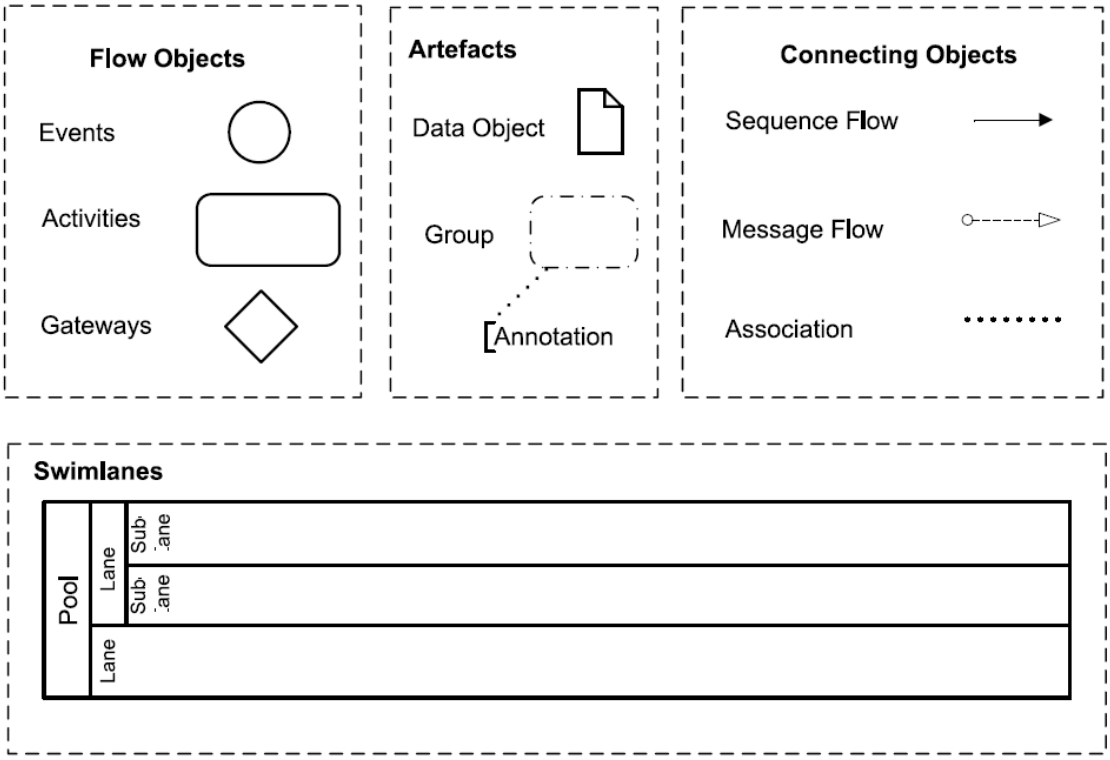

Figure 2: BPMN categories of elements (Weske, 2012)

The main elements of each category are explained in Table 1.

Flow objects	Events	Anything relevant that happens during the course of the project.
	Activities	Work or tasks carried out by members of the organization.
	Gateways	Split and join behavior of the sequence flow.
Artefacts	Data Object	Documentation of data used in the process as paper documents, electronic information, physical artefact.
	Group	Visual mechanism to group elements of a diagram informally.
Connecting objects	Sequence flow	Specify the ordering of flow objects.
	Message flow	Flow of messages between business partners.
	Association	Link artefacts to elements in business process diagrams.
Swimlanes	Pool	Container of a single process.
	Lane	Sub-partition within the process that represents functional areas that may be responsible for tasks.
	Milestone	Indicate different stages during the process.

Table 1: BPMN elements

The process starts with a starting event that triggers a sequence of activities that ends with an end event. There are many types of gateways that are useful to slit and join the process flow, to identify parallel paths or exception flow as illustrated in

.

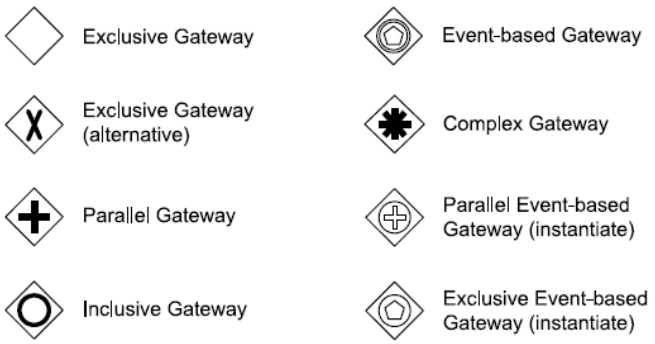

Figure 3: Gateway types in BPMN (OMG, 2011)

As for the gateway, there are many types of activities and events as can be verified respectively in Figure 4 and in Figure 5.

Figure 4: Task (activity) type in BPMN (OMG, 2011)

	Start Events	Intermediate Events				End Events
	Catching	Catching	Boundary Interrupting, Catching	Boundary Non-Interrupting, Catching	Throwing	Throwing
None or blanco: Untyped events, indicate start point, state changes or final states.	○				○	○
Message: Receiving and sending messages.	✉	✉	✉	✉	✉	✉
Timer: Cyclic timer events, points in time, time spans or timeouts.	🕒	🕒	🕒	🕒		
Escalation: Escalating to an higher level of responsibility.			▲	▲	▲	▲
Conditional: Reacting to changed business conditions or integrating business rules.	≡	≡	≡	≡		
Link: Off-page connectors. Two corresponding link events equal a sequence flow.		⇨			➡	
Error: Catching or throwing named errors.			⚡			⚡
Cancel: Reacting to cancelled transactions or triggering cancellation.			✕			✕
Compensation: Handling or triggering compensation.			◀◀		◀◀	◀◀
Signal: Signalling across different processes. A signal thrown can be caught multiple times.	△	△	△	△	▲	▲
Multiple: Catching one out of a set of events. Throwing all events defined.	⬠	⬠	⬠	⬠	⬟	⬟
Parallel Multiple: Catching all out of a set of parallel events.	✚	✚	✚	✚		
Terminate: Triggering the immediate termination of a process.						●

Figure 5:Event type in BPMN (BPM offensive Berlin, 2011)

1.2.2 BPM Lifecycle and utility of business models

Process models and Business Process Management play an important role in large organizations where they are employed for more than one scope (Aalst, 2016):

- Insight: analyze the process from different points of view
- Discussion: use the model as a base in managerial discussion
- Documentation: certification and training purpose
- Verification: find errors in the procedures
- Performance analysis: simulation techniques can be implemented to evaluate KPI
- Animation: imagine different scenarios
- Configuration: models can be used to configure information systems

The business models can be formal or informal. Formal models are employed to analyze the process, while informal models are high-level processes used during managerial discussions (Aalst, 2016). While formal models are too detailed to be understood by the stakeholder, informal ones are vague. In both cases, it is important to reflect on the quality of the model created and in particular on their alignment with reality. Indeed, many hand-made models are too idealized and do not represent the real processes and so they cannot be trusted (Aalst, 2016).

Business Process Management life-cycle in Figure 6 describes the different phases needed to manage a business process.

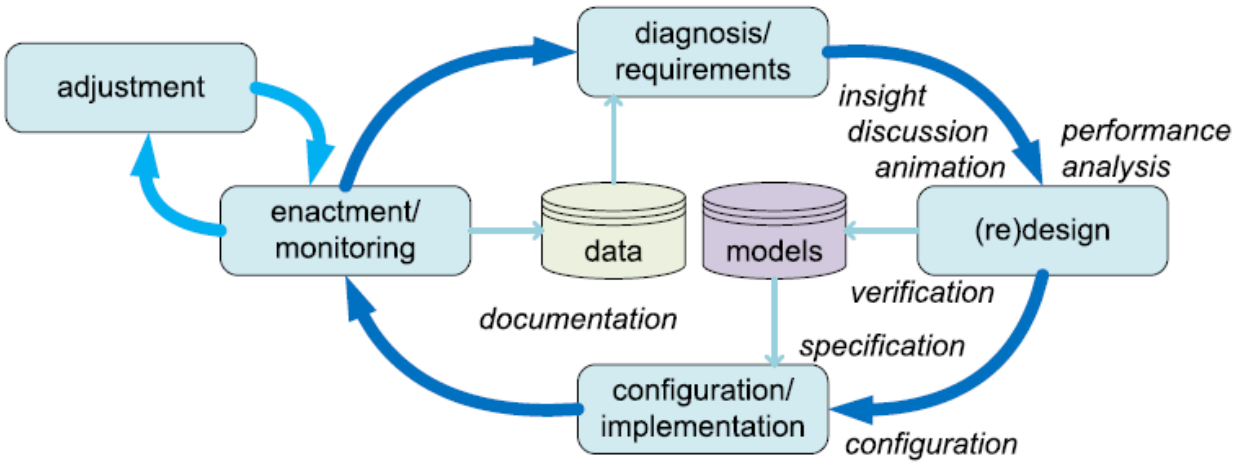

Figure 6: Business Process Management life-cycle (Aalst, 2016)

First of all, the process is designed in the design phase and then it is transformed into a running system in the configuration/implementation phase. After the system is able to support the implemented process, the monitoring phase starts. In this phase, the process flow is monitored

through a series of KPIs that are useful to identify inefficiency in the process that can be fixed in the adjustment phase. With the diagnosis/requirement phase the eventual changes in the process are evaluated and implemented. If radical changes to the process are needed the redesign phase triggers another cycle (Aalst, 2016).

In the first phases of the Business Process Management life-cycle, the focus is on the process models, while in the enactment/monitoring phase and in the diagnosis/requirements phase the data play a more important role. Thanks to process mining it is possible to deeply link all the phases of the Business Process Management life-cycle analyzing the data collected by the information system to have a better view of the process.

1.3 Lean Manufacturing

Lean Manufacturing is a production method whose aim is to reduce waste to increase manufacturing quality and efficiency. The term Lean was first employed in the 80s by the International Motor Vehicle Program of the Massachusetts Institute of Technology to describe the production method developed by Toyota and known as Toyota Production System (Aalst, 2016).

The Toyota Production System was developed by Sakichi Toyoda and Taiichi Ohno in the 50s and it is based on the maximization of the value offered to the customer. Everything that does not create value is a *muda*, a waste that must be eliminated to optimize the operations.

The most important principle of the Lean Philosophy is the attention paid to the customers. the customer plays a fundamental role in the company because every activity performed is justified only if it brings value to the customer. For value, it is intended everything the customer is willing to pay. Communication with the customer has primary importance to investigate the customer needs and the activity value.

Also, the personnel know-how and its contribution is necessary to implement a shared mission and strategy able to align the effort of all actors involved in lean manufacturing.

Since no process is perfect and can always be improved (Ohno, 1978), for the lean philosophy it is important to continuously improve the company activities (*kaizen* principle) to reach more effective results.

Lean Thinking is based on five principles (Workman & Jones, 1996) :

- Identify value
- Map the value stream
- Create flow
- Establish pull
- Seek perfection

Value is the starting point of Lean Thinking and it can only be defined by the customer.

Value is a specific product (a good or a service, and often both at once) which meets the customer's needs at a specific price at a specific time. (Wormack & Jones, 1996).

So the value is created by the producer and is sustained in the long term by the customer.

Once the customer's needs and the value of the product have been defined, it is important to identify the specific actions required to bring the value to the customer and therefore to produce the good. This sequence of action is defined as Value Stream. When all the tasks needed to create a good have been mapped in the value stream map (VSM), it will be possible to divide them into three groups:

- Activities that bring value
- Type one *muda*, activities that create no value, but are necessary and unavoidable
- Type two *muda*, activities that create no value and can be avoided

Through the analysis of the VSM, the process *muda* can be detected and eliminated.

Once the type two *muda* has been eliminated, the remaining activities must be rearranged to keep the process flow. This activity is done taking into consideration the whole process together and not focusing on the single departments of the company.

In short, things work better when you focus on the product and its needs, rather than the organization or the equipment, so that all the activities needed to design, order, and provide a product occur in continuous flow. (Wormack & Jones, 1996)

When the flow is introduced the product time to market significantly reduces as well as throughput time (Wormack & Jones, 1996). Therefore, it is possible to implement a pull strategy where the production is not defined by the forecasted demand, but by the real demand of the customer. Moreover, the demand of the customer tends to become much more stable when they know that their request will be satisfied in a short time (Wormack & Jones, 1996).

Finally, through the *kaizen* principle, it is possible to seek perfection specifying value more accurately and implementing a new and more effective way to make the process flow by deleting wastes.

Since the aim of Lean Thinking is to eliminate *muda*, it is important to deeply understand how wastes are classified (Ohno, 1978):

- Overproduction
- Work in progress - Inventory
- Transportation
- Waiting and idle time
- Movement
- Inappropriate resources and process
- Failure and scraps

The overproduction waste is generated every time the company does not produce according to the pull principle and Just-In-Time but with a push strategy. In the push model the company produces based on the forecast demand and then pushes the products into the market. On the other side, the pull principle is based on the actual demand: thanks to the Just-In-Time principle the company is able to adapt the volume of production to the customer demand. Unlike the push model, a pull model avoids overproduction and excess inventory. The overproduction waste is also generated when the product is produced too soon or faster than required by the next process. Ohno considered the overproduction as the worst waste since it generates other wastes such as the waiting one for the big size of the batch and the high inventories.

The work-in-progress warehousing waste is based on keeping unnecessary raw materials, parts or work in progress (WIP). It is generated by overproduction and by the push principle. Moreover, high inventories increase the company capital and increase costs.

Transportation waste is the unnecessary movement of material without adding value. It could be generated when the product is not stocked near the place of use, so it must be moved back and forth in the plant without generating any value.

Waiting waste occurs when there is a production line stoppage or the worker must wait for the material without being productive. It can be generated by a high level of WIP.

The movement waste is generated when the workplace ergonomics is not optimized and the worker must walk, reach or twist without a real reason.

The inappropriate resource and process include all wastes generated by overprocessing as endless product or process refinement, process bottlenecks, redundant approvals and unnecessary information. It is mainly caused by inefficient procedures and lack of customer inputs.

The scraps and failures are all those parts that deviate from the standards of the products and need to be repaired and reworked to be employed. This waste is mainly generated by the lack of training and standard and by incorrect information.

Dayco decided to consider one more waste with respect to the traditional ones proposed by Ohno (**Errore. L'origine riferimento non è stata trovata.**): talent waste. This waste is generated whenever Dayco does not support his personnel in growing their skills and ability and when the sharing of knowledge, ideas and creativity is not encouraged. This could take the form of employees performing unnecessary work when their talent could be utilized in activities that add greater value as well as not considering employees' abilities and feedbacks in the processes.

Figure 7: Dayco 8 wastes [1]

To ensure waste reduction it is important to develop a Just-In-Time methodology and automation (*jidoka*).

Just-in-time is a methodology to manage the production according to the pull logic of Lean Production. It is the customer who triggers the production and the company activities. For this reason, the inventory must be kept as low as possible to produce just what was already sold and to

satisfy the customer's needs. The Just-in-Time principle aims to fix the most important problems linked to mass production. The production of big batches is sustained by a large number of stocks that take up the warehouse space, increase costs and tied up the company's capital. Moreover, the mass production system is not able to meet customer needs for tailored products (Holweg, 2007).
To ensure the application of the Lean principles, some instruments have been developed as 5W and 5S analysis.

1.3.1 5W analysis

The 5WHYS technique is useful to deeply analyze the cause of wastes and inefficiencies. The operator must ask himself the question "why?" five consecutive times. This will enable the identification of the problem's root cause and the corrective actions that will be applied can be more effective.
This tool is very easy and rapid to use, furthermore it can be integrated into the mindset of every problem solver and employed in every situation. Ohno's (1988) most famous example for illustrating the 5-whys analysis is the following:

Question 1: Why did the robot stop?

Answer: The circuit is overloaded, causing a fuse to blow.

Question 2: Why is the circuit overloaded?

Answer: There was insufficient lubrication on the bearings, so they locked up.

Question 3: Why was there insufficient lubrication on the bearings?

Answer: The oil pump on the robot is not circulating sufficient oil.

Question 4: Why is the pump not circulating sufficient oil?

Answer: The pump intake is clogged with metal shavings.

Question 5: Why is the intake clogged with metal shavings?

Answer: Because there is no filter on the pump

In this example, the root cause of the problem is the lack of a filter on the bump that can be installed to solve the problem. Anyway, it is not always easy to identify the root cause of the problem or a possible solution.

1.3.2 5S analysis

The 5S method aims to reduce waste by cleaning the workspace and increasing its productivity (Al-Aomar, 2011). It is based on five principles:

- *Seiri* – Sort
- *Seiton* - Set in order
- *Seison* – Shine
- *Seiketsu* – Standardize
- *Shitsuke* – Sustain

With the sort step, the useful objects and activities are separated by the useless ones. First of all the working area and team must be identified, then the object or activity must be divided in three different groups:

- Useful object
- Undefined object
- Useless object

The undefined objects are those that could be potentially useful but are not often employed. A ret tag specifying a due date is attached to undefined objects (Figure 8). If the object is not employed before the due date, it is moved to the useless object group.

Figure 8: Red tag [1]

The step set in order aims to organize the useful items to be easily available and more visible. To the scope, the 4R principle can be employed: the Right item in the Right place, at the Right time and in the Right amount. Moreover, the more employed object must be stored near to the user, while the items that are just often used can be located outside the working area.

In the shine step, a cleaning process is implemented to keep the working area clean of useless objects. Moreover, the tools and the machinery employed are continuously inspected to assure the correct functioning.

The standardize step aims to set the standard of what developed in the previous steps. The standard must be visible and easily understandable and consultable.

Finally, the result reached with the previous steps must be maintained and sustained. It is necessary to implement periodic audits of the working area involved in the 5S project and to continuously update the standards fixing KPIs and evaluating trends. To the scope, a suggestion box can be positioned near the working area to collect inputs and suggestions from the workers.

1.4 Lean Production and Business Process Modeling

One of the main principles of Lean Production is the map of the value stream and process modeling plays an important role in identifying all the activities that take place in the product creation.

Just as activity that can't be measured can't be properly managed, the activity necessary to create, order, and produce a specific product which can't be precisely identified, analyzed, and linked together cannot be challenged, improved (or eliminated altogether), and, eventually perfected. (Wormack & Jones, 1996)

The process modeling helps to identify and link together the activity needed to develop a product. Moreover, associating to the process model the run time it is possible to evaluate how the process flows and the amount of time that is not associated with the creation of value and therefore is a waste of waiting. Also, it is possible to understand how the material is moved across the plant and the corresponding waste of transportation.

The process modeling is also the base of the define phase of the Lean Six Sigma projects. Lean Six Sigma is a structured approach to improve a process through variability reduction (Nandakumara & Saleeshyab & Harikumarc, 2018). The Lean Six Sigma methodology is based on the DMAIC cycle:

- Define – the process to be analyzed, the customer needs, team and time
- Measure – data of the process
- Analyze – the causes of the inefficiency
- Improve – the current condition through different solutions
- Control – the improved process to maintain the gains

The definition of the process is often done through process modeling tools such as BPMN or flow chart.

1.5 Process mining as possible future

Process mining is a science able to link end-to-end processes and event data created by every informatic source. For this reason, it could be considered as a future development of the process mapping project discussed in this thesis. It could enable to overcome the limits of the traditional business process modeling creating a more objective result based on data and not on the ability of the analyst.

Process mining research started in 1999 at Eindhoven University of Technology in the Netherlands thanks to the efforts of the computer scientist Wil van der Aalst. The discipline of process mining can be seen as the bridge between process science and data science (Aalst, 2016).

Process science is a discipline that "combines knowledge from information technology and knowledge from management science to improve and run operational processes" (Aalst, 2016). It mainly focuses on modeling processes rather than learning from the real data that can be mined from every organization's information system. To mind the gap, data science is an interdisciplinary field that aims to extract knowledge from unstructured and structured data creating value (Donoho, 2015). While data science is a powerful instrument to mine and manipulate data, it does not consider end-to-end processes. Only combing data and process science it is possible to analyze the processes exploiting the growing availability of data (**Errore. L'origine riferimento non è stata trovata.**9).

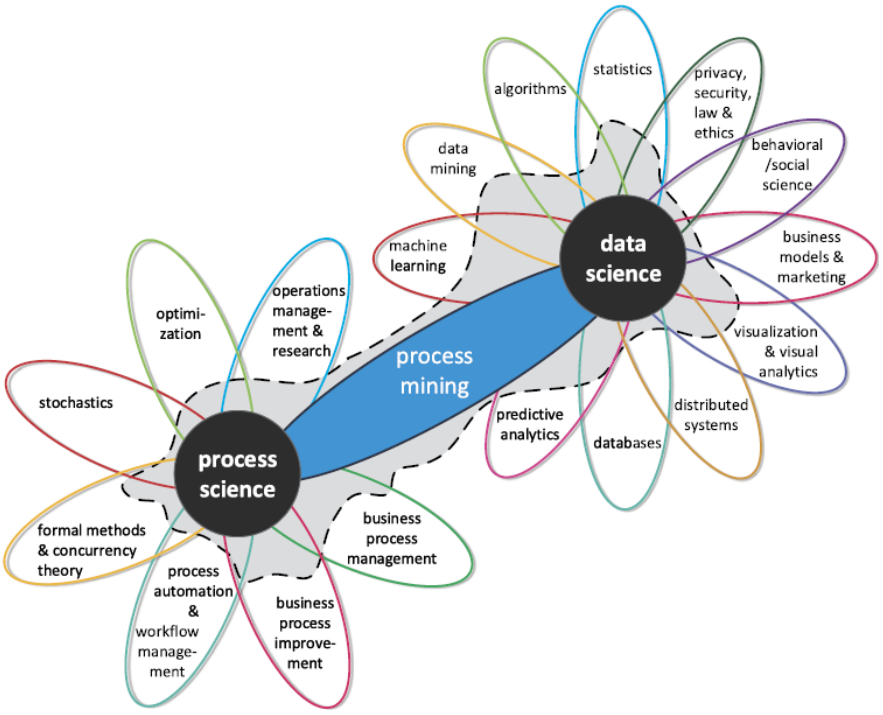

Figure 9:Process mining is the bridge between data science and process science (Aalst, 2016)

1.5.1 Different types of process mining

Event logs can be employed to implement different types of process mining:

- Discovery process mining
- Conformance process mining
- Enhancement process mining

The discovery process mining is based on the idea to use discovery techniques that elaborate data logs to create a model without using any a-priori information (Aalst, 2016). Given a large amount of event logs an algorithm such as the α-algorithm transforms event logs in a process diagram without using any additional knowledge.

On the other side the conformance process mining starts from an existing process model and analyzing its data log, it checks its conformity to reality. Conformance checking can be used to evaluate how the model deviates from the real cases and if procedures are performed as they should.

The enhancement process mining aims to improve and extend an a-priori model using information contained in the event log. One example of enhancement is repairing the model to better conform to reality or the extension to add new perspectives to the existing model with information as resources or quality metrics.

The most important perspectives are

- Organizational perspective: resources and organizational units
- Case perspective: property of cases i.e. value of data element corresponding to the activities
- Control-flow perspective: the ordering of activity
- Time perspective: time and frequency of events

2 Company presentation

In the second chapter, Dayco company will be presented highlighting its mission and products.

2.1 Dayco

Dayco is a global leader in the research, design, manufacturing and distribution of engine drive systems and aftermarket services for the automotive sector. Its headquarter is located in Roseville, Michigan in the USA, and the company operates in more than 22 countries all over the world as illustrated in Figure 10.

Figure 10: Dayco worldwide locations [1]

With more than 110 years of experience, Dayco has a history of industry-leading firsts that have improved the effectiveness through innovation, efficiency and impact of products in ways that are continuously benefiting the customer. Thanks to its values and its capability of delivering effective drive systems, Dayco has continuously improved the technology in the automotive market and has emerged as the leading global system solution provider for hybrid electric vehicles.

2.2 Mission and strategies

Dayco mission is to deliver innovative system solutions that move Original Equipment and Aftermarket customers forward, always.

Focusing on keeping promises and on the ability to deliver on time no matter the obstacles, Dayco has endured becoming stronger and more resilient. Dayco is able to meet customer-specific performance requirements thanks to its dedicated global team that respects one another, shows humility through continuous learning and acts like owners in everything they do.

Dayco principles and strategies are well explained in Figure 11.

Figure 11: Principles and strategies [1]

Thanks to its high attention to quality and customers' needs, Dayco awarded many certifications such as Ford "Q1 Certification" and "Supplier Quality Excellence Award 2020 from General Motors. According to its mission and strategies, Dayco gives great importance to lean production methods which are applied to optimize the production and the supply chain.

2.3 Products

With more than 50 locations in 20 countries, Dayco continues to globalize its operations to provide a high-quality service experience, from manufacturing to delivery to technical support. Dayco collaborates on product development building strong relationships to meet the high-quality standard of its customers. The essential engine products produced by Dayco minimize noise, vibration and harshness delivering exceptional performance, efficiency and economy.

Dayco has a wide product portfolio that can be divided into three main families:

- Original equipment manufacturer (OEM) as belts and hybrid solutions for companies in the automotive sector as FCA, Volkswagen, Audi, Maserati, Ford, Iveco.
- Original equipment spares (OES) for its big customers.
- Aftermarket (AM) products ideated by Dayco for automotive, truck, construction, agricultural and industrial applications.

Dayco offers to its customer both light and heavy-duty original equipment, paying attention to the different needs of each product family. Since 1979s, Dayco has been a leader in belt and tensioner

technology implementing manufacturing strategies that match materials to specific application needs.

Figure 12: Belt and tensioner [1]

As a complement to its belts and tensioners shown in Figure 12, Dayco provides additional products such as pulleys and idlers in stamped and formed plastic, steel and powdered material as well as dampers, decouplers and friction wheel.

For the aftermarket sector, Dayco offers a wider range of products able to satisfy the needs of different industries as illustrated in Figure 13.

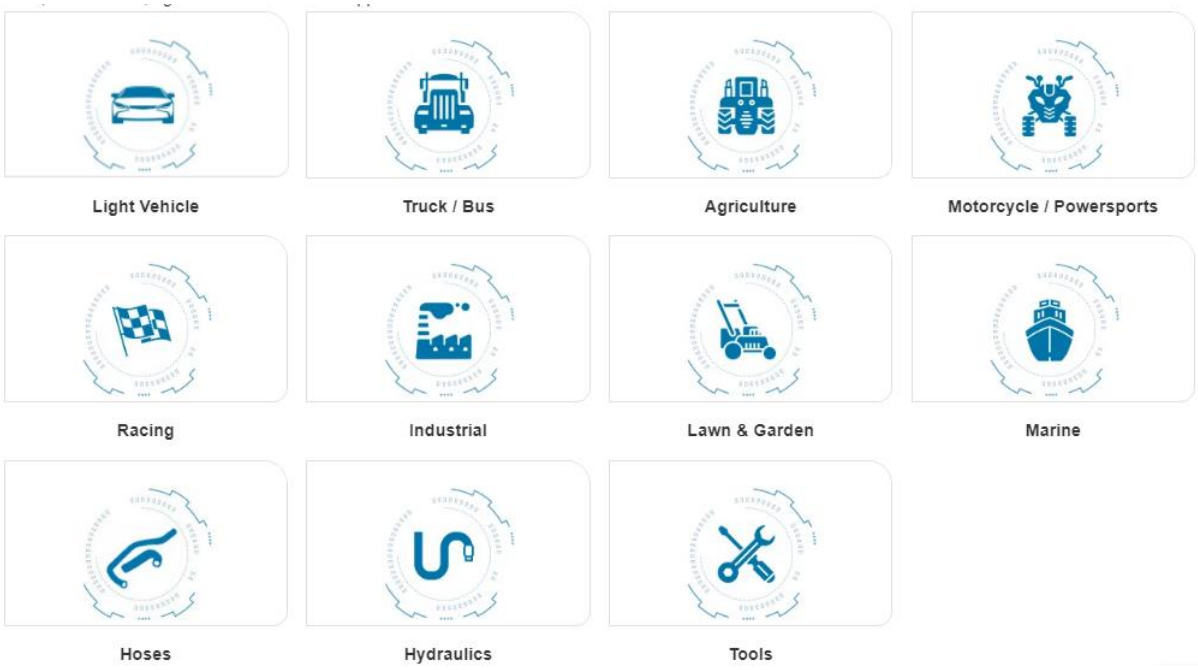

Figure 13: Aftermarket product application [1]

2.4 Hybrid system solutions

Dayco Hybrid System Solution aims to provide energy saving systems for P0 Mild Hybrid Powertrains as a consequence of the increasing E-Machine power

The mission of Hybrid Solution research is to improve fuel saving, CO_2 reduction and the durability of P0 Hybrid systems. Dayco purpose of offering a 12 to15% emissions reduction and life-long service as the next standard in the field.

To achieve the goal, Dayco is providing intelligent Control Logic designed to minimize CO_2 emissions and to guarantee the durability of components. It aims to provide more integrated solutions to optimize the performances of electric machines, pursuing smart system management.

The most recent products on the powertrain division are the twin tensioner for hybrid vehicles (Figure 14) and viscous crankshaft decoupler.

Figure 14: Twin tensioner [1]

2.5 San Bernardo di Ivrea plant

In Italy, Dayco counts four manufacturing plants and two distribution centers located in Piemonte and in the industrial area near Chieti in Abruzzo.

San Bernardo di Ivrea manufacturing plant counts more than 520 workers and manufactures products in the national and international market. Due to the high volume of material handled, the plant warehouse is well developed and needs particular attention to be managed.

The warehouse of the Ivrea plant is divided into four macro-areas that are:

1. Incoming
2. Production warehouse
3. Shipping preparation area
4. Shipping

In the incoming area, the material arrives and, after a primary quality check, it is registered in the information system and allocated in the raw material warehouse.

The production warehouse is a kanban area where the material is at the cost center of the production. When the kanban box is empty the material is moved from the raw material warehouse to the production warehouse both physically and on the information system.

When the end-product is ready, it is stored in the end product warehouse. Accordingly with customers' orders, the end products are collected by the shipping preparation area staff and prepared for shipping.

Once the pallet is ready to be shipped and the customer's truck arrives in Dayco, the end material is loaded up on the truck in the shipping area where also the documents required for the shipping are managed.

The information system of the Ivrea plant is AS 400. AS 400 is an application system created by IBM in 1988. It is a family of easy-to-use computers designed for small and intermediate-sized companies [9]. The AS 400 had become the most popular business computing system until it was substituted by the IBM eServer iSeries in 2000, a highly integrated business server for mid-market companies.

To archive the documents, Dayco employs the Activeinfo software. Activeinfo is an information management system that is useful to archive documents online [7].

3 Warehouse process

In the following chapter, the process of the Dayco warehouse will be mapped through the BPMN language. The aim of mapping the process as-is is to increase the awareness of the managers about what is really happening in the warehouse area and to try to optimize it. Also, it is useful to understand how the materials flow in the plant and how it is possible to keep them flowing as Lean principles suggest.

3.1 Introduction

The process is mapped through the Bizagi software. Bizagi is a free, effective business process mapping software developed by Bizagi company. Bizagi has more than one platform and in this thesis, the following ones have been employed:

- Bizagi Modeler enables organizations to model business processes in a central cloud repository to gain a better understanding of each step and identify process improvement opportunities to increase organizational efficiency [2]. The software use the BPMN language to map the process.
- Bizagi Studio enables business and IT teams to transform any business process and deliver end-to-end digital process automation across the organization. The platform's powerful drag and drop interface makes automating Classic, Experience-Centric, Tactical or Ad-Hoc processes simple, creating personalized and contextualized experiences for knowledge workers [2]. Through this software, it is possible to create a mobile application with low code.

Through Bizagi software and BPMN language, it is possible not only to map the procedures of the Dayco warehouse, but also to deeply understand what tasks each actor performs and is accountable for. The BPMN diagram is a powerful tool to create ISL documents for the business training of Dayco personnel and to compile the job description. Having a clear process enables the HR employee to identify immediately who are the actors involved and how an eventual change in the procedures can impact their workload.

For each warehouse area, the main process is defined through the tasks that each actor must perform. For each task, there is a brief description and the indication of the task performer and who is accountable for the task as illustrated in Figure 15.

