Reverse supply chain improvement strategies for returnable packaging material

A case study at Prysmian Netherlands

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Preface

This thesis report is my final requirement to obtain the MSc degree in Transportation, Infrastructure, and Logistics entitled "Reverse supply chain improvement strategies for returnable packaging material". This journey started in a "new normal" period of COVID-19, where I conducted my research at a company that I have visited only once in my life. For almost nine months, I have been planning, working, and writing on this research. Conducting research, or studying in TU Delft in general, has been great yet challenging for me. With that being said, I would like to thank those who make my whole journey possible and full of enjoyment.

First of all, I would like to thank my Father and Mother. Both of you always give constant and biggest support, no matter how hard your lives have been. You have shown me that with a strong will, nothing is impossible. I would not have gone this far without your continuous prayers. I present this achievement to you as my sign of gratitude. To Andi and Atria, my beloved brother and sister, thank you for all being there when I need my family the most, even with the time differences.

I would like also to express my gratitude to the graduation committee for all the help along the way. The guidance and challenges that you gave have not only improved this research but also made me grow as a person. Firstly, to Prof. Negenborn, for the opportunity of research under your supervision. Secondly, to Dr. Beelaerts, for linking me with Prysmian in the first place, and being attentive throughout this project. Thirdly, to Dr. Vleugel, for being so helpful particularly at times I felt like things are falling apart. Fourthly, to Mr. Middel, for your patience and challenges during my memorable experience at Prysmian. Lastly, to Mr. Holtrop, for the knowledge, time, and effort you put into this project. I would like to extend my gratitude also to other Prysmian colleagues that I cannot mention individually.

On a personal note, I would like to thank my friends that always provide unconditional support all these times. To my fellow combatant, overworking friends at TU Delft Library, Ranar, Sulthon, Ricky, Kanya, Panji, Fadhil, and Reddhi, thank you for all the fun times and empathetic ears. Also, to Julivius, for your effort to teach simulation to a novice like me in a very short time. For my Indonesian and international friends, I wish I could express how much you have all helped me through ups and downs.

Finally, I would like to thank Gabby for her support and love during my studies. Even with the time difference, you are always there to motivate me every time I need one and be so understanding.

Thank you and I hope you have an enjoyable read!

Andrian Wicaksono Supriyanto

Delft, December 2021.

Summary

Research Background: The increasing domain of reverse supply chain (RSC) drives the direction of this research. In the electrical cable industry, manufacturers use cable drums as transport packaging. These returnable packaging materials (RPM), however, are not returned by the customers despite the potential benefits of reuse. Moreover, the bad condition from the returned drums also prevents reusing the drums. It leads to more drums required for replacing the lost assets, hence leading to further RSC inefficiency. Therefore, this research attempts to answer how can an RPM be improved in terms of RSC efficiency and reverse logistics (RL) cycle time.

Research Approach: The research follows the research steps of SIMILAR (State the Problem, Investigate Alternatives, Model the System, Integrate, Assess performance, and Re-evaluate). Literature review reveals that few studies focus on RPM with high residual value. It is also found that despite the increasingly important sustainability factors, most companies focus on the economical and logistics aspect for evaluating RSC feasibility. A case study is performed in Prysmian Netherlands (PYNL) to analyze the current state and challenges faced in RSC implementation. The analysis highlights two drum types that are lost and damaged the most. To assess the impacts of potential improvement strategies, several performance metrics are established. Furthermore, improvement strategies are developed using approaches from technological advancements, logistics system design, and compliance policy. Multi-criteria analysis is carried out to narrow down the solution space, leaving six improvement scenarios. Finally, the scenario performance is evaluated against RSC efficiency and RL cycle time.

Results: The performance assessment shows that Scenario 3 yields the highest efficiency at 66%, but followed by a higher CO2 emission. This scenario implements a non-return penalty system that enforces customers to return empty drums. The lowest RSC efficiency is accounted for in the scenarios with the new drum label redesign. The highest RL cycle time is obtained by Scenario 6, which takes 21 and 16 days to return from small and large installers, respectively. The scenarios which depend more on customers' participation come out as the worst-performing in terms of RL cycle time. Finally, Scenario 3 turns out to be the favorable improvement strategy with a 3.7 CBR ratio.

Conclusion: The research suggests that improving the return and reuse rate leads to higher recovery financial benefits. This is more promising when RPM has a high residual value such as cable drums. Furthermore, maintaining an RPM condition has the utmost importance. Recovering damaged drums from customers only leads to pure cost from transportation and scrap activities. This also should be considered when setting up a return flow in the wholesalers' supply chain. Failure to ensure drum integrity from end customers incur bigger financial impacts from setting up the return flow, in addition to the scrap cost. It can also lead to stockouts due to miscalculation of future inventory stock at the wholesalers. Increasing the return and reuse rate results in higher CO2 emissions. This trade-off is inevitable as one cannot satisfy economic and environmental at the same time. In addition, shorter RL cycle time only has a marginal effect on RSC efficiency. This might be caused by the scrap rate overpowering the benefits of a shorter lead time. The use of RFID can increase RSC visibility, allowing resource allocation to focus on specific customers and better stock accuracy. The decentralized return management flow involving the wholesalers does not provide substantial advantages in comparison to centralized management by PYNL. Although they do not perform as well as the others, the QR code and mobile app enhancements can provide real-time stock calculation thus increasing drum inventory forecasting accuracy. The strategy using non-return may impose a business risk where the customers can get discouraged from such policy and switch to another brand.

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List of Abbreviations

AS/IS	Application System/Information System
B2B	Business-to-Business
BDA	Big Data Analytics
BSC	Balanced Scorecard
CLSC	Closed-loop supply chain
CPS	Cyber-Physical System
DES	Discrete Event Simulation
DRM	Drum Manager
EMF	Emmen Manufacturing Facility
ESCAPE	Efficient Supply Chain via Agile Performance Evaluation
IND 4.0	Industry 4.0
IOT	Iron Ore Tailings
IoT	Internet of Things
IoS	Internet of Service
LT	Lead time
MCDM	Multi-criteria Decision Making
PM	Performance Management
PP	Performance Prism
PRV	Product Residual Value
PYGR	Prysmian Group
PYNL	Prysmian Netherlands
RFID	Radio Frequency Identification
RL	Reverse Logistics
RPM	Returnable Packaging Material
RSC	Reverse Supply Chain
RTI	Returnable Transport Items (*see RPM)*
SC	Supply Chain
SD	System Dynamics
SSR	Shrink, scrap, and return (rate)
SE	Systems Engineering
TBL	Triple Bottom Line

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PART I - STATE OF THE PROBLEM

1
Introduction

The research is conducted in Prysmian Netherlands, a part of Prysmian Group. Prysmian Group itself is the largest cable system solution provider in the energy and telecommunication sector. The company has a strong presence throughout the globe with 23 plants in North America, 48 in Europe, 13 in Latin America, 7 in Middle East-Africa-Turkey, and 13 in Asia-Pacific. In 2011, Prysmian acquired a Dutch company, Draka which was the fourth-largest cable and optical cable manufacturer in the world at that time. In the Netherlands, Prysmian Group operates under Prysmian Netherlands B.V. (PYNL). The company has 4 branches in Emmen, Nieuw-Bergen, Eindhoven and head office in Delft for Benelux operations (Prysmian Group, 2017).

PYNL endorses two commercial brands, Draka and Prysmian. These brands are active in the Benelux market. The Draka brand is active in the low voltage and telecom market segment, where Prysmian cables target the high-voltage and energy distribution networks market. PYNL is also active in the energy and telecom sectors (Prysmian Group, 2017).

1.1 Research context

In delivering their products to the customer, the company uses cable drums made from plastics or wood. Cable drums can be classified as returnable packaging material (RPM) where customers return the empty drums to be repaired/cleaned before being refilled by the retailer/producer (Coelho et al., 2020). Manufacturers ship power and telecommunication cables in form of drums to protect against external damages during handling processes. For more protection against transportation damages, additional plastic protective sheets can be used.

The company aims to increase the return rate of drums for the Emmen factory, which is currently 50-60% for wooden and plastic drums. The reuse rate for wooden drums is approximately similar to the return rate percentage, however, only 1-2% of returned plastics drums can be reused. The goal is to reach a 75% return rate in 2023 for the Emmen factory. The return management in the Emmen factory involves high drum numbers and types with many customers in the supply chain, thus making it costly and complex. The main causes for the initiatives are a) cost savings (where 1% rate increase equals to €[redacted], b) new drums supply shortage due to high wood price, c) growth of demand, and d) the company direction towards a more circular economy. The cost of drums is currently accounted for partially by clients and the company.

1.2 Problem definition

The main issue arises after the cables are delivered to the customer, where over half of the cable drums are disposed to landfill annually by electrical contractors (FP Cables, 2012). The problem persists, even though PYNL does not charge any collection cost to customers as their approach to increase drum returns (Prysmian Group, 2020). In Emmen, the handling and delivery process of cable drums are shown in Figure 1-1. The company sources the cable drums and carries out visual checks before storing them. The drums are then taken for cable reeling and shipped by logistics providers to wholesalers or directly to end customers. End customers, i.e., installers, can send larger empty drums directly to Prysmian while smaller drums are via the wholesalers. All returned drums are checked for necessary repairs. If the drum has too much damage to repair, it will be sent to waste processing companies. Drums with modest damages are repaired in the warehouse and stored for further reuse.

Based on the Prysmian procedure, drums purchases (y) are dependent on three values: the number of drums returned (z) from the clients and the number of repairable drums (d), and the number of drums to be shipped. The decision on drum purchase is based on the forecast of these variables. The return rate from clients (z divided by y) and reuse rate after return check (d divided by y) are currently less than 1. This means the company purchases more drums to compensate for the low return and reuse rate. To increase the return rate, improved coordination between the manufacturer, logistics services providers, and customers (i.e., wholesalers and electrotechnical installers) is required.

The importance and awareness of the drum values are not shared by all stakeholders involved, which contributes to the low rate of returns. According to interview 1.5 (0), both wholesalers and installers support drum return in principle. Nonetheless, these customers do not always participate to return the drums in practice. Customers do not share the urgency of returning the drums, thus most of the time these drums are left unnoticed in their premises. Prysmian's limited visibility on their drums also contributes to the main issue, resulting in dependency on the customers' proactive attitude to return the drums.

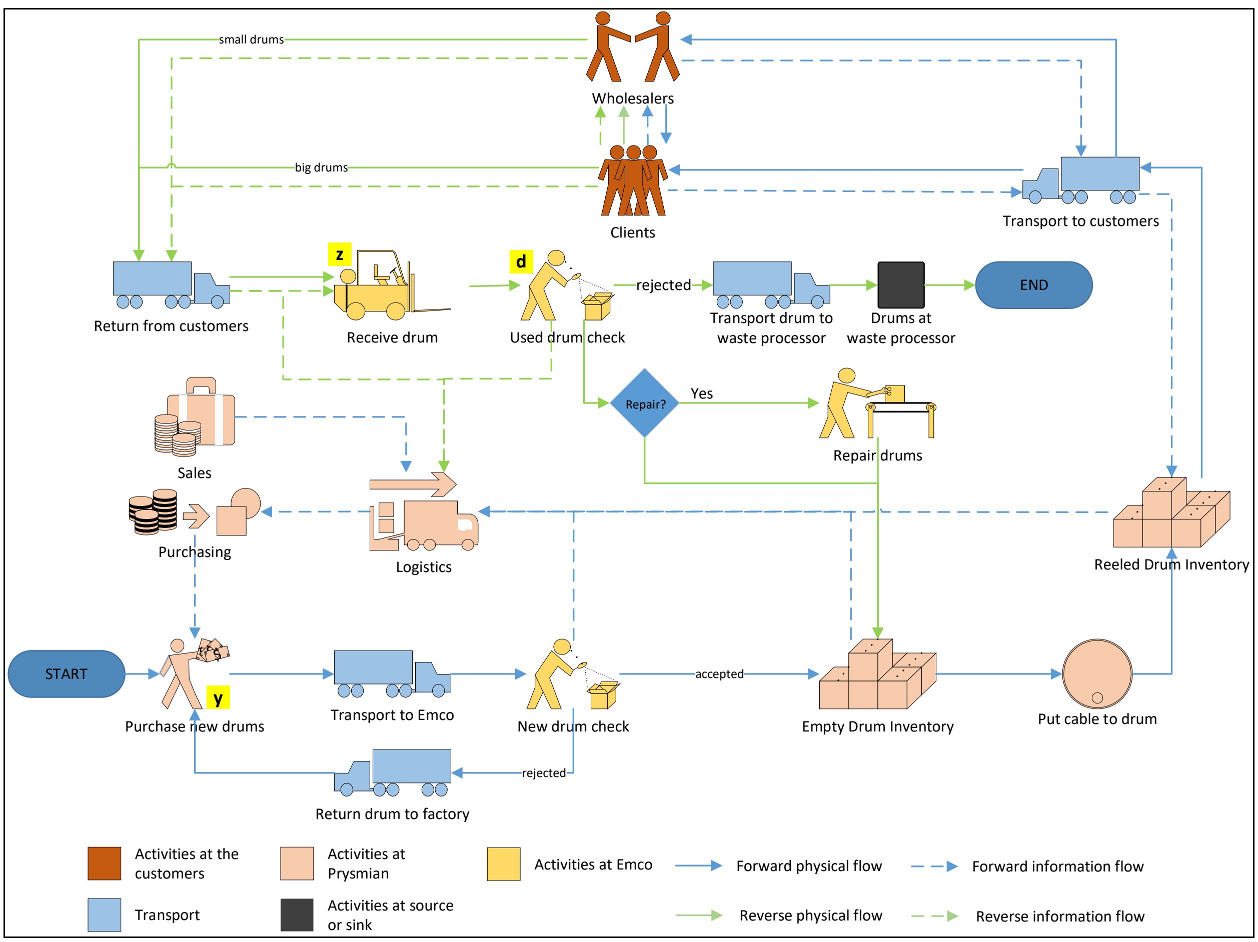

Figure 1-1 Reverse logistics process of drums at Prysmian Netherlands

1.3 Research questions

Based on the previous problem definition, the main research question for those purposes are as follows:

"How can the returnable packaging material in a reverse supply chain (RSC) be improved in terms of RSC efficiency and return cycle time?"

According to Shaik et al (2012), recovery efficiency in reverse logistics (RL) indicates the enterprise's capacity to recover value from RPM, while at the same time maintaining the cost, quality, and environmental impacts. In this proposed study, a similar definition is used to describe RSC efficiency, yet to a wider extent. Instead of focusing only on the transport logistics aspects as one would in the RL system, the RSC efficiency depicts the efficiency as a whole system. Hence, the RSC efficiency is defined as an enterprise's attempt to recover value from retrieved RPM in a supply chain system, while simultaneously maintaining resource, cost, quality, and environmental impact. On the other hand, return cycle time is defined as the average cycle time an RPM is leaving to customers' premises to the time the RPM is put back into the inventory for reuse or scrapped (Hall et al., 2013). In this context, the enterprise is Prysmian Netherlands. Customers are defined as the related parties to whom Prysmian delivers their returnable packaging in the form of drums, either as a part of a commercial cable product item or an empty drum for transport and storage packaging.

To answer the main research question, the corresponding sub-research questions are formulated as follows:

1. How does literature describe returnable packaging material in the context of the reverse supply chain?
2. How can reverse supply chain performance be measured and evaluated?
3. How is the current supply chain structured and performed?
4. How can the RSC performance be simulated and assessed?
5. What alternative reverse supply chain strategies can be proposed?
6. How do the proposed strategies perform in terms of the transport logistics performance of the RSC?

1.4 Research objectives

This thesis aims to search the potential strategies in improving the reverse supply chain (RSC) to increase the RSC efficiency while decreasing the return cycle time of cable drums. It is carried out in collaboration with Prysmian Netherlands. The research objectives are as follows:

- Explore the literature about RPM in RSC, process improvements, performance indicators, and simulation tools
- Identify key stakeholders and their respective requirements for the future reverse supply chain
- Determine performance indicators for the logistics processes
- Map the current state of the supply chain
- Build a simulation tool for reverse supply chain performance assessment
- Develop reverse supply chain improvement strategies
- Assess and evaluate the proposed improvement strategies

1.5 Research structure and methodology

The problem in this research involves interdisciplinarity and interrelationships of the system aspects. Hence, the methodology to carry out this research follows the SIMILAR process of Systems Engineering (SE). The SIMILAR process model outlined the set of interrelated SE activities which turn input into outputs in a working system. SIMILAR is an acronym for the seven main steps it represents, which consist of (Ramos et al., 2010):

- State the problem;

- Investigate alternatives;
- Model the system;
- Integrate;
- Launch the system;
- Assess performance, and
- Re-evaluate.

In this section, the methodology of this research is laid out with an overview shown in Figure 1-2. The methodology follows the process suggested by Ramos et al. (2010). The research starts with problem definition where research objectives, questions, and scope must be determined. The main driver of this research is the problem statement provided by PYNL to improve the reverse supply chain of cable drums. The research objectives are identified based on this purpose. The inputs are the customer's needs and expectations along with the project constraints. P*roblem identification* is carried out to satisfy such a purpose.

The second step "investigate alternatives" dives into the literature about the current state of the art of the subject and explores the potential alternatives concepts suitable for the problem. A *literature review* is carried out to identify the research gaps found in the research area. Performance metrics are also explored during this step.

The third step is "model the system" which involves systems modeling through a current state mapping. In the attempt of building a simulation model, it is important to define the system under consideration. Observation on the current state of the system is done to capture the "as-is" conditions for the system, then captured in a *swimlane analysis*. *Root cause analysis* is used to highlight the contributing factors to the low RPM return and reuse, and responsible parties are mapped in a *RACI* matrix. Further, a *stakeholder analysis* is performed to analyze the behavior of key stakeholders in the RSC. Data collection will involve *explorative interviews* with key stakeholders relevant to the reverse supply chain processes, including, logistics, warehouse, & sales functions. This approach is iterative, with multiple interviews that will follow through with the development of the model. The data obtained from key stakeholders need to undergo cleansing and structuring to become usable for the next steps. The requirements and constraints for future strategies are also formulated in this section.

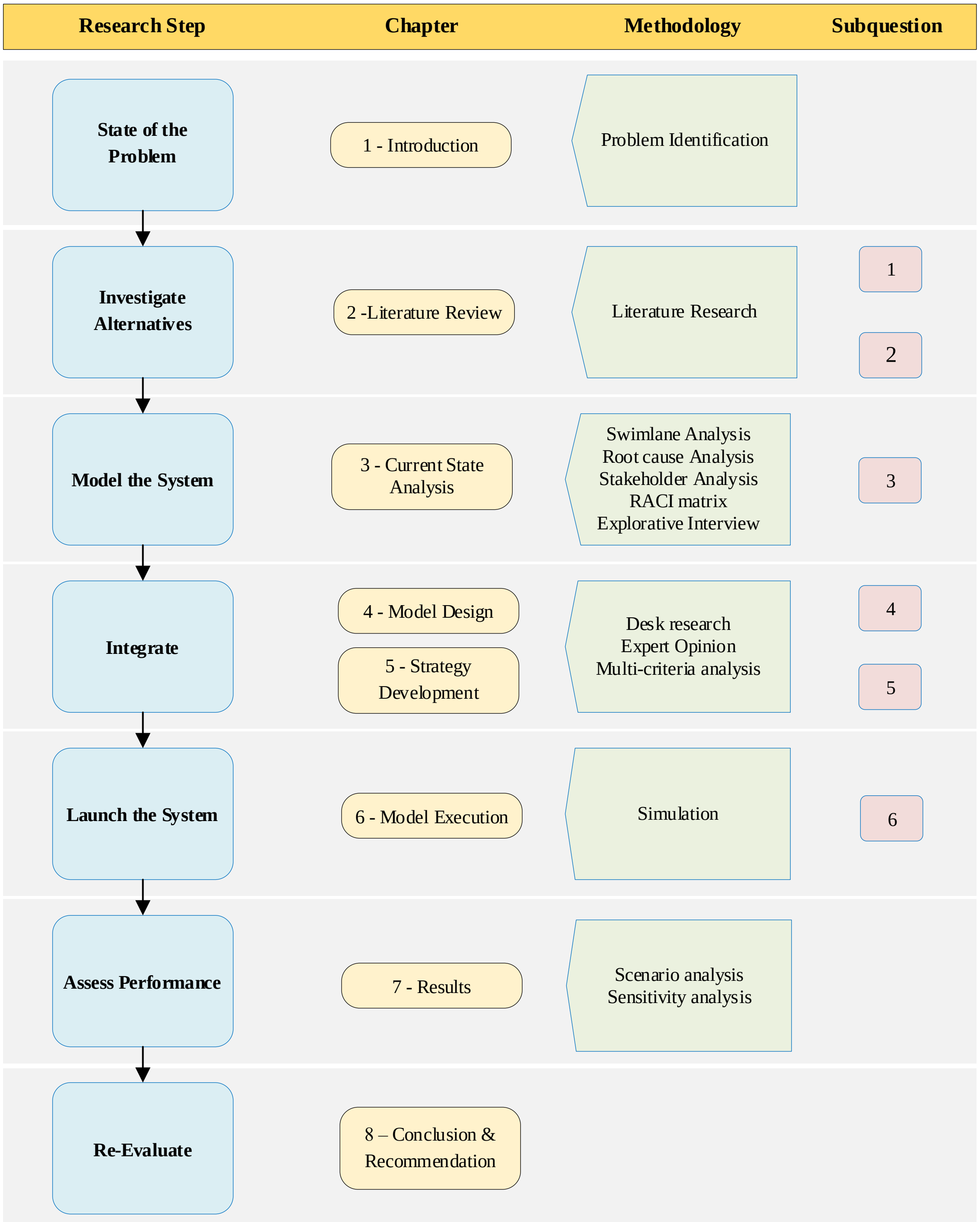

Figure 1-2 Research Structure

The fourth step is "integrate", where interrelated activities in the system can work as a unit. Model building and development are the core activities in this function. The performance metrics used for simulation are established in this step. Strategy development also takes place in this phase to obtain a set of RSC improvement scenarios. *Desk research* and *expert opinion* are used to explore and evaluate the potential improvement strategies. Strategic options are narrowed down based on the predefined requirements and *multi-criteria analysis*.

The fifth step "launch the system" includes specifying the model inputs, then running the system to obtain output values through model simulations. Certain additional assumptions are expected to support the simulation. A set of verification tests are carried out to ensure the model's correctness. The verified model is validated afterward by *expert opinion* to ensure sufficient representation of the system.

Simulation results are then assessed in the sixth step "assess performance" through *scenario analysis*. The analysis outlines the results from the base model and improvement scenarios. *Sensitivity analysis* takes place to understand the robustness of the results. Finally, the results are analyzed in the "re-evaluate" step and interpreted to arrive at a general conclusion to the initial problem statement. The different methods answering the sub-questions can be found in Table 1-1 below.

Table 1-1 Research Questions - Methods

No	Questions	Method(s)
1	How does literature describe returnable packaging in the context of the reverse supply chain?	Literature research
2	How can reverse supply chain performance be measured and evaluated?	Literature research
3	How is the current supply chain structured and performed?	Swimlane analysis, root cause analysis, stakeholder analysis, RACI matrix, explorative interview
4	How can the RSC performance be simulated and assessed?	Simulation
5	What alternative logistics strategies can be formulated?	Desk research, expert opinion, multi-criteria analysis
6	How do the proposed strategies perform in terms of the transport logistics performance of the RSC?	Scenario analysis, sensitivity analysis
	"How can the returnable packaging material in a reverse supply chain (RSC) be improved in terms of RSC efficiency and return cycle time?"	**Conclusion**

1.6 Research scope

This research aims to provide reverse supply chain strategy recommendations to Prysmian Netherlands. Since there are many ways to achieve such a goal, this project is limited by certain scope. The type of RPM under study is cable drums that are used for serving customer demands. Therefore, it excludes the drums obtained due to outsourced or contract manufacturing. Products distribution flow towards PYNL affiliated distributors are also excluded in this research context.

The research only focuses on improving RSC efficiency and RL, thus does not consider the optimum RPM fleet sizing. Furthermore, the study area focuses on the Netherlands. As stated previously, the proposed solutions are re-scoped in Chapter 5, since implementing and assessing each potential solution is cumbersome. The improvement is based on estimations from literature and experts.

PART II - INVESTIGATE ALTERNATIVES

2

Literature review

Following the introduction in the previous chapter, the subsequent research step is **Investigate Alternative**. A literature review is carried out to discuss the current state-of-the-art of RSC and RPM. The review will describe the RPM utilization in the RSC context to provide a comprehensive overview of the subject. Sources such as scientific papers, journals, books, reports, particularly those from digital sources (Scopus, ScienceDirect, and Google Scholar) are used. As stated in the research structure, this chapter also deliberates the performance metrics in evaluating RSC. These metrics are considered further in Chapter 4 for strategy performance assessment.

2.1 Reverse supply chain

A reverse supply chain (RSC) is a set of activities involving the collection and reprocessing of used products to recover the residual market value or to dispose of them. An effective RSC management of transportation, inventory, and warehousing returns better profitability and environmental performance (Battaïa & Gupta, 2015). RSC is also often discussed from reverse logistics (RL) perspectives, where defined as "the process of planning, implementing, and controlling the flow of raw materials, inventories, finished products, and information, from the point of consumption or disposal of the goods to point of origin, to recover remaining value or provide appropriate disposal" (Pushpamali et al., 2021a). Figure 2-1 illustrates key processes in typical RSC.

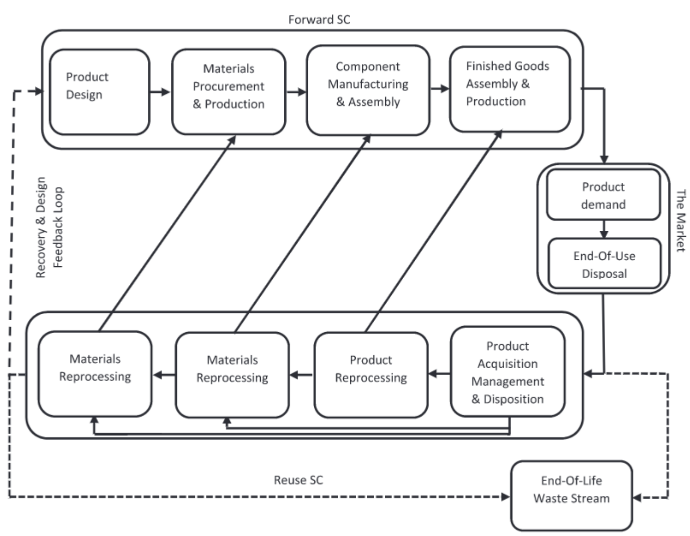

Figure 2-1 Key processes in an RSC (Kazemi et al., 2019)

The reverse supply chain differs from the forward supply chain. In a traditional forward supply chain, the focus of a firm is to distribute products to distributors or customers. Physical transportation flows from one-to-many destinations, meanwhile, it is many-to-one in RSC (Ilgin & Gupta, 2013). The main differences between reverse and forward supply chains are shown in Figure 2-2.

Differences between Reverse and Forward Supply Chains

Forward	Reverse
Based on profit and cost optimization	Based on environmentally conscious principles and laws as well as on profit and cost optimization
Relatively easier and straightforward forecasting for product demand	More difficult forecasting for product returns
Less variation in product quality	Highly stochastic product quality
Traditional marketing techniques can be applied	There are factors complicating marketing
Processing times and steps are well defined	Processing times and steps depend on the condition of the returned product
Goods are transported from one location to many other locations	Returned products collected from many locations arrive in one processing facility
Speed is a competitive advantage	Speed is not a critical factor
Standard product packaging	Highly variable packaging/lack of packaging
Standard product structure	Modified product structure
Cost estimation is easier due to accounting systems	Determination and visualization of cost factors is complicated
Disposition alternatives are clear	Disposition options for a returned product depend on its condition
Consistent inventory management	Inconsistent inventory management
Financial implications are clear	Financial implications are not clear
Highly visible processes due to real-time product tracking	Less visible processes due to lack of information system capabilities for product tracking
Relatively easier management of product life cycle changes	Adjusting to the product life cycle changes is more difficult
Relatively more deterministic	Relatively more stochastic
Primary importance to manufacturers	Primary importance to EOL processors (i.e., remanufacturers, recyclers)

Figure 2-2 Differences between reverse and forward supply chains (Ilgin & Gupta, 2013)

RL becomes a very critical issue for a company. According to Jayant et al. (2012), their findings show that RL costs are huge which can take up to 4% of the total logistics costs. Thus, selecting suitable collection points becomes very vital. Even though the total processing cost for return products is higher than manufacturing costs, a good collection strategy may result in repetitive purchases and less risk from material demand and costs variation. RL implementation in construction projects, for example, leads to a significant reduction of new material purchase costs without compromising project duration and quality. Nonetheless, the SC becomes less flexible to sudden changes (Pushpamali et al., 2021b). An environmental push towards sustainable business practices has also put reverse logistics into the spotlight in improving processes and products. This is mainly driven by financial causes, strategic, marketing, and environmental requirements (Silva et al., 2013).