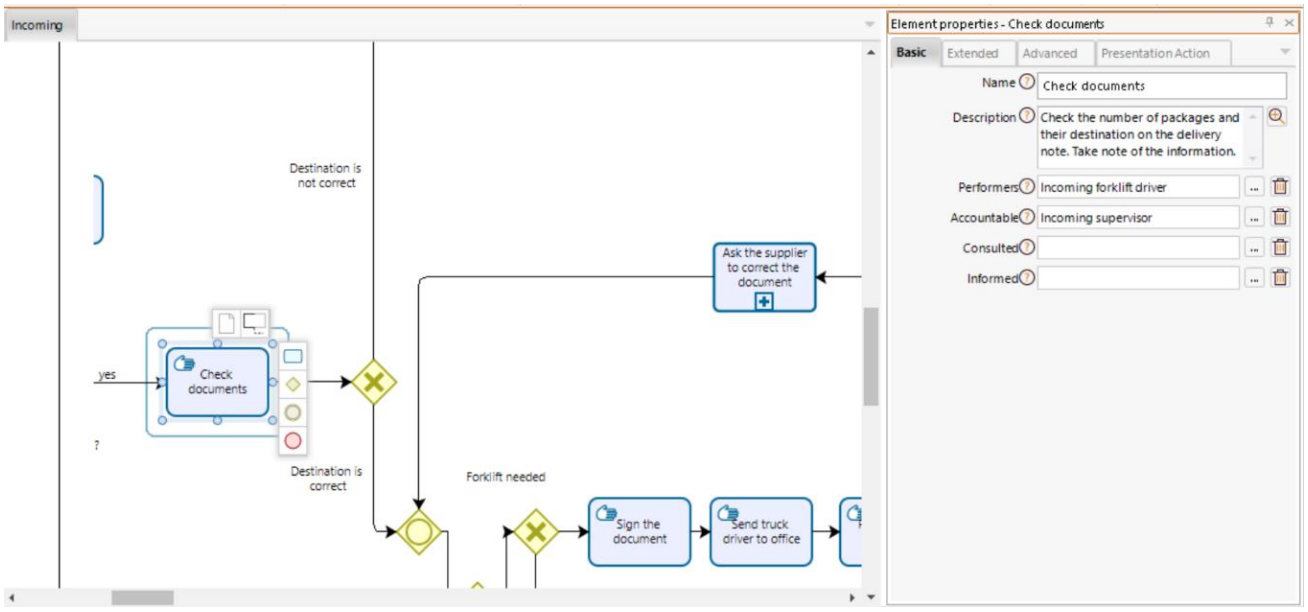

Figure 15: Task description

When a particular process was repeated in the main process or was too complex to keep in the main diagram, a subprocess called by the main diagram was created. In Figure 16, it is possible to see how subprocesses are linked to each area of the warehouse.

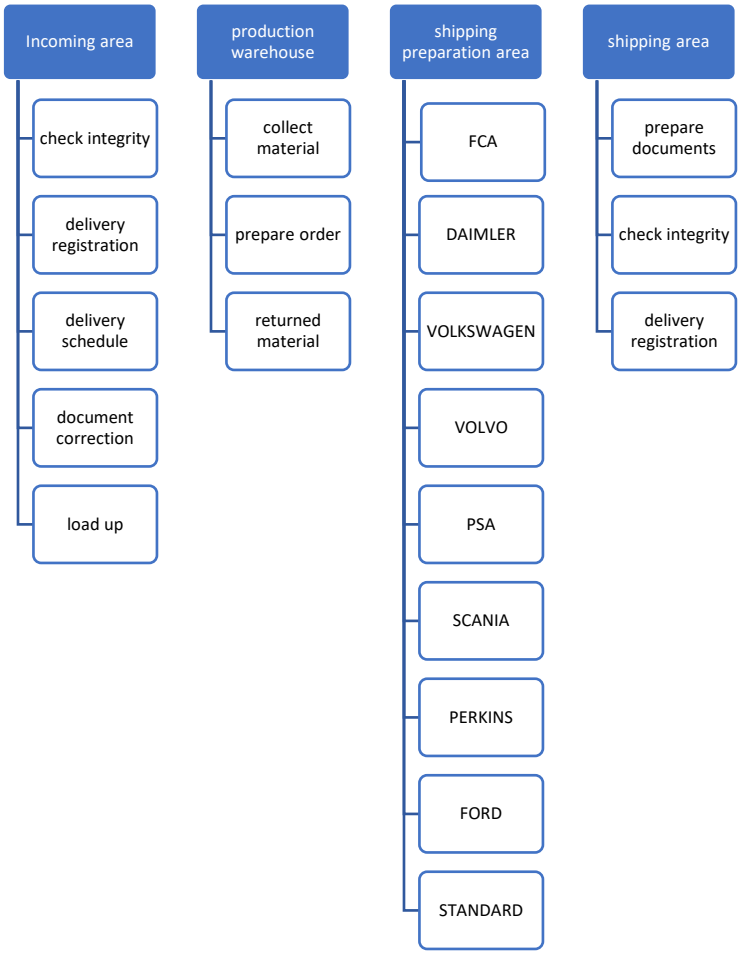

Figure 16: Subprocess hierarchy

The decision to create different diagrams for each area of the warehouse was led by the complexity of the process that otherwise would have been too difficult to read and this would have been in conflict to increase the awareness of managers about the procedures.

Even if the process is written in BPMN language, the focus is not on the interaction between the user and the information system but on the process itself. The majority of the tasks are performed without the support of the information system so to have a clear and broader framework of the process the BPMN was intended as a tool to easily understand the procedures and to give it higher visibility.

Great focus is also given to the material itself: it is always the material flowing through the warehouse that triggers the procedures. This choice was made for more than one reason:

- Give visibility to the transit of the material through the company
- Material is the real center where value is accumulated
- As it stands, the procedures are modeled on human resources.

Focusing the attention on the material more than on the human resources will be helpful to model the work of the resources on the needs of the material accordingly to the value stream map.

The warehouse of the Ivrea plant is divided into four macro-areas that are:

5. Incoming area
6. Production warehouse
7. Shipping preparation area
8. Shipping area

In the incoming area the material arrives and, after a primary quality check, it is registered in the information system and allocated in the raw material warehouse.

The production warehouse is a kanban area where the material is at the cost center of the production. The production warehouse is composed of shelves that can bear up to six pallets for each of the three levels. Every area of the shelves, kanban box, is assigned to the stock of a particular material. When the kanban box is empty the material is moved from the raw material warehouse to the production warehouse both physically and on the information system.

When the end-product is ready, it is stored in the end product warehouse. Accordingly with customers' orders, the end product is collected by the shipping preparation area staff and prepared for the shipping.

Once the pallet is ready to be shipped and the customer's truck arrives in Dayco, the end material is loaded up on the truck in the shipping area where also the documents required for the shipping are managed.

The warehouse is composed of a traditional pallet racking system where the forklift can easily move, and a narrow aisle pallet racking. Narrow Aisle Pallet Racking (VNA) is an adaptation of standard pallet racking systems, but thanks to a high-density storage possibility, it makes it possible to increase the capacity of the warehouse without expanding the space. The compaction of the system is mainly generated by narrowing the work aisles, which can save up to 40% in space. To store the pallets in the narrow aisle pallet racking, VNA forklifts with rotating forks and floor guidance are employed to simplify operations.

Dayco warehouse does not have a well-defined activity layout. The different areas of the warehouse such as raw material warehouse, production warehouse and end product warehouse are mixed together so it is not possible to distinguish which material is stored in a particular rack. Some simple rules manage the allocation activity of the pallet in the racks:

- High rotation materials are stored in lower levels of the racking system
- Kanban shelves are signaled with a yellow adhesive tape on the rack and are located in the first three levels of the racking system
- The end product is allocated near the shipping preparation area
- Different areas of the racking system near the shipping preparation area are designated to specific customer

In this scenario, two kinds of actors can interact:

- Internal actors as Dayco personnel
- External actors as customer or supplier truck drivers

Each area of the warehouse has its personnel composed by:

- Supervisor
- Warehouse worker
- Forklift driver

Moreover, a manager warehouse is present and there are some interactions with supply chain and quality departments.

3.2 Incoming

The processes in the incoming area of the warehouse are many and they are triggered in different ways. The main processes are:

- Receiving of material from suppliers
- Return material to suppliers
- Data conversion
- Triangulation

3.2.1 Receiving

When the supplier truck arrives in front of Dayco gates, the incoming area forklift driver answers the doorbell and checks that the truck driver wears the personal protection equipment needed to enter in Dayco plant (Figure 17). If it is not the case, the forklift driver must ask the truck driver to wear the safety shoes and the high-visibility jacket and wait until this is done.

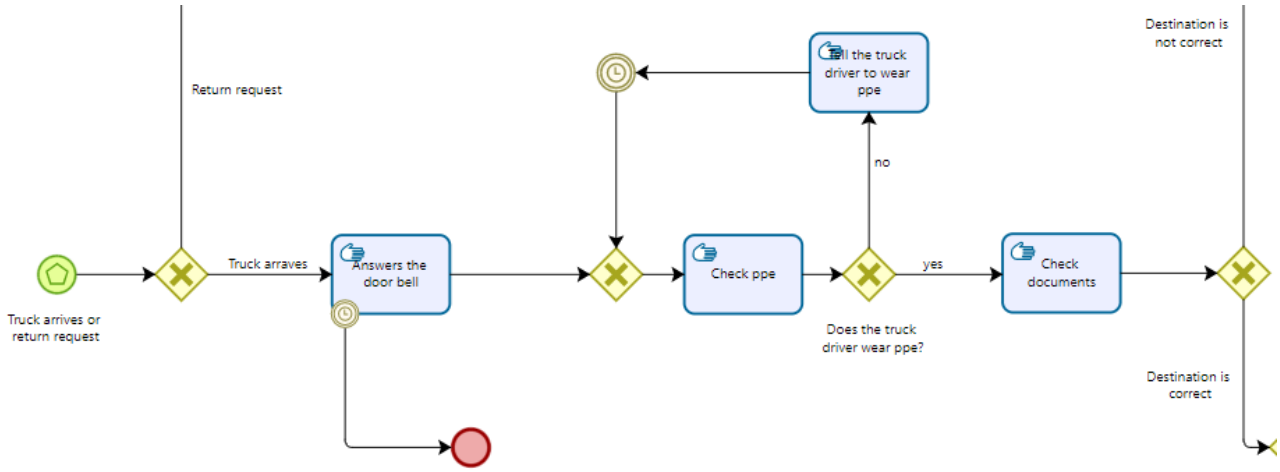

Figure 17: Check of personal protection equipment

If the incoming is not accepted for a long time due to delays in the incoming area or overload of work, the truck driver may decide to leave the Dayco plant without delivering the truckload. In this case, the company may occur in extra costs due to the disruption.

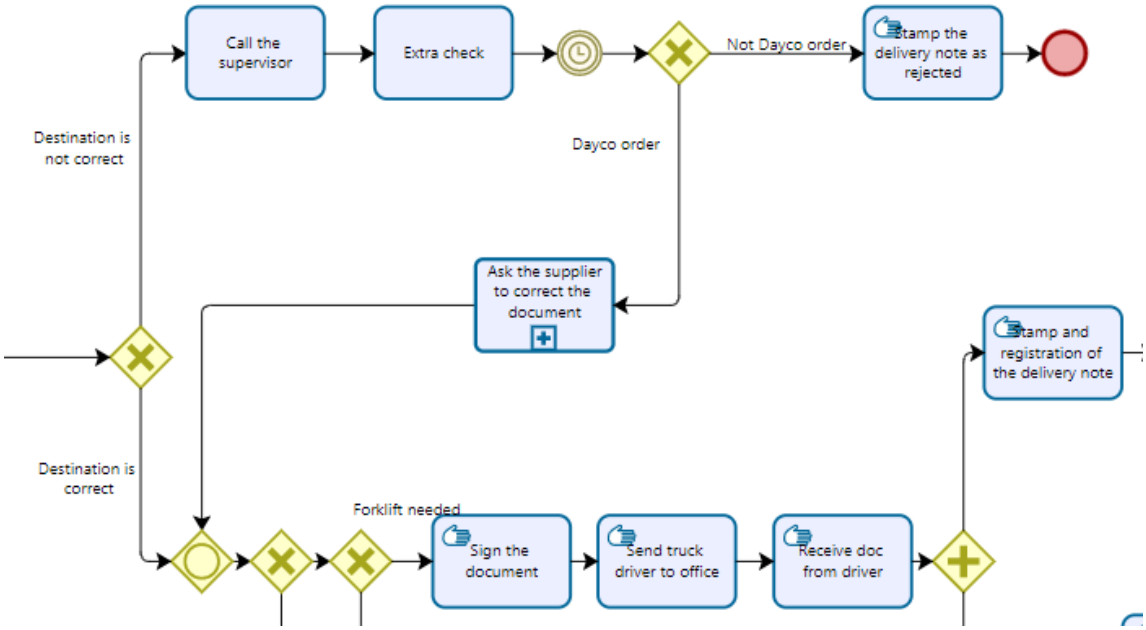

Figure 18: Check destination and number of pallets

Later, the forklift driver checks the transportation documents to verify the truck destination and the number of pallets to unload (Figure 18). If the destination indicated in the document is not correct, the forklift driver must call the incoming area supervisor to manage the situation. The supervisor then must compare the delivery note with the truckload and contact the supplier to get more information. Usually, the situation is solved and the supplier must correct the delivery note, in extreme cases the truck is rejected and the process end.

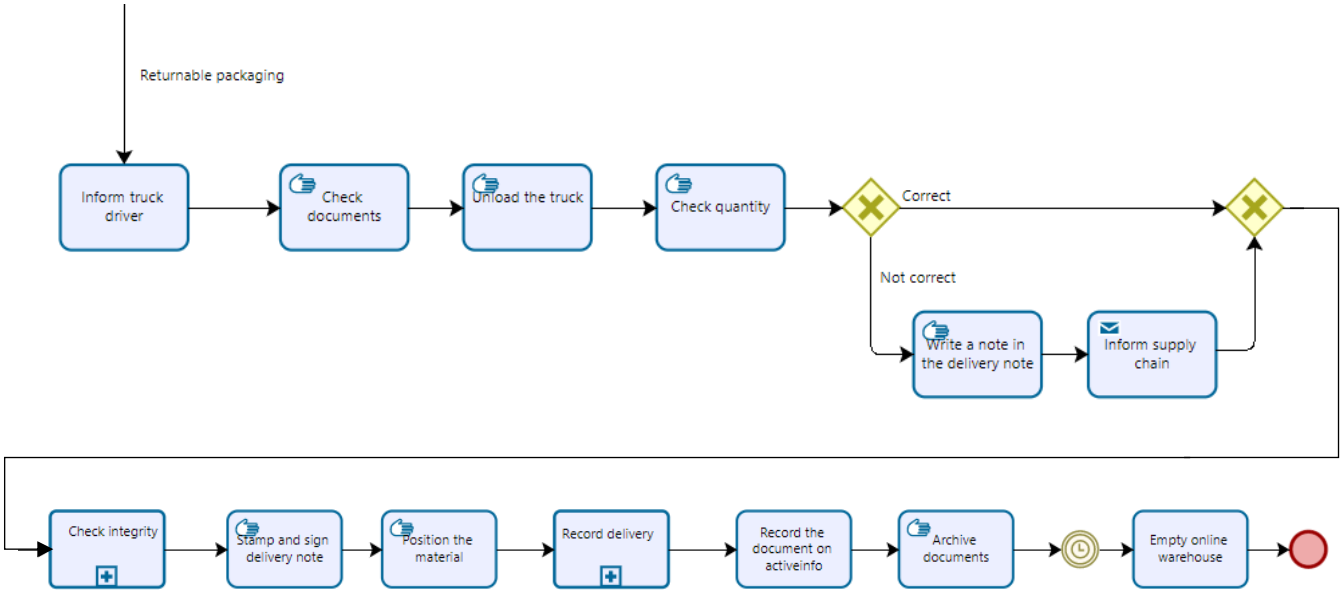

Figure 19: Returnable packaging

Sometimes the truck might be loaded with returnable packaging that a Dayco customer must give back to the company. In this case (Figure 19), the truck driver is invited to go to the packaging area of the warehouse where the packaging area forklift driver checks if that type of packaging is used by Dayco. Then, the forklift driver unloads the truck and checks that the quantity declared in the delivery note is coherent with the unloaded one. If the data do not coincide, a note on the document is written to claim the real quantity and a supply chain employee is informed.

After that, the integrity of the packaging is verified through the check integrity subprocess. The delivery note is then stamped as subject to inspection and signed by the packaging area forklift driver who positions the material in the packaging warehouse.

Finally, the incoming is registered through the record delivery subprocess and all paper documents are archived also in the Activeinfo database. With regular intervals of time the warehouse on the information system is emptied and the process end.

If the truckload is not packaging, two cases can be identified:

- The forklift is not needed since the incoming material is delivered by a courier
- The forklift is needed to unload the truck

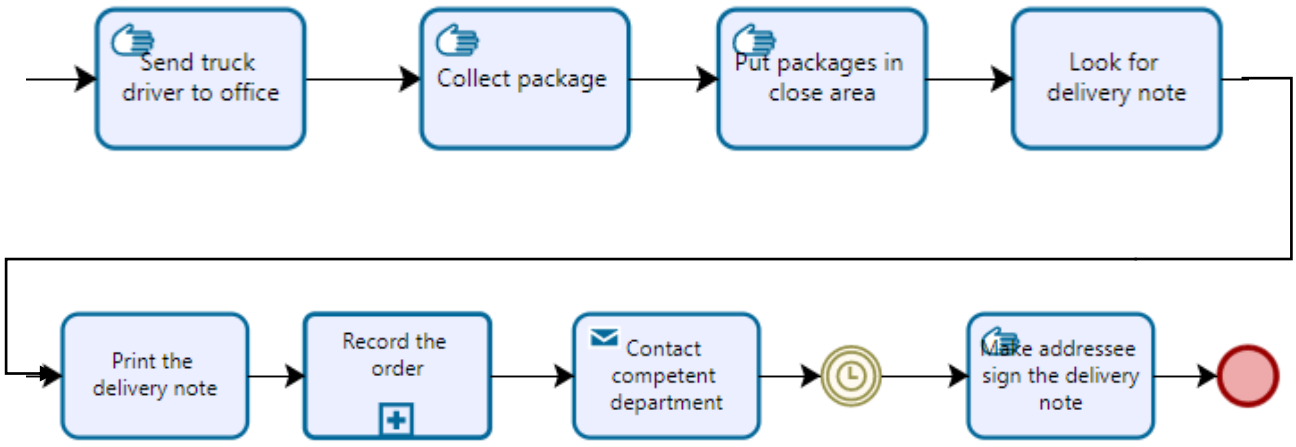

Figure 20: Incoming when the forklift is not needed

If the forklift is not needed, the courier is sent to the incoming office where the incoming area worker collects the package and stores it in a closed area as shown in Figure 20. Then the incoming area worker looks for the delivery note of the package referring to the invoice document which is often placed inside the box itself.

Later the delivery note is printed and the incoming is recorded through the delivery registration subprocess. All the packages delivered by a courier are considered closed orders. Finally, the warehouse worker contacts the competent department to inform it that the material ordered was received by Dayco. When the addressee of the delivery arrives, the warehouse worker makes him sign the delivery note and deliver the received material.

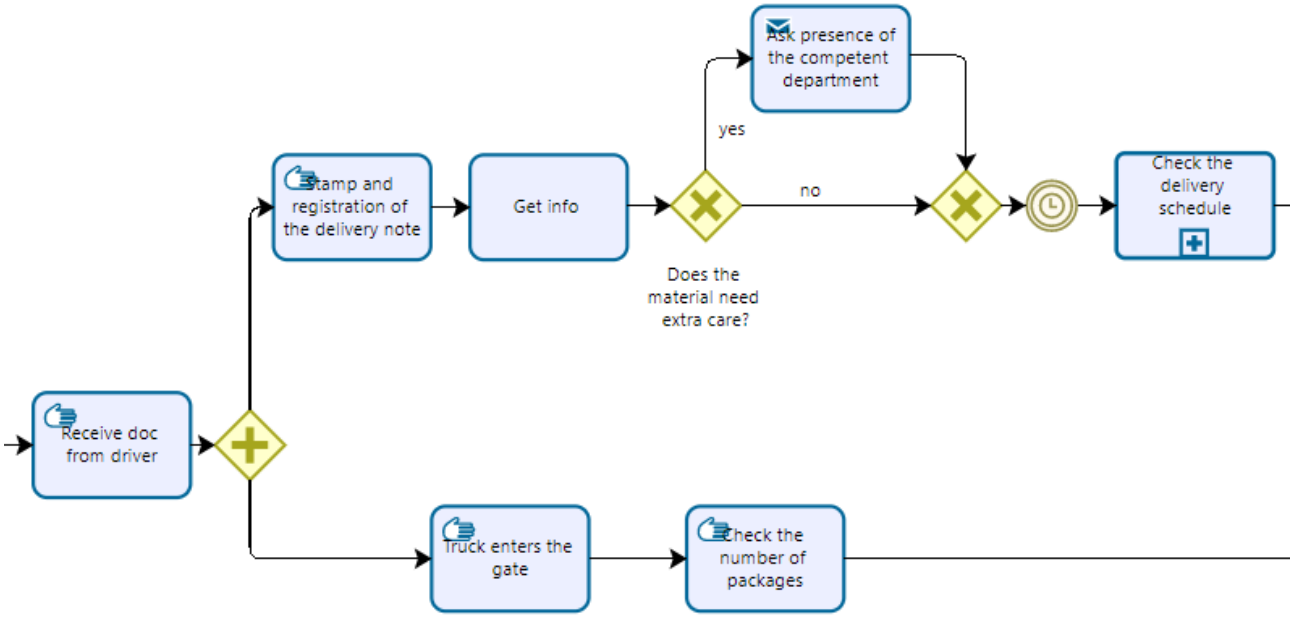

Figure 21: Incoming when the forklift is needed

If the forklift is needed to unload the truck (Figure 21) the incoming forklift driver signs the delivery note for acknowledgment and invites the truck driver to deliver the transport documents to the incoming office where he should also sign the register recording the arrival time and the license plate.

At this point, the process is split. On one hand, the truck will enter the gate and all the unloading procedures will take place, on the other hand, the office will handle the delivery note.

After the truck enters the gate and the loading area is opened, the incoming area forklift driver verifies that the number of packages in the truck is coherent with what is declared by the transportation documents.

If the data are not coherent the forklift driver communicates the non-conformity to the incoming office where the supervisor contacts the supply chain if the delivery should be accepted or not.

The supply chain department can give two different answers (Figure 22):

- Accept the delivery
- Accept part of the delivery

In the first case, the supplier is asked to correct the delivery note through the document correction subprocess, a note is written on the transportation document and the truck driver signs it for acknowledgment.

The supply chain department can decide to accept a part of the delivery in the case that the truck contains material with different delivery notes. If the truck is loaded with three pallets of material A with the delivery note A and 4 pallets of material B with the delivery note B, Dayco can decide to accept just the material A listed in the delivery note A and to reject the material B listed in the delivery note B. In any case, Dayco cannot accept two pallets of A and reject the last one, receiving just part of the goods listed in the delivery note A. If part of the truckload is accepted, the incoming area supervisor communicates to the forklift driver which pallets must be unloaded and then write a note on the delivery note to register what happened. If the supply chain department is late in answering the incoming area supervisor accepts the delivery, because is better to have more material in the warehouse than cause downtime of production.

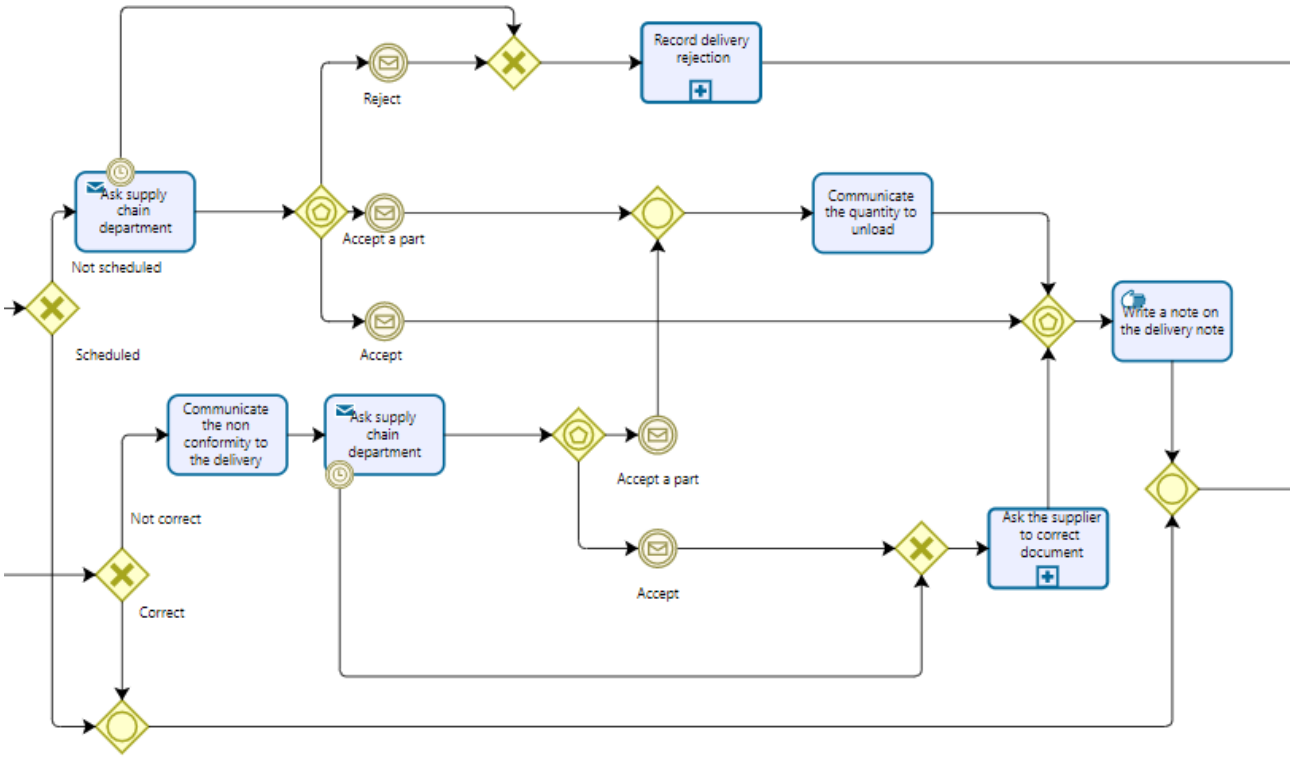

Figure 22: Decision process

While the tasks just explained are performed, the incoming area worker stamps the delivery notes as subject to inspection and registers them on a book specifying date, supplier and document identification number.

Then the incoming area worker read all useful information from the delivery note and, if necessary, ask the competent department to be present during the unloading of the truck to verify the integrity of packages and to react rapidly in case of problems. This passage is often done for high-cost or fragile goods such as machinery.

Later, the warehouse worker verifies that the delivery was scheduled for that period through the check delivery schedule subprocess. If the delivery was scheduled the process proceed smoothly, otherwise the incoming area supervisor must ask the supply chain department if to accept or reject the delivery. The supply chain department can give three different answers:

- Reject the delivery
- Accept part of the delivery
- Accept the delivery

If the delivery is rejected, the material must be registered in the information system as delivered and rejected through the delivery registration subprocess and all documents must be filed in the Activeinfo archive before the process end. If part of the material is accepted, according to what was explained before, the quantity to unload is communicated to the forklift driver and a note is written in the transportation documents. If the delivery is accepted, a note is written in the delivery note for acknowledgment.

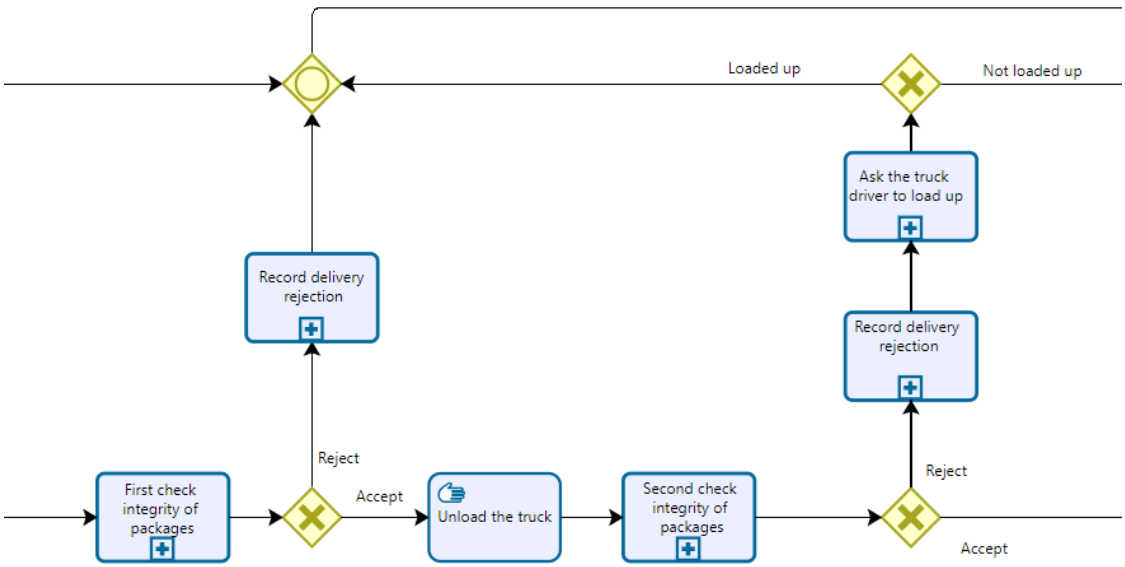

Figure 23: Integrity check and unloading

When the delivery or part of it is accepted, the truck driver opens the truck and, before the material could be unloaded, a first integrity check is done by the forklift driver through the check integrity subprocess (Figure 23). If the delivery is rejected due to severe damage, the delivery rejection is registered with the delivery registration subprocess and all documents are filed in the Activeinfo archive before the process end.

If the delivery is accepted, the incoming area forklift driver unloads the truck positioning the pallets in front of the warehouse. When the material is well visible a second integrity check is performed. Again, the delivery can be rejected: the document must be recorded through the delivery rejection subprocess and filed in the Activeinfo database before the process ends. Moreover, it is possible to ask the truck driver if the damaged material can be directly loaded up in his truck to be shipped back to the supplier through the load-up subprocess. If the material is loaded up, there are no other tasks to be performed, if the goods cannot be loaded up a return shipping is arranged: the incoming area supervisor calls the supplier to inform him to arrange the transport of returned material. In case of supplier delay, the supervisor arranges the transport on his own and notifies the supplier and the administration department to charge the transport cost to the supplier. Then, the documents are registered in the Activeinfo database and the pallets are correctly allocated until the truck for the return arrives.

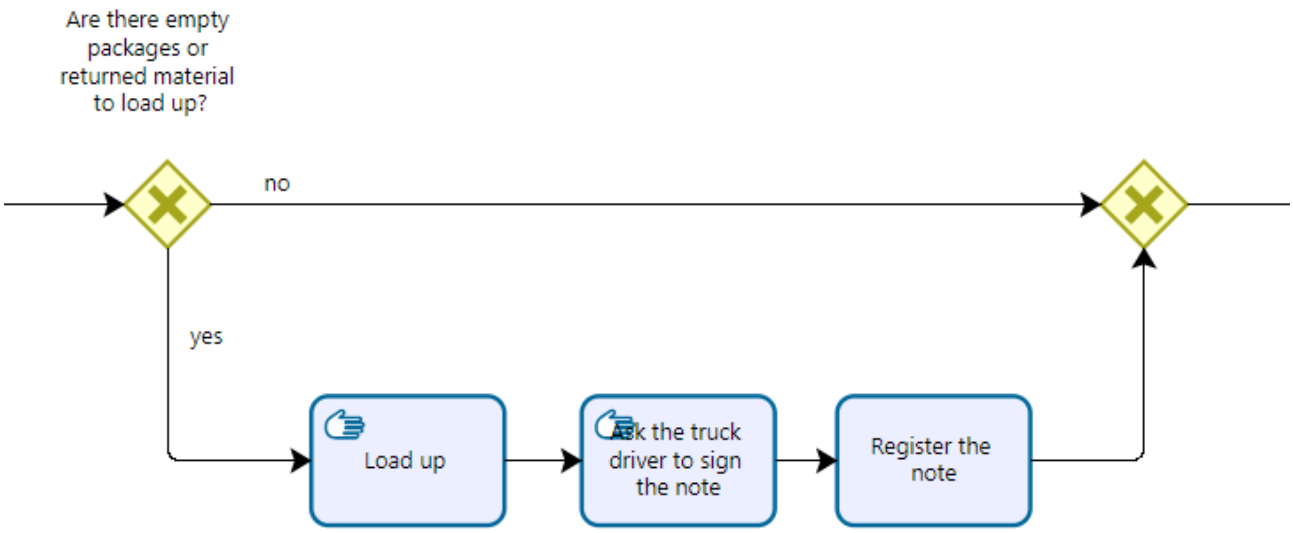

Figure 24: Load up procedure

When the integrity check is concluded, the forklift driver verifies if there is some material that the truck should collect as illustrated in Figure 24. Such goods can be empty packaging that must be

given back to the supplier or a scheduled return of material. If this is the case, the pallets are loaded up in the truck by the forklift driver who makes the truck driver sign the shipping note. After, the incoming area worker will register the note.