Before integrating RL practices, one must also take into account the carbon footprint and emissions from supply chain activities. The direct and indirect generation of CO_2 emissions occurs in the life cycle of goods and services, starting at the raw materials extraction, production, storage, transportation, usage, and disposal. A well-organized reverse logistics structure will not only help reduce carbon emissions but also increase customer loyalty and future sales. Therefore, a strategic approach is a key to limiting emission production along the chain (Aljuneidi et al., 2019).

There are various challenges in implementing RL in their supply chain. Pushpamali et al. (2021b) cited clients' preferences as the main determinant of successful RL since they aim to make the most of their money. The planning and design phase becomes longer to ensure sufficient flexibility if a disruption occurs. The research, however, suggests that there is no connection between customer satisfaction and the reuse of materials because customers do not specifically request reused materials. Thus, reduction in SC cost without sacrificing customer satisfaction is possible. On the other hand, Fen (2011) stated that time and costs as the inhibiting factors for logistics services providers, since it demands more labor work than the forward SC. However, both researchers agree that RL takes more time in the planning phase.

2.2 Returnable packaging material

In the packaging industry, types of packages are classified depending on their purpose or level of layers. Three main packaging categories are identified in Table 2-1. Returnable packaging material (RPM) is used to describe all forms of returnable tertiary packaging that is used in transport processes, such as drums, pallets, dunnage, and crates. The term itself is used interchangeably with returnable transport items (RTI) in the literature (Thoroe et al., 2009). Limbourg et al. (2016) examine the management of various RPM types in multiple industries. The investment and management costs of each RPM are also highlighted.

Table 2-1 Categories of product packaging (Mahmoudi & Parviziomran, 2020)

Category	Functionality
Primary packaging	Contact directly with the product. Aims to cover and hold the product
Secondary packaging	The outer layer of the primary packaging to bundle products or prevent theft
Tertiary packaging	For product handling, storage, and shipping

Cable drum (or reel) also falls into the RPM category as tertiary packaging, mainly used for storing and shipping ropes, cables, optical fibers, and chains. Their dimensions may vary, as well as the composing materials. Typical materials for drums are wood or wood composites, plastic, and steel (Sydor et al., 2017). The main dimension of a typical wooden cable drum is shown in Figure 2-3.

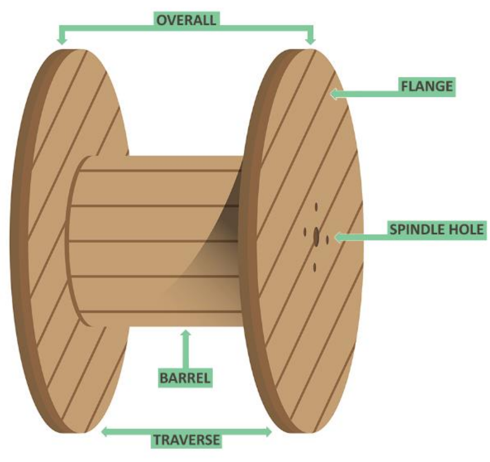

Figure 2-3 Cable drum main dimensions (Reelmen Australia, 2016)

Wood, one of the base materials for drums, becomes very expensive in the past year. According to the National Association of Home Builders, the lumber price skyrocketed by almost 200% after reopening due to COVID-19 (Sheffey & Brandt, 2021). This adds the cost to soar where the wood supply could not meet the rising demands for houses. Lumber production prices have also increased in terms of transportation and labor. The pandemic put wood production in uncertainty which also imposes a supply risk to the cable businesses (Flood, n.d.).

On the other hand, environmental considerations have pushed stakeholders towards more sustainable practices in the packaging industry. Societies have demanded ways to increase resource material efficiency and reduce the amount of packing produced. Therefore, the transition to a so-called circular economy poses a challenge in closing the material loops. This means ensuring the smallest cycle possible in Figure 2-4, by retaining the required material qualities in serving its original purpose. The change from single-use to reusable packaging may lead to different economic benefits, involved stakeholders, logistics structure, and the type of organization (Coelho et al., 2020).

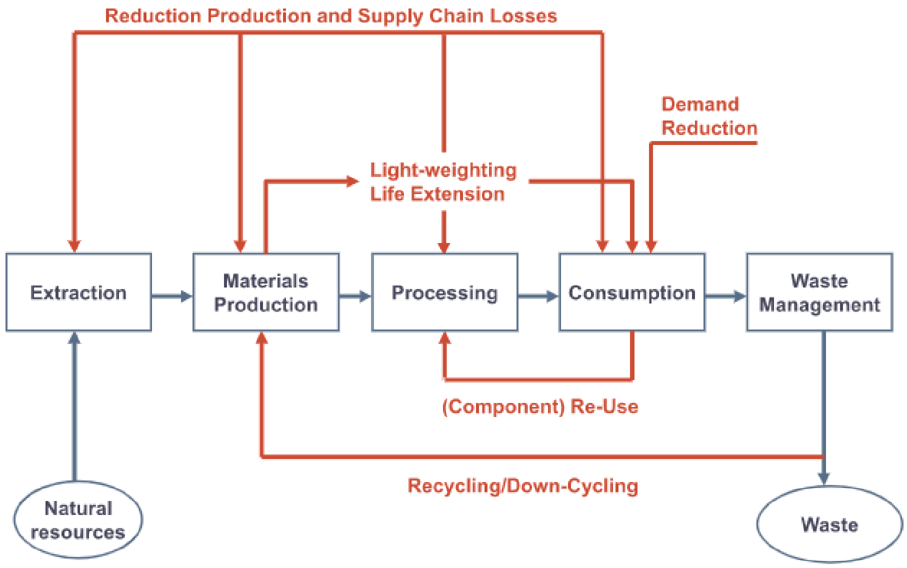

Figure 2-4 Material Efficiency Opportunities (Coelho et al., 2020)

RPM system may sound environmentally beneficial; however, interested companies will first take into account the economical and logistical considerations. In a Business-to-Business (B2B) environment, RPM promises cost savings when implemented (Coelho et al., 2020). Kroon et al. (1995) argue that the service fee affects the attractiveness of using such an RPM system, especially if there are insufficient participating parties. Money deposits may also discourage users to support returnable containers.

Gobbi (2011) examines the product residual value (PRV) and the marginal value of time (MVT) in the RSC. PRV is how much value does a product retains after usage, whereas MVT is the rate of value loss over time. Their findings suggest that the residual value of a product after a certain period dictates the type of recovery options, hence the design of the RL strategy. Repair, refurbishment, or remanufacturing are suitable recovery options for products with high PRV. For products that have low to no residual value, recycling or incineration can be considered. Higher product PRV also calls for more responsive RSC design, whereas cost-efficiency should be the focus in the RSC for low PRV products. The decision between centralized and decentralized RSC structures depends on the size of inbound volumes and the required expertise in reconditioning the RPM.

2.3 RPM management strategy

The issues faced in RPM management are high capital costs and shrinkage. The latter term refers to the loss of assets due to theft, unregistered damage, or customers' failure in returning empty containers (Thoroe et al., 2009). The losses can lead to a decrease in financial return on RPM assets, disturbs network viability, and additional supply chain cost. An organization can suffer the cumulative negative effect from the losses until the RPM is replaced (Aggarwal & Lim, 2012). To tackle this issue, one could consider solutions from logistics system design, introducing tracking technologies, and compliance strategy.

2.3.1 Logistics system design

Mahmoudi et al. (2020) examine the logistics system design of RPM based on the studies of Kroon et al. (1995) and Hellström et al. (2010). The design of the reverse logistics system is typically based on

RPM ownership, the responsibility of managing, cleaning, controlling, maintaining, and storing the RPM. There are three logistics system designs laid out in the literature; switch-pool systems, systems with return logistics. The comparison between logistics system design is shown in Table 2-2.

In the switch-pool systems, each participant possesses their share of RPMs and is responsible for the maintenance, storage, and management. Two configurations may take place, where in the first, the sender is responsible for the return flow management. The second configuration assumes that the RPMs switch ownership at every exchange between participants. In this case, the carrier has the ultimate responsibility for return flow management.

Table 2-2 Logistics system design configuration (Mahmoudi & Parviziomran, 2020)

Logistics system design	**Participants**	**Ownership**	**Cleaning responsibility**	**Managing, maintaining, & storing responsibility**
Switch-pool systems	Sender-recipient	All participants	All participants	Sender
Switch-pool systems	Sender-carrier-recipient	All participants	All participants	Carrier
Systems with return logistics, transfer system	Sender-central agency-recipient	Central agency	Sender	Sender
Systems with return logistics, depot system	Sender-central agency-recipient	Central agency	Central agency	Central agency
Systems without return logistics	Sender-central agency-recipient	Central agency	Sender	Sender

In the system with return logistics, a third-party central agency owns the RPMs (or containers) and is responsible to return the items to the sender after they are emptied at the recipient. The containers are accumulated until a certain threshold before being sent to the sender. The central agency can adopt two types of systems, namely the transfer or the depot system. The transfer system mandates the central agency to only return the containers from the recipient, while the sender is responsible for the maintenance, storage, and management. In the depot system, the central agency stacks the empty containers at their depot, cleaning and maintaining them if necessary.

The depot system has two design options, one with booking or with deposit. The booking system requires the sender to register an account at the central agency to control the flow of returns. When the sender delivers a container to the recipient, the agency debited a certain quantity of containers at the sender's account. On the contrary, the agency debits the recipient account (and credits the sender) for the return flow. With the deposit system, the sender pays a certain amount of money to the agency in exchange for the containers received. When the sender delivers the containers, the recipient is debited to the amount of the delivered containers. At the final destination, the central agency collects the containers and returns the deposits to the initial sender. Any shrinkage will be charged on the deposit. This refund practice can reduce the holding time in each participant's premises.

In the system without return logistics, the central agency owns the containers whom the senders rent from. The sender has complete responsibility for the management, maintenance, and storage of the containers, including shrinkage.

2.3.2 Uses of technology in RPM management

An RPM management strategy involving tracking technologies has been found in many industrial applications. Maleki et al. (2011) compare the pros and cons of various tracking tools, namely barcode, active and passive Radio Frequency Identification (RFID), Wi-Fi (wireless fidelity), and GPS (global positioning system). In the study, the barcode system emerges as the most economical option. On the other hand, de Jonge (2003) outlined the superiority of RFID from the barcode in terms of reading speed, flexibility (line-of-sight not required), robustness against the rough environment, practicality (no manual labor), and rewritable, hence the RFID is found more frequently as the selected tracking technology. Among the various RFID tags available, the UHF type is considered because it has a longer read range and cheaper transponders (Uckelmann, Hamann, & Mansfeld, 2009).

On top of that, RFID can stand against metal interference and offers a wide communication range, particularly for high and ultra-high frequency devices. Additional features include asset tracking, quick payments, safety monitoring, and counterfeit prevention. (Garrido-Hidalgo et al., 2019; Shah et al., 2019). The usage of RFID on RPM is effective when it is used in a closed-loop supply chain, the partnership between stakeholders is already established, and the service provider (for cleaning, repair, and refurbishing) can provide tagging services (Uckelmann, Hamann, & Zschintzsch, 2009). However, the benefits of increased RSC visibility are unequally distributed between stakeholders. In a two-echelon SC case study by Hellström et al. (2010), a milk producer and bottler experiences backlog improvements, higher capacity utilization, and lower empties inventory. At the wholesalers, however, the inventory for both full and empty bottles only changed slightly, even though the backlog was improved. This difference in benefits gained calls for a fair investment scheme among stakeholders, should there be an RSC integration plan in the future.

The development of technology has allowed effective operations within the internal organization and across external players in the RSC. There are ubiquitous attempts to integrate Industry 4.0 (IND 4.0) solutions in the operation. IND 4.0 depends on the interaction between Cyber-Physical Systems (CPS), Internet of Things (IoT), and Internet of Services (IoS) as the basic operating platform. CPS improves the communication and information exchange in the system, enabling decision-making based on real-time data from machines, processes, and business operations. CPS consists of three fundamental layers (shown in Figure 2-5), namely connected devices, stored data in a cloud environment, and Application/Information System (AS/IS). The physical devices are interconnected and share information in which is stored in the cloud. The AS/IS aid users to interact virtually with the connected devices, assets, products, and services (Manavalan & Jayakrishna, 2019).

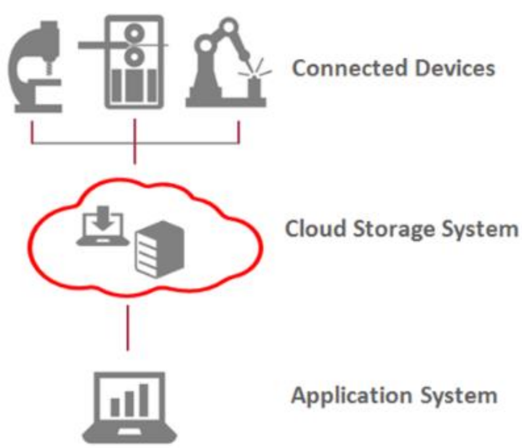

Figure 2-5 Fundamental Layers of CPS

These embedded sensors increase the visibility of the condition and status of the product across the SC. Stakeholders can monitor the product condition and be alerted of any missing items. (Manavalan & Jayakrishna, 2019). Sha et al (2019) noted RFID as embedded sensor technology that can identify products and manage networks.

IoT, on the other hand, provides interconnection between humans, machines, and devices to the internet, while supported by artificial intelligence to enhance SC operations (Fatorachian & Kazemi, 2021). In the SC context, the application spans from the manufacturer to e-retailers. Smart products with IoT devices can, for instance, share tracking information and keep SC partners informed regarding the product's availability. Warehouse supervisors can remotely locate certain products and give live instructions to floor workers on how to handle certain equipment and sensitive materials. IoT provides better visibility of stock levels and supports warehouse managers in inventory decisions.

The benefits of implementing IND 4.0 in the SC are discussed in the literature. Shah et al (2019) suggest that the SC can be more efficient in terms of asset utilization, network connectivity, demand/supply planning, and time. Responsiveness towards changing markets and competition is also attributed to this digital transformation. Fatorachian et al (2021) mentioned that information sharing can eliminate the bullwhip effect and intermediation, thus less transaction and transportation are required, which leads to a better environmental footprint. SC visibility on suppliers allows scheduled auditing for their sustainable practices in the sourcing processes, hence improving the supplier-buyer relationship. The data obtained from the SC operations can be used as inputs to Big Data Analysis (BDA) platform, where transportations can be optimized in real-time. Stocktaking processes take significantly less time compared to manual count.

2.3.3 Facilitators in encouraging return behaviors

To attain high RPM returns, tangible actions are required on top of collecting information from tracking devices. The supply chain visibility should be coupled with proper measures (Johansson & Hell. ström, 2007). The strategies to combat non-compliance in returning RPM are outlined in Table 2-3, where they are suitable for the B2B relationship (Breen, 2006).

Table 2-3 Return encouragement strategy towards customers (Breen, 2006)

No	Strategy Option	Description
1	Communication	Communication by evaluating relationship development between organizations, or direct approach to remark on customer’s behavior.
2	Incentives	The use of incentives e.g., deposits are considered. Still, the incentive level should be determined carefully. Undesired behavior may occur if the ease of not returning outweighs the incentives.
3	Introduce contracts	The contract ensures both parties agreed on the points and how to monitor performance.
4	Enforcement	The enforcement through the penalty system. This system is complemented with educating customers regarding responsibilities and expectations.
5	Reminding corporate responsibility	Emphasizing the importance of environmental awareness, legal, and economic factors to the customers. Their reputation and potential trade can be affected by the development and others' influence in these issues.
6	Asset management	Assign the RPM expediting activities to an asset management firm.

7	Outsource logistics	Assign a logistics company specialized in managing returns. This option uses fewer in-house resources yet incurs more costs and time to engage during the initial phase.

2.4 RSC performance metrics

Appropriate metrics can help decision-makers to determine actions on the current and future state of the RSC and focus on the possible areas of improvement. However, the interdependencies and complexities of an organization make metrics development processes difficult (Hall et al., 2013).

In literature, there are various perspectives taken to assess reverse logistics performance, shown in Table 2-4. Some studies derive performance measurements (PM) factors based on balanced scorecard (BSC), adapted BSC, or consolidated expert opinions. In addition, each research took multi-criteria decision-making (MCDM) approach to weigh the importance of each factor to the respective stakeholders.

Table 2-4 Performance measurement factors from literature

Author	Application	PM Framework	Performance measurement perspectives
(Bansia et al., 2014)	RL performance measurement	BSC	Financial, Stakeholder, Process, Learning, and growth
(Kongar, 2004)	RSC performance measurement	ESCAPE (adapted BSC)	Customer perspective, Internal business processes, Financial, Leaning and growth, Environmental.
(Shaik & Abdul-Kader, 2014)	RLE performance measurement	BSC and PP combination	Financial, Process, Stakeholder, Innovation and growth, Environmental, and Social
(Olugu & Wong, 2012)	RL performance	Consolidated expert opinions based on case study	Supplier commitment, Customer involvement, Management Commitment, Material features, Recycling efficiency, Recycling cost
(Hall et al., 2013)	RL performance in a military setting	Consolidated expert opinions based on case study	Inbound: Customers, Disposition, Costs, Process efficiency, and effectiveness. Outbound: Service from supplier, process efficiency, and effectiveness.

Kaplan (2009) introduced the BSC framework for organizations to observe business from four different perspectives as shown in Figure 2-6. Financial metrics hold the utmost importance and are complemented with the other three perspectives (customer, internal process, and learning and growth). Each of the perspectives has a goal with measurable targets.

Several attempts have been recorded to measure RSC and RL performance using BSC. Bansia et al (2014) propose nine parameters from the four BSC perspectives. Financial perspectives focus on return on investment (ROI) and profit from investing and operating a recycling plant. On top of ROI, Kongar (2004) included increment in market share and cost/benefit ratio into the perspective. Shaik (2014) mentions specific measures in RL such as total RL costs, capital input, and revenue recovered.

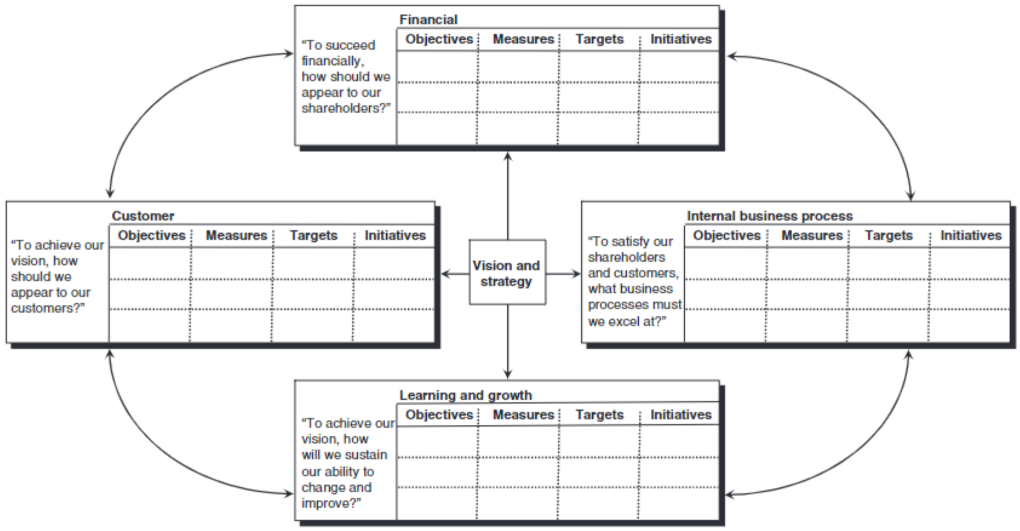

Figure 2-6 The BSC four perspectives

From customer perspectives, the buyer-supplier relationship and fuel consumption have been considered. The on-time in-full (OTIF) ratio and returning customer indicators relate to customer satisfaction. Instead of focusing only on end-customer, a thorough stakeholder perspective can capture satisfaction levels from various parties involved, including customer, government, employee, and investor. From the internal business process perspective, the production and RL cycle time indicates the efficiency of the return process. The accuracy of demand and inventory forecast is important to avoid bottlenecks and smooth return flow. Several pieces of research also mention capacity usage and efficiency in the facility and transportation aspects (Bansia et al., 2014; Kongar, 2004; Shaik & Abdul-Kader, 2014).

In the literature, there are various approaches towards measuring innovation and growth perspectives. One has focused on administration and coordination, while others suggest financial budgets on R&D and IT investments. People's development in terms of the number of training and seminar participants has also been mentioned (Bansia et al., 2014; Shaik & Abdul-Kader, 2014). In addition to the four standard BSC perspectives, Kongar (2004) suggests an environmental perspective in their Efficient Supply Chain via Agile Performance Evaluation (ESCAPE) framework, which includes health and safety expenditures and the amount of waste generated. Shaik (2014) mentioned material and energy (re)utilization along with disposing capacity as sustainability metrics. On top of that, the author included a social perspective to measure whether the expectations of communities and societies are met.

In another attempt to identify the metrics in RL, Hall (2013) used consolidated expert opinion based on specific case studies. Similar to the BSC, the studies propose a framework that includes financial and customer/stakeholder perspectives, namely the costs of returns, waiting time, satisfaction level. Process efficiency is measured by the shipment time, return rate, and inventory value. Olugu et al (2012) also opted to use expert opinion in which the SC is split into two chains: forward and reverse. The author added flexibility and responsiveness in the forward chain metrics, where it's deemed important to have recycling efficiency, customer involvement, and management & supplier commitment in the reverse chain metrics.

The performance metrics in Table 2-5 follow the multi-perspective features of the BSC framework. These metrics are defined further in Chapter 4. The framework consists of financial, customer, process, and environmental perspectives.

Table 2-5 Performance metrics for RSC evaluation

Indicators	Description	Author
Financial		
Recovery value	The value recaptured from recovered products leads to cost reduction in operation or investment, increased profitability, and labor productivity	(Banihashemi et al., 2019; Sangwan, 2017)
RL cost	The total cost incurred in the RL processes for an item return	(Shaik & Abdul-Kader, 2012)
Recovery efficiency rate	The ratio of value recovered from the returns in comparison with resources used	(Arun et al., 2011)
Cost-benefit ratio	The ratio of the overall cost to total benefit gained in RSC improvements	(Kongar, 2004)
Customer		
Service level	The percentage of the total quantity demanded that was immediately satisfied from inventory on hand. Also known as customer quantity fill rate.	(Cai et al., 2009; Kongar, 2004; Wittstruck & Teuteberg, 2011)
Process		
Return rate	The ratio between the total amount of RPM returned and received by customers.	(Hall et al., 2013)
Reuse rate	The ratio between the total amount of RPM received from customers and put back to inventory for reuse. Also defined as material utilization.	(Shaik & Abdul-Kader, 2012)
RL cycle time	Average cycle time an RPM is leaving to customers' premises to the time the RPM is put back into the inventory for reuse or scrapped	(Shaik & Abdul-Kader, 2012)
Mean inventory level	Inventory level at each related stakeholder	(Umeda, 2013)
Environmental		
Environmental impact	Externalities towards the environment due to processing, scrapping, and disposing of RPM.	(Sangwan, 2017)
Amount of waste	The total amount of disposed of RPM	(Kongar, 2004)

2.5 Simulation methods in RSC

The previous studies mainly discuss RL and closed-loop supply chain (CLSC) in two research areas: a) inventory and product return optimization and b) optimal network design (Dominguez et al., 2021).

Kazemi et al. (2019) carried out a bibliometric and content analysis. Their findings suggest that papers using multi-criteria decision-making (MCDM) and simulation methods are less popular, compared to mathematical programming, heuristics, and classical differential approaches. The study carried out by Tako et al. (2012), also aligns with the notion that simulation methods such as discrete event simulation (DES) and system dynamics (SD) are less common for RL applications.

In the literature, several attempts use simulation methods to study RSC and RPM. Umeda (2013) proposed a reverse logistics model with two PUSH and PULL types for electronic product remanufacturing. The remanufacturer acts as the decoupling point between the waste collector and the principal manufacturer. DES is carried out for customer's order volume in a uniform distribution with costs being the only aspect considered. De Araújo et al (2020) develop a discrete simulation to model the fictional storage and transportation of iron ore tailings (IOT) from the processing plant to the construction site. The main objective is to estimate the number of resources (excavators, loaders, trucks) required and pinpoint the operational constraints along the chain in reusing IOT. Similar to Umeda (2013), this study takes an economic approach as the main assessment factors i.e., transportation and storage costs.

As mentioned previously, financial feasibility is key for stakeholders in RSC integration. Škerlič et al (2020) analyze the feasibility of using non-returnable, conventional RPM, and foldable RPM. Using a cost model, the authors suggest that non-returnable costs are more than conventional RPM and foldable RPM in the automotive industry. Transport cost is also highlighted as the factor with the strongest impact on the feasibility. This aligns with the study of Katephap et al. (2017). Using multi-trip reusable packaging is more operational and environmentally viable, even though using single disposable packaging gives a shorter payback period due to a shorter cycle time. In practice, financial incentives have been introduced to improve RSC performance. Using discounts and revenue-sharing contracts generates benefits for all stakeholders (Govindan & Popiuc, 2014). The presence of a distributor affects the profit of the manufacturer. Still, the distributor can act as the collector from retailers on behalf of the manufacturer.

Beiler et al. (2020) propose an approach by focusing on three pillars of sustainability named triple bottom line (TBL). The authors study the direct and reverse flows in a beverage company to achieve TBL goals from social, environmental, and economic perspectives. Their findings indicate that the three aspects are unable to be satisfied simultaneously, thus tradeoffs have to be made. This aligns with the study by Vlachos et al. (2007), where tradeoffs have to be made between capacity planning policies, market share, capacity utilization, and "green" corporate image. A more comprehensive assessment is carried out using adapted BSC (Wittstruck & Teuteberg, 2011). The study examines the effect of budget increases in sustainable practices, information systems, and sales towards financial profit as the ultimate indicator.

Streamline coordination is deemed important for a successful RSC. Uckelmann et al (2009) studied the impact of information exchange between SC partners using RFID. The technological advances enable a billing model shared with SC stakeholders to fairly distribute the IT investment costs. Kim and Glock (2014) took similar tools by using the RFID system. The RSC performance is affected by the return rate and serviceability of the RPM. Therefore, the authors emphasize the importance to maintain the RPM condition and consider using more robust materials.

Matsumoto (2010) proposes an interaction model in the reuse businesses and markets with multi-agent simulation. The author attempts to incorporate decision-making features into the actors (agents) with the factors to join the reuse market while showing the observed patterns of reuse markets. The behavior of the agents is sensitive to the parameter setting in the simulation, due to deterministic assumptions. Dominguez et al. (2021) use similar methods to evaluate the impacts of centralized vs decentralized RSC structure towards the bullwhip effect. The author suggests that the centralized configuration decreases uncertainty in RSC, streamline production orders, and boost inventory operations.

Zolfagharinia et al. (2014) and Cobb (2016b) both use the inventory control model for RSC evaluation. The model allows distinction between inventory based on type or location. The first authors incorporate two stock inventory models for serviceable and low-priced manufacturable RPM. It enables postponement of remanufacturing, hence carried out only if needed. The potential of using separate two separate inventories depends on product lifetime, costs, demand variation, and purchase lead time. On the other hand, Cobb proposes individual inventory for used, inspected, repaired, and purchased RPM. The holding costs of each inventory consist of fixed and variable costs. The overview of previous studies of RSC and RPM is shown in Table 2-6.