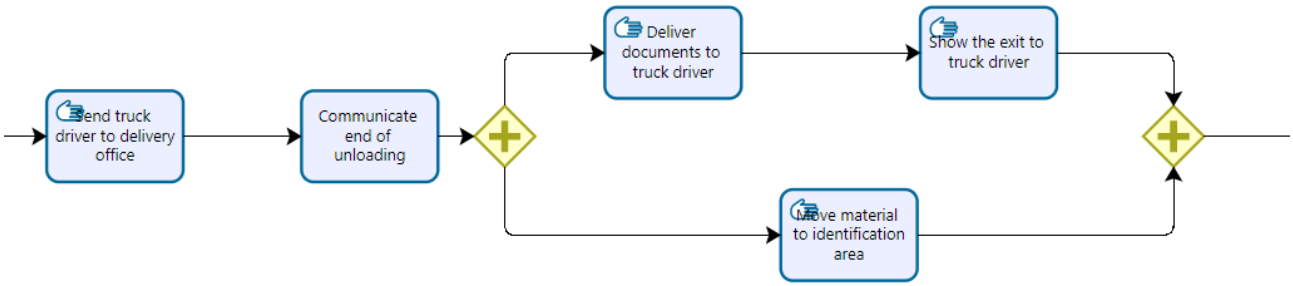

Figure 25: End of unloading

After the eventual load-up operation is performed, the forklift driver sent the truck driver to the incoming office to collect the transportation documents and communicate the end of the unloading task to the incoming area worker (Figure 25). While the forklift driver moves the received material to the identification area inside the warehouse, the incoming area worker delivers the transportation documents and shows the exit to the truck driver.

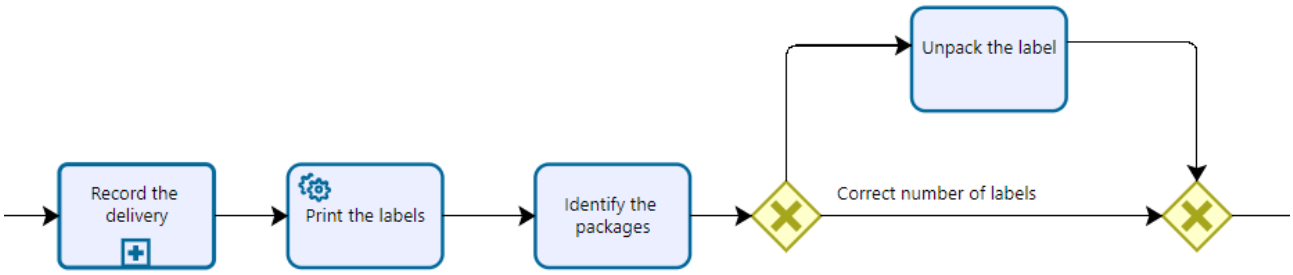

Figure 26: Delivery registration and label print

Once the unloading operations are completed, the incoming area worker registers the delivery through the delivery registration subprocess. The system then prints the labels that must be attached to the received material before the allocation in the warehouse. The warehouse worker takes the labels and goes to the identification area of the warehouse where he can identify the material and verify that the system printed the correct number of labels (Figure 26).

It could happen that the system printed fewer labels than needed. This is due to the fact that AS 400 read the quantity received and the packaging used, but the supplier can change the quantity on

each pallet without informing Dayco and, since it is the first time that the warehouse worker sees the pallets, he can make a mistake in registering the packaging. If this is the case, the warehouse worker should go back to the desk and unpack the labels in the information system specifying the quantity of goods for each pallet.

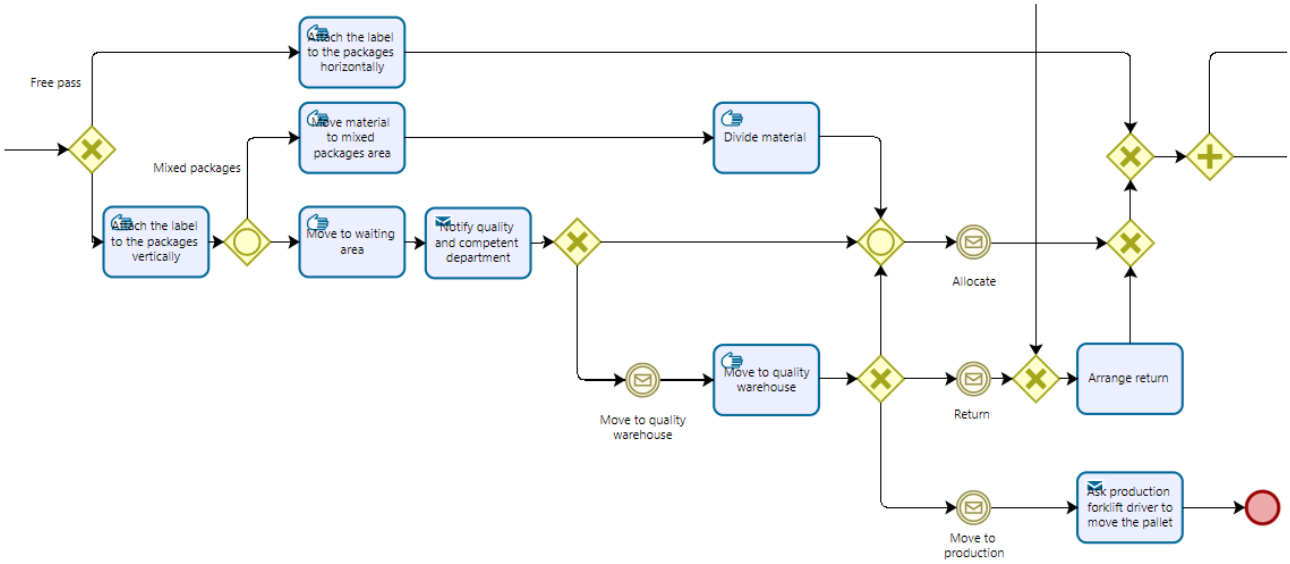

Figure 27: Label process

The received material could be divided into two categories as illustrated in Figure 27:

- Free pass material: high rotation material which, due to the high quantity and frequent delivery, does not undergo the quality department controls
- Non free pass material: lower rotation material that must be approved by the quality department before being used

If the goods delivered are free pass material, the warehouse worker attaches the label to the pallet horizontally to signal to the forklift driver that the goods can be allocated in the raw material warehouse.

If the material is no free pass or if the pallet is a mixed package, the label is vertically attached to the pallet.

The material that must be approved by the quality department is then moved to the waiting area by the forklift driver and a notification is sent to the competent quality department worker. The quality department can then choose to approve the material without inspecting it or to check it. In the second case, the material is moved to the quality warehouse. Last, the material can be approved and consequently allocated, or it can be rejected and the incoming area supervisor must arrange the return. If the goods are urgently needed by the production department, the production forklift driver is asked to move the pallet to the production line.

On the other side, the mixed packages are positioned to the mixed package area where they will be unpacked before being allocated.

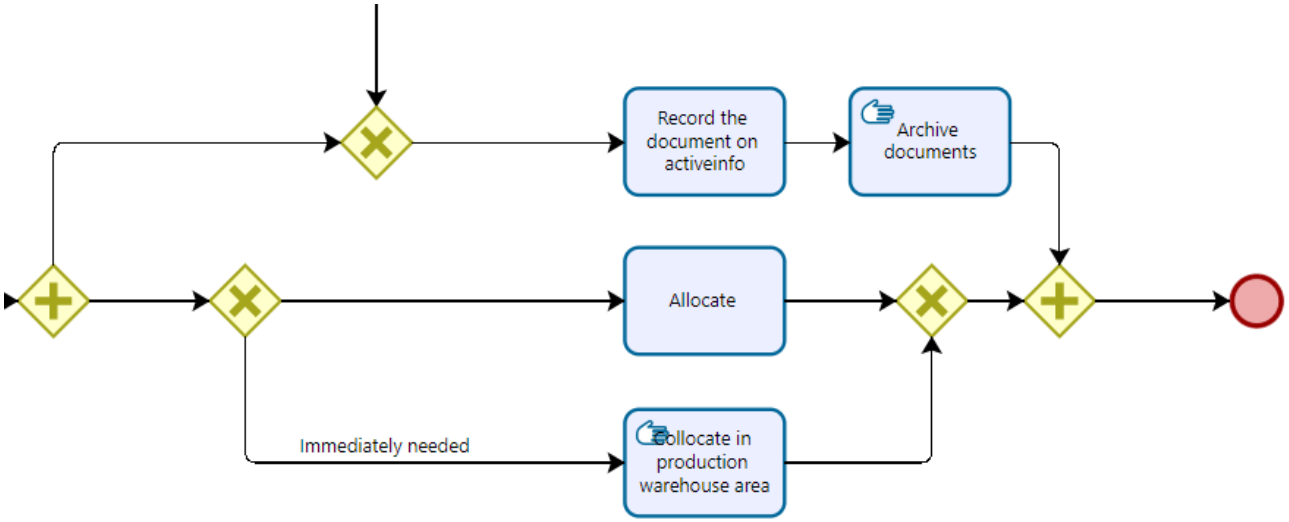

Figure 28: End of receiving process

While the incoming area worker archive paper documents and file them on the Activeinfo database (Figure 28), the forklift driver allocates the goods in the raw material warehouse or in the production warehouse area if the product is immediately needed. So the process ends here.

Special attention should be paid to the allocation task, where the forklift driver reads the label and decide where to allocate the package. Using the forklift, he moves the package to the designed allocation then he scans the label barcode, scans the allocation barcode and he positions the package in the allocation scanned.

3.2.1.1 Document correction subprocess

As illustrated in Figure 29, when the incoming area supervisor asks the supplier to correct the delivery note, he can receive a positive or a negative answer according to the supplier's will. In the case the delivery note will not be corrected or if the correction will take too much time, the supervisor writes a note on the delivery note to register the differences with respect to real truckload or destination.

Last, the truck driver is asked to sign the document for acknowledging the delivery.

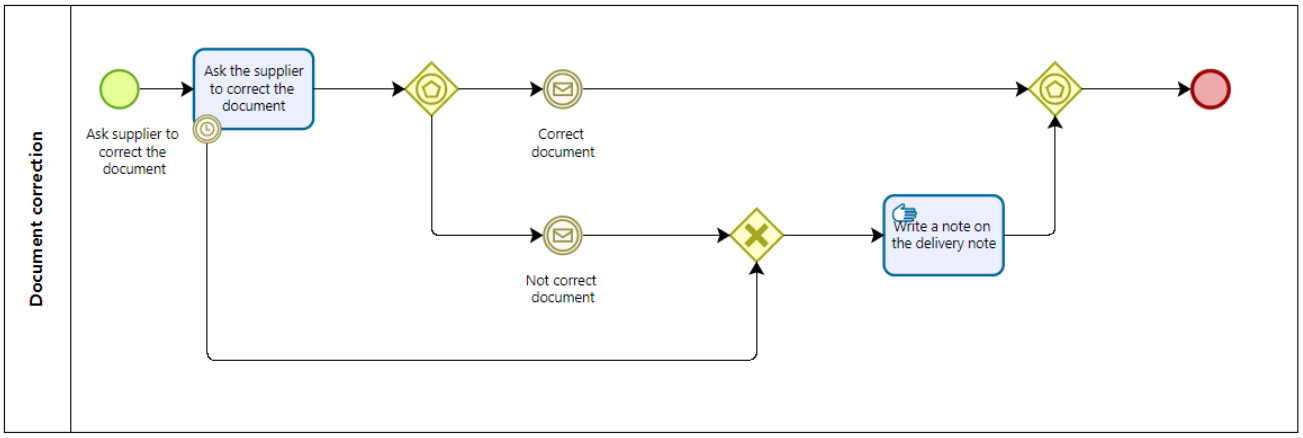

Figure 29: Document correction subprocess

3.2.1.2 Check integrity subprocess

If the material received is damaged (Figure 30), we can distinguish two cases. If the material received is packaging, the packaging area forklift driver writes a note on the transport documents and informs the supply chain about the status of the goods.

In the case the truckload is raw material, the incoming area forklift driver informs the incoming supervisor who takes picture of the material to prove the damage.

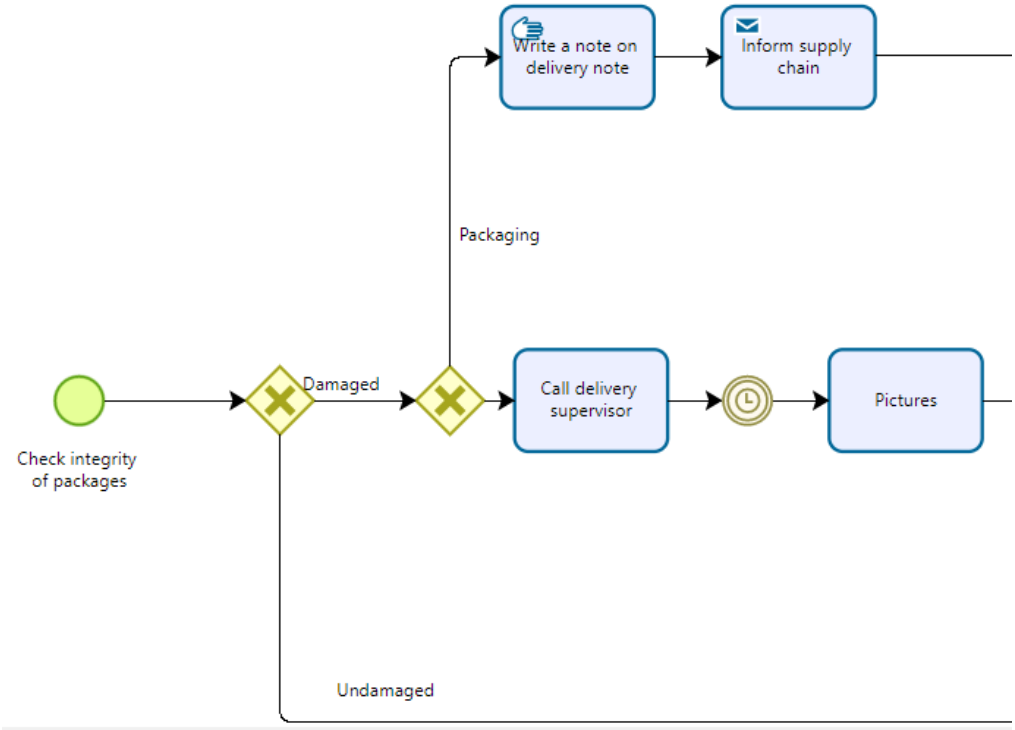

Figure 30: Check integrity subprocess

The pictures are then sent to the supply chain and quality departments (Figure 31). Each department evaluates the situation to decide if to accept or deny the delivery and communicate its decision to the incoming area supervisor.

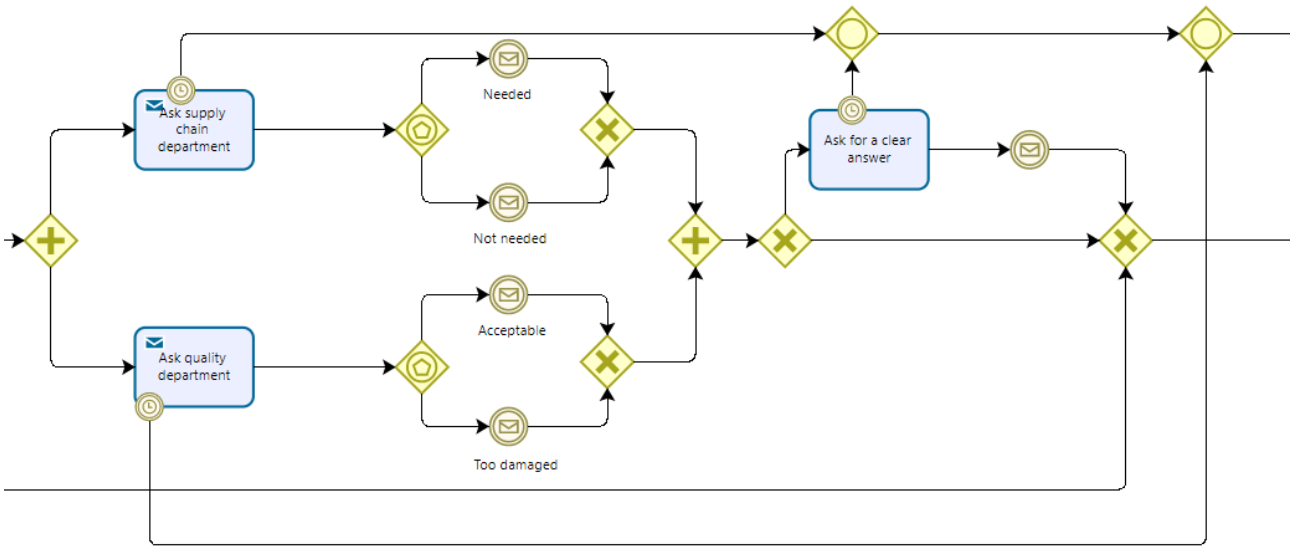

Figure 31: Decisional process in the check integrity subprocess

To proceed with the process, the two answers must be coherent, otherwise the supervisor must ask for a clear answer to both departments which should communicate one with each other to make a decision.

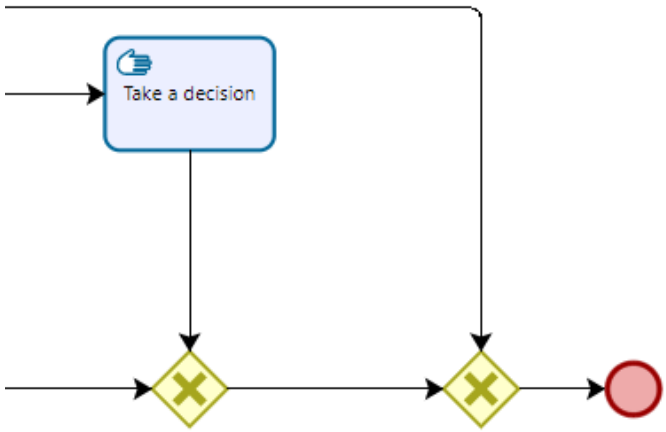

Figure 32: End of check integrity subprocess

If the answer from the supply chain and the quality departments are late, the incoming supervisor is obliged to make a decision on his own to not interrupt all the activity in the incoming area since just one truck at a time can enter the gate (Figure 32).

3.2.1.3 Delivery registration subprocess

When the delivery must be recorded (Figure 33) the delivery note number is registered in the information system. If the warehouse worker cannot find the note number, he must check again the delivery note or try to find it. Not all delivery notes are clear to be read.

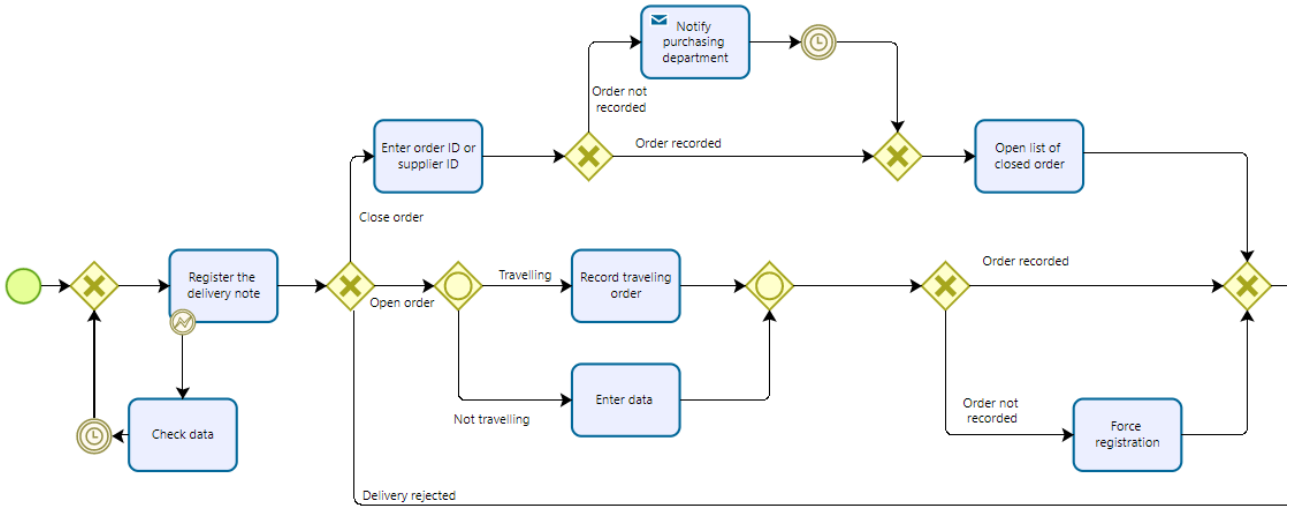

Figure 33: Delivery registration subprocess start

If the delivery comes from a close order, this should be specified in the delivery note itself, the warehouse worker enters in AS 400 the order or the supplier id to select in the list of closed orders the correct one. Sometimes the received material might be not listed in the closed order group, this is a procedural error of the purchasing department so the incoming area supervisor must notify the disruption to have it fixed.

If the received material comes from an open order, the incoming area worker can search in the list of traveling orders to recover all the data needed, otherwise he can enter manually the data as supplier ID, delivery note ID, delivery note data of emission, delivery date, total quantity of material received. If the system signals that no order was made to the supplier, the registration can be forced. This can happen because sometimes suppliers try to anticipate the following month's delivery for accounting reasons.

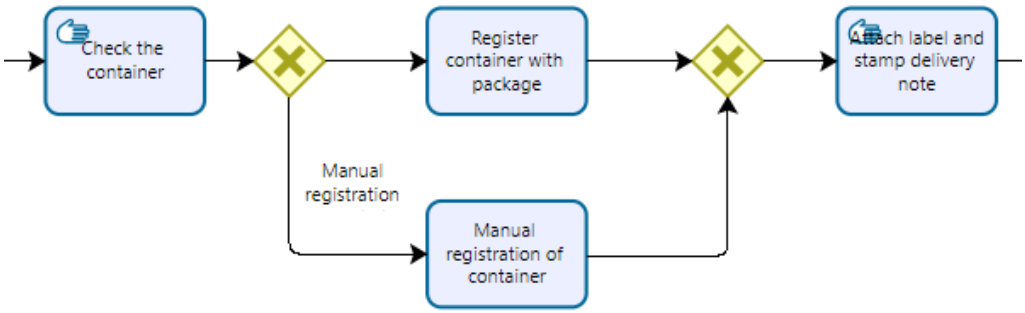

Figure 34: Container registration

Once the material is registered, it is time to record the packaging as indicated in Figure 34. Usually, the number and the type of packaging are indicated on the delivery note, but to be sure and avoid the unpacking of the labels, the warehouse worker can verify the real packaging used going to the identification area. Often the registration of packaging is done relying entirely on the incoming area worker memory since each supplier usually ships similar packaging for the same item.

If the system does not allow registering the packaging together with the material, the containers must be manually recorded.

When the recording operations are concluded the system prints a small label that must be attached to the delivery note. This is useful to file the documents in the Activeinfo database.

If an amendment or a return procedure must be registered (Figure 35), the incoming warehouse worker registers it in the system and notify it to the administration department and the supplier or contracting company.

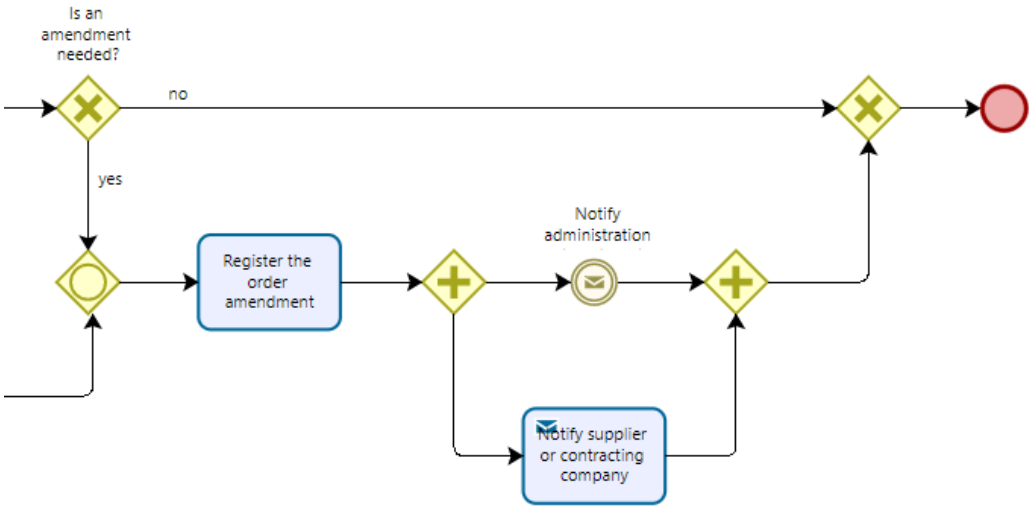

Figure 35: Amendment registration

3.2.1.4 Check delivery schedule subprocess

To check if the material arrived in Dayco is scheduled for the current period, a different procedure is performed on the information system depending on the type of order as shown in Figure 36. If the order is close, it is sufficient to enter the order id or the supplier id to verify the schedule. Otherwise, if the order is open the incoming area worker must first check the traveling information and if no data can be found, he enters the main information of the delivery note to search for the material manually. The data could be:

- Supplier id
- Delivery note id
- Delivery note data of emission
- Quantity of material delivered

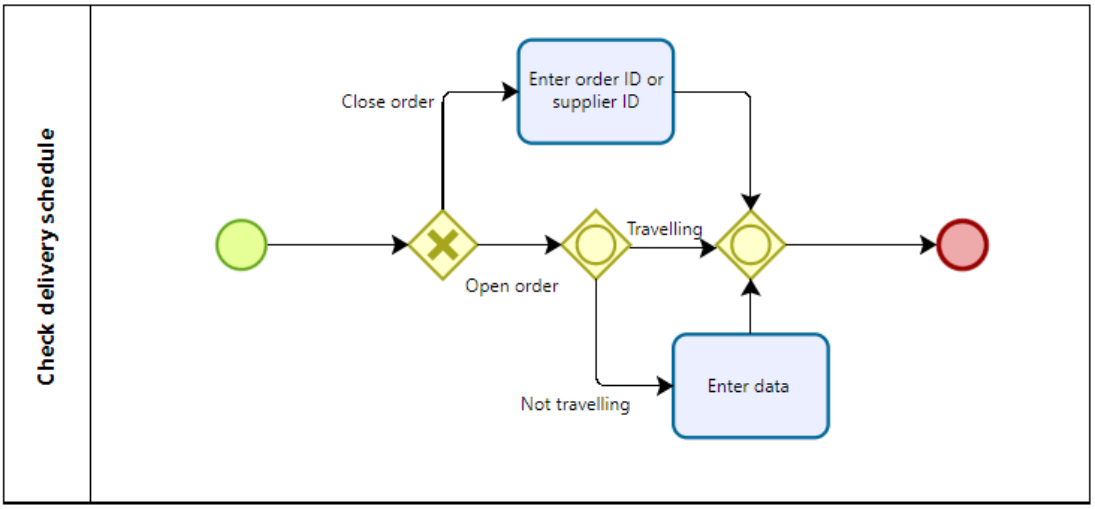

Figure 36: Check delivery schedule subprocess

3.2.1.5 Load up subprocess

When a damaged delivery already unloaded is rejected, it is possible to ask the truck driver to load up again the material to bring it back to the supplier as illustrated in Figure 37. If the truck driver gives a positive answer, the material is loaded up again, otherwise the material will be managed in a different way. If the truck driver is late in answering the goods are not loaded up again but Kept in the Dayco warehouse.

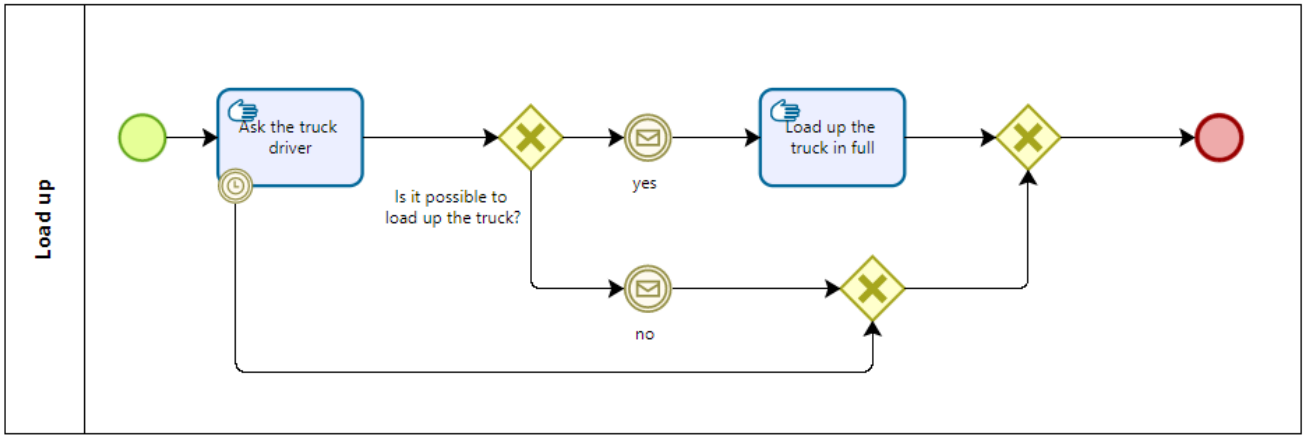

Figure 37: Load up subprocess

3.2.2 Return request

When a department, usually the quality, requests that a certain material is returned to the supplier (Figure 38), the incoming area supervisor contacts the supplier to arrange the collection. Then the return is registered in the information system and, after the supplier truck arrives, the material is prepared for the shipping and loaded on the truck.

During the registration, the information about the material might be lost and the incoming area supervisor must spend time looking for it by contacting the quality department or whoever can have information. If the supervisor is not able to find any, he must identify and count the items.

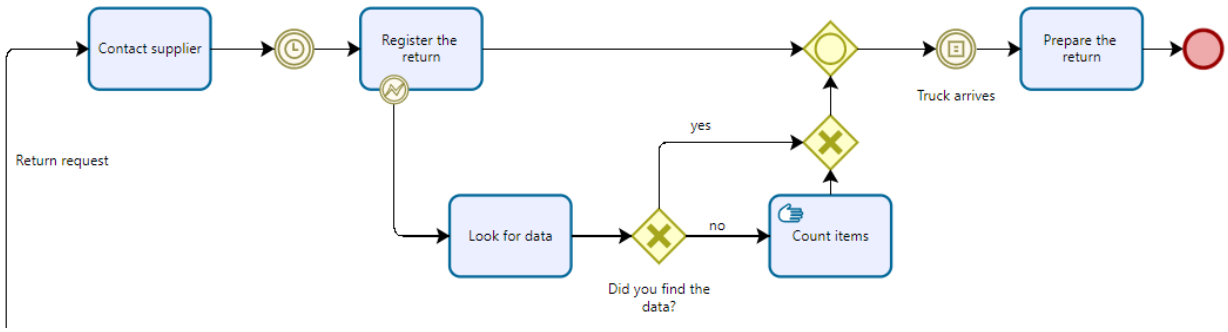

Figure 38: Return request

3.2.3 Data conversion and triangulation

Triangulation operation occurs when raw material is purchased by the Dayco Ivrea plant, but it is delivered to a contractor or another Dayco plant (Figure 39). In this case, when the goods are received the contractor sent to Ivrea plant the copy of the stamped delivery note as proof of the transaction.

When the incoming area supervisor receives the stamped delivery note he registers the material in the warehouse dedicated to the contractors through the delivery registration subprocess.

Data conversions could be required by a Dayco department or by a contractor, when the request is received the incoming area supervisor changes the warehouse destination of the material as required.

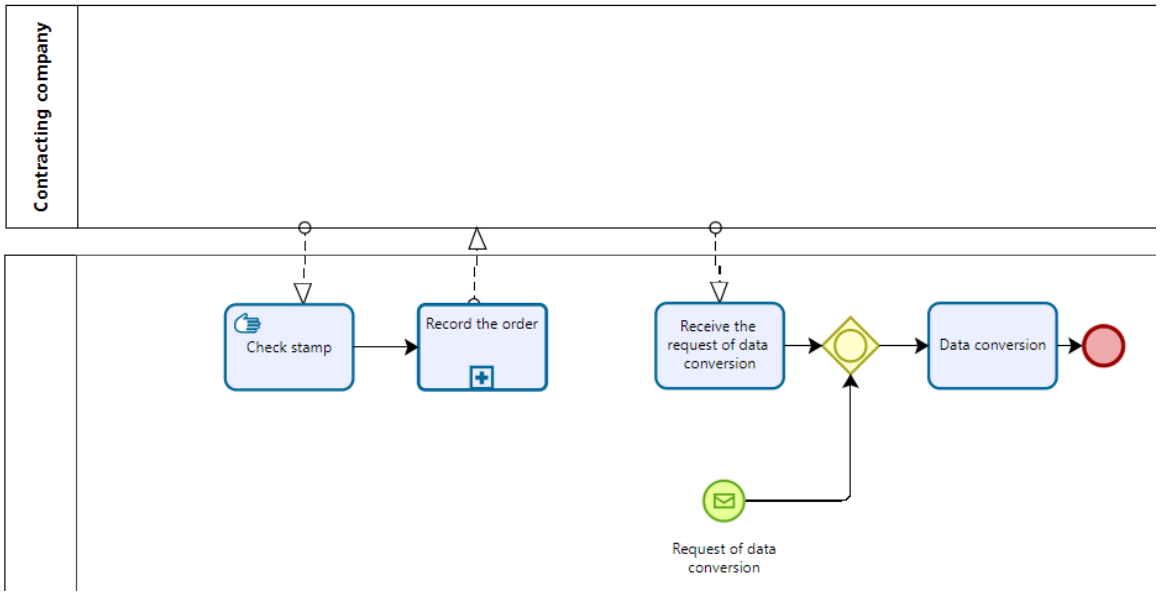

Figure 39: Data conversion and triangulation

3.2.4 Other subprocesses

Since the packaging warehouse is distant from the production lines, an area of the warehouse near the production warehouse is employed to store a small quantity of high-rotation packaging. This is done to facilitate production area forklift drivers and to avoid downtime in production. The packaging area forklift driver, from the start of his shift, periodically verifies that the packaging area near production is well provided with all the material needed, if it is not the case he collects the packaging in the packaging warehouse and then bring it near production area (Figure 40).