Table 2-6 Literature review matrix

Author	**Method**	**Study object**	**Real case**	**Echelon**	**F**	**C**	**P**	**E**	**S**
(Dominguez et al., 2021)	Multi-agent-system	Undefined multi-use containers	No	Multi			✓		
(Matsumoto, 2010)	Agent-based simulation	Electronic and automotive parts	Yes	Single	✓	✓	✓		
(Umeda, 2013)	Discrete-event simulation	Home electric appliances	No	Multi			✓	✓	
(de Araújo et al., 2020)	Discrete-event simulation	Iron ore tailings	Yes	Single			✓	✓	
(Hellström & Johansson, 2010)	Discrete-event simulation	Glass bottles	Yes	Multi	✓	✓	✓		
(Beiler et al., 2020)	System dynamics	Glass bottles	Yes	Multi	✓			✓	✓
(Wittstruck & Teuteberg, 2011)	System dynamics	Ink cartridges	Yes	Multi	✓	✓	✓	✓	✓
(Uckelmann, Hamann, & Mansfeld, 2009)	System dynamics	Glass bottles	Yes	Multi	✓	✓	✓		
(Vlachos et al., 2007)	System dynamics	Mobile phones	Yes	Multi	✓	✓	✓		
(Katephap & Limnararat, 2017)	Cost model	Automotive parts	Yes	Multi	✓		✓	✓	
(Škerlič & Muha, 2020)	Cost model	Wire mesh containers	Yes	Multi	✓				
(Govindan & Popiuc, 2014)	Cost model	Consumer electrical products	Yes	Multi	✓				
(Zolfagharinia et al., 2014)	Inventory control model	Ink cartridges	Yes	Multi	✓		✓		
(Cobb, 2016b)	Inventory control model	Beverage kegs	Yes	Single	✓		✓		
(Kim & Glock, 2014)	Mathematical planning model	Undefined multi-use containers	No	Multi	✓		✓		
This research	Discrete-event simulation	Cable drums	Yes	Multi	✓	✓	✓	✓	

**abbreviated columns F: financial, C: customer, P: process, E: environment, S: social*

2.6 Scientific gap

Based on the papers discussed in Table 2-6, the item under examination in the RSC context are mainly end-of-life products and returned retail products. Furthermore, the RPMs discussed in current studies are RPMs with low residual value, as discussed by Limbourg et al (2016).

The review also suggests that simulation methods are less exploited in comparison to mathematical optimization and differential approaches. Furthermore, RSC performance assessment is based predominantly on financial and logistics/process perspectives, despite the increasing societal demand to be more sustainable. From the available approaches to tackle RSC issues, most of the research roots in a single perspective, either logistics design, use of technology, or behavior facilitators.

Hence, it is interesting to see the impact of RPM with high residual value (such as cable drums) on RSC feasibility. The developed strategies may integrate approaches from logistics designs, technological implementations, and behavior facilitators. The performance evaluation can embed multiple perspectives, namely financial, process, customer, and environmental.

2.7 Conclusion

A literature review is carried out in this chapter on returnable packaging material and reverse supply chain. The challenges and current solutions in RSC are addressed. Performance metrics in RSC evaluation are explored. An interesting point can be made that not so many highly valuable RPMs are available. Hence, the following sub-research question can be answered:

Sub-research question 1: How does literature describe returnable packaging material in the context of the reverse supply chain?

The residual value of an RPM dictates the feasibility of RSC implementation. It also determines in what way the product should be recovered. The increasing raw material price for cable drums makes the reuse of this RPM an imperative task. Economical and logistical aspects are still considered the important aspects for RSC evaluation, despite the ever-growing pressure on sustainability practices. In RSC that manages non-returnable items such as the retail industry, the organizations attempt to minimize product returns. Meanwhile, for the RPM context, the aim is quite the contrary.

The approach to developing RSC strategies may be rooted in logistics system design, technological implementation, or compliance strategy. The logistics system design configures separates the owner, the operator, and the manager of the RPM. From a technological perspective, tracking tools are commonly used to improve RSC visibility nowadays. Several advanced tools use the concept of IND 4.0 where real-time, precise tracking and intersystem communication are possible. Even though a successful RSC operation demands both technical improvement and proper management actions, these studies typically examine the strategies only from one of the approaches. Therefore, compliance strategy takes a different step by getting into a more managerial approach. It aims to encourage return behaviors from customers.

Sub-research question 2: How can reverse supply chain performance be measured and evaluated?

A comprehensive evaluation of RSC performance can be carried out by incorporating multi-dimensional aspects. Trade-offs that reflect real human behavior can be seen only if assessed and evaluated through multiple perspectives, namely financial, process, customer, and environmental. The actors are different and what factors are considered important to them also vary. This multi-perspective approach can achieve that aim and help related stakeholders evaluate the feasibility of potential improvement strategies. Furthermore, simulation methods are less exploited for usage in RSC application to the more popular mathematical optimization and differential approaches. This method allows evaluation from multiple perspectives in RSC performance.

PART III - MODEL THE SYSTEM

3

Current State Analysis

In this chapter, the current state analysis is performed. It is a part of the **Model the System** step in this research. The performance of PYNL RSC operations is analyzed along with the current initiative to improve the drum return. A root cause analysis is executed to identify the causes of such performance in RSC. This analysis is complemented with an additional swimlane analysis to understand the related processes and locate in which process do the issues take place. Further, the stakeholder's analysis is carried out to explore the behavior of each stakeholder through interviews. Lastly, the requirements from the key stakeholders are defined for determining the feasible solutions in the next steps.

3.1 RSC operations in PYNL

In this subsection, the current state of RSC operations in PYNL is explained. The data analysis outlined in the following paragraphs is derived from data described in detail in Appendix 3. The current state of the PYNL RSC is depicted in Figure 3-1. PYNL serves three types of customers, namely wholesalers, large and small electrical installers, and distributors. The latter are companies that are affiliated distributors with PYGR and serve other regional areas e.g., the Scandinavian region. According to Interviewee H in Appendix 1, PYNL approaches the cable industry market by cooperating with wholesalers to sell their products to end customers. The wholesalers have a variety of products in their portfolio; hence installers can purchase the products of their choice not limiting them to only cable products. The wholesale-driven approach also carries less financial risk for PYNL. This preference is shown also in Figure 3-1 where wholesalers receive a higher drum flow, followed by installers and distributors. In this research, the distribution flow towards the affiliated distributors is out of the research scope, as mentioned in Section 1.6. Therefore, the distributors are not discussed further from this point on.

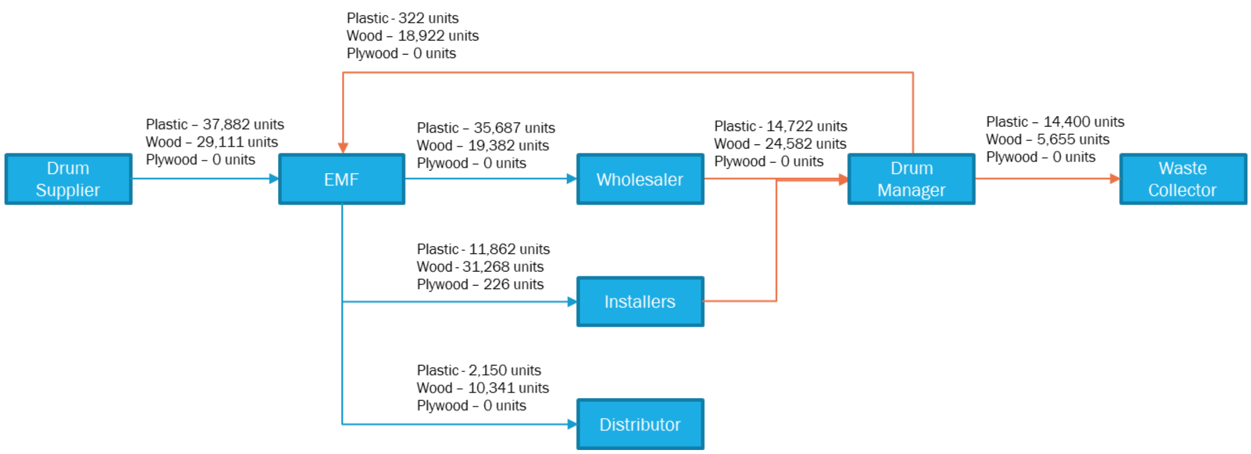

Figure 3-1 Current state of PYNL RSC

PYNL offers two types of cable brands: "Draka" for the low voltage cable market, and "Prysmian" for medium voltage and markets such as wind parks and solar parks. It is estimated that 80% of the overall business in The Netherlands is coming from Emmen Facility (EMF) via the wholesalers. For big cable drums, the wholesalers are [redacted] (part of [redacted], one of the biggest global wholesalers), [redacted], [redacted], where [redacted] and [redacted] handle smaller cable drums. Draka markets are low voltage installers, for instance, residential houses, large construction areas. 95% of Draka products sold via wholesale and 5% sold direct using full-truck load (FTL) shipments. In the current practice, the wholesalers receive cables in bulk form. Each wholesaler can cut bulk cable they receive from EMF, then wind on an empty cable drum. The cutting allows the end customers to receive the cables of the requested lengths.

EMF delivers cable products with drums as the transport packaging. There are three types of drum materials used: plastic, wood, and plywood. Plywood drums are less used in comparison to plastic and wooden drums. PYNL is the drum owner, hence each drum has to be returned after use.

To visualize PYNL outbound and inbound flow in Figure 3-1, two rates are defined. The return rate is the number of drums received by the drum manager compared to the drums delivered to customers. On the other hand, the Reuse rate is the number of drums that are sent back to EMF by the drum manager in comparison to the drums delivered to customers. Both rates in the current condition are shown in Table 3-1.

Table 3-1 Return and reuse rate

Rate type	Drum type	Value
Return rate	Wood	40.3%
	Plywood	0.0%
	Plastic	29.6%
Reuse rate	Wood	31.0%
	Plywood	0.0%
	Plastic	0.6%

PYNL has tried several attempts to increase the return and reuse rate. A drum return clause is included in the sales contracts between PYNL and a customer. However, enforcing such a clause risks PYNL customer retention. According to Interviewee A, a deposit system was introduced in the past to thousands of drums. The initiative failed as it is very complicated to track the drums, reconcile the administrative task, and determine the fair deposit cost. Hence, the deposit system is stopped.

A more recent attempt is to redesign the plastic drum label which includes A QR code and a sustainability tag line as shown in Figure 3-2. The QR code redirects to a drum return webpage that allows customers to request empty drum pickup. If the cable products are purchased from a wholesaler, then the customer can return the empty drums to the respective wholesaler.

Figure 3-2 Information label on a plastic drum

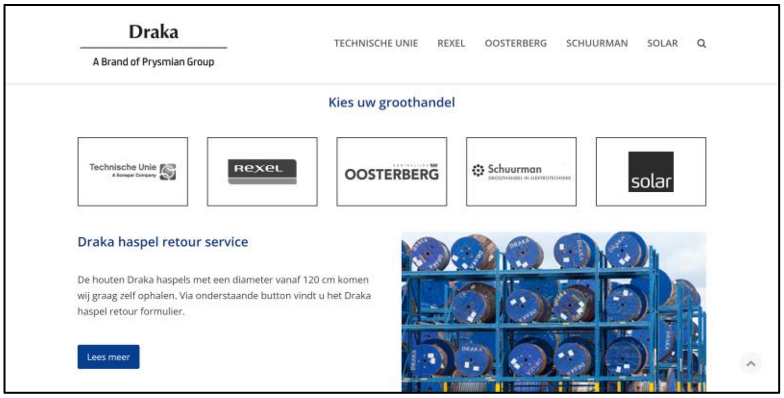

Figure 3-3 PYNL drum return webpage

Figure 3-4 shows the comparison between the value of drums to the customers and the recovery value of drums (i.e., picked up from customers' premises and returned to EMF). It can be seen that the outbound value for all drums (in blue) is mostly higher than the recovered drum. This means that there are imbalances PYNL supply chain that most of the empty drums are not returned. A further look at the remaining value and costs of recovery activity is shown in Figure 3-5. The recovery value i.e., the value of returned drums is compared with the drum management cost, namely repair cost, cleaning cost, and scrap cost. There is significant value that remains even after taking into account the drum management costs. This calculation, however, excludes the transportation cost due to the data unavailability. To compensate for the non-returned drums, PYNL has to replace their missing asset. If the purchase expenditures for drum replacement are subtracted with the gain on the remaining value from Figure 3-5, then a net value of drum type can be determined as shown in Figure 3-6. It can be seen that there are more negative net values for all drums, rather than positive values. This also means that PYNL is incurring financial losses as a result of the drums not being returned.

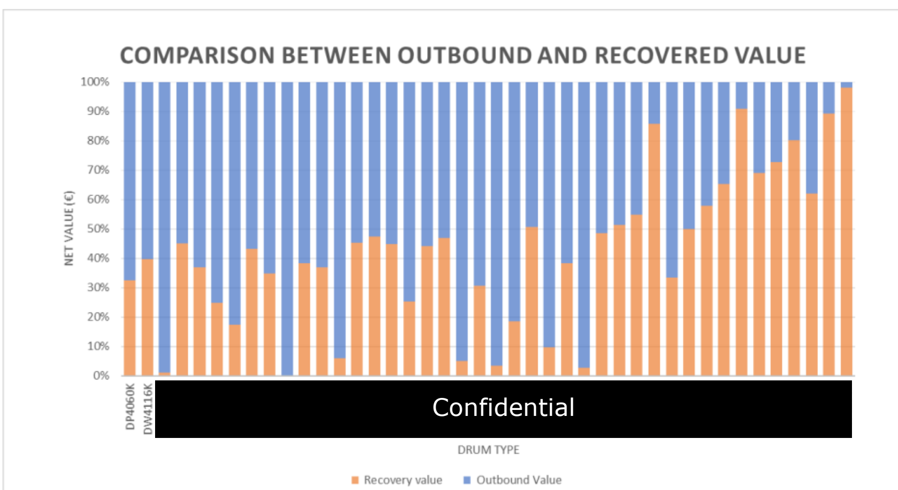

Figure 3-4 Comparison between outbound and recovered value

In an attempt to understand the financial losses, shrink value and scrap value are determined. Shrink value is the monetary value of the drums that are not returned by the customers, whereas scrap value is the value of the drums that are damaged and cannot be reused. In Figure 3-7, the shrinkage and scrap value based on drum material are shown. The pie chart suggests that most of the unreturned drums are wooden drums, which are increasingly important considering the increasing wood price emphasized in Section 2. The aggregated sum of shrink scrap values is shown in Figure 3-7. Drum type

DP4060K and DW4116K stand out in terms of financial losses. Based on this fact, the research will consider these two drums as the case study.

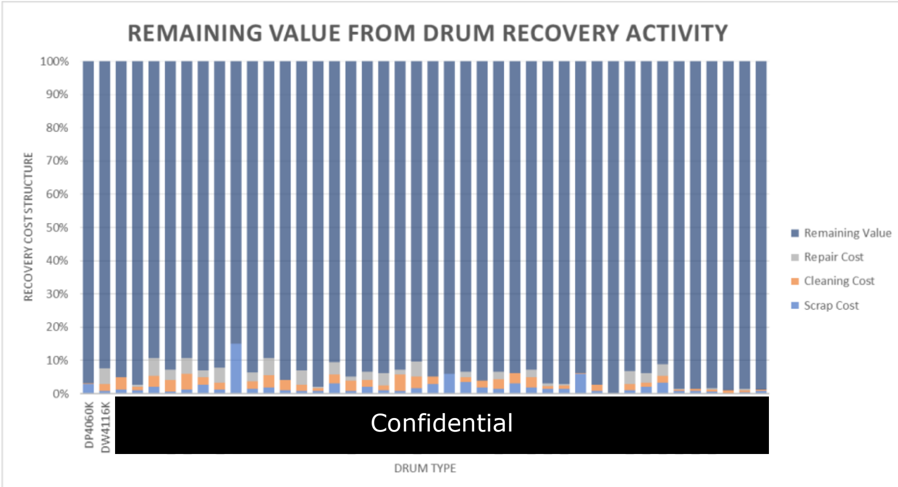

Figure 3-5 Remaining value from drum recovery activity

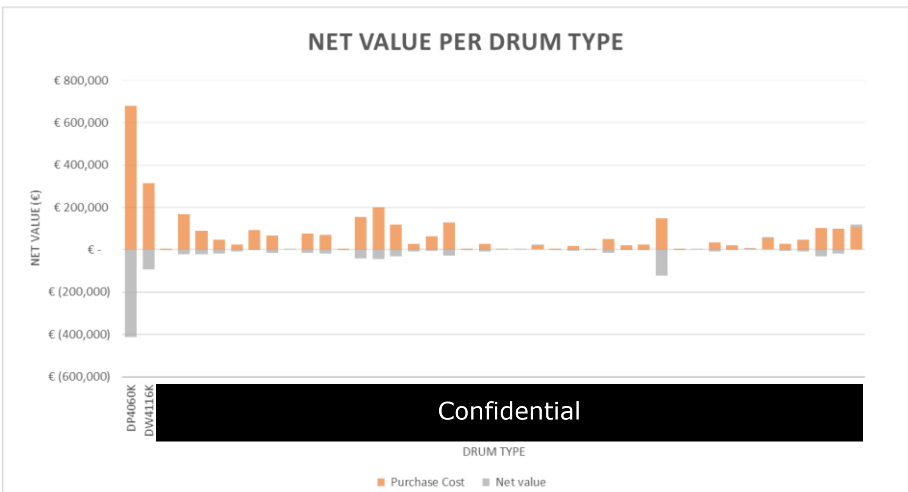

Figure 3-6 Net value per drum type

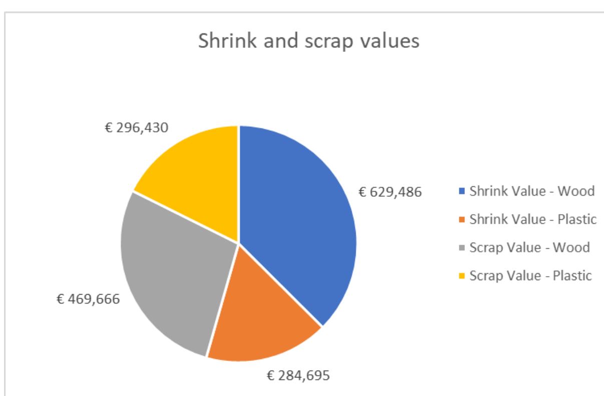

Figure 3-7 Shrinkage value based on drum material

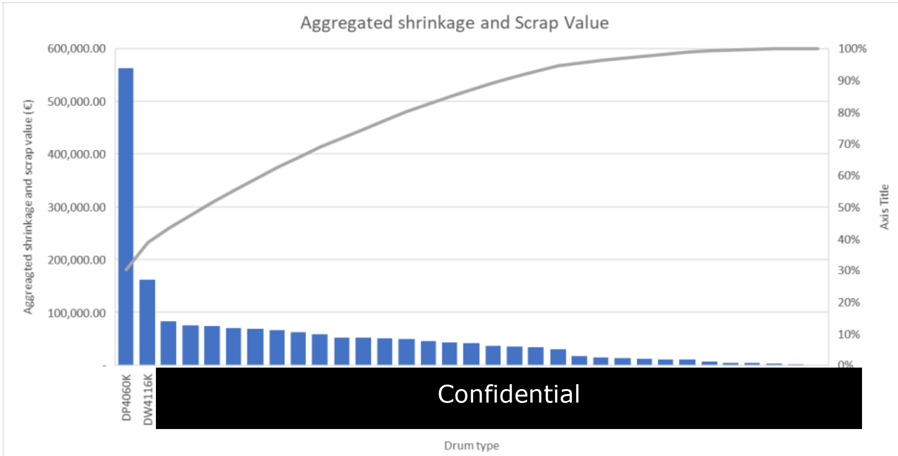

Figure 3-8 Shrinkage and scrap value based on drum type

The transporter performance for the drum return request in the first 24 weeks of 2020 is shown in Figure 3-9. As explained in Appendix 2, the transporter has a 5-day window to pick up the empty drum from the customer. The pie chart suggests that the transporter responds to the customer requests very well where 99.9% of orders are satisfied on time.

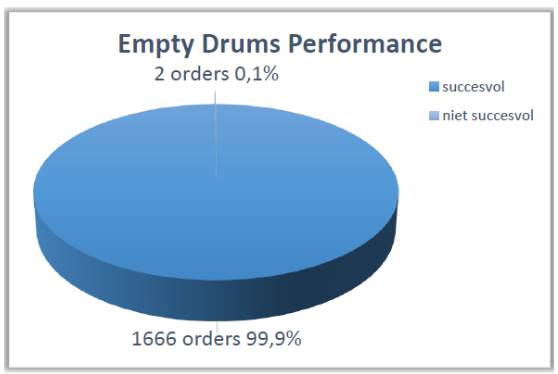

Figure 3-9 Return pickup performance by transporter

3.2 Root Cause Analysis

To identify the contributing factors leading to the drum return issue outlined in Section 3.1, a root cause analysis is performed. This analysis helps to identify and group the causes into main six roots: man, method, machine, material, measurement, and environment (Ilie & Ciocoiu, 2010). The root cause analysis, or also known as the fishbone diagram, shown in Figure 3-10 below is derived from the stakeholders' interview in Appendix 1 and swimlane analysis in Appendix 2. The contributing factors are explained from six different factors, as follows:

A) Man

A1 Lack of participation, caused by several factors. First, there are too few drums to return, thus customers tend to neglect its existence. Small orders coming from small installers can be significant if aggregated since they accounted for one-third of total PYNL customers. Customers' awareness of the value of drums and the secondary purpose (e.g., use the drums as tables, etc) also contribute to this factor. In addition, the wholesalers are not proactive in collecting empty drums until recently. In the past, customers' requests for drum returns were often not addressed. The benefits of returning are not distributed equally among stakeholders, therefore may cause the lack of motivation to return the drum.

A2 Lack of management focus. A successful drum return demands more commitment and resources to become a part of the supply chain. The prevalent focus is predominantly put on forward (outbound) flow to the customers. The relatively small drums to product ratio between 2-6% may be not too appealing for management focus.

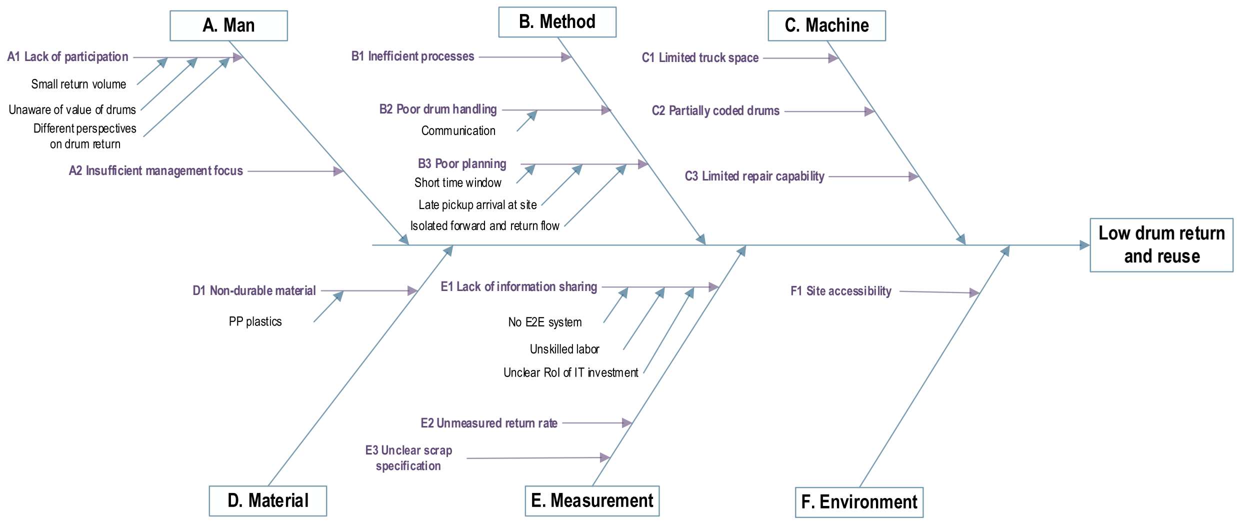

Figure 3-10 Root cause analysis

B) Method

B1 Inefficient processes, due to related stakeholders are working in non-uniform systems. Customers also think that this makes drum return request is effortful.

B2 Poor drum handling, due to lack of communication towards customers on correct drum handling.

B3 Poor planning, caused by two reasons. A short time window is given to the transporter to plan backhaul trips carrying drums. The fact that forward and return flows are separated also disables the opportunity of carrying drums on backhaul trips.

C) Machine

C1 Lack of storage, due to limited truck space. Trucks delivering products do not necessarily have the space for picking up drums, particularly the returns which are not registered. Thus, the drums cannot be picked up.

C2 Partially coded drums, where only selected plastic drums are coded when bought from suppliers as a part of a pilot program. The existing facilities at the plant do not support any code tagging.

C3 Limited repair capability, due to limited equipment for more advanced repairs

D) Material

D1 Polypropylene (PP) is not a durable material for plastic drums, thus can be easily damaged if mishandled. The cost and benefit of increasing the durability are unknown.

E) Measurement

E1 Lack of information sharing, due to several causes. First, there is no end-to-end (E2E) information system that enables the exchange of information between related parties. In the fulfillment process, the lack of visibility in customer demand fluctuation affects the remaining chain, resulting in inaccurate demand planning for the wholesalers and PYNL sales department. The inaccuracy also leads to unreliable drum stock calculation. The system is not integrated between stakeholders that cause delayed response to ensure sufficient loaded and empty drums, both in EMF and wholesalers.

In the drum return process, there is inaccurate and/or incomplete information exchange between the related parties. Some of the issues include no drum dimension information, incorrect number of drums to be picked up, and dispersed pickup location. These occur along the supply chain; during return order placement at the customer. Even though there is a drum size threshold of 120 cm, the transporter requires more detailed information to ensure optimal use of the truck fleet and space utilization.

Second, unskilled labor in digital reporting also creates unexplainable gaps, making it difficult to track or trace any issue in the chain. in reports. There is indeed a push for digitalization, however, the benefits (particularly the RoI and increased return volumes) are unclear. Attaran (2010) suggests that digitalization (i.e., using RFID) does not directly impact business unless it brings cost savings from higher scan speed and accuracy.

E2 No return rate is measured at the wholesalers, which creates uncertainty of the total number of drums that exist in the present supply chain. At EMF, the return rate is also not measured regularly, only during ad-hoc requests.

E3 Unclear scrap specification leaves the drum manager the ultimate authority in determining which drums can be reused.

F) Environment

F1 Site accessibility, due to remote project areas. A harsh environment could lead to failed pickup attempts.

To understand the process in PYNL regarding the drum returns and other related processes, a swimlane process approach is taken. The swimlane analysis aids users to understand where the bottlenecks and issues are located along the process (Ezeonwumelu et al., 2016). The processes related to the drums are new drum purchase, order fulfillment, empty drum return, and waste treatment process. These processes are visualized by the swimlane diagram shown in Appendix 2 by Figure 2-1, Figure 2-2, Figure 2-3, Figure 2-4, respectively.

A RACI matrix is performed to analyze the involvement of each stakeholder in each issue in the process outlined in Appendix 2 RACI matrix is a tool to map the task or decisions in a project. The matrix states which party is Responsible (R) for the action item, who is Accountable (A), who can/needs to be Consulted (C), and Informed (I) (Kantor, 2018). Table 3-2 and Table 3-3 explain the role of the stakeholders in the order fulfillment and drum return process, respectively.