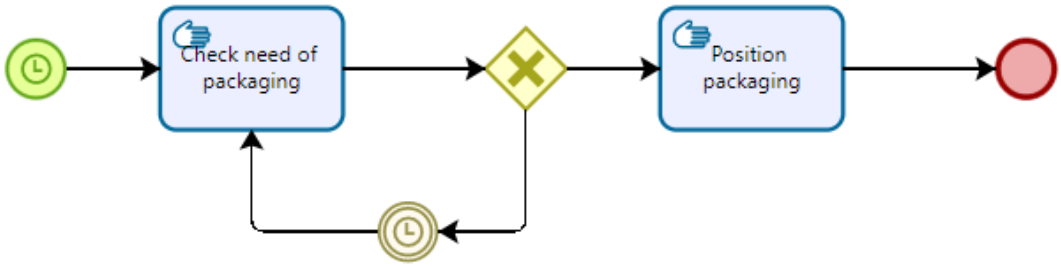

Figure 40: Verify the availability of packaging

Periodically, an inventory of the material in whatever warehouse of the Dayco plan can be requested by the supply chain department or by a customer as illustrated in Figure 41.

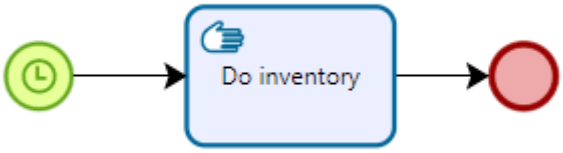

Figure 41: Inventory

3.3 Production warehouse

The process in the production warehouse is triggered in two ways. The prototype department can place an order of material from the warehouse, or an item production can be scheduled and so the material is needed on the production line.

3.3.1 Prototype department order

When the prototype department makes an order requiring some goods from the warehouse, the production forklift driver prepares the ordered material and does the picking operation (Figure 42). The picking operation is needed because the prototypes department usually asks for a small number of goods that must be picked from bigger boxes. Once the goods are ready, the forklift driver delivers them to the prototype department.

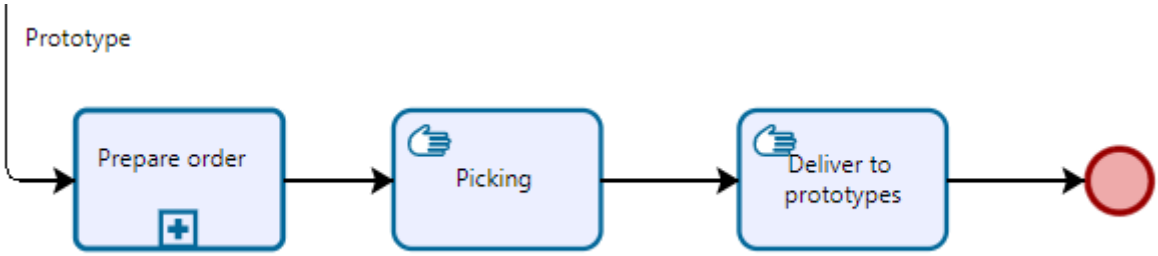

Figure 42: Prototype department order

3.3.1.1 Prepare order subprocess

To prepare the order, the production forklift driver must first print the order. If the material is present in the kanban area the process ends because the goods are already in charge of the production department.

If the goods are stored in the raw material warehouse, the production forklift driver collects the material and positions it near the computer area in the warehouse as illustrated in Figure 43. If the material is stocked in the narrow aisle forklift area, the forklift driver assigned to that area is appointed to collect the pallets. If the narrow aisle forklift driver is not available, the production forklift driver who is preparing the order collects the material and positions it near the computer area.

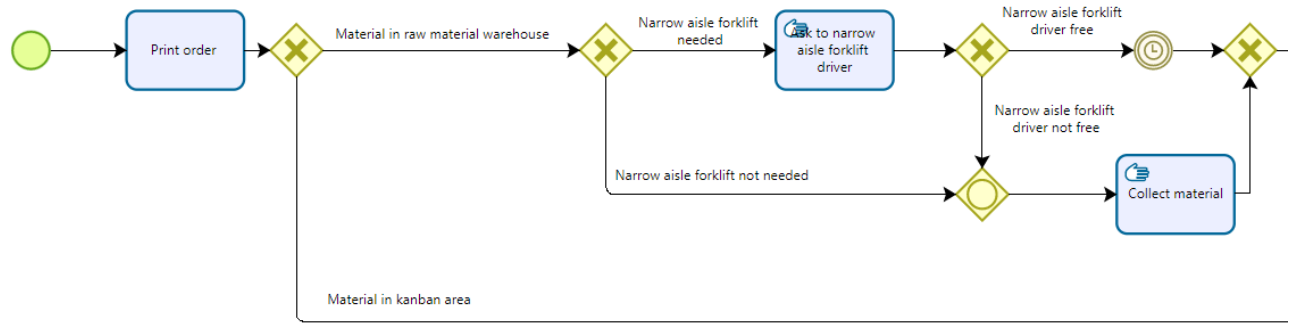

Figure 43: Prepare order subprocess with material in the raw material warehouse

Later, the warehouse worker registers the movement of the goods from the raw material warehouse to the production warehouse and the new yellow labels are printed. The withe labels of the raw material warehouse are then substituted with the new ones.

If the material is immediately needed by the production or by the prototype department, the process end, otherwise the pallets are positioned in the kanban area (Figure 44).

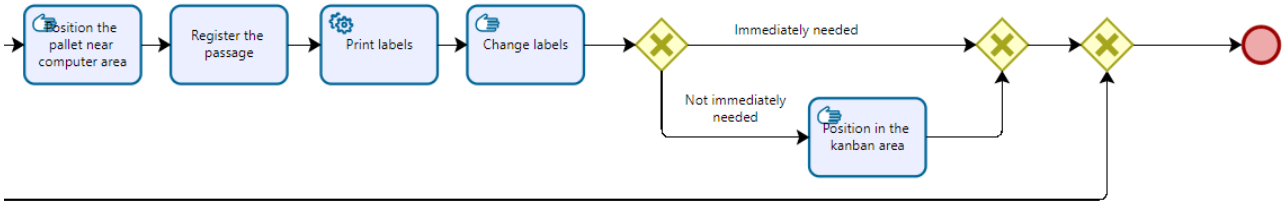

Figure 44: End of prepare order subprocess

3.3.2 Item production schedule

Every 8 hours a new shift starts: the new production forklift driver substitutes the previous one and asks him for information about the orders already released for the next shift as indicated in Figure 45.

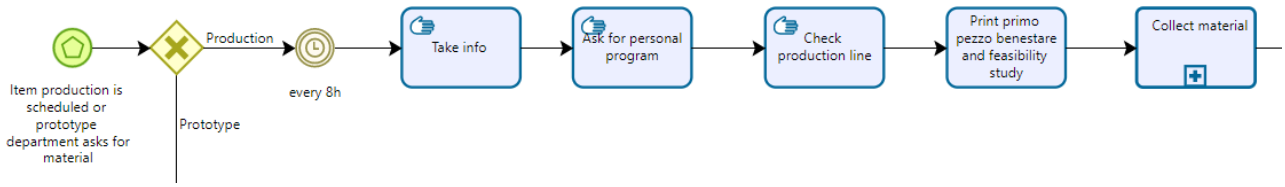

Figure 45: Procedures at the beginning of the shift

Then, the production forklift driver asks his personal program to the production worker and checks which material is present in the production lines informing the line workers about eventual changes of line. Checking the production line is a tricky task because the forklift driver must calculate how much material the production line will consume in the shift knowing the production time and the quantity of product to be produced. Then he must calculate if there is enough raw material stocked near the production line, what is the reorder point and when it should occur. All the calculations are made without the support of a calculator and of a tested methodology. To avoid downtime the production forklift driver should do periodic checks to ensure that all the lines have the required raw material. The frequency of the checks is decided by the forklift driver through the information he has.

When the production forklift driver knows how much material bring to each line, the feasibility study is performed. Starting from the bill of material of the products, the forklift driver verifies in the information system that the warehouse contains all the material needed to produce each product. Sometimes, due to the lack of time, the feasibility study is omitted because avoiding downtime is more important than checking the real availability of the raw material: the forklift driver just takes the goods where they are stored and brings them where they are needed, postponing all the task performed on the information system. Moreover, the feasibility study could be useless since many semi-assembled products are not recorded as such in the information system, but they are still recorded as raw material. In this case, if the forklift driver checks the availability of the raw material in the system, he could find it as available even if the goods were already used to create a semi-assembled product.

It is then time to collect the material to bring it to the production lines as shown in the collect material subprocess.

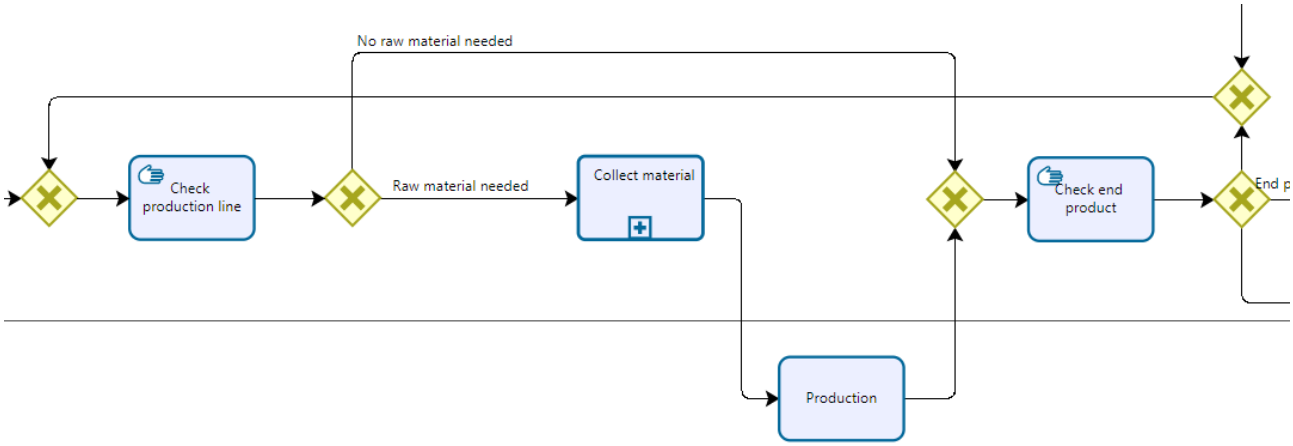

Figure 46: Continuous check of the material

While the forklift driver is around the production lines (Figure 46) he evaluates again if there is enough raw material to avoid downtime. If more raw material is needed, the collect material subprocess is performed again, otherwise the forklift driver checks if a pallet of the end product is ready to be collected and brought to the shipping preparation area to be allocated in the end product warehouse.

If there is no end product to collect, the forklift driver goes back to the check production line task performing a loop based on the two activities of checking the presence of raw material near the production line and checking the presence of end product to be allocated in the end product warehouse.

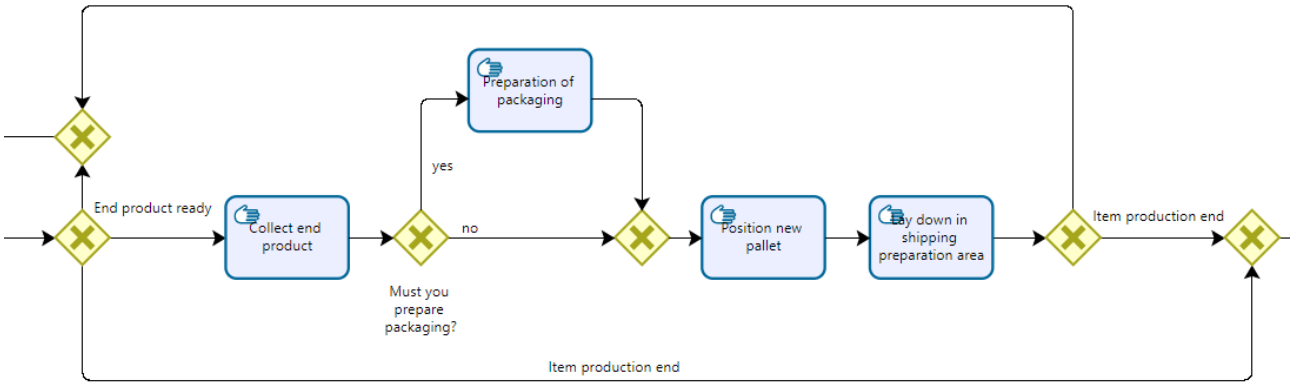

Figure 47: End product is collected from the production line

If there is a pallet ready for the end product (Figure 47), the production forklift driver collects it and, if needed he also positions the new pallet in place of the old one. All the packaging needed for the

production is considered as raw material. Finally, the product is collocated in the shipping preparation area to be allocated in the warehouse.

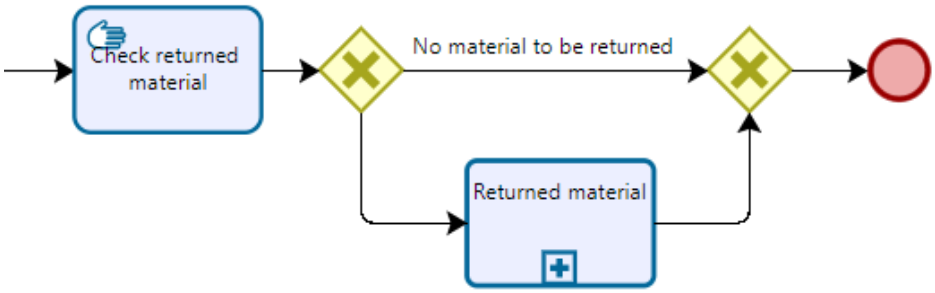

Figure 48: Check the presence of material to return to the warehouse

When an item production end and a change in the line is needed, the forklift driver checks if there is any material that must be returned to the kanban area or the raw material warehouse (Figure 48). In this case, the returned material subprocess is performed and then the process ends.

3.3.2.1 Collect material subprocess

When the forklift driver must collect the material from the warehouse (Figure 49), he goes to the kanban area to check the real availability of the materials estimating the quantity of goods present on each shelf. Since the warehouse is organized according to the kanban theory, there are no fixed quantities on the pallets, so the warehouse worker evaluation could not be precise. The scope of this task is to decide if there is a need to move some material from the raw material warehouse to the production warehouse.

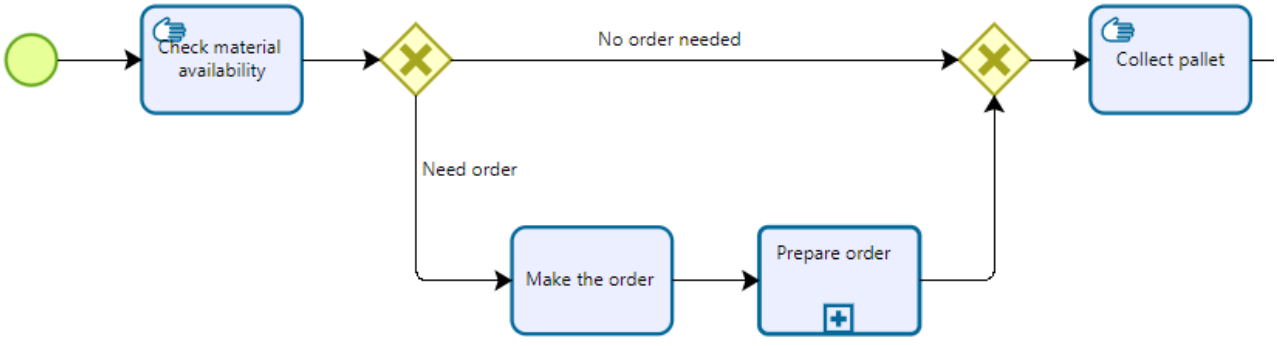

Figure 49: Start of collect material subprocess

If an order of goods from the raw material warehouse is needed, the production forklift driver performs the task on the information system and prepares the order as seen in prepare order

subprocess. Once the passage of warehouses is done, the material is collected and positioned near the assembly line on a specific rack or directly on the ground (Figure 50). In the case the batch number of the goods just positioned is different from the one of the goods already present on the production line, a copy of the label of the new batch is attached to the box for traceability.

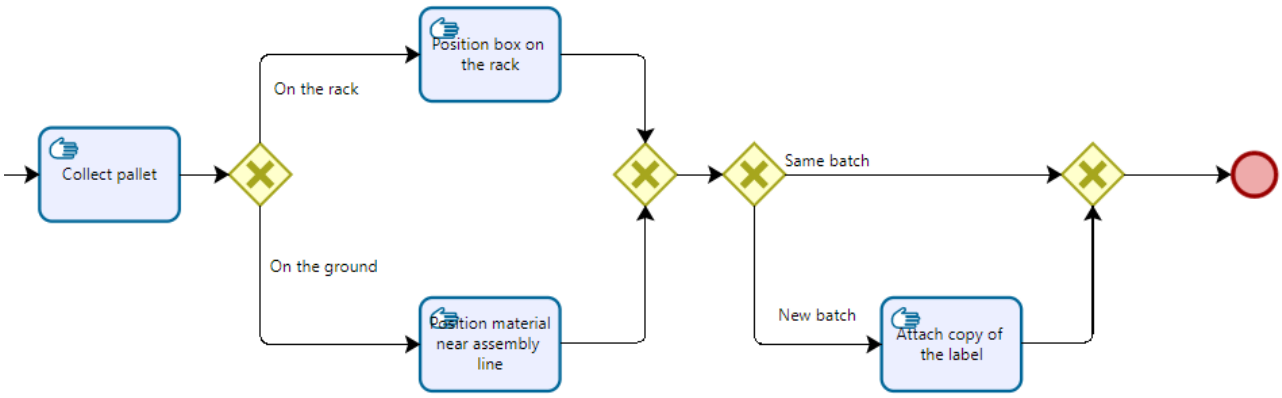

Figure 50: End of collect material subprocess

3.3.2.2 Returned material subprocess

At the end of an item production, there could be some raw material that must be allocated again in the warehouse (Figure 51).

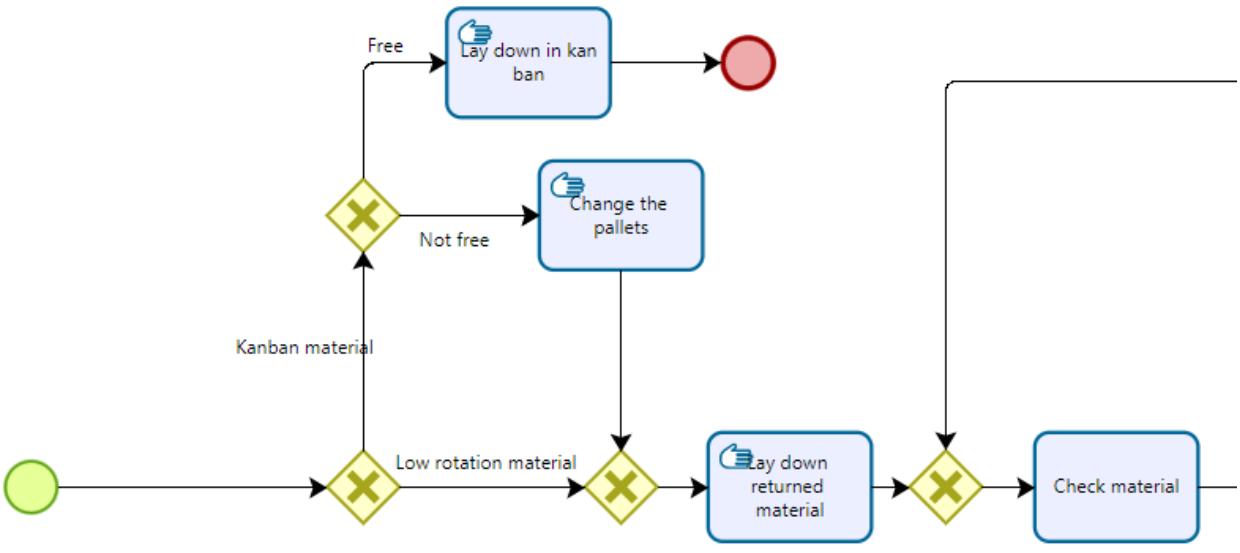

Figure 51: Start of returned material subprocess

If the material is usually stored in the kanban area, the goods to be returned are stored again on their shelves. It could happen that the shelf is not free due to a mistake in the feasibility study or in

the calculation of the forklift driver. To not break the FIFO rule, the oldest material is positioned on the shelf while the newest one is positioned in the returned material area.

Some very low rotation materials are not stored in the kanban area, but are directly collected from the raw material warehouse and collocated near the production line. If such material must be returned, it is directly positioned in the returned material area.

The returned material is then identified, weighted and counted. This task is time-consuming and, for that reason, sometimes it is done without the needed attention, creating inaccuracy in the information system. Moreover, if the returned material is a semi-assembled good, it is just positioned on a dedicated area, but registered in the information system as raw material generating an even more serious inaccuracy.

Finally, the movement from the production warehouse to the raw material warehouse is computed and recorded in the returned material register. To conclude the pallet is correctly allocated in the raw material warehouse.

The passage from one warehouse to the other could present two different errors (Figure 52):

- The traceability of the returned material is lost and the information system must be forced to register the returned material.
- The quantity indicated by the information system is lower than the real one.

If the second type of error occurs, the quantity of goods indicated by the AS 400 is allocated as explained before, the quantity in excess is stored in a dedicated area and reintegrated in the information system with the following inventory. The inventory is done every six months and until that time the material in excess is not registered anywhere, so it could easily be lost since almost no one knows it is there.

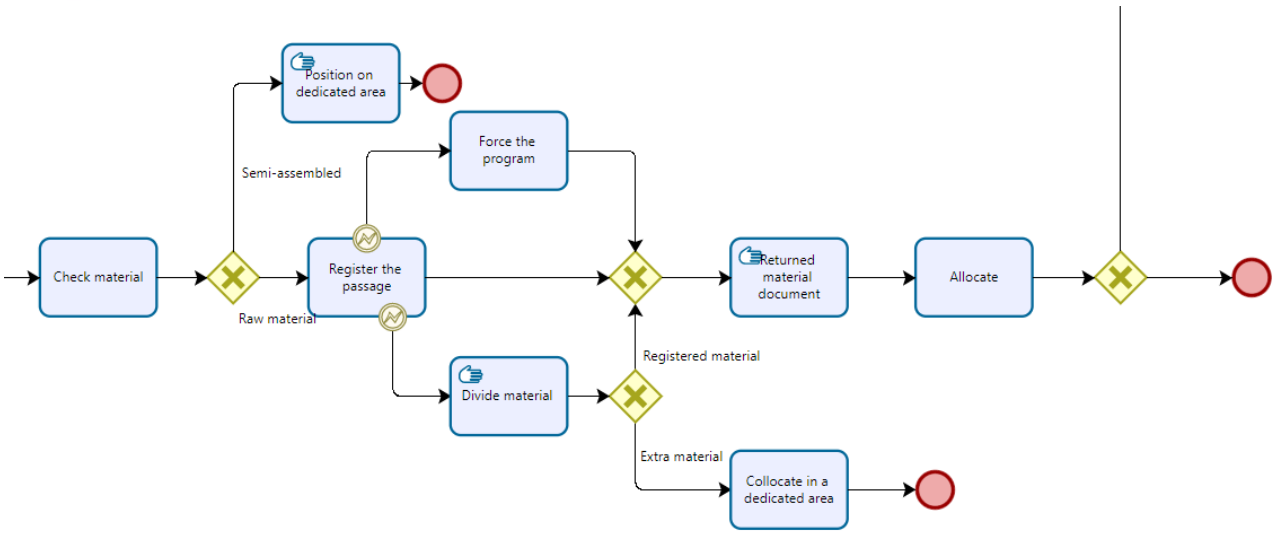

Figure 52: End of returned material subprocess

3.4 Shipping preparation area

The process in the shipping preparation area starts when one of the starting events took place:

- End product needs to be allocated in the end product warehouse
- A shipping request arrives
- A request for data conversion arrives

3.4.1 End product to be allocated in the warehouse

When the pallet of the end product is positioned in the shipping preparation area by the production forklift driver, the shipping preparation area worker takes the material in charge (Figure 53). First, the warehouse worker checks the product type and its correct registration in the information system. If the pallet is not visible in the correct warehouse of AS 400, an error of the procedure is observed: it will be a duty of the shipping preparation area worker to register the product in the right way.

Secondly, a check of the packaging of the material is done. If the pallet has the correct top and base, it is ready to be allocated otherwise a second error is present and the pallet must be correctly assembled.

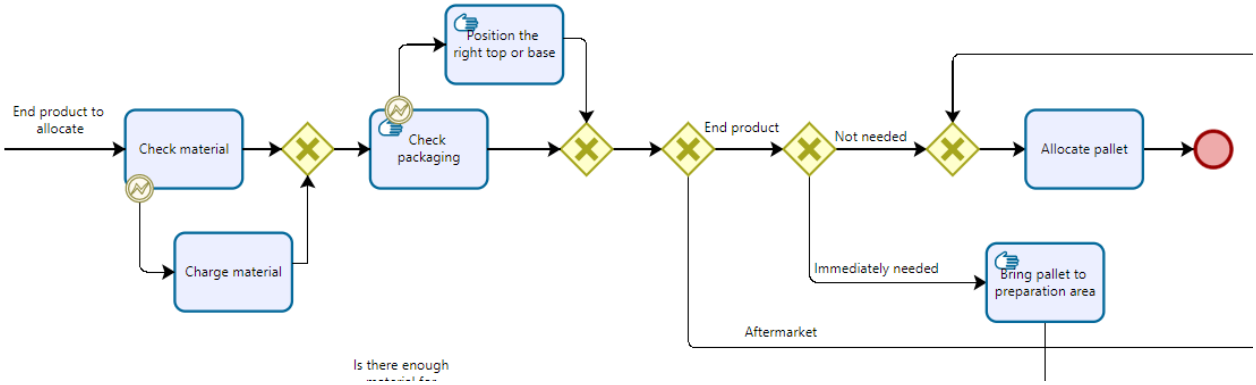

Figure 53: End product to be allocated in the warehouse

Finally, two different cases can be distinguished. If the end product is not for the aftermarket sector, it is allocated in the warehouse or it is transported to a specific area of the warehouse to be prepared for shipping. If the end product is for the aftermarket, the pallet is immediately positioned to be prepared for shipping accordingly to its customer destination.

3.4.2 Shipping request

When a shipping request arrives (Figure 54), it is collected by the shipping preparation area worker. Usually, the shipping requests are received every morning, but they could arrive at every moment of the day. The warehouse worker must then check the order printout to understand which quantity of product to ship to which customer.

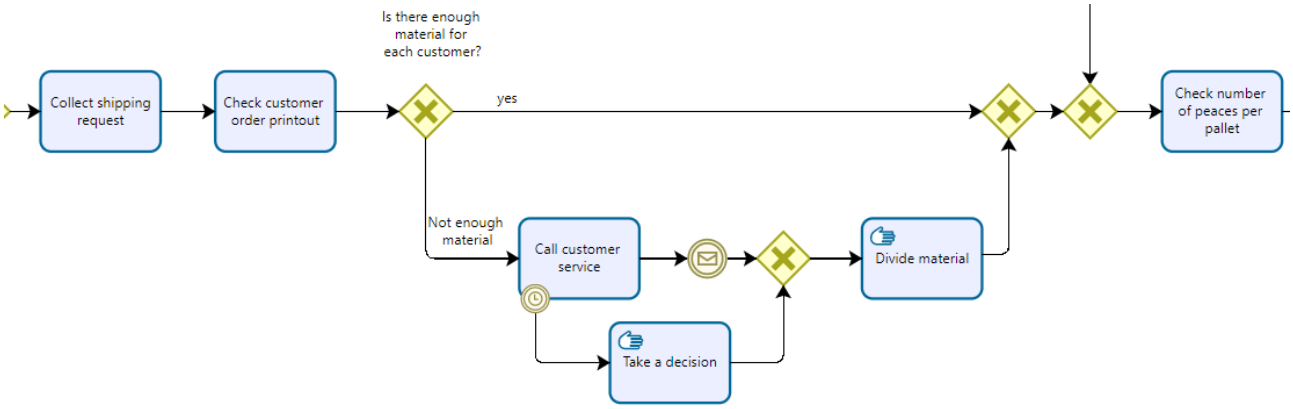

Figure 54: Check customer order printout

The same end product can go to different customers so the worker checks that there is enough product for each customer. If it is not the case, it is necessary to refer to customer service that indicates how to divide the available end product. Many customers ask Dayco to claim within a certain hour, usually around 11.00 am, the quantity and the type of product Dayco will ship in the next few days. This is done to enable the customer, who bears the shipping cost and so decide which company will collect the pallets, to organize and optimize the shipping. If a particular end product

is not available to Dayco to satisfy the shipping request of the customer and the customer service is not fast enough to solve the situation, then it is the shipping preparation area worker's duty to make a decision and allocate the material.

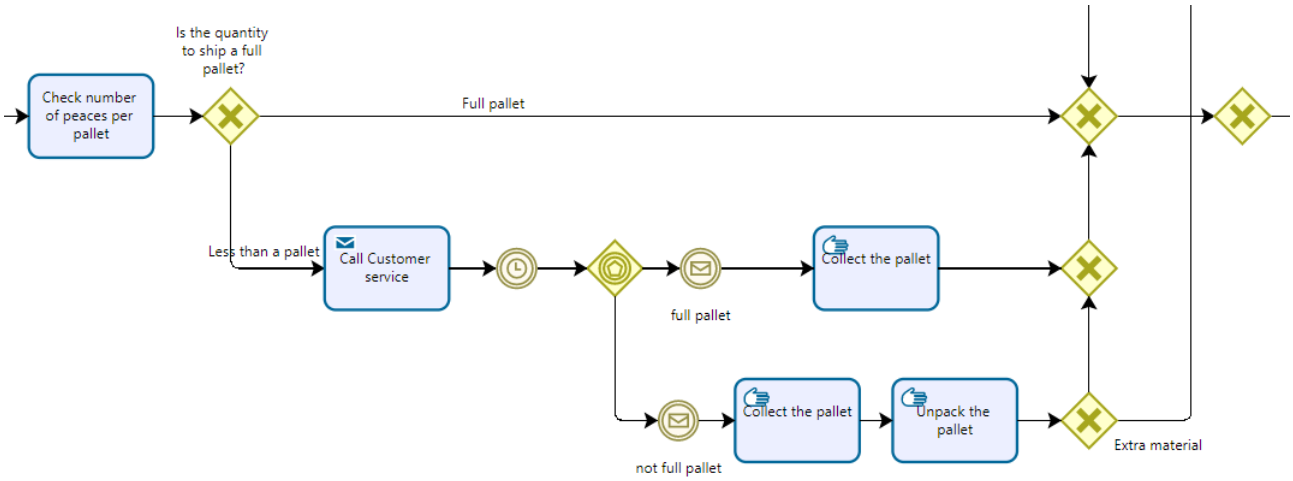

Figure 55: Check the number of pieces per pallet

The customer can also specify the type of packaging and the quantity of product that must be positioned in one pallet, taking into consideration the standards of the sector. Anyway, the customer can also request a quantity that is not a multiple of the pallet quantity and so the warehouse worker must check that the pallets that are going to be shipped contain the correct quantity of product (Figure 55). If this is not the case, the shipping preparation area worker must contact customer service to ask if it is possible to ship more end products than requested. If the product has a high cost, it could be that the authorization is not given and the worker must collect the pallet and unpack it in order to ship the right quantity. The end product that will not be shipped is again allocated in a specific area of the warehouse where single boxes are stored.

When the warehouse worker is sure about the quantity of end product he will ship to each customer, the pallets are prepared accordingly to the customer's request.

As stated before, the customer can request a certain type of packaging and label. In almost all cases, the labels are customized and they are printed and attached to the pallets according to the customer's will.

The procedures have been differentiated for the following customers:

- Volkswagen
- FCA
- Daimler
- PSA
- Scania
- Volvo
- Perkins
- Ford

In all other cases, the process is defined as standard. When the pallets have been correctly prepared, they are positioned in the shipping area.

3.4.2.1 Volkswagen subprocess

The process is triggered when the end product for Volkswagen is positioned in the shipping preparation area as indicated in Figure 56. First, the warehouse worker scans the production barcode to acquire information about the end product, then he performs different tasks accordingly to the type of packaging that can be cardboard, odette and box.

When the end product is stored in cardboard and metallic box, the production label is removed and the system prints a new master label. The new master label is then attached to the packaging and the pallet is ready to be shipped.

If the product is stored in odette, the system print both master and small labels. Small labels are attached to each odette, while the master label is attached to the front of the pallet.

When all labels have been correctly applied, they are scanned again to enable the correct registration of the product on AS 400 and the creation of the shipping note.

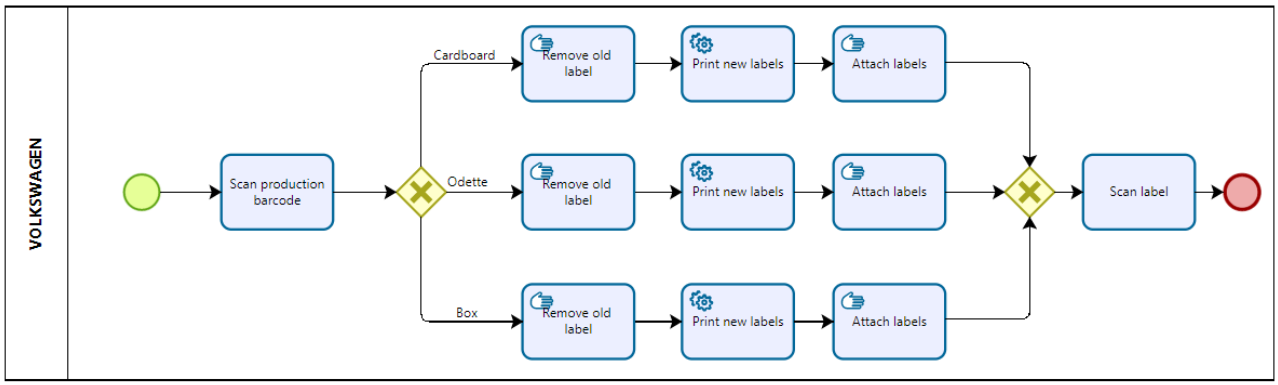

Figure 56: Volkswagen subprocess

3.4.2.2 FCA subprocess

FCA has three possible packaging as shown in Figure 57: cardboard, odette, metallic box. For each type of packaging both small and master labels are printed after the production barcodes have been scanned.

When the end product is stored in cardboard the old labels are not removed because the new labels are directly attached over the old ones. For odette and boxes the old label are removed before attaching the new ones as in the Volkswagen case.

To conclude, all new labels are scanned and the shipping note created.

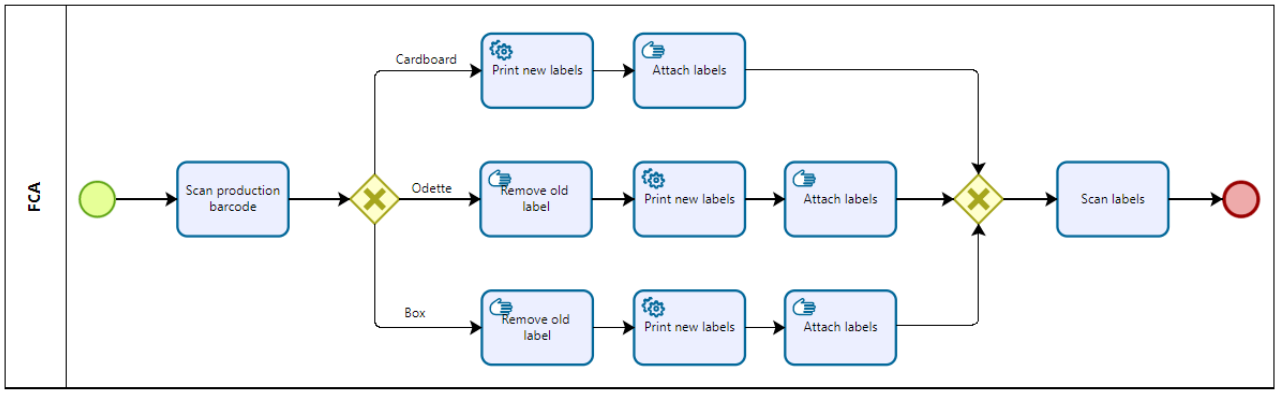

Figure 57: FCA subprocess

3.4.2.3 Daimler subprocess

Daimler packaging includes odette, classic boxes. As illustrated in Figure 58, after the production barcodes have been scanned, the old labels are removed and the new labels (master and small) are attached to the pallets. In the case of grilled box two master labels are attached on two sides of the box. All new labels are then scanned to create the shipping note.

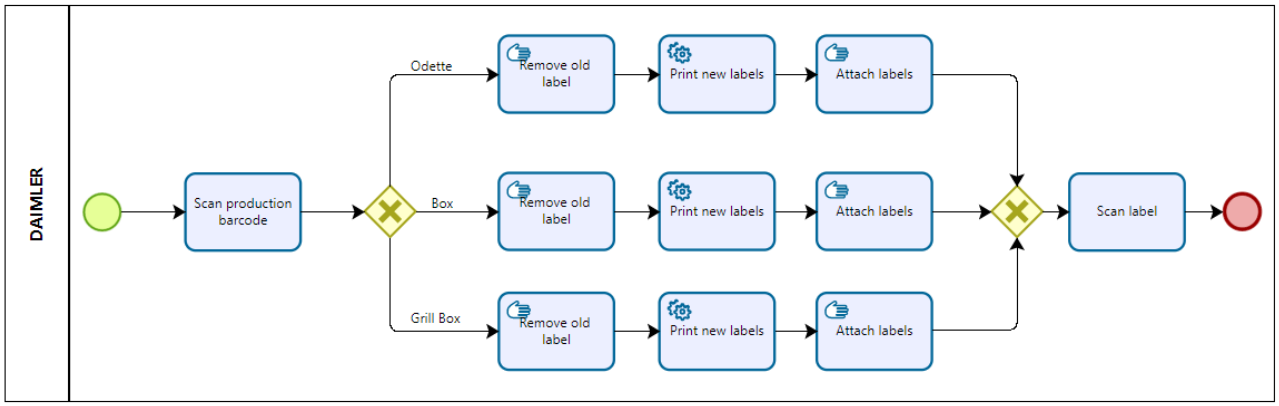

Figure 58: Daimler subprocess

3.4.2.4 PSA subprocess

PSA has two possible packagings (Figure 59): cardboard and odette. For odette, both small and master labels are printed and substituted to the production labels after these have been scanned. For cardboards, just the master label is printed. To conclude, all new labels are scanned and the shipping note created.

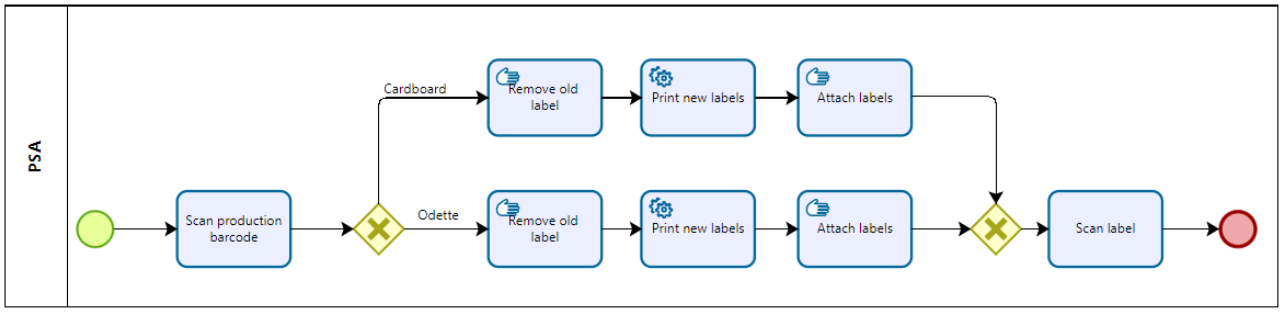

Figure 59: PSA subprocess

3.4.2.5 Scania and Volvo subprocess

Scania and Volvo have similar types of packaging and procedures even if the information on the labels can vary as illustrated in Figure 60 and Figure 61. For odette, both master and small labels are printed, while for boxes only master labels are attached to the pallet with paper clips.

All new labels are then scanned and the shipping note created.

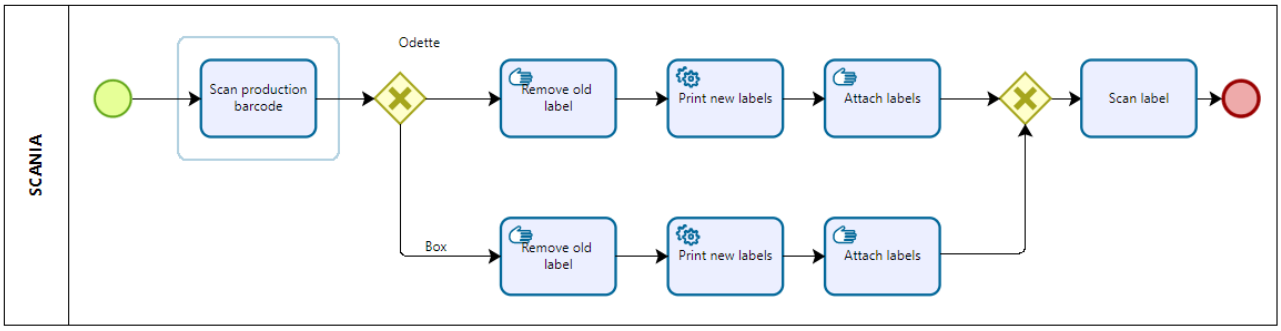

Figure 60: Scania subprocess

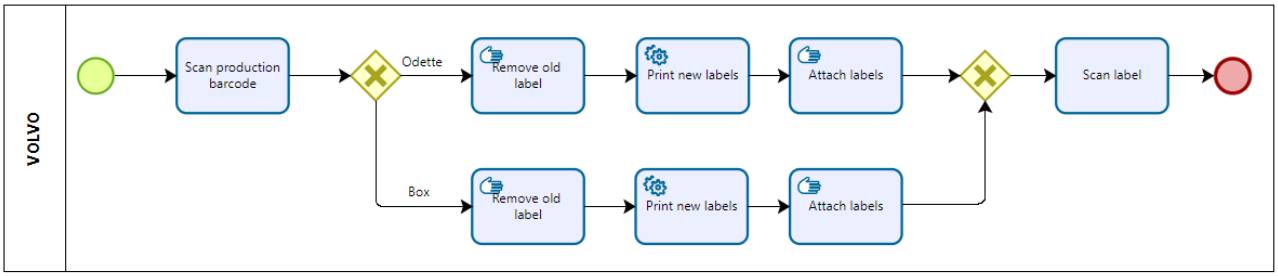

Figure 61: Volvo subprocess

3.4.2.6 Ford subprocess

Ford receives the end product just in odette packaging as indicated in Figure 62. After the production barcodes are scanned, they are removed and substituted with new master and small labels which are scanned again to create the shipping note.

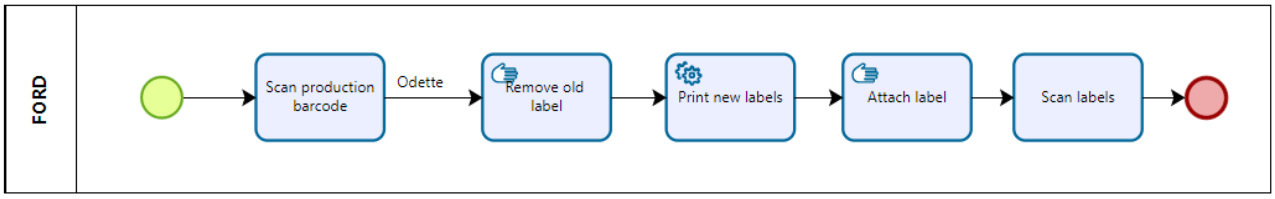

Figure 62: Ford subprocess

3.4.2.7 Perkins subprocess

Perkins requires the use cardboard packaging with small and master labels attached directly over production barcode as illustrated in Figure 63.

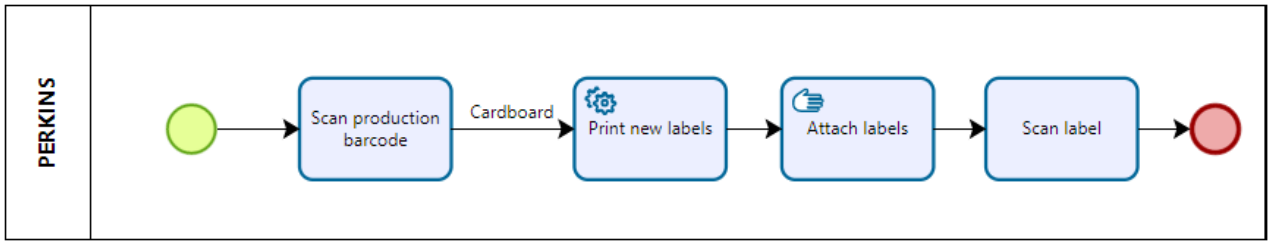

Figure 63: Perkins subprocess

3.4.2.8 Standard subprocess

In the standard case (Figure 64), cardboard is used. Just master labels are printed and substituted with old production labels after they have been scanned. To conclude, the new master label is scanned to create the shipping note.

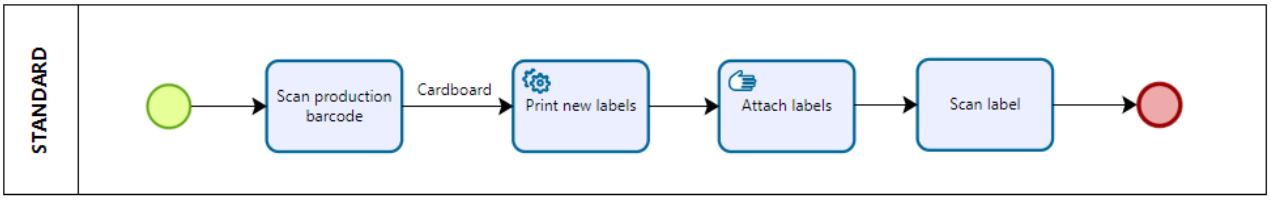

Figure 64: Standard subprocess

3.4.3 Request for data conversion

Sometimes a required end product might be present in the Dayco warehouse, but not available for that particular customer. The same product could be sold to more than one customer, but each customer requires customized packaging, so the product could be present in the warehouse as packaged for customer A but it could be needed to satisfy an urgent order of customer B. This implies that a data conversion is requested to enable the system to see the product for customer B as available, but also that the material must be transferred from the packaging of customer A to the packaging of customer B (Figure 65).

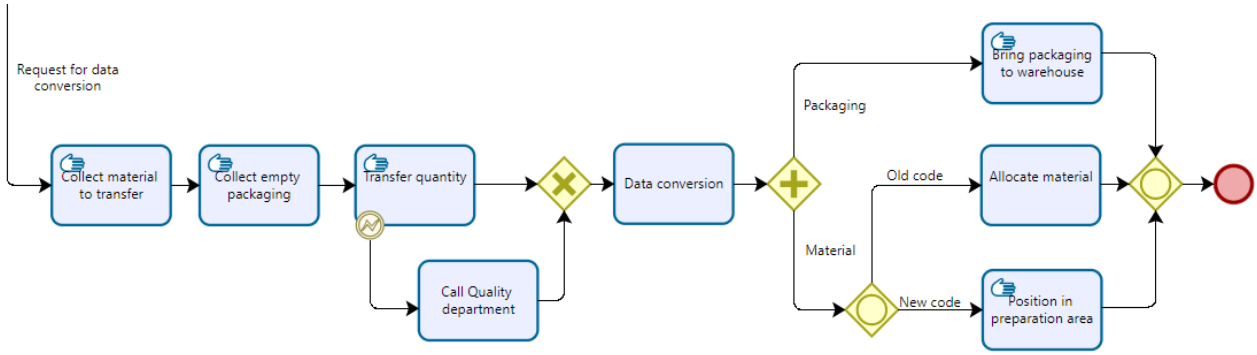

Figure 65: Request for data conversion

When the shipping preparation area worker receives the data conversion request, he collects the product to transfer and the packaging needed to do it. Secondly, the product is transferred from one kind of packaging to the other (from packaging type A to packaging type B). When the task is performed, the end product might be damaged and the shipping preparation area must call the quality department to ask for a check of the material or how to proceed.

When the product is transferred to the correct packaging, the data conversion in AS 400 is realized to enable the shipping. To conclude, the old packaging in good condition is stored in the packaging warehouse, if the packaging is damaged it is thrown away. The pallet with the transferred product is positioned in the preparation area and, if some product with the old packaging is remaining it is again allocated in the warehouse.

3.5 Shipping

After the shipping preparation worker positioned the ready end product in the shipping warehouse, the process of the shipping area starts.

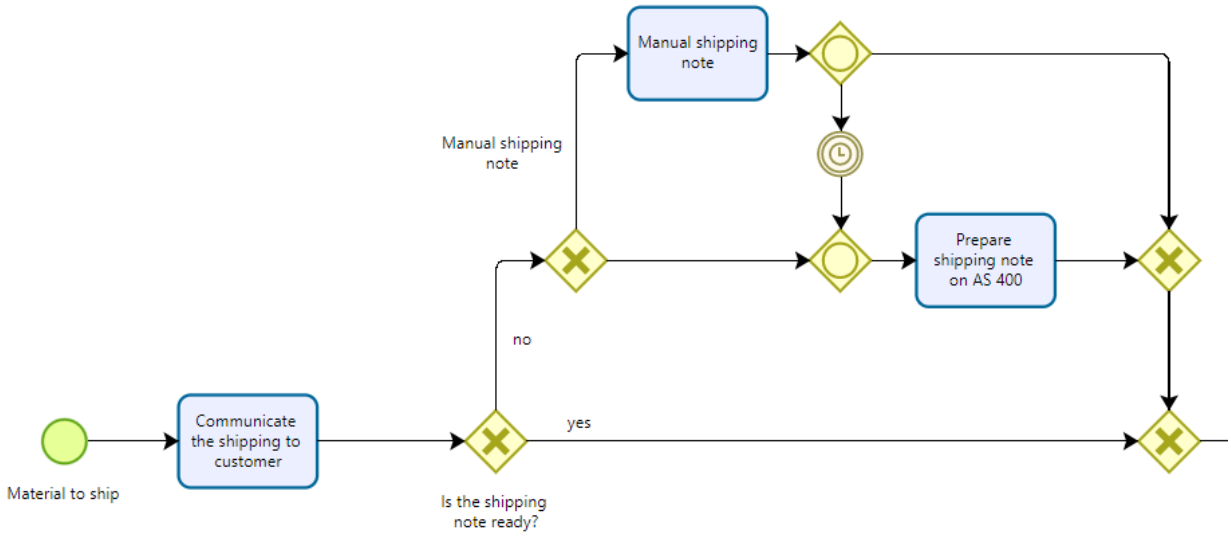

Figure 66: Communicate the shipping to the customer

The first task that the shipping area worker performs is to communicate the shipping to the customer as illustrated in Figure 66. As stated before, it is the customer who bears the cost and so decides which company will be appointed for the shipping. The process is complicated and not always easy. Each customer has a specific portal where Dayco warehouse workers should claim which product is going to be delivered and which are the product characteristics like weight and volume. All this process should be done within a certain hour usually between 11.00 am and 12.00 am. Basically, with this task Dayco commits that the following day a certain amount of product with certain characteristics will be shipped to a specific customer to fulfill an order.

Since Dayco produces just in time, it could happen that the shipping area worker must communicate the shipping to the customer without the effective presence of the product in the warehouse. The product that should be shipped the next day at 12.00 am could be produced in the twenty-four hours between the communication and the real shipping. This can be verified in the production plan which is often subject to last-minute changes. So communicating the shipping to the customer can be seen as a bet: the shipping area worker bets that the next day, Dayco will be able to ship a certain product as committed before. If the production is not able to respect the production plan and to deliver to the shipping department the needed product, Dayco could incur in extra costs due to the

disruption and to the urgent shipping that the company must organize to deliver the product to the customer.

Once the shipping has been communicated to the customer, the warehouse worker checks the presence of the shipping note. If the shipping note has not been compiled by the shipping preparation area worker, the shipping area worker must compile it in AS 400 or in an excel template. The shipping notes compiled in the excel template are considered manual shipping notes because they are not present in the information system and so must be manually compiled and registered in the tax book. Some manual shipping notes are converted into AS 400 shipping notes at the end of the month as in the case of production scraps like metallic shavings.

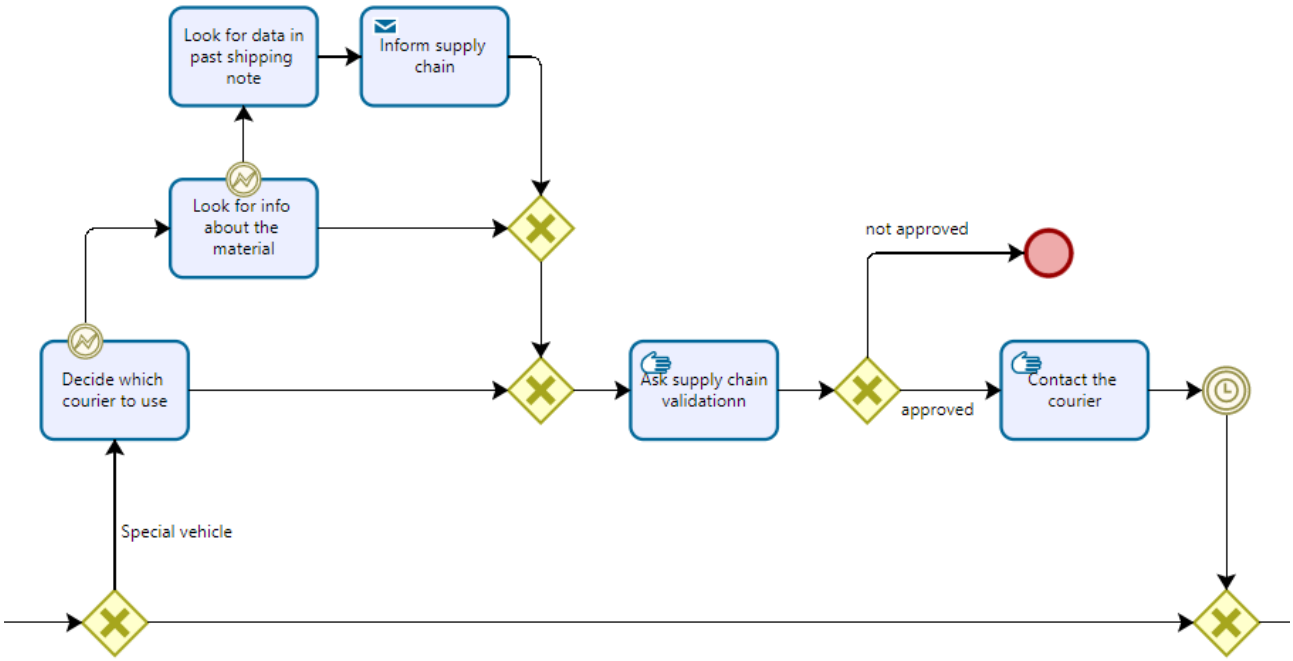

Figure 67: Special vehicle shipping

The shipping area worker could be asked to arrange a special vehicle shipping in case the customer needs the product in a short time or in case of Dayco disruption (Figure 67). Depending on the material to ship, the warehouse worker must decide which courier to use and must communicate all material specifications such as weight and volume to the courier. The Dayco worker who asked for the shipping by email should have communicated all information about the material to the shipping area, but often this is not the case and an error in the procedures could be identified. If the shipping area worker doesn't have the information needed, he asks again to the one who required the shipping and, if he doesn't receive any answer, he will look for the data in past shipping notes and he will inform the supply chain of the error.

Once all specifications of the material are available, the shipping area worker asks the supply chain manager to approve the shipping. Usually, it is the customer who bears the shipping cost, but for special vehicles Dayco pays the shipping, so the approval of the supply chain manager is required. If the shipping is approved, the warehouse worker contacts the courier to arrange the collection, otherwise the process ends because no material is going to be shipped.

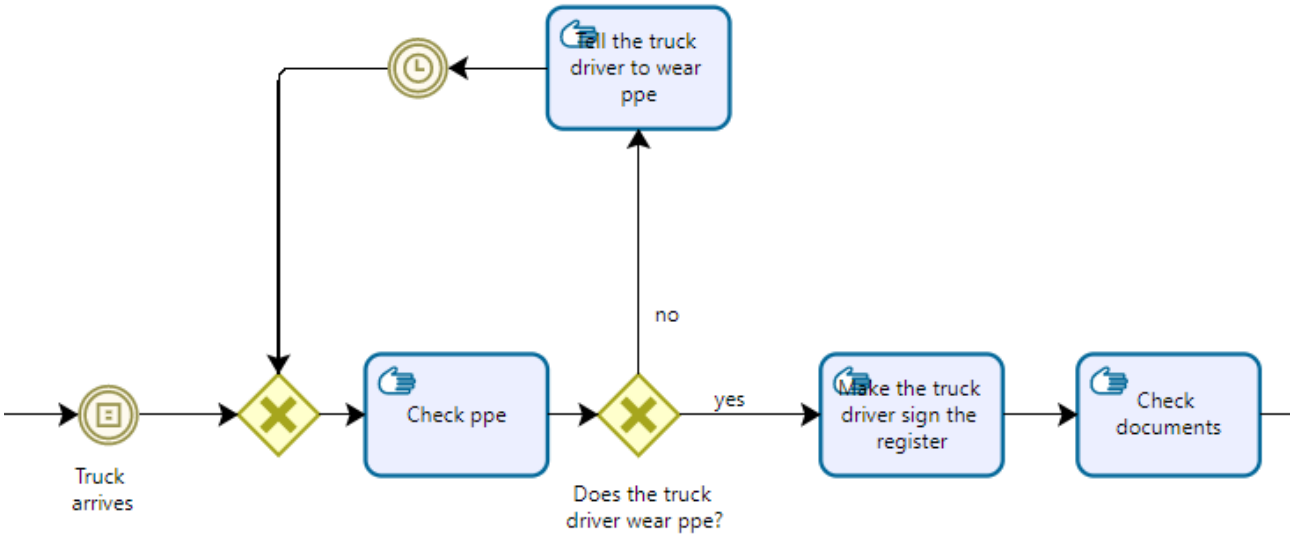

Figure 68: The truck for the shipping arrives

When the truck or the courier arrives at the Dayco shipping area (Figure 68), the shipping area worker checks that the truck driver wears the personal protection equipment. If this is not the case, the warehouse worker must ask the truck driver to wear the safety shoes and the high-visibility jacket and wait until this is done.

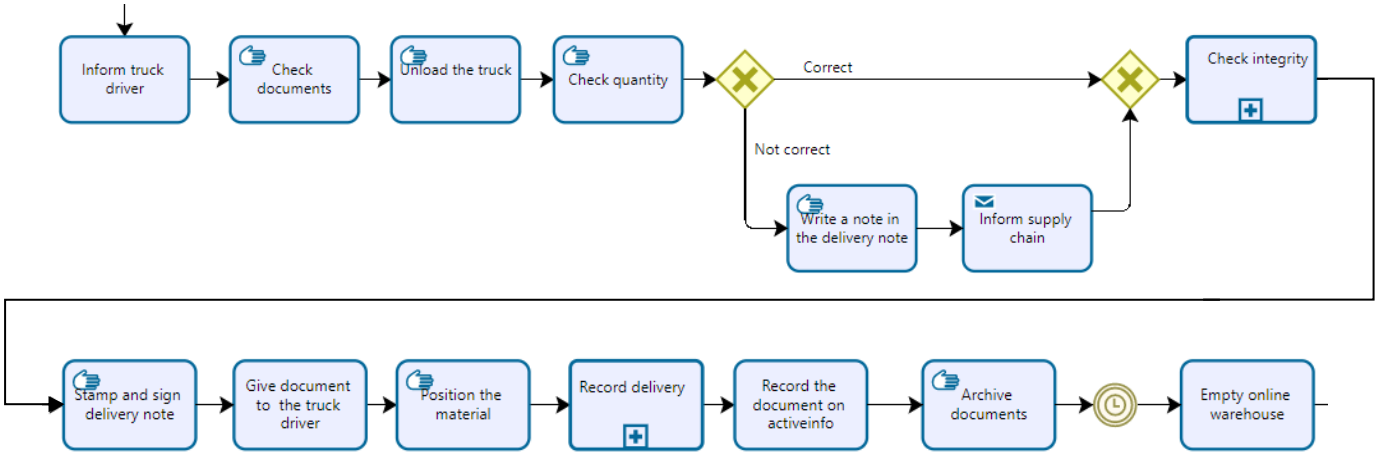

Figure 69: Returnable packaging in shipping area

Later, the truck driver signs the register to record the arrival time and license plate of the truck. Then, the shipping worker checks the document to understand which shipping the truck driver must collect and the presence of returnable packaging. Since some products are delivered to the customer in returnable packaging, it may happen that the customer's truck must both unload the empty returnable packaging and collect the product for the customer.

The procedure for returnable packaging (Figure 69) is the same as the one seen in the incoming area. The truck driver is sent to the packaging warehouse where the packaging forklift driver checks the documents, unloads the truck verifying the quality and quantity of the goods. Finally, he registers the delivery.

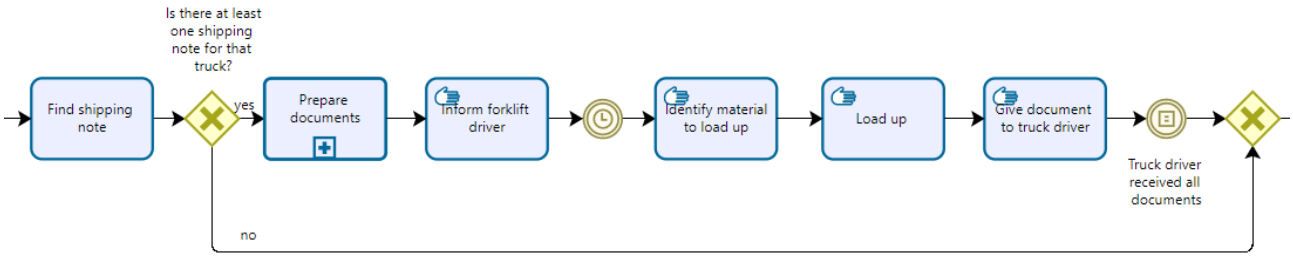

Figure 70: The truck driver receives the shipping note

The warehouse worker must then look for the correct shipping note as illustrated in Figure 70. If he is not able to find any shipping note, it means that even if he communicated the shipping to the customer, the production was not able to respect the production plan and there is no product to ship. In this case, the empty truck leaves the Dayco plant and the cost of the travel is charged to Dayco due to the disruption. In the end, there is no shipping and so no document to be registered.

If the shipping area worker finds the shipping note, he can prepare the document and inform the shipping area forklift driver to start the loading up of the truck. When the forklift driver is free, he identifies the material described by the shipping note and he loads up the truck. Finally, the forklift driver delivers the shipping note to the truck driver.

If the truck driver received all the needed documents, the shipping note and the delivery note of returnable packaging if present, he can leave the Dayco plant.