Table 3-2 RACI matrix for order fulfillment issues

Order fulfillment process		INTERNAL								EXTERNAL							
Code	Short description	LOGISTICS	BUSINESS - WHOLESALERS	BUSINESS - INSTALLERS	PRODUCTION	CUSTOMER CARE	MARKETING COMMUNICATION	PROCUREMENT	QHSE	LARGE INSTALLERS	SMALL INSTALLERS	WHOLESALERS	TRANSPORTER	INDIRECT TRANSPORTER	DRUM MANAGER	DRUM SUPPLIER	WASTE COLLECTOR
F.B3.1	Isolated forward and reverse chain planning	R/A					C			I	I	I	R				
F.B3.2	Short time window to plan backhaul drums	R/A											R				
F.C2.1	Limited equipment capability to code drums	I			R/A												
F.C2.2	Limited equipment capability to code drums	I			R/A												
F.D1.1	Requested drum material is not durable	R/A						C								C	
F.E1.1	Non integrated sales order information system			A		I				R	R						
F.E1.2	Delayed order fullfillment response		A			I						R					
F.E1.3	Delayed order fullfillment response	A	R			I											
F.E1.4	Inaccurate drum stock calculation	R/A	I	I				R							R		
F.E1.5	Unmonitored drums at customers site	A	C	C						R	R						
F.E1.6	Unmonitored drums at wholesalers	A	C	C								R					
F.E1.7	Inaccurate drum stock calculation	A	I	I				I							R		

Table 3-3 RACI matrix for drum return issues

Drum return process		INTERNAL								EXTERNAL							
Code	Short description	LOGISTICS	BUSINESS - WHOLESALERS	BUSINESS - INSTALLERS	PRODUCTION	CUSTOMER CARE	MARKETING COMMUNICATION	PROCUREMENT	QHSE	LARGE INSTALLERS	SMALL INSTALLERS	WHOLESALERS	TRANSPORTER	INDIRECT TRANSPORTER	DRUM MANAGER	DRUM SUPPLIER	WASTE COLLECTOR
R.A1.1	Small drum volume at customers	A	A	A			C		I	R	R						
R.A1.2	Unwilling to pickup drums from customers	A	A				C		I			R					
R.B2.1	Poor drum handling	A					C			R	R	R	R	R	R		
R.B3.1	Short time window to plan backhaul drums	R/A	C	C		I				I	I	I	R/A				
R.B4.1	Unclear scrap specification & assessment	A						C							R		
R.C1.1	Limited (wholesalers') truck space									I	I	C		R/A			
R.C1.2	Limited (transporter) truck space	C				I				I	I		R/A				
R.E1.1	Incomplete/inaccurate return information	A								R	R	R	I	I			
R.E1.2	Unregistered drum pickup by wholesalers									R	R	A		I			
R.E1.3	Siloed reporting of drum returns at wholesaler	A										R					
R.E1.4	Incomplete/inaccurate return information	A		C						R	R						
R.E1.5	Incomplete/inaccurate return information	R/A								C	C		I				
R.E1.6	Unskilled labor in information reporting	A											R				
R.E1.7	Incomplete information of scrapping report	C							I				R/A				I
R.E1.8	Non integrated reporting system used	A											R				
R.E1.9	Non integrated reporting system used	R/A															
R.E1.10	Calculation based on in- and outbound drums	R/A													C		

3.3 Stakeholder analysis

The decision-making process in the RSC requires the participation of different actors which vary in interests, perspectives, and expectations. Their participation is increasingly important to obtain a successful and valuable decision. Stakeholder management becomes a useful tool to manage stakeholders by incorporating the main actors' interests during the decision-making process. (Haial et al., 2020).

The key stakeholders in the RSC for PYNL are elaborated in Table 3-4 below. Bryson et al. (2010), defines stakeholders as "*individuals, groups, organizations that can affect or are affected by an evaluation of a process and/or its findings*". Since the stakeholders' opinions are diverse and competing on numerous occasions, this demands a focused analysis, targeted at the potential actors regarded as the primary intended users. Patton ((2008) characterizes the primary intended users as the person that have a stake and obligation in using the results of the evaluation or be closely affected by the findings.

From the techniques available to identify stakeholders, the power versus interest grid can be used to map the stakeholders by their interest in the issue in question, and their relative power to influence the evaluation. The source of power can originate from access or command over a variety of resources, such as expertise, money, legal authority, coercive ability, numbers/data, and connection to influence. The directions of interests demonstrated stakeholders' desires or concerns. The scales indicate that power and interest are relative rather than absolute, which in practice means that some actors may have higher interests or powers against other actors (Bryson et al., 2010).

In Table 3-4, each stakeholder stake is elaborated with their individual perceived or assumed attitude. The attitudes derived from the stakeholder interview in Appendix A are considered as perceived attitudes while constructing the assumed attitude for the non-interviewed stakeholders is consulted with the relevant parties. The split between internal and external stakeholders relies on whether the actors are directly involved in the decision-making process or not (Haial et al., 2020).

Hillson et al. (2007) suggest a stakeholder identification method based on each attitude, power, and interest towards the project. A sign is attached to each dimension, indicating that each stakeholder has:

- Supportive (+) or resistant (-) attitude
- High (+) or low (-) power to influence for better or worse
- High (+) or low (-) interest in successful project implementation.

Table 3-4 Stakeholder Analysis

Stakeholder	Stake in the chain	Perceived attitudes/risks	Attitude	Power	Interest
Internal					
Logistics department (See 0 1.3 and 1.8)	Plans the logistics of loaded and empty drums, including decisions on managing (minimum-maximum) inventory levels. The planning horizon is set to 8 weeks ahead. Has access and control over resources related to forward and reverse chain.	Perceived supportive attitude. Concerned about increased workload and space usage in increased drum return.	+	+	+
Business - Wholesale department (See 0 1.1 and 1.5)	Responsible for market research and sales forecast. Possesses formal authority for sales contracts. Engage closely with wholesalers as main customers.	Perceived supportive attitude. Can encourage customers to participate, but not enforce. Could experience difficulties in meeting sales targets due to drum shortage. Emphasize the importance the role of wholesalers.	+	+	+
Business - Installer department (See 0 1.7)	Responsible for generating demand from installers as customers (per region). Engage closely with installers as main customers.	Perceived supportive attitude. Can encourage customers to participate, but not enforce. Could experience difficulties in meeting targets due to drum shortage.	+	+	+
Plant/production department	Produce and wind the cables, wires, and packaging materials on to drums before	Assumed supportive attitude. Could	+	-	+

	shipment in EMF. This function requires a steady flow of empty drums for production.	experience back orders due to drum shortage.			
Customer care department (See 0 1.10)	Manages the relationship with customers (end and intermediate). Involved in any initiated project performed by the PYNL and the customers.	Perceived supportive attitude. Smooth product & return flow affects satisfaction level and the number of complaints.	+	-	+
Marketing communication	Promote a sustainable image in corporate branding. Educate the importance of sustainability to customers.	Assumed supportive attitude. Sustainable practices can improve corporate image.	+	-	+
Purchasing department (See 0 1.2 and 1.11)	Responsible for sourcing new drums and cost reduction while satisfying sustainability goals. Manages contracts with transporters, waste companies, and drum managers. Implement the quality standard developed by Production Engineering function for reused drums at drum manager.	Perceived supportive attitude. Increased returns put less pressure on buying expensive drums and more purchase savings.	+	+	+
QHSE department (See 0 1.9)	Interested in improving sustainability with increasing drum returns. Provide support to sales and procurement on driving the corporate KPI with their respective stakeholders, particularly on sustainability. Has connections to the influential.	Perceived supportive attitude. Act as the driver of the initiative and mediate cooperation between functions and organization.	+	+	+

External					
Large-sized Installers	The end customers who use the cable for their projects.	Assumed supportive attitude, interested in sustainability, however lacking action (see 0 1.5.13). Unaware of value in drums.	+	+	-
Small-sized Installers	The end customers who use the cable for their projects.	Assumed supportive attitude. Interested in sustainability in general, but lacking action (see 0 1.5.13). Unaware of value in drums.	+	+	-
Wholesalers	Intermediate customers who purchase products from PYNL and resell them to installers	Assumed supportive attitude, however not too interested (see 0 1.5.13). Not-in-my-back-yard (NIMBY) attitude, lack of motivation of returning drums (see 0 1.5.8).	+	+	-
Direct transporter (See 0 1.6)	A trucking/logistics company responsible for transporting the drums appointed by PYNL. Its pickup performance affects the customer satisfaction of the drum	Perceived supportive attitude. The new initiative should be economically feasible.	+	+	-

	return program (see 0 1.7.14 and 1.10.5).				
Indirect transporter	A trucking/logistics company responsible for transporting the drums appointed by wholesalers.	Assumed supportive attitude, since they will act on any request from wholesalers.	+	+	-
Drum manager	Arranges the inventory of returned (wooden and plastic) drums including quality checks and repairs (see 0 1.11.5, 1.11.6, and 1.11.8)	Assumed supportive attitude and will act based on PYNL request. Concerned about workload.	+	+	-
Drum suppliers	Provides the new drums to PYNL. Communicate weekly with the Logistics department for drums replenishment.	Assumed resistant attitude. More return means less drum purchased from them. Has little to offer since situated outside the supply chain.	-	-	-
Waste collector (See 0 1.4)	Collects and processes the waste from unrepairable drums.	Perceived supportive attitude for sustainability. However, their business is driven by waste availability in the market. Has little to offer because situated at the end of the supply chain.	+	-	-
Competitor	Engaged in a similar business with PYNL. Also, use drums for cable transportation and storage. Some competitors already have their return flow (Nexans, 2018; TKF Nederland, n.d.).	Assumed resistant attitude. The drum is considered a corporate branding tool.	-	-	-
Government	Impose regulations that impact the industrial practice, particularly in sustainability issues.	Assumed supportive attitude. Regulation changes, however, may increase the urgency to become more sustainable.	+	+	+
Society	Drive the demand for socially responsible supply chain practices.	Assumed positive attitude. Support the initiative for ensuring sustainable goods and services. (Gong et al., 2019)	+	-	-

Based on the information in Table 3-4, a stakeholder map is created as shown in Figure 3-11. The horizontal and vertical axes indicate interest and power. The attitude is illustrated with three colors, green for positive, red for negative, and blue for neutral or unknown attitude. The map divides the stakeholder into four types, as follows (Bryson et al., 2010):

- Players who have an interest in notable power. These stakeholders are very likely to be the primary intended users. They generally can affect the decisions for their interest or how they affect other users.
- Subjects who have an interest but with low power. Increasing their involvement is important, particularly if they may be affected by the decision.
- Context setters who have little interest but have power. It is worth considering to increase their interest, especially if they might put a barrier due to their indifference.
- Crowd, who only have limited power and interest. However, these stakeholders can turn into a growing mob, if good communication is not maintained. Thus, it is vital to keep them informed of

the decisions made.

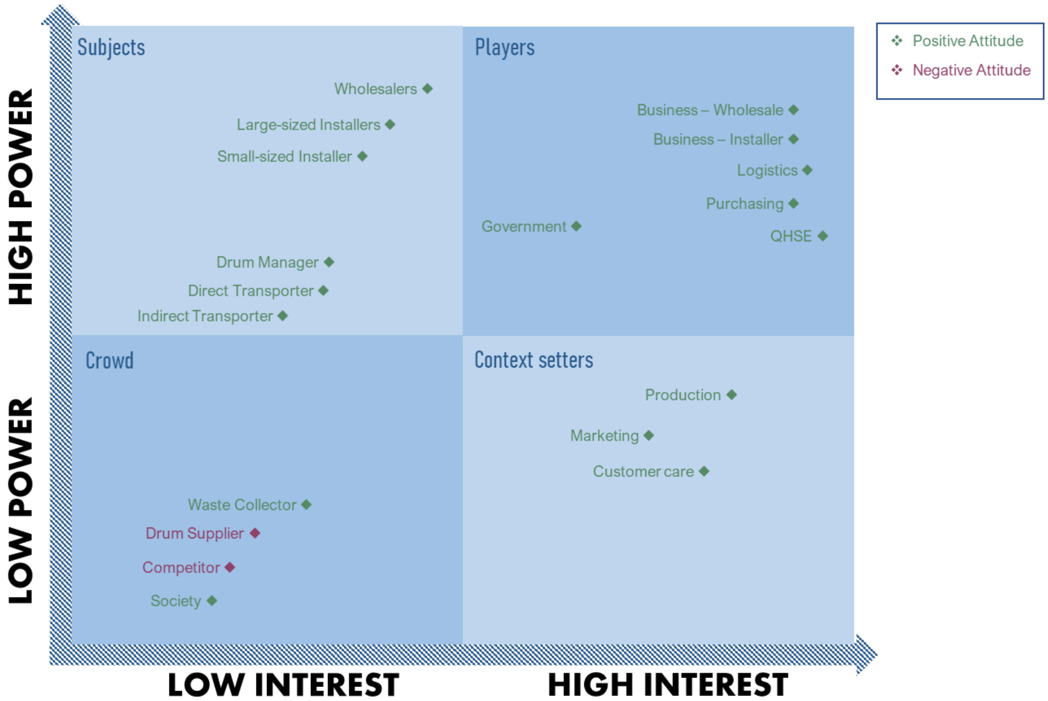

Figure 3-11 Stakeholder Map

3.4 Requirement analysis

The requirement analysis is used to narrow down the solution space of potential strategies to improve PYNL RSC operations in upcoming Chapter 5. The points laid out in the analysis are derived from interviews in Appendix 1 and brainstorming with PYNL experts. In this context, the system refers to the potential strategy or solutions for improving the drum return rate. The customers include the wholesalers and installers.

Constraints are "*specified influences that affect the way that we meet the requirement*". Constraints are typically described in time, money, and specified technology (Robertson, 2001). The system must comply with these constraints, otherwise, it is not well-designed. Each constraint should be binary in the sense that the system either complies or not, which can be either functional or non-functional (Verbraeck, 2019). The constraints are as follows:

Stakeholder	Description
PYNL	• The system must ensure PYNL have full ownership of the drums • The system must assign PYNL to have the ultimate control of the system. • The system must be designed exclusively for PYNL without the involvement of competitors. • The system must assign drum management responsibilities to the drum manager. • The system must cost each drum less than 40% of the new drum purchase price.