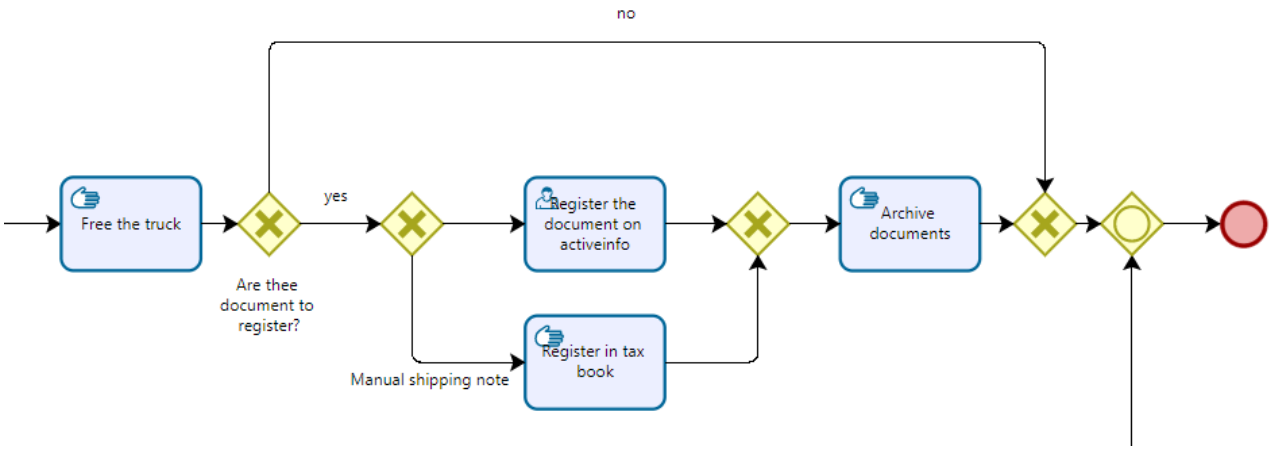

Figure 71: End of the shipping procedure

At the end of the shipping procedure (Figure 71), there are documents like shipping notes and packing lists that must be registered on the Activeinfo archive. All manual shipping notes must be registered in the tax book and all paper documents must be archived.

3.5.1.1 Prepare document subprocess

To prepare the documents, the shipping area worker must print the shipping note and the packing list (Figure 73Figure 72). If for the same shipping more than one shipping note is present, a comprehensive packing list must be compiled and printed.

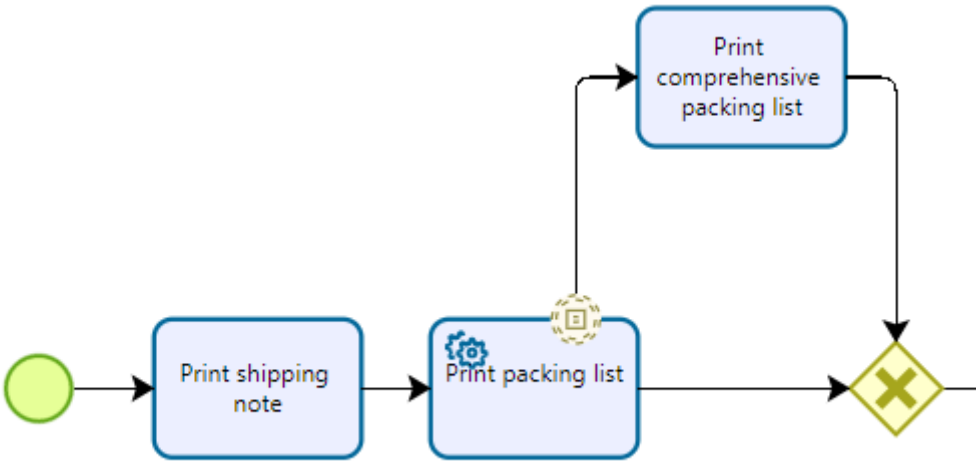

Figure 72: Start of prepare document subprocess

If the shipping is national no other document is needed, otherwise the CMR transport document is required. The CMR transport document certifies the contract of carriage by road and determines the scope and responsibility for the operation performed identifying the parties involved and the goods being transported.

If the shipping is extra EU the also the invoice and the bill of entry, a document showing the details of goods that are being transported into or out of a country, must be attached to CMR transport document and shipping note. The product invoice must be validated and signed by the supply chain manager, while the bill of entry must be compiled and double-checked.

When all documents are ready, the shipping area worker makes the needed copies for the truck driver as illustrated in Figure 73.

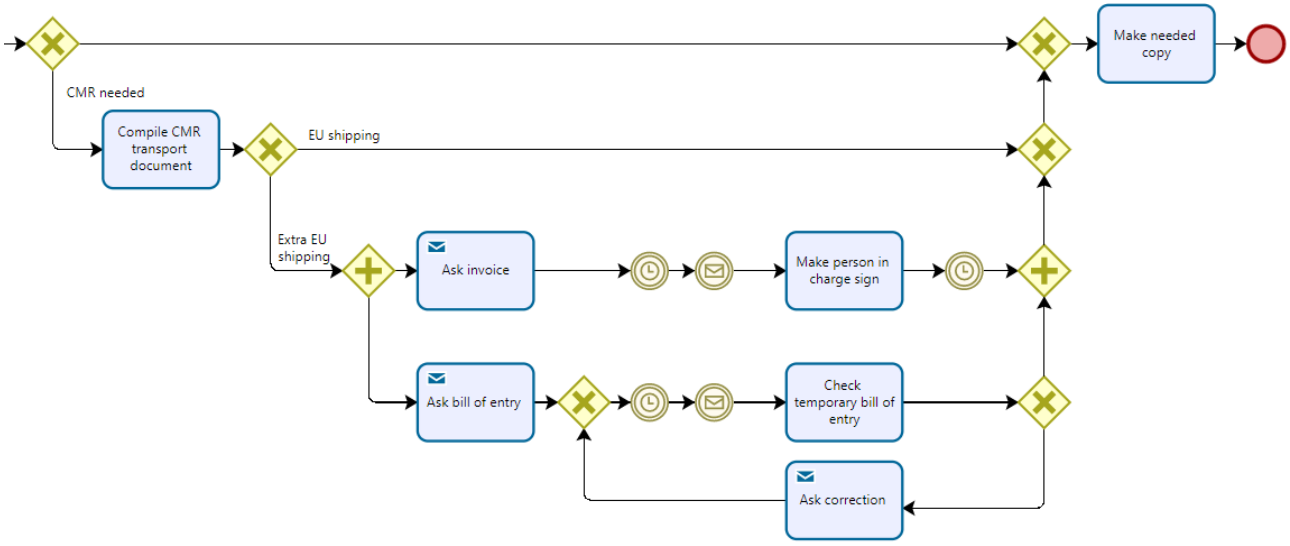

Figure 73: End of prepare document subprocess

4 Analysis of Dayco processes and possible solutions

Once the process has been modeled with the BPMB language, it is possible to identify its inefficiencies. The inefficiencies are then analyzed with the 5 Whys method. According to the company request, the focus is then moved to the incoming material area where a possible solution to the inefficiencies is proposed.

In particular, a mobile application, developed according to the outcomes of the 5S analysis, could make the process easier and leaner. Since the process has been modeled through the Bizagi software, the same tool has been employed to implement the application.

4.1 Analysis of Dayco warehouse

Starting from the model created in chapter 3 and from the interview of the warehouse worker, it is possible to understand which are the main inefficiencies in the Dayco warehouse. If a particular passage of the process flow is difficult to perform for the operator or if it is skipped due to lack of time, then probably the process can be managed in a better way. Inefficiencies can also be intended as a passage where a waste can be identified.

Some inefficiencies are not linked to a single area of the warehouse, but they can be found in more than one process. The general inefficiencies of the Dayco warehouse are the following:

- Communication
- Accuracy
- Manual tasks and personnel

4.1.1 Communication

One of the first and most incisive problems in Dayco is that communication between different departments is often difficult and ineffective. This happens because employees use a lot of emails to exchange information unless the urgency requires a phone call. This inefficiency generates waste of time for the operators that must manage each request and email in a customized way, without the possibility to standardize the process.

Each worker has his own way to write, manage and process the emails, so the communications can be incomplete (the email does not contain all information that the sender should communicate) or difficult to understand (the recipient does not understand what the sender wants to communicate). Moreover, using a phone call does not permit to keep trace of the communication and so data

exchanged can easily be lost. In addition, emails and phone calls are often used to push for an answer or for a problem solution: it is a loss of time both for the sender and the recipient.

5 WHYS ANALYSIS	
INEFFICIENCY	*Shipping area workers must ask more than once for information about the material to be shipped.*
Why must the worker ask for information more than once?	People asking the urgent shipping do not know which information is needed to arrange the shipping.
Why did people do not know the information they should specify?	No one trained them on how to do an urgent shipping request and what information is needed.
Why does no one tell the worker requiring the shipping, which information he needs to specify?	The request for urgent shipping is done by email. Doing specific training on such a procedure is time-consuming since it should be implemented for all the company members. Moreover, the worker requiring the shipping has no time to learn by doing.
Why is the request for urgent shipping done by email?	It is done by email because there is no other way to do it.
Why cannot the worker requiring the shipping learn by doing the procedure?	The low frequency of the procedure and the worker's high workload make it impossible for him to learn by doing.

Table 2: 5W analysis of shipping area inefficiency

Let's see an example. In the shipping area, the warehouse worker could be asked to arrange a special vehicle shipping if the customer needs the product in a short time or in case of Dayco disruption. Depending on the material to ship, the warehouse worker must decide which courier to use and must communicate all material specifications such as weight and volume to the courier. The Dayco worker, who asked for the shipping by email, should communicate all information about the material to the shipping area. If the information is not complete, it could be identified an inefficiency in the procedure. If the shipping area worker does not have the information needed, he must

contact the worker who required the shipping. If he does not receive any answer, he may look for the data in past shipping notes and he will inform the supply chain of the error.

Why does this inefficiency occur? A 5WHY analysis is performed as shown in Table 2.

From the 5WHYS analysis, it is possible to conclude that the cause of the problem is the lack of training and information about how to do an urgent shipping request. A standard form, where all needed information is listed, could solve such a situation and the shipping area worker could avoid asking twice the data.

Finally, it is possible to conclude that the main causes of inefficiencies linked to the communication between departments are:

- Lack of standard forms for the requests
- The worker has difficulties in archiving the emails and in processing them in the most efficient way
- Phone calls are fast but not traceable

4.1.2 Allocation task and accuracy

As stated in chapter 3, the Dayco warehouse is not organized according to the material stocked. The different areas of the warehouse, such as raw material warehouse, production warehouse, and end product warehouse are mixed, so it is not possible to distinguish which material is stored in a particular rack. Moreover, it is a duty of the warehouse forklift driver to decide where to allocate a pallet, therefore no algorithm is employed to optimize the operation.

Even if there is no software to optimize the allocations some simple rules are employed:

- High rotation materials are stored in lower levels of the racking system
- Kanban shelves are signaled with a yellow adhesive tape on the rack and are located in the first three levels of the racking system
- The end products are allocated near the shipping preparation area
- Different areas of the racking system near the shipping preparation area are designated to specific customer

Another important factor must be considered: it could happen that a pallet is not in the specific location. This underlines how accuracy is one of the main problems in the Dayco warehouse. Moreover, whenever the material is not located in the assigned allocation, the warehouse workers lose a lot of time looking for the pallet and making a visual inspection of the warehouse. This waste of time could be easily avoided by increasing the accuracy of the warehouse.

Another important inefficiency can be identified by analyzing the data about the returned material from the production warehouse to the raw material warehouse. To allocate the returned material, its traceability must be confirmed. If the traceability is lost, not all information required from AS 400 is available, so the system must be forced to proceed with the return. The traceability can be lost if the labels are not correctly attached to the pallet. This is again a waste of time and resources.

Comparing the number of times that the traceability is lost with the total number of returns to the raw material in one month (Table 3), it is possible to see how the inefficiency does not occur with a high frequency. Anyway, the analysis is based on data that were collected during the summer months, when the workload can be significantly reduced. In September, the number of returns has a pick due to an inventory performed in the production warehouse.

Even if the inefficiency frequency is low, it must be considered that the loss of the traceability of the material is a serious problem. If the traceability is lost and a quality problem occurs, the quality department cannot go back up to the batch of the raw material responsible for the defect and cannot identifies which products are involved. Moreover, from when the label is lost until the worker forces the registration in the system, the material is not registered anywhere and could be lost.

Sometimes it is possible to trace back the material analyzing the registration on AS 400 and identifying the flow of the material in the warehouse. Anyway, this process is very time-consuming and could involve both the production area worker and the incoming area supervisor slowing down the operation in both areas.

	July	**August**	**September**
Number of returns	543	433	290
Returns in which the traceability was lost	2	3	33

Table 3: Returns of material

4.1.3 Manual task and personnel

Analyzing the process and interviewing the warehouse workers, it is possible to see that the process is designed by the operator according to their own capacity. Since the role of each worker is fixed for a long time, each one specializes in some particular tasks and with time modifies the process to better conform with his way of working regardless of the company standards. According to Lean Production principles, the warehouse workers can act autonomously in their field, but there is low flexibility. The high specialization makes it impossible for the worker to change his role in the warehouse and so he has no or little idea of the rest of the process. Moreover, most workers have no multidisciplinary competencies and the documents needed for the training are incomplete.

As can be verified in the BPMN diagrams illustrated in chapter 3, a high percentage of the task is a manual task, so it is performed without the use of the information system.

4.2 Inefficiencies in the incoming area

According to Dayco request, greater attention is paid to the analysis of the incoming area due to the high number of inefficiencies present. The inefficiencies are generated by a process that is not always systematic and clear and by the inefficient use of resources.

While analyzing the inefficiency, if the primary cause of the problem was exogenous, so not depending on the supply chain department and the warehouse, the problem is no more analyzed. Given the number of inefficiencies, the focus is on those that can be solved working in the department considered. This way of action is not in line with the lean production method which suggests analyzing the whole process together. This kind of analysis would require too much time and effort bringing the discussion off-topic.

Analyzing the incoming area procedure, it could be seen how the data are registered in the information system in different moments of the receiving process. Moreover, the same data is often inserted more than once. As it can be seen in Table 4, in the check delivery schedule subprocess the data are entered to consult the scheduling. Anyway, they are not saved in the information system since the registration of the data will be performed later in the process with the delivery registration subprocess. Sometimes the check delivery schedule subprocess could not be performed because of the lack of time and because it is a waste of worker efforts. For this reason, in the process as-is the check schedule subprocess does not bring enough value to the company to be correctly performed.

5 WHYS ANALYSIS	
INEFFICIENCY	*Data are entered more than once in the information system.*
Why are data entered more than once in the information system?	The check delivery schedule subprocess is performed at the beginning of the procedure, while the registration of the delivery is at the end.
Why are those tasks performed in a different moment?	It is important to verify if the delivery is scheduled before unloading the truck, while the delivery registration is performed at the end of the process when the incoming area worker has time to do it. The scheduling check is often not performed.
Why could the scheduling check be not performed?	The scheduling check needs the worker to enter the data, without registering them. The process as-is is a loss of time, so it is often skipped for open orders that are regular in time.
Why does the incoming area worker wait until the end of the process to register the delivery?	Register the delivery requires time and the warehouse worker must check the pallets in person to verify the number of goods per pallet. If the registration would be done at the beginning and would not be fast, the whole procedure will be slowed down.
Why could the delivery registration take time?	The packages and the end material are usually entered at different points of the information system.
Why are the packages and the material received entered at different points of the information system?	Even if there are some standard packages, they are not always followed by the suppliers.

Table 4: 5W analysis of schedule check inefficiency

It is possible to observe another example of how tasks are skipped in the process to manage close orders delivered from a courier. Interviewing the warehouse workers, it has been highlighted how the procedure for receiving the high-value closed order is rarely followed (Table 5). When the courier arrives in Dayco he positions the material on a desk. The desk is not located in a closed area, so it is not safe to leave it there for a long time. Anyway, due to the lack of time, the shipping area worker can wait even a whole day before storing the goods in the correct way. Moreover, the addressee wants to collect the order urgently and, if no warehouse worker is available, he could decide to leave without signing the delivery note. This is a problem because if the goods are lost, it is not possible to go back to the worker who collects them, so the incoming area office is accountable.

5 WHYS ANALYSIS	
INEFFICIENCY	*Orders delivered by couriers are not correctly managed.*
Why are the close orders delivered by a courier not well managed?	Many tasks are skipped or performed with a considerable delay.
Why are those tasks performed with a considerable delay?	The workload derived from the process as-is of the incoming area worker is too high.
Why are some tasks skipped?	Due to lack of time, some tasks such as contacting the competent department or making the addressee sign the delivery note are skipped.

Table 5: 5W analysis of the close order delivered by couriers

Another inefficiency linked to close order is that sometimes it is impossible to register the delivery in the information system. Each closed order needs that a purchase request is compiled and then approved by a supervisor. After the purchase request is approved, the purchasing department can send the order to the supplier and register it on AS 400 software.

When the material arrives in Dayco incoming area, the warehouse worker must register the delivery note on AS 400 system to accept the delivery. To do so, in AS 400 there should be the order already recorded by the purchasing department.

Sometimes it happens that the warehouse worker is unable to find the order of the purchasing department on the AS 400 system. This is inefficiency because it leads the warehouse worker to ask

explanations from purchasing department and to the addressee of the material. To be as fast as possible the communication is done by phone call, which is not traceable, or by email, which is too slow. It is an inefficiency also because it leads the warehouse worker to skip an important part of the process for a material that usually has a high value.

As stated in Table 6, sometimes the purchase request may be approved, and the order communicated to the supplier, but not yet processed on AS 400 by the purchasing department. Since the supplier received the purchasing order, the material is shipped. On the other hand, due to the inefficiency of the purchasing department, the order is not yet registered in the information system so the delivery note of the incoming cannot be correctly recorded. Anyway, close orders are usually urgent and linked to high-value products as prototypes. For this reason, the warehouse worker finds himself between the hammer and the anvil: the department who compiled the purchasing request wants the material as soon as possible but the material cannot be accepted due to the delay of the purchasing department and if it is not withdrawn on an acceptable time, the courier leaves the company without delivering. In this case, the company can fall into the cost of a second urgent shipping as soon as the order is registered on AS 400.

5 WHYS ANALYSIS	
INEFFICIENCY	*Order not found on AS 400.*
Why could we not find the order on AS 400?	The order was made to the supplier without being properly registered by the Purchasing Department.
Why is the order not properly registered?	The Purchasing Department was overloaded with work and the employee who filled in the purchasing request decide to does not follow the procedure.
Why does the employee decide to not follow the correct procedure?	The procedures take too much time.
Why are the procedures too long?	The procedures are not optimized.

Table 6: 5W analysis of delivery registration subprocess

Another problem linked to the incoming area is the high waiting time of the truck in front of the gate. Since at the beginning of the month there is a greater number of deliveries and since just one truck at a time can enter the gate, the queues can become significant (Table 7).

5 WHYS ANALYSIS	
INEFFICIENCY	*Queues in front of the gate*
Why are there queues in front of the gate?	The trucks can enter the gate one at a time. There is no delivery schedule.
Why can the trucks enter one at a time?	There is just one unloading bay.
Why is there no delivery scheduling?	No project to implement a delivery schedule has been started.
Why is there just one unloading bay?	The plant is not Dayco property and it is in leasing from a third party. There is not an agreement between Dayco and the third party to increase the number of unloading bays.
Why there is no project to develop a delivery schedule?	There is not enough information about the problem, no feasibility study has been performed.
Why there is no agreement to build another unloading bay?	Building a new unloading bay may have a high cost.
Why is there no information?	In the past three years, there was no stability in the supply chain department. Three supply chain managers changed in 18 months.
Why to building a new unloading bay has a high cost?	The layout of the plant must be revised and changed since there is just a little space
Why there is no stability in the supply chain department?	The crisis derived from the pandemic changed the labor market and the needs of the company as well as workers' needs.

Table 7: 5W analysis of the unloading bay

As stated before, the returns of material from the production warehouse to the raw material warehouse have an impact on the incoming area work as well as the returns from Dayco to the supplier (Table 8). In this second case, the incoming area worker must contact the supplier to

arrange the transportation of the goods and, to do so, he must communicate the quantity, the weight and the volume of pallets shipped. A return of raw material to the supplier is usually required by the quality department after an inspection that involves the use of destructive tests and the consequent destruction of the pieces. Moreover, a batch of raw material could be used in the production before the quality department identifies the defect and asks the return to the supplier. For these reasons, the material must be counted before arranging the shipping to the supplier. The counting task is very time-consuming and often done with low attention due to the high workload of the warehouse worker. Anyway, it is very important to communicate to the supplier the real quantity of returned material because otherwise, Dayco would pay for defective material that was returned to the producer. Moreover, the requests of return are not always complete as they should be. This could slow down the work of the incoming area worker that must look for the date before arranging the return.

5 WHYS ANALYSIS	
INEFFICIENCY	*Returns of material to the supplier are difficult to manage.*
Why are they difficult to manage?	The incoming area worker must count the pieces to return to the supplier. Return request forms are not always clear.
Why is important to count the pieces?	If the quantity declared for the return is different from the real quantity of pieces returned, there will be a discrepancy between the quantities registered in the information system and the real quantity of pieces available.
Why is the return request not always clear?	The quantity indicated by the Quality Department is not always correct.
Why is the quantity indicated by the quality department not reliable?	The quality department is full of work and they do not have time to count the pieces.

Table 8: 5W analysis of the return of the material to the supplier

4.3 Bizagi application as a possible solution

Thanks to the analysis done on the process as-is, it is possible to conceive possible solutions to the inefficiencies identified.

To solve the inefficiencies and to optimize the process, many different actions must be taken to enhance the procedures. The higher the number of initiatives, the longer the time to implement the solutions, the higher the costs. For this reason, a unique solution is identified to solve a high number of inefficiencies at the same time.

To the scope, a demonstrative application is developed. Such application is intended to be integrative to the in-use AS 400 system and aims to give to the warehouse manager greater knowledge and control of the procedures.

The application is developed through the software Bizagi which enables to keep the process flow as a fundamental principle of the whole application. The design of the application starts from the design of the process itself through the BPMN language. In this way, every time the process changes, the application changes with it and the flowing of the process is always guaranteed. For that reason, the process is reengineered to find a possible solution to the inefficiencies highlighted above.

To create the application, the 5S principle of the Lean method is applied as indicated in Table 9.

5S ANALYSIS	
Seiri - Sort	Tasks and procedures that do give value to the product are sorted from those which do not.
Seiton - Set in order	The tasks are ordered most efficiently and each worker can see the task according to their priority.
Seison - Shine	Eliminate repetitive tasks.
Seiketsu - Standardize	Procedures are standardized and more rigid, so exceptions are less likely to occur.
Shitsuke - Sustain	Making the process easier to learn, creating more accurate and flexible instruments for personnel training.

Table 9: 5S analysis

All process is designed to let the worker enter the data just once at the beginning of the procedure, in order to avoid mistakes due to the late recording and to save time by eliminating the useless repetition of tasks. Moreover, the application is programmed to send automatic notifications to each actor. This will help to avoid a huge amount of emails and phone calls. To save the worker time,

a runtime is assigned to each task. In this way, it is possible to monitor the duration of the task and send notifications to avoid delay. Thanks to the time saved, the warehouse worker will be able to better manage all those inefficiencies linked to the too high workload and to the lack of time. Given the amount of information collected through the user-friendly application is possible to create reports to analyze the performance of the workers and of the process itself.

To develop the application, a BPMN map to-be is created as well as a database able to host all the information needed to run the process. Then, all user interfaces are defined specifying which information the system needs to run and in which database they should be stored. Finally, a performer is assigned to each task and the business rules that govern the application are defined. Business rules con be conditions and validation and all the statements and constraints that control the behavior of the business. All the codes useful to implement the business rules are explained in Appendix A.

The application created is purely demonstrative and, for this reason, it is much simpler than the incoming process mapped in chapter 3. To the scope, just the receiving process is considered and four internal actors can interact:

- The supply chain employee
- The quality department employee
- The incoming area worker
- Two incoming area forklift drivers, one assigned to the unloading procedures and one to the allocation tasks

To enable the demonstrative use of the Bizagi application a fake database of orders is created both for close and open orders.

Since the application was revised with the warehouse supervisor and workers, part of it is in Italian to facilitate its comprehension.

4.3.1 Model process

In the BPMN model for the new application (**Errore. L'origine riferimento non è stata trovata.**68), it is possible to identify three milestones:

- Approval
- Main process
- Allocation

In the approval milestone, the supplier truck arrives in Dayco and the incoming area worker opens the procedure specifying all data useful to identify the shipping. Thanks to this information, the system checks if the order was scheduled or if more material than the one expected arrived. If the delivery was not scheduled at all, the procedure ends. If the delivery was partially scheduled, a validation is asked to the supply chain department that can decide to approve or reject the incoming.

In the main process milestone, the material is unloaded and its integrity is verified as illustrated in chapter 3. Finally, the material is identified and allocated in the warehouse.

3.5.2 Model data

Once the process has been modeled, a database to host the data was created. The database consists of:

- One master entity named incoming (*Ingressomateriale*)
- Two symmetrical master entities, one for close order (*Ordini chiusi*) and one for open order (*Ordini aperti*)
- One parameter entity for the type of order (*Tipologia ordine*)
- One parameter entity for the suppliers (*Fornitori*)

The incoming master entity is the main entity: there could not exist a procedure in the system without a corresponding record in the incoming entity.

The incoming entity is linked to the close order and open order master entities through a relation one-to-many. A record in the incoming table can be linked to many records of close order or open order entities. Since each order has just one typology (open or close), one record of the incoming entity cannot be linked at the same time to both close order and open order tables.

The parameter entities are compiled by the program and represent a list of values from which the user can select the desired one.

The attributes of the incoming master entity are illustrated in Table 10.

Name	Display name	Type
Delivery identification number	*Codice rimesso*	String
Delivery note date of emission	*Data rimesso*	Date-time
Delivery date	*Data ricevimento*	Date-time
Order ID	*Anno/Numero d'ordine*	String
Worker ID	*Operatore*	WFUSER
Scheduled order	*Ordine programmato*	Boolean
Packaging	*Packaging*	Boolean
Free the truck	*Manda via il camion*	Boolean
Packages in the delivery note	*Numero colli in bolla*	Integer
Packages in the truck	*Numero colli sul camion*	Integer
Quantity validation	*Validazione quantità*	Boolean
Delivery note quantity validation	*Validazione quantità bolla*	Boolean
Administration quantity validation	*Validazione quantità amministrazione*	Boolean
Incoming deleted	*Ingresso cancellato*	Boolean
Quality validation	*Validazione qualità*	Boolean
Quality photo 1	*Fotografia qualità 1*	Image
Quality photo 2	*Fotografia qualità 2*	Image
Quality photo 3	*Fotografia qualità 3*	Image
Note	*Note*	Extended text
Supply chain quality validation	*Validazione qualità supply chain*	Boolean
Quality department quality validation	*Validazione dipartimento qualità*	Boolean
Unloaded	*Materiale scaricato*	Boolean
Load up	*Material caricato*	Boolean
Identification area	*Area smistamento*	Boolean
Possible to load up	*Possible caricare*	Boolean

Returned area	*Posizionato area resi*	Boolean
Label attached	*Materiale etichettato*	Boolean
Error message	*Error message*	String
Show error message	*Mostra error message*	Boolean
Close order check	*Ordinechiuso check*	String
Supplier	*Fornitore*	Link to supplier entity
Type of order	*Tipologia ordine*	Link to type of order entity

Table 10: Incoming master entity attributes

The attributes of the open order master entity are illustrated in Table 1.

Name	Display name	Type
Accept wrong quantity	*Accetta quantità errata*	Boolean
Accept extra quantity	*Accetta quantità non programmata*	Boolean
Supplier	*Fornitore*	String
Supplier description	*Descrizione fornitore*	String
Item ID	*Codice articolo*	String
Item description	*Descrizione articolo*	String
Number of packages	*Numero colli*	Float
Quantity to be received	*Quantità da ricevere*	Float
Ordered quantity	*Quantità ordinate*	Float
Received quantity	*Quantità ricevuta*	Float
Ask quantity validation	*Chiedi validazione quantità*	Boolean

Table 11: Open order master entity attributes

The attributes of the close order master entity are illustrated in Table 12.

Name	Display name	Type
Order ID	*Anno/Numero d'ordine*	String
Item ID	*Codice articolo*	String
Item description	*Descrizione articolo*	String
Number of packages	*Numero colli*	Float
Quantity to be received	*Quantità da ricevere*	Float
Ordered quantity	*Quantità ordinate*	Float
Received quantity	*Quantità ricevuta*	Float
Order reason	*Causale*	String
Accept extra quantity	*Accetta quantità non programmata*	Boolean
Returned quantity	*Quantità reso*	Float
Supplier	*Fornitore*	String
Supplier description	*Descrizione fornitore*	String
Accept wrong quantity	*Accetta quantità errata*	Boolean
Ask quantity validation	*Chiedi validazione quantità*	Boolean

Table 12: Close order master entity attributes

The attributes of the supplier entity and of the type of order entity are respectively illustrated in Table 13 and Table 4.

Name	Display name	Type
Supplier ID	*Codice fornitore*	Integer
Supplier description	*Descrizione fornitore*	String

Table 13: Supplier parameter entity attributes

Name	Display name	Type
Type of order	*Type of order*	String

Table 14: Type of order parameter entity attributes

4.3.2 User interface

As for the process as-is illustrated in the previous chapter 3, the receiving process is triggered when the supplier truck arrives in front of Dayco gates. Differently from the as-is process, it is the incoming area worker who answers the doorbell and receives the transportation documents. According to the delivery note, a new procedure is opened selecting the type of order (open or close) as shown in **Errore. L'origine riferimento non è stata trovata.**74. Some data are mandatory to proceed with the process and they are signaled with a red bar on the left of the data field.

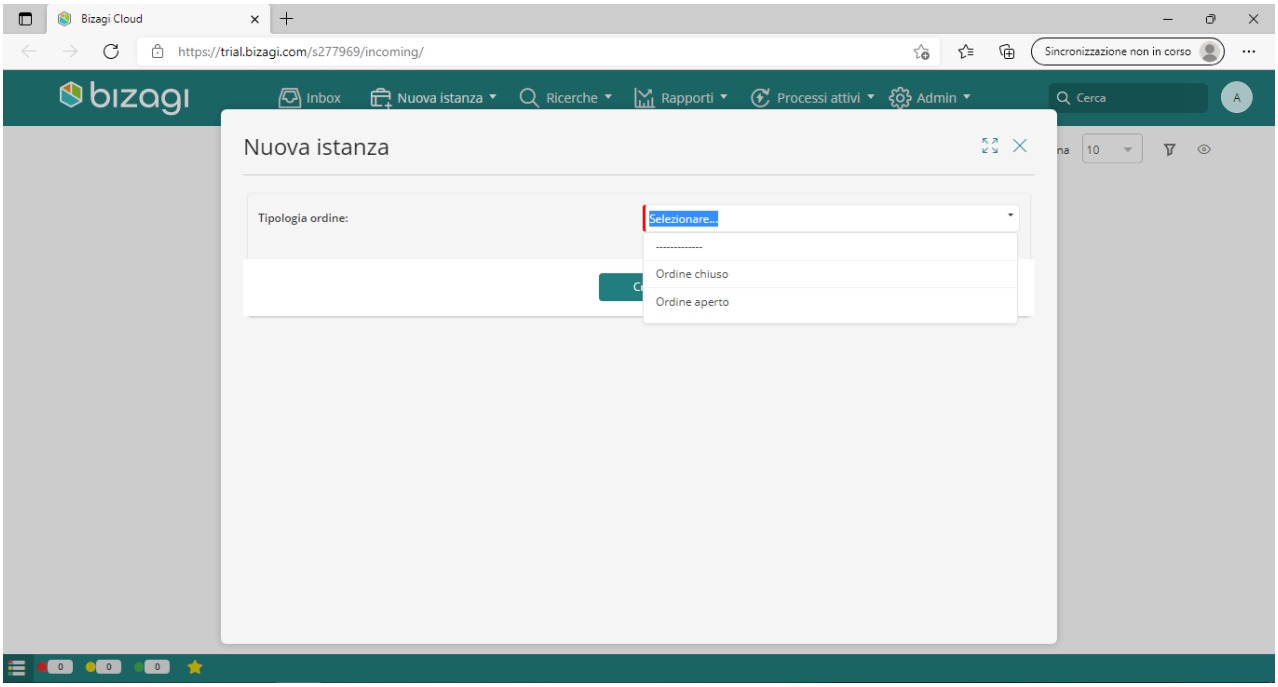

Figure 74: The procedure starts entering the type of order

Then the application will display two different masks one for the close orders and one for the open ones.

For the close orders, the application asks the incoming area worker to enter the delivery identification number, the delivery note date of emission and the orderID as indicated in **Errore. L'origine riferimento non è stata trovata.**75.

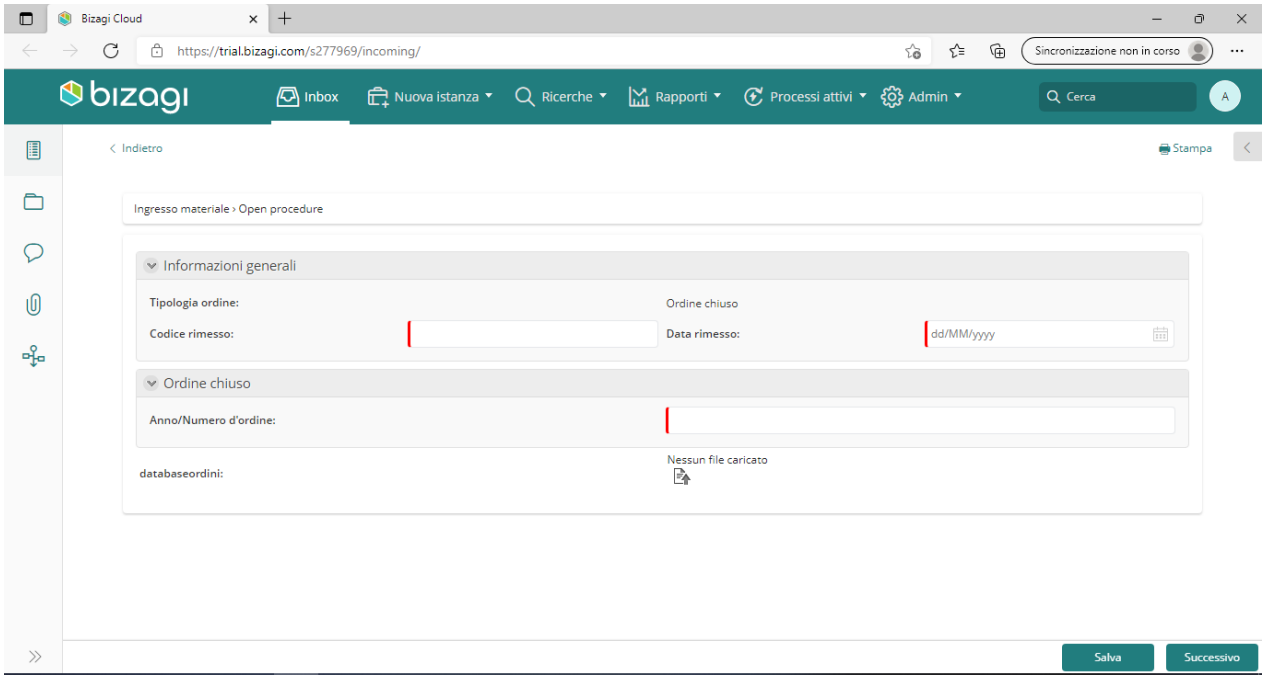

Figure 75: Open procedure for close orders

For the open order, the delivery identification number and the delivery note date of emission are requested. Moreover, the supplier can be selected by a list of supplier ID as shown in **Errore. L'origine riferimento non è stata trovata.** 76.

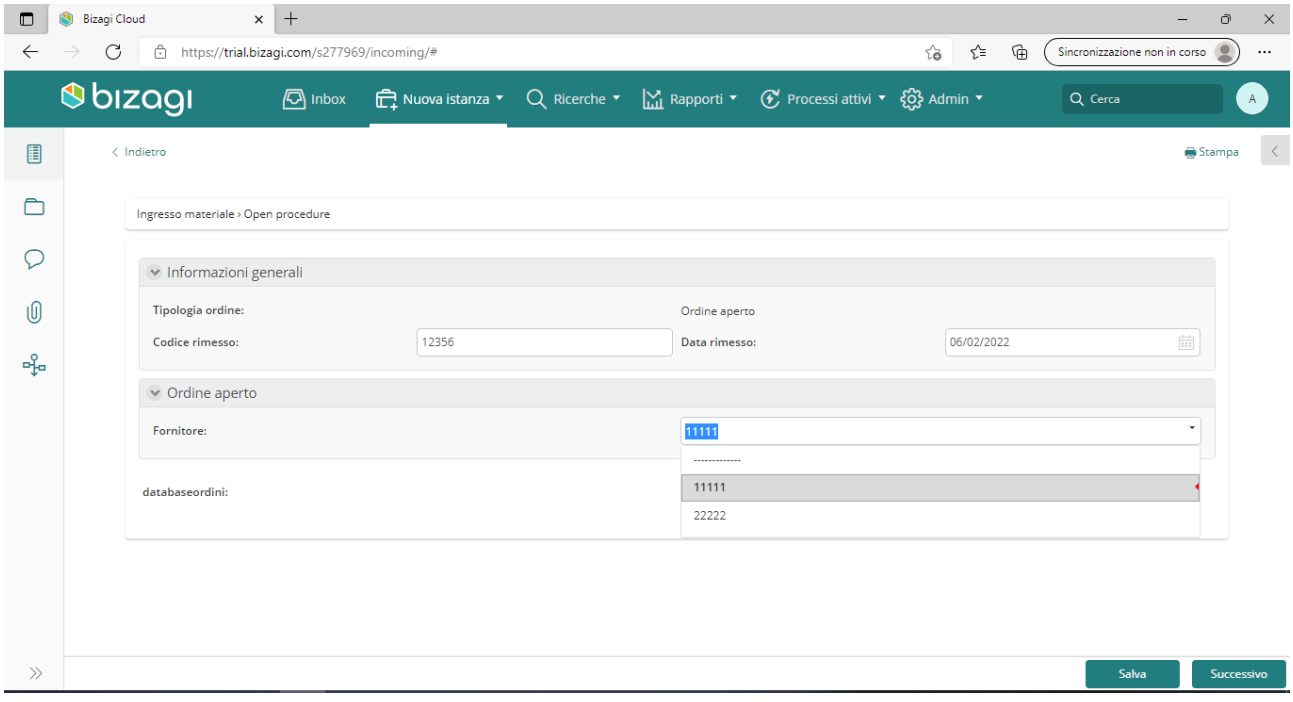

Figure 76: Open procedure for open orders

The application then opens all the scheduled orders with the same orderID in case of close orders and with the same supplier for open orders. The display shows also the supplier description, the order reason (just for close order), the itemID, the item description, the quantity to be received, the

quantity received and the number of packages received as indicated in Figure 77. A synthesis with the type of order, the delivery identification number and the delivery note date of emission is always present.

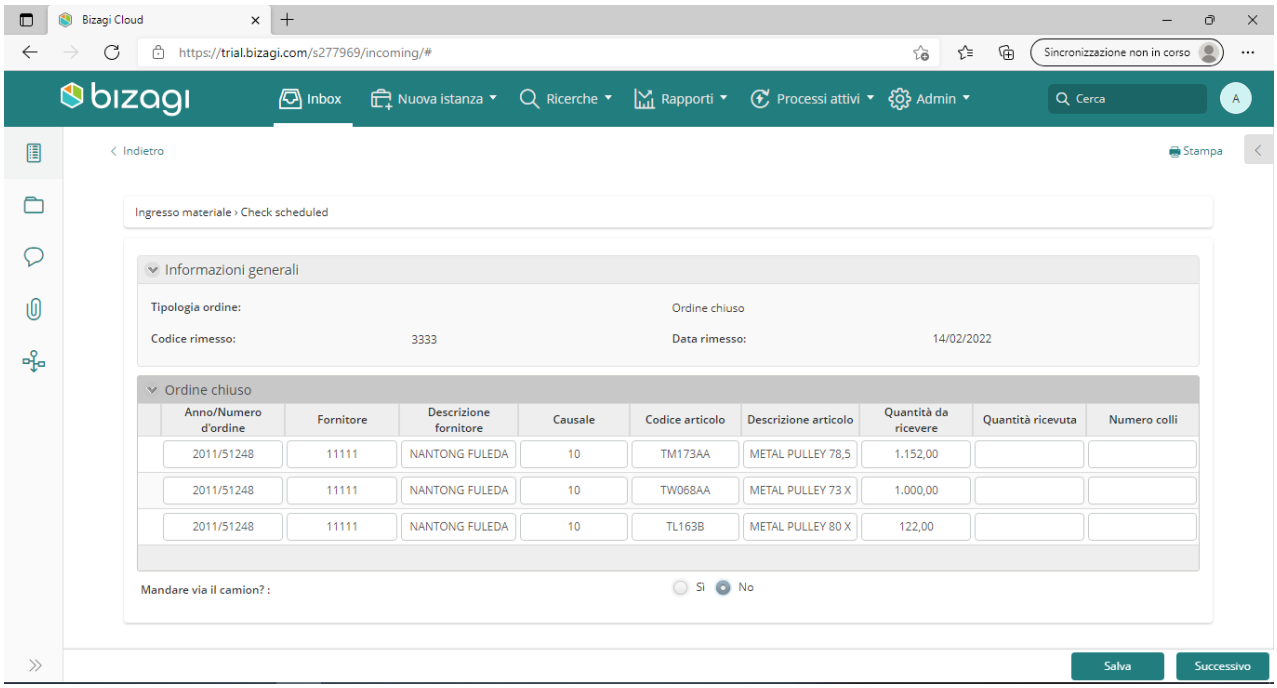

Figure 77: Check schedule for close orders

If for any item the quantity received is greater than the quantity to be received, the validation of the supply chain department is required as in the procedure explained in chapter 3. Anyway, with the application, no email must be sent because the application sends directly a notification to the supply chain employee that will just see a new procedure open on his personal page. As illustrated in Figure 788, the supply chain employee must select if to accept (*Sì*) or to reject (*No*) the extra material received.

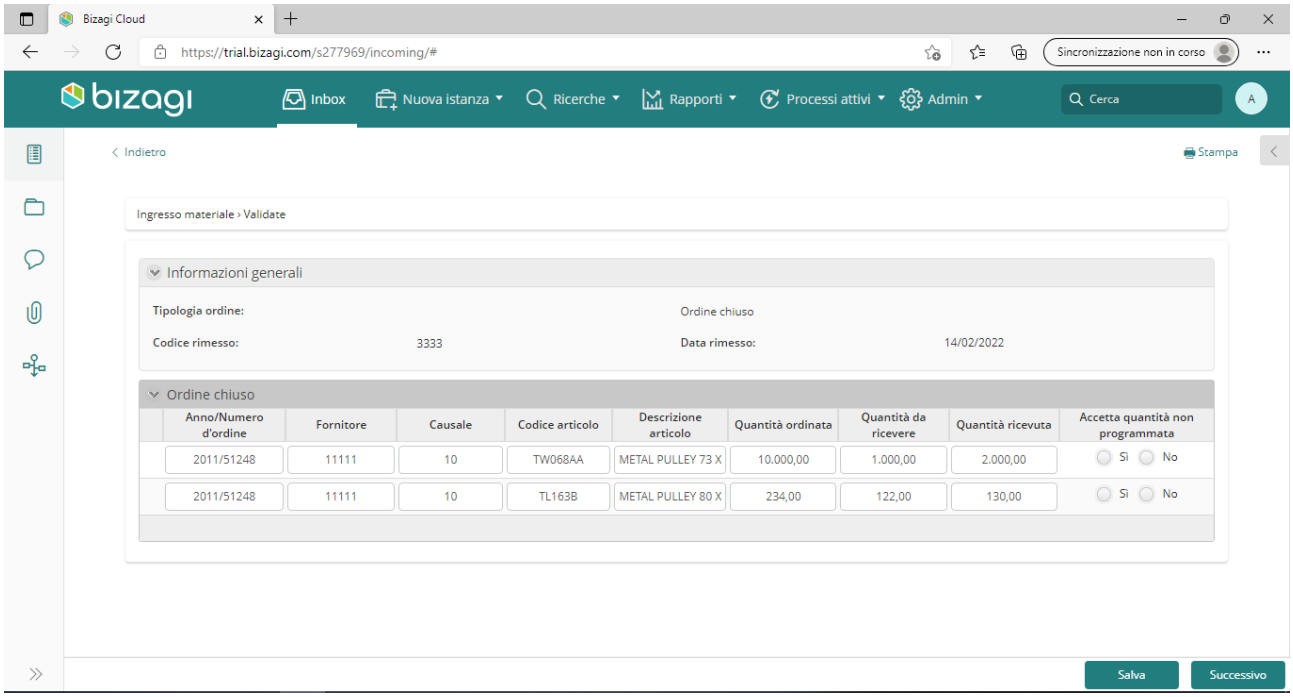

Figure 78: Supply chain validation

Once the supply chain validation is concluded, a notification arrives to the incoming area forklift drive assigned to the unloading process who will indicate the real number of packages present in the truck (Figure 79) to be sure that it is coherent with what is declared in the delivery note.

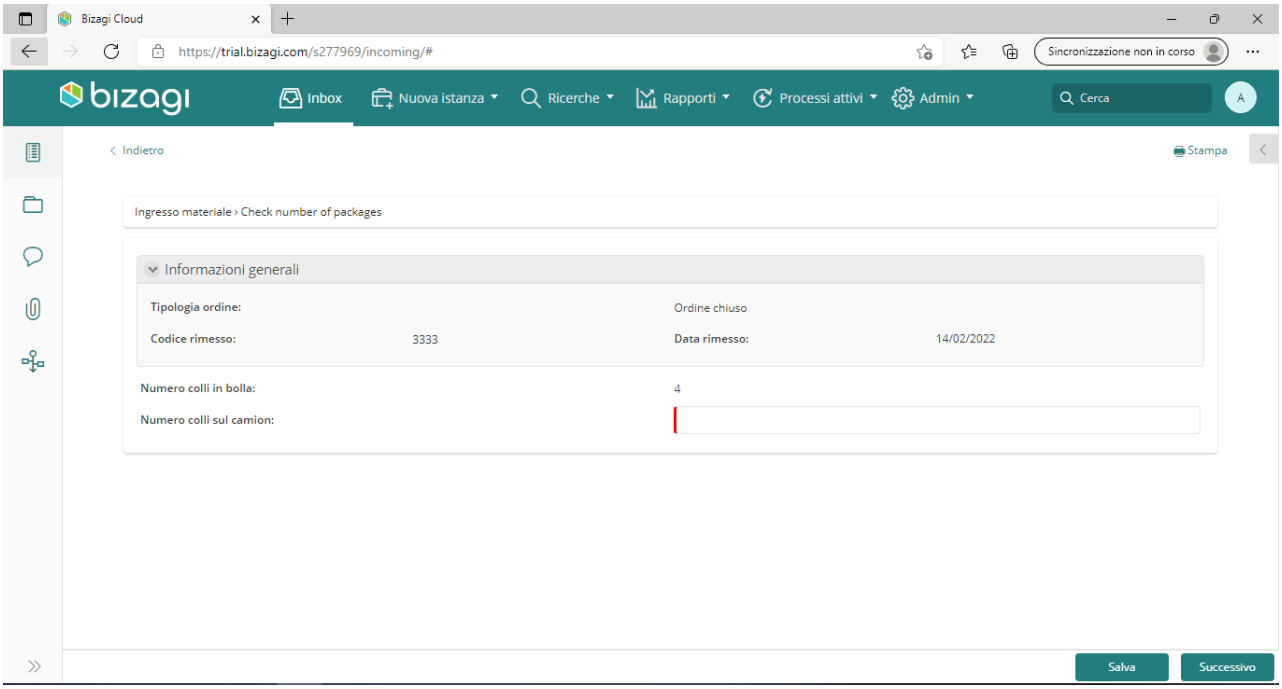

Figure 79: Number of packages in the truck

If the number of packages is coherent, the procedure flows on. If it is not the case, the incoming area supervisor receives a notification and he must calculate the real quantity of material considering the truckload. If he believes that the validation of the supply chain is needed for the

modified quantities, he could require it as shown in **Errore. L'origine riferimento non è stata trovata.**80. The validation could be asked if the real quantity is much greater than the one indicated in the delivery note.

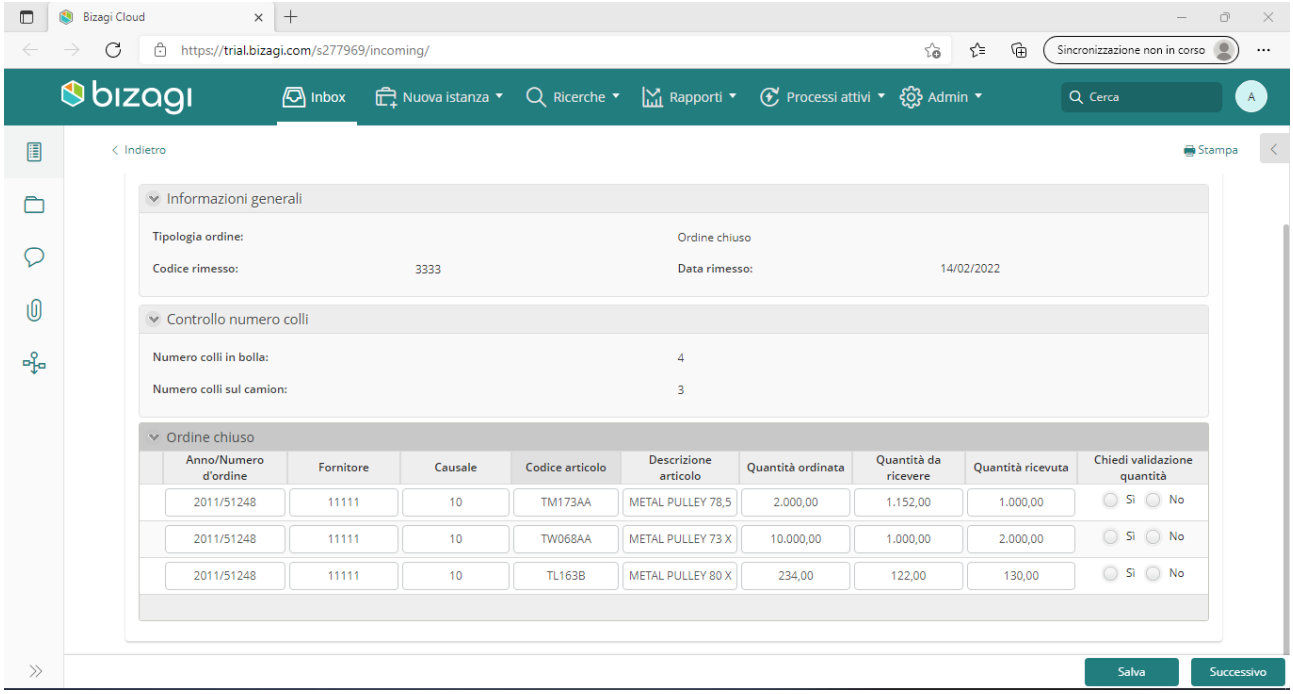

Figure 80: Supply chain validation request

Again, the supply chain employee will need to validate the quantity as seen in Figure 78. If the supply chain decides to accept the exceeding quantity, the incoming area supervisor must contact via email the supplier to inform him of the discrepancy and to ask for the correct delivery note. To keep the administration updated and to remember to the incoming area supervisor to compile the return request if needed, the Bizagi application compiles and sends automatic emails (**Errore. L'origine riferimento non è stata trovata.** 81).

Figure 81: Automatic email example

At this point, a first integrity check of the goods is performed through the check integrity subprocess before the unloading of the truck.

First of all, the forklift driver verifies the integrity of packages. If the forklift driver thinks that a validation from the quality department is needed, he asks the incoming area supervisor to intervene (**Errore. L'origine riferimento non è stata trovata.** 82). The supervisor makes some pictures to prove the status of the material and, if necessary, writes some notes (**Errore. L'origine riferimento non è stata trovata.**3).

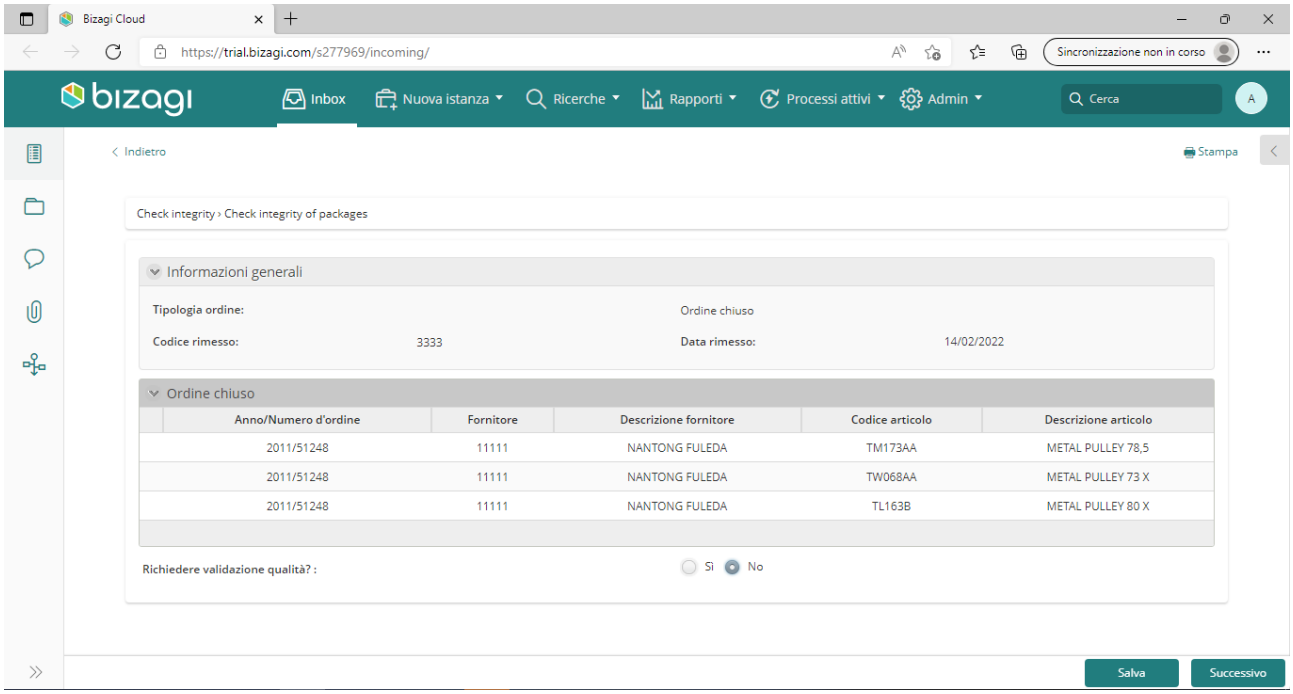

Figure 82: The forklift driver asks for a quality check

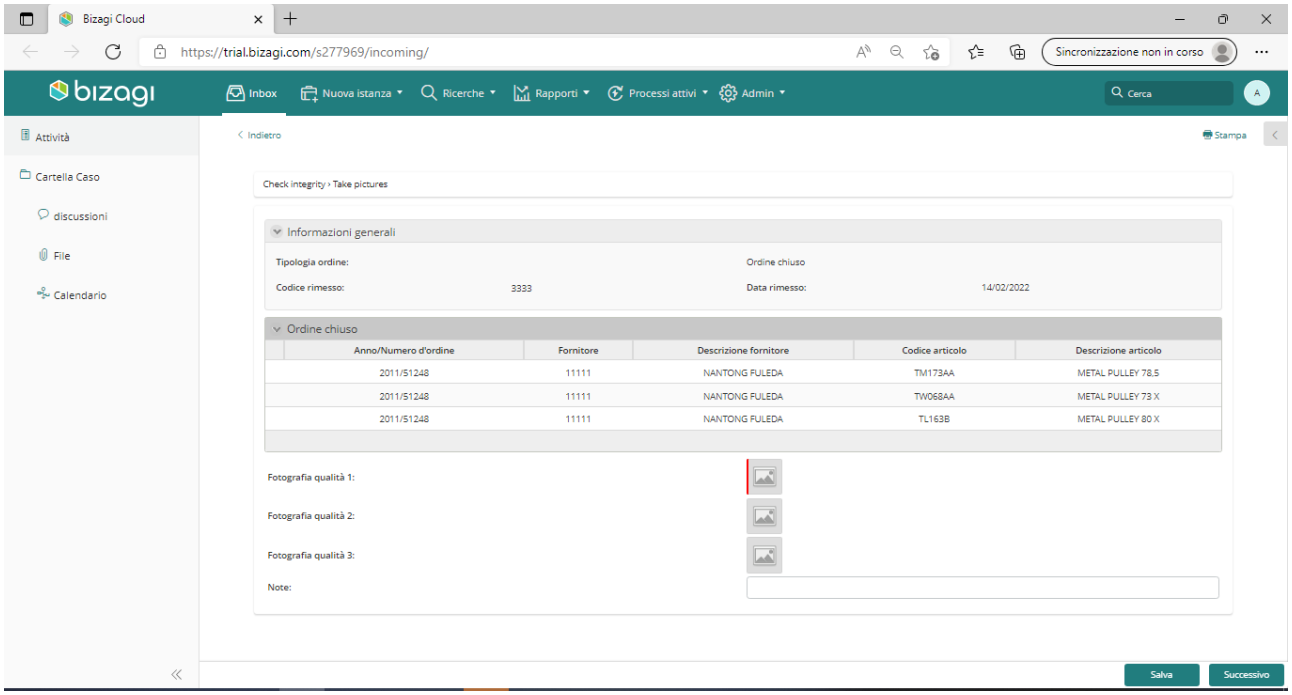

Figure 83: The supervisor takes pictures of the material

Both the supply chain and the quality department are asked to accept the material (Figure 84). The supply chain employee can affirm if the material is urgently needed to avoid downtime of production and the quality department must verify if the received material can be employed.

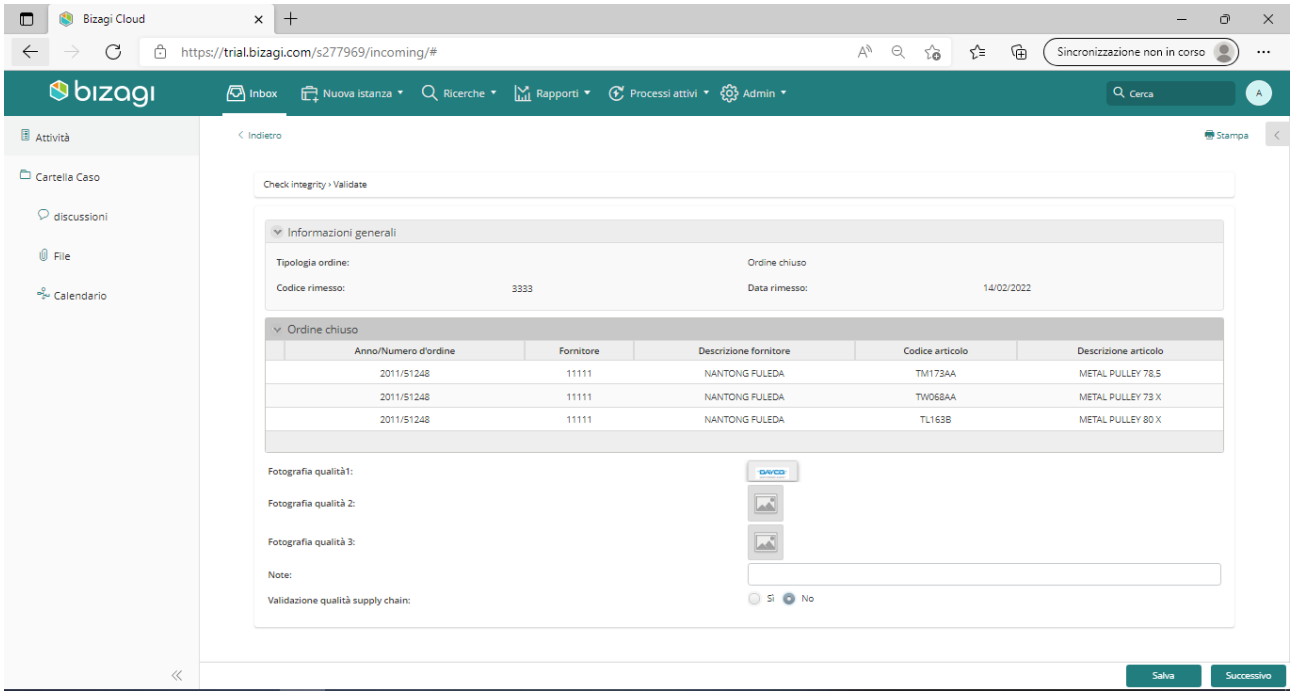

Figure 84: Supply chain and quality department validation

As in the case presented in chapter 3, the answers of the two departments must be coherent and if it is not the case the task is repeated and a warning message is visualized as shown in Figure 85. With the validation from the quality and the supply chain departments, the subprocess ends.

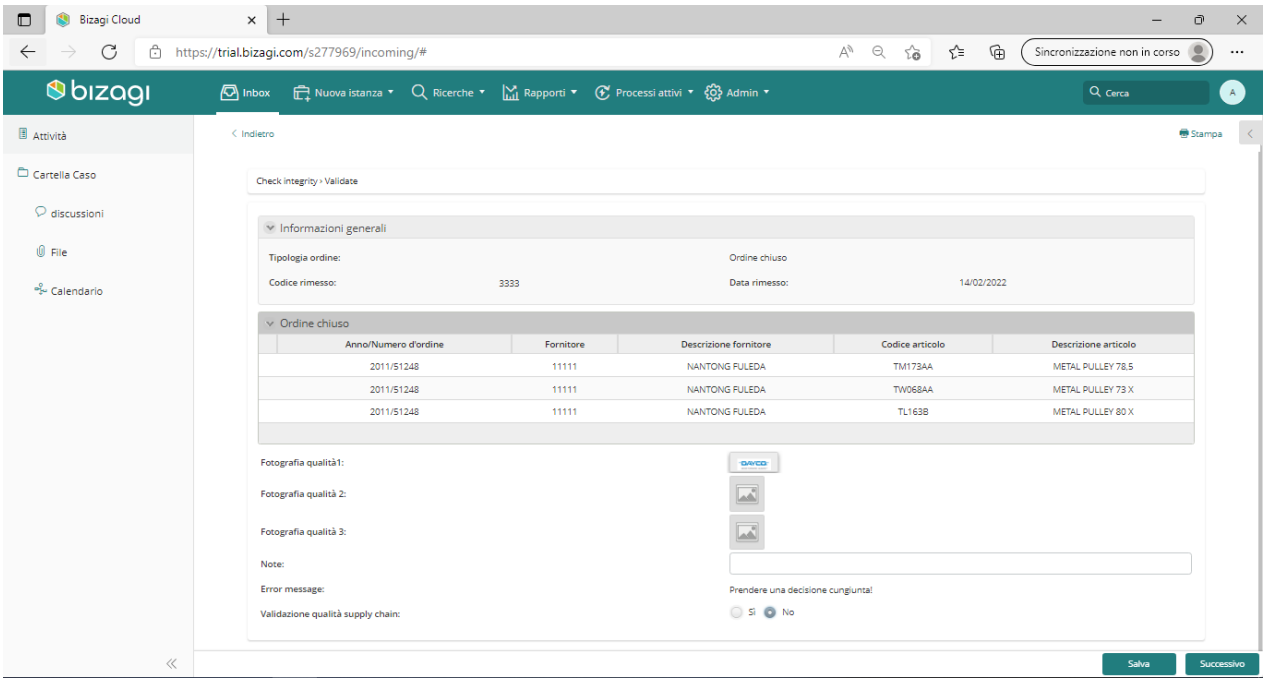

Figure 85: Quality validation with warning

If the delivery is rejected the procedure is closed by the incoming area supervisor (Figure 86), otherwise the external area forklift driver unloads the material.

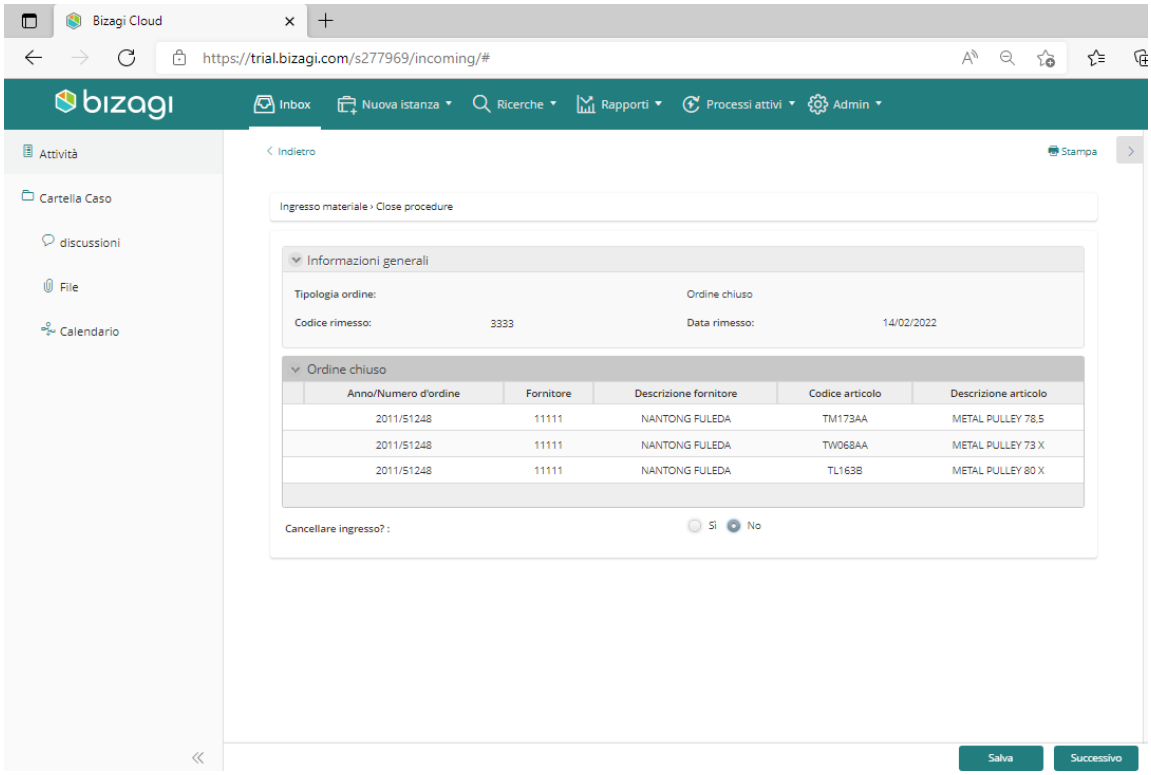

Figure 86: Close procedure

When the unloading task is performed, the forklift driver notifies the end of the unloading through the application (Figure 87) and performs a second integrity check as seen before.

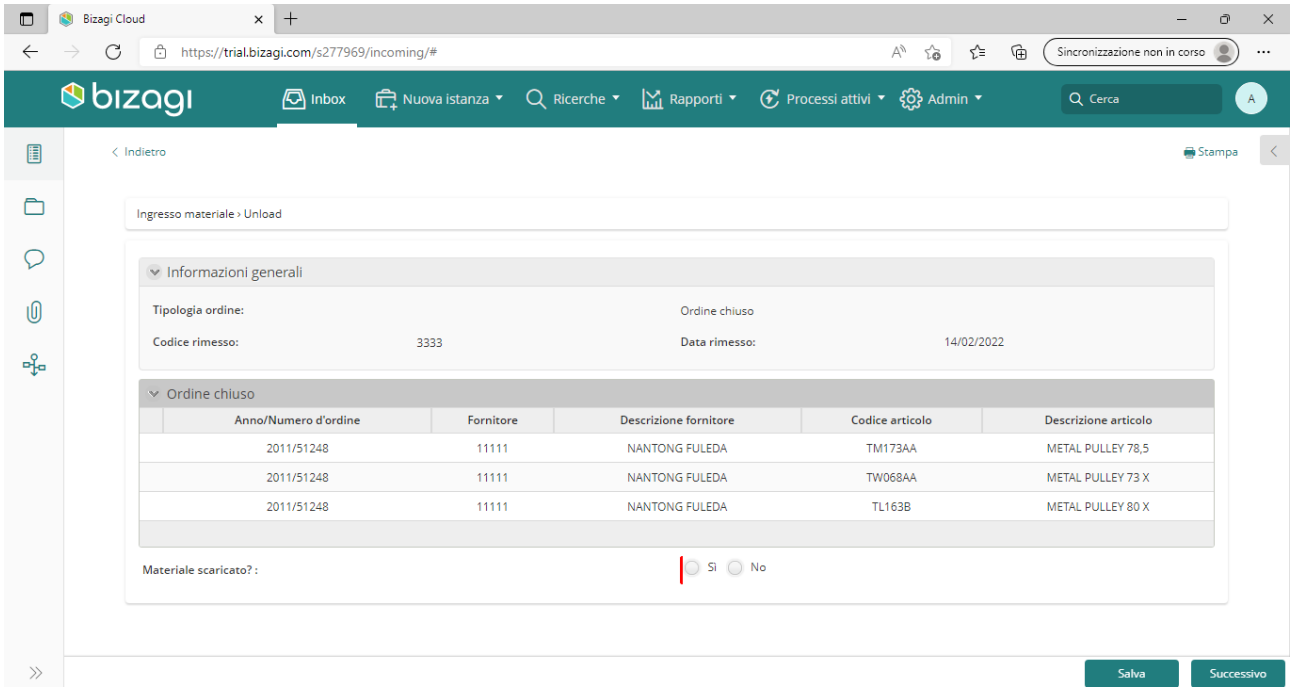

Figure 87: Unloading

If after the second integrity check, the material is rejected, the supervisor asks the truck driver if it is possible to load up the goods to ship them back to the supplier (**Errore. L'origine riferimento non**

è stata trovata.8). If the answer is negative the process flow as the material is accepted, but at the end the goods are positioned in the returned material area and a return request is compiled. If the answer is positive, the forklift driver loads up the material and notify the end of the task through the application (**Errore. L'origine riferimento non è stata trovata.**9).

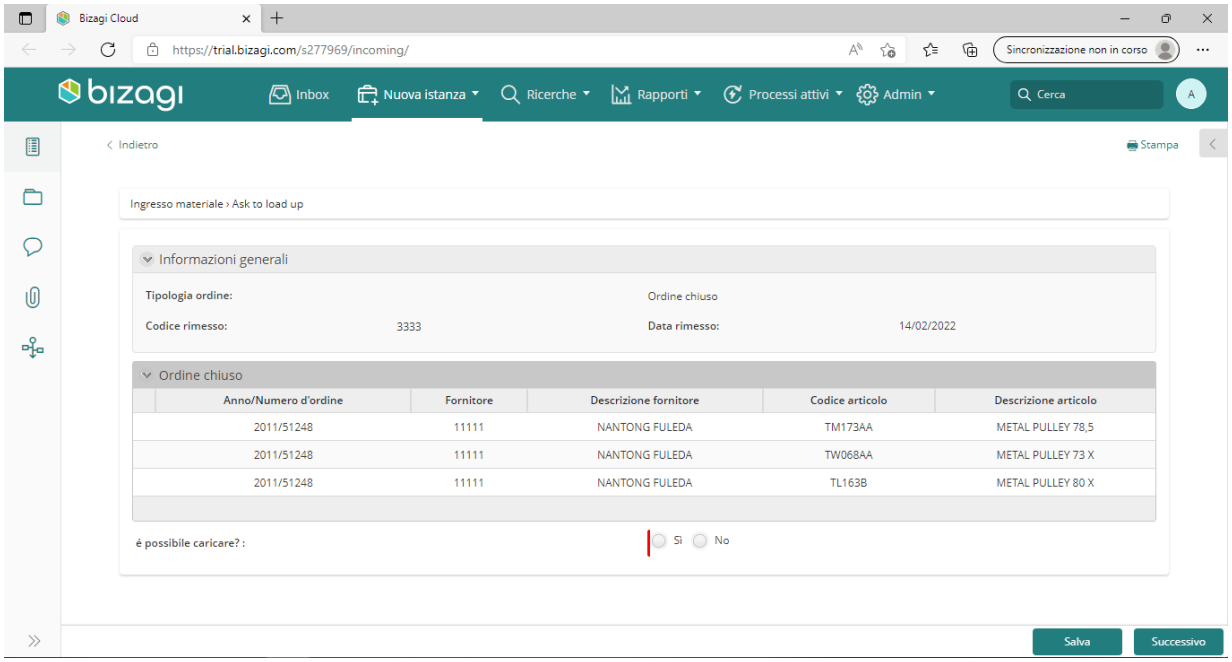

Figure 88: Ask the truck driver to load up

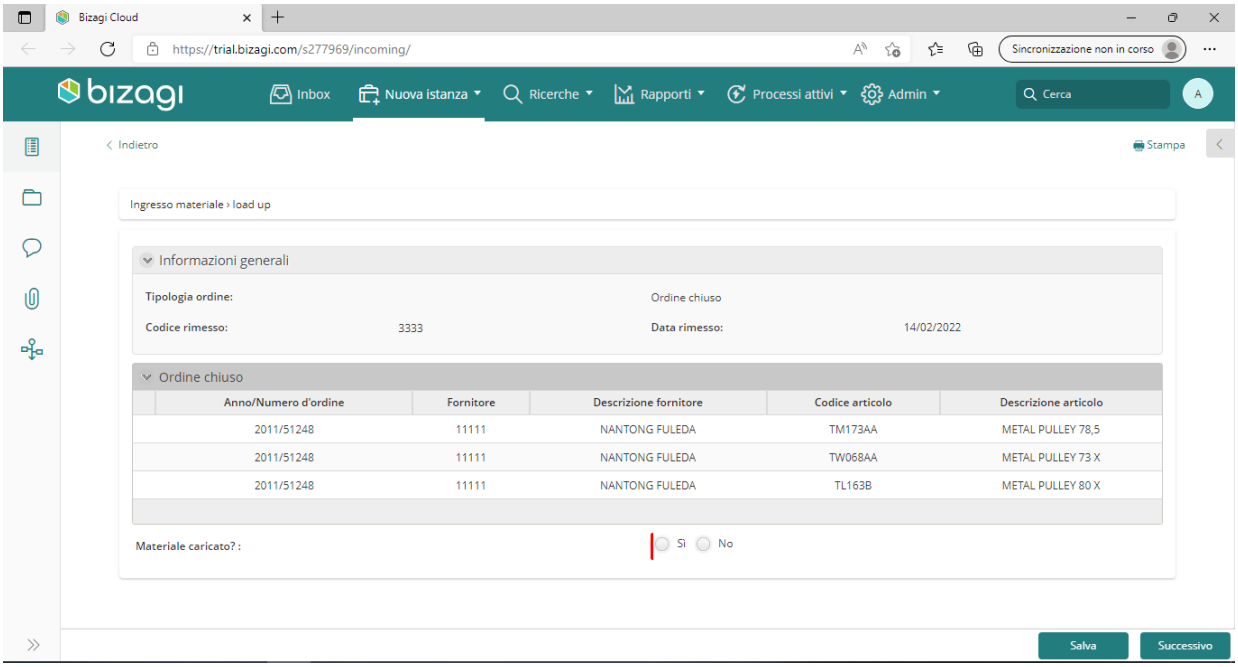

Figure 89: Material is loaded up

Once the material is unloaded in the external area, the forklift driver positions the material in the identification area (*area smistamento*) and notify the end of the work through the application as

shown in **Errore. L'origine riferimento non è stata trovata.**. At the same time, the incoming area worker stamps the delivery note.

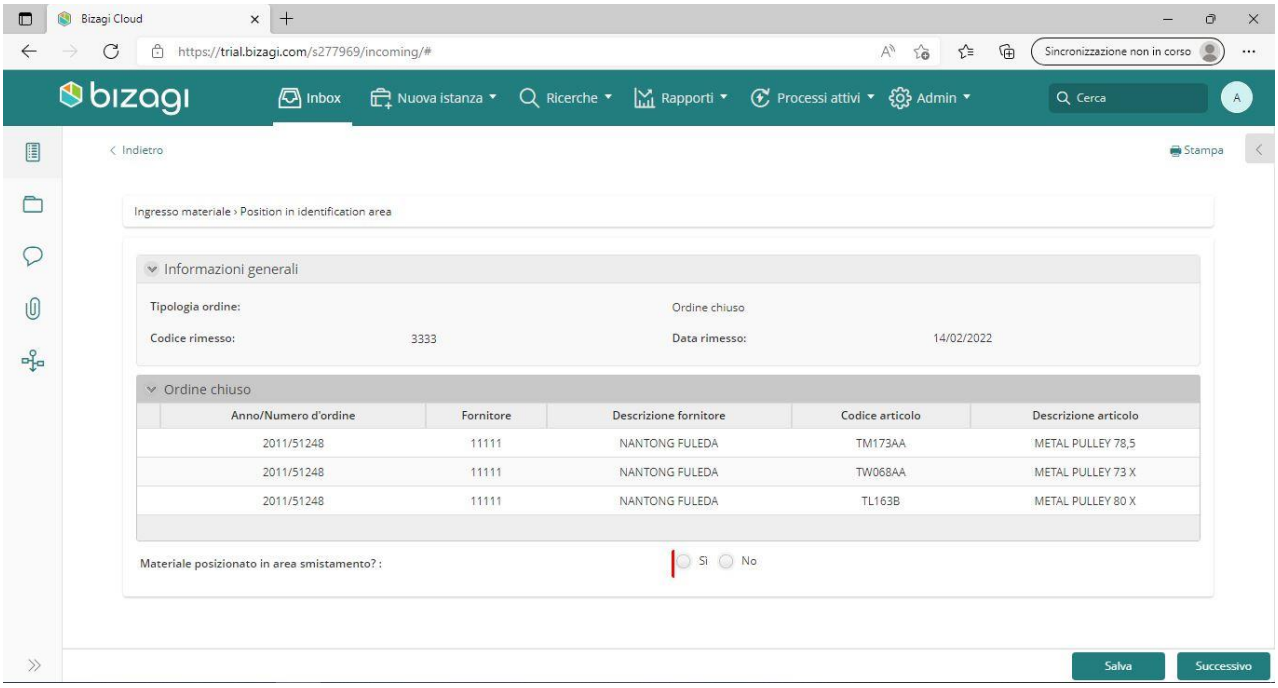

Figure 90: Material is positioned in the identification area

Now that the received material is in the identification area the warehouse worker attaches the label printed automatically by the system to the pallets. The end of the task is notified through the application as shown in **Errore. L'origine riferimento non è stata trovata.**.

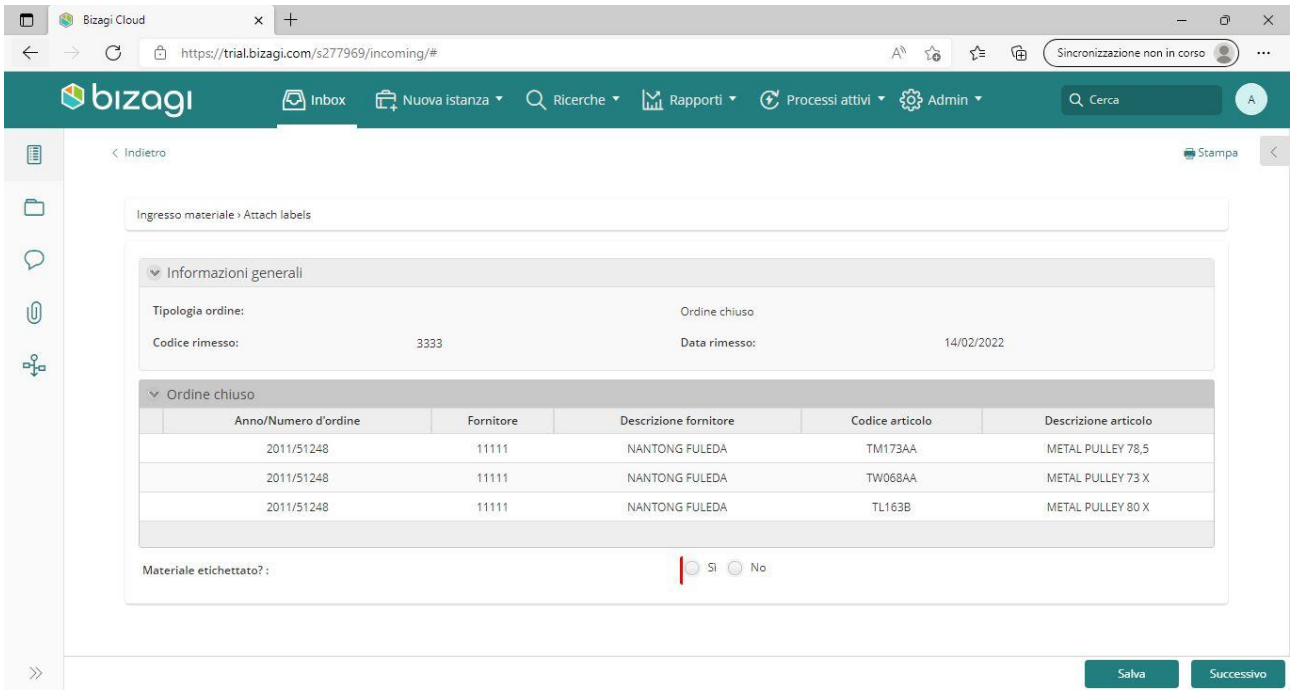

Figure 91: Labels attached to the pallets

To close the process the material is allocated in the raw material warehouse with the help of the caiman as seen in chapter 3. If the material must be returned to the supplier, the goods are collocated in the returned material area.

4.4 Other projects

To facilitate and optimize the operation in the warehouse, Dayco is already implementing some important projects as the labels and packaging ones.

The label project includes the possibility to have Dayco warehouse labels printed and attached by the supplier before the delivery to the Dayco warehouse, as what the company is already doing for its customers.

The attach label task is problematic for more than one reason:

- The incoming area worker must be sure of the quantity of material on the pallet
- Print, divide and allocate hundreds of labels every day is time-consuming

The suppliers attach their labels to the pallets before the material is shipped to Dayco. When the goods arrive in the Dayco warehouse the suppliers' labels are removed and new labels are attached to include all information useful for Dayco operation. This task can be outsourced to the suppliers in order to lighten the Dayco warehouse workers' workload and avoid ambiguity in the quantity of material per pallet.

The new procedure has already been tested with two Dayco suppliers with good results. Anyway, the complete implementation of the project will require an important amount of time because all the agreements with the suppliers must be revised.

To optimize the allocation in the Dayco warehouse and to optimize all operations a standardization of the packaging employed by the suppliers is required. To solve the problem, the supply chain department is coordinating with the suppliers to find the most effective solution. A feasibility study regarding the use of returnable packaging was carried on.

5 Conclusions

The last chapter illustrates the conclusion of the thesis. First, the benefits for Dayco company are analyzed together with the solution to the inefficiency developed in the case study. Then, the limits of the thesis and of the Bizagi application are explained. Finally, possible ideas for the future are presented.

5.1 Benefits for the company

Thanks to the process model developed, Dayco has a better idea of the procedures of the company warehouse and of its inefficiencies. The BPMN map is a powerful tool to visualize the process and to understand workers' workload and duties. Every task has a performer, an accountable supervisor and a run time, so it is possible to make process simulations and to define important KPIs to keep the procedures under control.

Thanks to the Bizagi application, it is possible to have a more fluid and optimized process. Since the focus is on the process itself, it is easier to have a better overview of the procedures and to keep the material flowing. Moreover, as soon as the process is modified, the information system changes and it is easy to identify which are the resources involved.

Thanks to its more rigid procedure and user-friendly interface, it is easier to create the document needed for personnel training and to learn how to use the application. In this way, the workers can be more flexible and autonomous in the use of the information system.

The application ensures better communication between the actors and between different departments since it is more automatic and traceable. The worker must write fewer emails and can use forms to exchange information.

Each worker can also check the pending procedures and perform them according to their priority thanks to an easy-to-read work portal as shown in Figure87.Figure87 Work portal

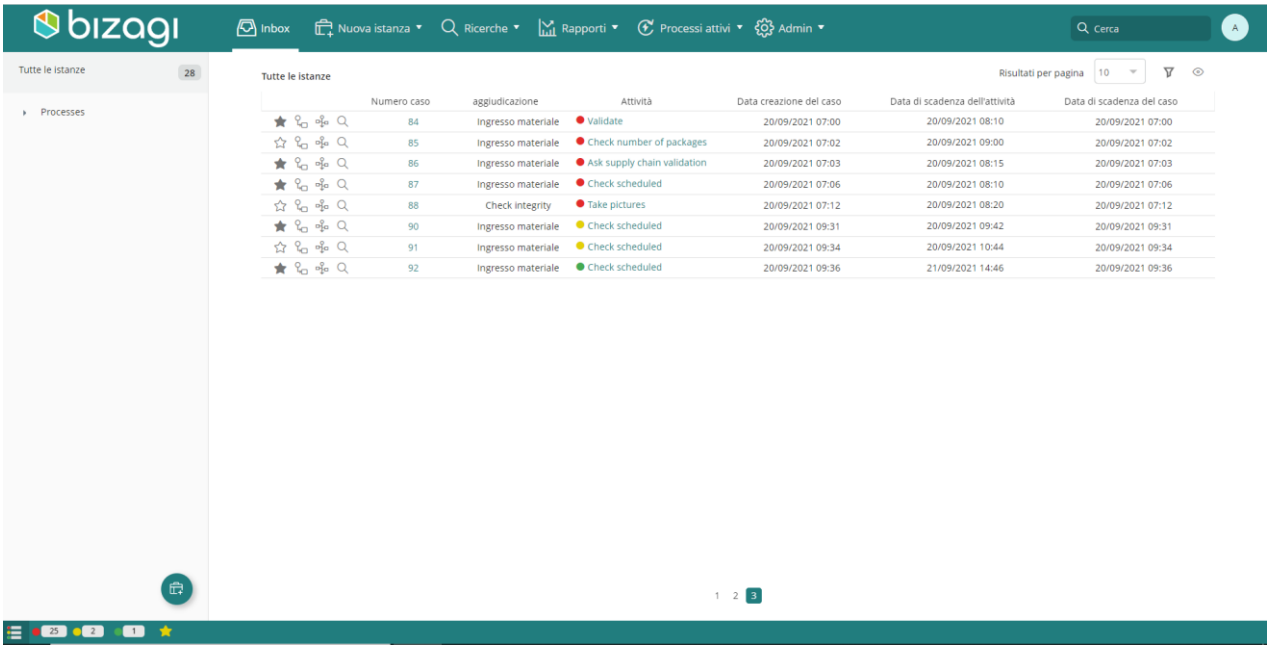

Figure87 Work portal

To be more user-friendly, the Bizagi software has a dedicated mobile app supported by the Android system. In this way, the workers can always bring the information with them and be updated on the status of the procedures.

5.2 Limits of the work

Even if the application was just demonstrative, it is important to evaluate if it could really be implemented on the Dayco plant. The advantages of the application are many, but also the problematics are relevant. Implementing the application in a single area of the plant will be inefficient. It will be necessary to maintain two information systems at the same time and this will lead to lower accuracy, more incongruencies and it will double the work of the personnel. On the other side, to study the feasibility of the new application this should be implemented one department at a time and not in the whole plant at the same time.

Bizagi software is really powerful and useful for all administrative processes, but it could be inefficient in a manufacturing company like Dayco. It is really performing when the same process is started many times, but there are too many variables and too many interconnected processes that make the implementation of the Bizagi software for Dayco difficult and potentially expensive. Every time a delivery note is not complete, every time the material is not in the correct location, every time the information system must be forced to enter the needed information, those are times where Bizagi software will be not effective in managing the situation.

On the other hand, AS 400 software is old and soon or later it will be dismissed and replaced. Right now, it is possible to integrate the functionality of AS 400 through some software that downloads row data from AS 400 and manipulates them to be easier to read and to perform analysis on data. Even if the inefficiencies of AS 400 are clear, the switching cost of a new information system is really high both in terms of money and effort. For this reason, the best choice for Dayco could be to keep the current information system as much as possible, integrating it with other software.

5.3 Ideas for the future

To further optimize the process in the Dayco warehouse, process mining could be employed.
Traditional business process modeling depends greatly on the ability of the analyst. For this reason, many hand-made models are too idealized and do not represent the real processes and so cannot be trusted (Aalst, 2016). To solve this problem it is possible to relate the event data generated by the information system to the process model through a process mining analysis.
Process mining is the link between data science and process science. Starting from a traditional process model it is possible to develop a conformance process mining project able to validate and enhance the model as-is. Since process mining is able to link the great amount of data generated by the information systems to the end-to-end process, it could be used to deeply understand the real process of a company to optimize the procedure according to the lean principle of continuous improvement.

Appendix A

In appendix A all codes of the business rules employed to develop the Bizagi application have been listed.

A.1 Fill data to the fake database

The business rule “populate collection” is applied at the end of the open procedure task. It takes data from an excel file and copy it in the application database.

```
1. // Obtain the file collection from the data model
2. var oFile =<Ingressomateriale.databaseordini>;
3. // Empty file validation
4. if(!oFile.size() > 0)
5. {
6. CHelper.ThrowValidationError("Please load a file");
7. }

8. // Obtain the first loaded file and its data
9. var oFileDef = oFile.get(0);
10. var oFileDataDef = oFileDef.getXPath("Data");

11. // Extract file content
12. var dtContenIn = CHelper.GetDataTableFromWorkSheet(oFileDataDef, 0);

13. // Obtain each record and add it to ordini chiusi
14. if(
    <like(Ingressomateriale.tipologiaordine.Tipologia,Ingressomateriale.ordinechiusoc
    heck)> == true )
15. {
16. for(var j=0; j < dtContenIn.Rows.Count;j++)
17. {

18. var oRecord = dtContenIn.Rows[j];
19. var newRecord = Me.newCollectionItem("Ingressomateriale.Ordinichiusis");

20. newRecord.setXPath("AnnoNumerodordine",oRecord[0]);
21. newRecord.setXPath("Codicearticolo",oRecord[1]);
22. newRecord.setXPath("Descrizionearticolo",oRecord[2]);
23. newRecord.setXPath("Quantitaordinata",oRecord[3]);
24. newRecord.setXPath("Quantitadaricevere",oRecord[4]);
25. newRecord.setXPath("Causale",oRecord[5]);
26. newRecord.setXPath("Descrizionefornitore",oRecord[6]);
27. newRecord.setXPath("Fornitore",oRecord[7]);
28. }
29. }

30. // Obtain each record and add it to ordini aperti
31. else
32. {
33. for(var j=0; j < dtContenIn.Rows.Count;j++)
34. {
35. var oRecord = dtContenIn.Rows[j];
36. var newRecord = Me.newCollectionItem("Ingressomateriale.Ordiniapertis");
37. newRecord.setXPath("Codicearticolo",oRecord[1]);
38. newRecord.setXPath("Descrizionearticolo",oRecord[2]);
```

```
39. newRecord.setXPath("Quantitaordinata",oRecord[3]);
40. newRecord.setXPath("Quantitadaricevere",oRecord[4]);
41. newRecord.setXPath("Descrizionefornitore",oRecord[6]);
42. newRecord.setXPath("Fornitore",oRecord[7]);
43. }
44. }
```

A.2 General information and check the schedule

With the business rule “general information” the data of the delivery is automatically registered in the check schedule task.

```
1. <Ingressomateriale.Dataricevimento>=DateTime.Today;
```

The business rule “Check the schedule” is useful to verify if for any item the quantity received is greater than the quantity to be received. If this is the case the scheduled order flag is triggered. The business rule is executed in check schedule task.

```
1. var check= <or(exists(Ingressomateriale.Ordinichiusis[Quantitaricevuta >
   Quantitadaricevere]),exists(Ingressomateriale.Ordiniapertis[Quantitaricevuta >
   Quantitadaricevere]))>;

2. if(check==true)
3. {
4. nordininonprogram++;
5. }


6. if(nordininonprogram>0)
7. {
8. <Ingressomateriale.Ordineprogrammato>=false;
9.              }
```

A.3 Number of packages in the delivery note

The aim of the “Number of packages in the delivery note” business rule is to sum the number of packages of each item and store the result in the correct attribute of the database. The business rule is executed in the check schedule task.

```
1. if(
   <like(Ingressomateriale.tipologiaordine.Tipologia,Ingressomateriale.ordinechiusoc
   heck)> == true )
2. {
3. <Ingressomateriale.Numerocolliinbolla>=<sum(Ingressomateriale.Ordinichiusis.Numer
   ocolli)>;
4. }
5. else
6. {
7. <Ingressomateriale.Numerocolliinbolla>=<sum(Ingressomateriale.Ordiniapertis.Numer
   ocolli)>;
8. }
```

A.4 Quantity of material to be returned

The business rule “Quantity of material to be returned” calculate the amount of good that must be returned to the supplier and it is linked to the validate task.

```
1. //Get the collection XPath in the variable Collection
2. if(
   <like(Ingressomateriale.tipologiaordine.Tipologia,Ingressomateriale.ordinechiusoc
   heck)> == true )
3. {
4. var Collection=<Ingressomateriale.Ordinichiusis>;
5.
6. //Convert the Collection object to a collection to be iterated
7. var Array=CHelper.GetValueAsCollection(Collection);

8. //Iterate the collection to go through each record and obtain each product price
9. for (var I=0; I < Array.size(); I++)
10.{
11.//Obtain each element and for each one the needed data
12.var Element= Array.get(I);
13.var qtadaricevere=Element.getXPath("Quantitadaricevere");
14.var qtaricevuta=Element.getXPath("Quantitaricevuta");
15.var qtareso = qtaricevuta-qtadaricevere;

16.Array.get(I).setXPath("Quantitareso",qtareso);

17.if(qtareso>0)
18.{if(<Ingressomateriale.Ordinichiusis.Accettaquantitanonprogr> == false)
                {Array.get(I).setXPath("Quantitaricevuta",qtadaricevere);
                }
19.}

20.}
21.}
22.else
23.{
24.var CollectionB= <Ingressomateriale.Ordiniapertis>;

25.//Convert the Collection object to a collection to be iterated
26.var ArrayB=CHelper.GetValueAsCollection(CollectionB);

27.//Iterate the collection to go through each record and obtain each product price
28.for (var I=0; I < ArrayB.size(); I++)
29.{
30.//Obtain each element and for each one the needed data
31.var ElementB= ArrayB.get(I);
32.var qtadaricevereB=ElementB.getXPath("Quantitadaricevere") ;
33.var qtaricevutaB=ElementB.getXPath("Quantitaricevuta");
34.var qtaresoB = qtaricevutaB-qtadaricevereB;
35.ArrayB.get(I).setXPath("Quantitareso",qtaresoB);
36.if(qtaresoB>0)
37.{if(<Ingressomateriale.Ordiniapertis.Accettaquantitanonprogr>==false)
                {ArrayB.get(I).setXPath("Quantitaricevuta",qtadaricevereB);
                }
38.}
39.}
40.}
```

A.5 Changes in quantity of the delivery note

The business rule aims to correc the quantity recorded in the information system after the rejection or approval of the delivery. It is linked to the validation task.

```
var check0= <or(exists(Ingressomateriale.Ordinichiusis[Quantitaricevuta > Quantitadaricevere]),exists(Ingressomateriale.Ordiniapertis[Quantitaricevuta > Quantitadaricevere]))>;
var check1= <or(exists(Ingressomateriale.Ordinichiusis[Accettaquantitanonprogr = false]),exists(Ingressomateriale.Ordiniapertis[Accettaquantitanonprogr = false]))>;
var check2= <or(exists(Ingressomateriale.Ordinichiusis[Accettaquantitanonprogr = true]),exists(Ingressomateriale.Ordiniapertis[Accettaquantitanonprogr = true]))>;

if(check0==true)
{
if(check1==true)
{
<Ingressomateriale.Validazionequantitabolla>=false;
}
}


if(check2==true)
{
<Ingressomateriale.Validazionequantitaammin>=true;
            }
```

A.6 Request for quantity validation

Through this business rule the incoming are supervisor triggers the flag useful to ask the quantity validation to the supply chain. The business rule is executed in the ask supply validation task.

```
var check= <or(exists(Ingressomateriale.Ordinichiusis[Chiedivalidazionequantit = true]),exists(Ingressomateriale.Ordiniapertis[Chiedivalidazionequantit = true]))>;


if(check== true)

{
<Ingressomateriale.Validazionequantita>=true;
            }
```

A.7 Accept exceeding quantity

The business rule is linked to the validate task performed by the supply chain employee and aims to trigger the automatic emails.

```
1. //ordini chiusi
2. if(
   <like(Ingressomateriale.tipologiaordine.Tipologia,Ingressomateriale.ordinechiusoc
   heck)> == true )
3. {
4. if (<exists(Ingressomateriale.Ordinichiusis[Quantitaricevuta >
   Quantitadaricevere])>)
5. {if(<exists(Ingressomateriale.Ordinichiusis[Accettaquantitaerrata = false])> )
6. {
7. <Ingressomateriale.Validazionequantitabolla>=false;
8. }
9. }
10. if(<exists(Ingressomateriale.Ordinichiusis[Accettaquantitaerrata = true])>)
11. {
12. <Ingressomateriale.Validazionequantitaammin>=true;
13. }
14. }
15. else
16. {
17. //ordini aperti
18. if (<exists(Ingressomateriale.Ordiniapertis[Quantitaricevuta >
   Quantitadaricevere])>)
19. {if(<exists(Ingressomateriale.Ordiniapertis[Accettaquantitaerrata = false])> )
20. {
21. <Ingressomateriale.Validazionequantitabolla>=false;
22. }
23. }
24. if(<exists(Ingressomateriale.Ordiniapertis[Accettaquantitaerrata = true])>)
25. {
26. <Ingressomateriale.Validazionequantitaammin>=true;
27. }

28. }
```

A.8 Flag check

Flag check business rules are useful to trigger error messages.

```
1. if(<Ingressomateriale.Materialescaricato>==false)
2. {
3. CHelper.ThrowValidationAlert("Scaricare materiale");
4.             }
```

```
1. if(<Ingressomateriale.Areasmistamento>==false)
2. {
3. CHelper.ThrowValidationAlert("Posizionare materiale");
4.             }
```

```
1. if(<Ingressomateriale.Materialeetichettato>==false)
2. {
3. CHelper.ThrowValidationAlert("Etichettare materiale");
4.             }
```

```
1. if(<Ingressomateriale.Posizionatoarearesi>==false)
2. {
3. CHelper.ThrowValidationAlert("Posizionare materiale");
4.             }
5.
6. if(<Ingressomateriale.Validazionequalita>==false)
7. {
8. <Ingressomateriale.Validazionedipartimentoq>=true;
9. <Ingressomateriale.Validazionequalitasupply>=true;
10.     }
```

```
1. if(<Ingressomateriale.Validazionequalitasupply>!=<Ingressomateriale.Validazionedi
   partimentoq>)
                {
                <Ingressomateriale.MostraErrormessage>=true;
2.             }
```

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