Requirements are used to capture the features and functions of a system. A functional requirement is defined as "*things that a system has to do, like record a fact do a calculation or make a* *decision*"(Robertson, 2001). Requirements differ from constraints in the sense that a requirement allows multiple (design) options, whereas constraints offer no option other than to satisfy them (Bahill & Dean, 2008). A functional requirement can be either a constraint (must do) or an objective (should do)(Verbraeck, 2019). The functional requirements are as follows:

Stakeholder	Description
PYNL	• The system should allow customers to return the drums • The system should enable visibility in the supply chain • The system should allow return rate measurement

Non-functional requirements are "*qualities that a system has to have, like performance, security, usability, and maintainability*"(Robertson, 2001). It may incorporate scores, scales, or values for measurement. A non-functional requirement can be either a constraint (must have or be) or an objective (should have or be) (Verbraeck, 2019). The non-functional requirements are as follows:

Stakeholder	Description
PYNL	• The system should increase the overall drum return rate • The system should reduce the new drums purchase rate • The system should be practical for the main users • The system should not be labor-intensive • The system should have a positive return on investment rate
Customers	• The system should be practical for the customers • The system should not lead to a negative impression

3.5 Conclusion

An extensive analysis involving multiple tools is carried out in this chapter. First, a current state observation is carried out, followed by a swimlane analysis to identify related processes and issues in the exiting RSC operations. A root cause analysis reveals the contributing factors of the issues and the responsible parties are mapped using a RACI matrix. To obtain the required information for the analysis, interviews are conducted with key stakeholders. The forming of requirements also utilizes the provided information. Therefore, the following sub-research question can be answered:

Sub-research question 3: How is the current supply chain structured and performed?

PYNL is one of the leading players in the cable industry, which serves two types of customers: wholesalers and installers. Their products are segmented based on the market: Draka for low voltage and Prysmian for power distribution and high voltage markets. To transport such products, cable drums are used as transport packaging. In the current state, however, there is an imbalance between the outbound and return flow. The analysis carried out in Section 3.1 suggests that PYNL incurs financial losses from the low return and reuse of the drums shipped to the customers. The current wooden and plastic drums return rates are 40% and 29%, respectively. On the other hand, the reuse rates of wooden and plastic drums are 31% and 0.6%, respectively. Hence, PYNL has to replace the shortage of drums which leads up to a significant cost. The drums with the highest shrink and scrap value are wooden drum DW4116K and plastic drum DP4060K.

Another notable insight is that even though the remaining value of recovery operations yield positive results, PRYNL will experience the benefit from such operation, hence it is not shared equally across stakeholders. Various causes are outlined in Section 3.2 in which states that visibility issue along the RSC is shared among the key stakeholders. Customers' willingness to participate in drum returns is also highlighted, which may be caused by unequal benefits distribution. The stakeholder analysis and interviews also help to define the requirements for developing feasible RSC strategies to tackle the challenges in the RSC.

PART IV - INTEGRATE

4

Model Design

As stated in the research structure in Chapter 1, the subsequent step is **Integrate.** This chapter explains the model design for simulation. The model building is based on the current state described in Chapter 3. The method used is Discrete Event Simulation (DES) as laid out in Chapter 2. This method allows the examination of system behavior that incorporates stochasticity, the interaction between model components, and state changes in a discrete-time (Ullrich & Lückerath, 2017). The model scope and assumptions are determined, along with the conceptual model of the system. To evaluate the system, a set of performance metrics are established. It refers to the metrics explored in Chapter 2.

4.1 Model scope and assumptions

Based on the RSC current state in Chapter 3, the scope of the model is scoped as shown in Figure 4-1. The following model incorporates 7 actors: supplier, Emmen Facility (EMF), wholesalers, small installers, large installers, drum manager, and waste collector. The PYNL-affiliated distributors are not included in the model since the main goal is to improve the return and reuse rate with the customers. Another reason is that the distribution company also operates outside the Netherlands, hence it is out of the scope of this case study as explained in Section 1.6. Based on the analysis in Section 3.1, the drums that will be modeled are one plastic drum DP4060K and one wooden drum DW4116K. The details regarding the drums can be found in Section 6.1.6. The model aims to obtain the impacts of improvement strategies in Chapter 5, by varying the shrink rate, scrap rate, repair (SSR) rate, customer process lead time, and inbound transport unit cost. in the RSC. The impacts are evaluated based on the performance metrics outlined in Section 4.3. The logic of the model is explained in the following section.

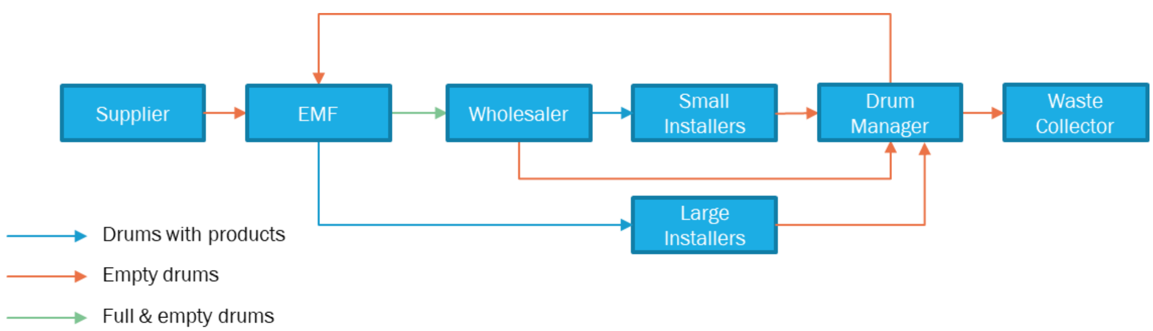

Figure 4-1 Model scope

Several model assumptions are made for this model, as follows:

- The small installers are assumed to obtain their drums supply from the wholesalers; thus, their demands are represented by the wholesalers. On the other hand, large installers are served directly via direct selling
- The simulation models the drums only, hence no cable products are modeled. The only distinction between full (drum with cable products) and empty drums flow can be seen in Figure 4-1. It is assumed that the blue line indicates the flow of full drums, whereas the orange line indicates the

empty drums. The green line represents a mixed flow between full and empty drums.

- The returned products due to issues emerging from customer satisfaction, quality, and inaccurate product are not considered
- Drum shrinkage (not returned, damaged, lost) occurs only in small and large installers.
- There are a sufficient amount of transporter trucks for any type of transport request.
- The transportation lead time is deterministic. This is considering that the stochastic element of transportation is out of the scope of this research and also preventing the model from becoming too complex. Another consideration is that the current transporter performance outlined in Section 3.1 has satisfied the service level almost on every occasion.
- The model assumes 24 working hours

4.2 Conceptual Model

The conceptual model is shown in Figure 4-2 consists of five logic: Logic A for customer demand consumption & replenishment, Logic B for EMF replenishment, Logic C for forward flow, Logic D for reverse flow, and Logic E for drum maintenance. The box with a clock represents a lead time. The following section elaborates on how each logic works.

Logic A – Customer Demand Consumption & Replenishment

The system starts with Logic A; drum consumption at both the wholesalers and large installers. The demand quantity and average interarrival time between orders (AIT) dictate the rate of consumption at each location, using the values described in Section 6.1.1. The demands are triggered only in these two locations. As explained in Section 4.1 previously, the small installers are assumed to obtain their drums supply from the wholesalers; thus, no demands are created from these installers. EMF has a direct sales connection with the large installers. The demand is fulfilled with the inventory on hand at customers' premises.

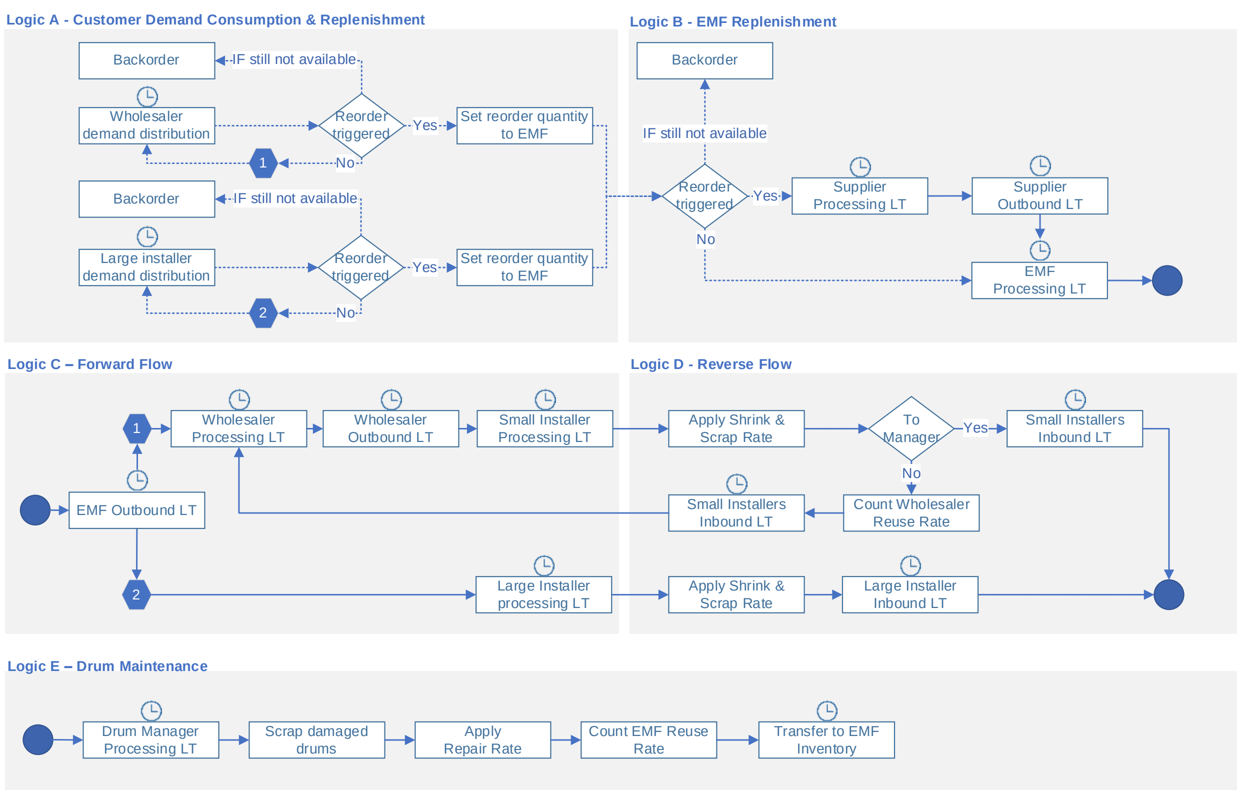

Figure 4-2 Conceptual Model

Each customer continuously reviews their inventory level. In the case of sufficient stock on hand, the wholesaler consumes the drums from the inventory (indicated by hexagonal box 1 in Logic A). The replenishment is based on a minimum-maximum policy, as stated by Interviewee I and Section 3.1 in Appendix 3. The process is repeated until the reorder point (minimum level) is met. Drums consumed from on-hand inventory continue to hexagonal box 1 in Logic C, where the wholesaler processes and holds the drum. The same approach applies to the large installer, which is indicated by hexagonal box 2. The remainder of the process of Logic C will be explained in a later section below. In another case where the quantity in stock at each customer reaches the reorder level, the respective customer sends a replenishment signal to EMF. The replenishment policy for each customer is described in Section 6.1.2.

Logic B – EMF Replenishment

A similar replenishment behavior also takes place in the EMF, shown by Logic B. If the reorder point (minimum level) is reached, the drum supplier is contacted for resupply. The supplier takes a certain time to process the order before the drums can be delivered. Otherwise, EMF can fulfill customers' demands should it have sufficient inventory on-hand. In both cases, EMF prepares the drums before being picked up for delivery to the requesting customers. Backorder is recorded at each location if there is no inventory in hand to satisfy the incoming demand. The replenishment policy for EMF and suppliers is also described in Section 6.1.2.

Logic C – Forward Flow

Logic C explains the forward flow at customers, both for those which came from on-hand inventory or replenishment by EMF. After receiving the drums, the wholesaler further ships the drums to the small installers. Unlike the wholesaler, the large installer is the end customer; hence, no further shipment is required. Upon receiving, the customers process and hold the drums for a certain period as described in Section 6.1.4. The activity on the drums during the processing phase differs per location as mentioned in the same section. The outbound transportation lead times for supplier and EMF are mentioned in Section 6.1.3.

Logic D – Reverse Flow

After the processing period has elapsed, some of the drums remain at customers’ premises, while others are returned. The shrink rate in Section 6.1.6 determines how many drums are returned. The returned drums' final destination is defined as well in that section, either returning to the drum manager or the wholesalers. The shrink rates are applied only in the small and large installers, as assumed in Section 4.1. The inbound transportation lead times for small and large installers follow the values in Section 6.1.3. The return rate is calculated using the formula stated in Section 4.3.1.

The scrap rate for each drum is also explained in Section 6.1.6. The scrap rate determines how many drums are unusable in the small and large installers due to damage. In contrast to the EMF reverse flow, incoming drums at the wholesaler do not undergo any sort of maintenance, also in the case of the drums being unusable hence need to be scrapped by the drum manager. The wholesaler reuse rate is then calculated with the formula in Section 4.3.1.

Logic E – Drum Maintenance

The drum manager starts the drum maintenance process upon arrival of the returned drums at Emmen. Unrepairable drums are scrapped, leaving only drums that can be reused or require minor repair(s). The number of drums requiring repairs, i.e., have minor damage, is determined by the repair rate at Section 6.1.6. All of the reusable drums are cleaned before being put back to Prysmian inventory for further reuse. The lead time for maintaining the drums is explained in Section 6.1.4. Similar to the wholesaler reuse rate, the EMF reuse rate is calculated with the formula in Section 4.3.1.

4.3 Performance Metrics Formulation

In the following subsection, the metrics used to evaluate the system's performance are described. The metrics are derived from the performance metrics explored in Section 2.4. There are four perspectives included for the performance evaluation, namely process, environment, customer, and financial. The two key metrics in this research, namely RSC efficiency and RL cycle time, are dependent on the remaining metrics.

4.3.1 Process Metrics

Return rate – P1

The return rate measures the total weight of drums received at the drum manager in comparison to the total weight of outbound drums to customers. The return rate is calculated as follows:

$$Return\ rate\ (\%) = \frac{total\ weight\ of\ returned\ drum\ at\ drum\ manager\ (ton)}{total\ weight\ of\ outbound\ drums\ from\ EMF\ (ton)} \quad (4.1)$$

Reuse Rate – P2

After arrival, the returned drums are sorted, repaired (if necessary), and cleaned. A drum is considered reusable only if it completes all of those steps. Reuse rate indicates the total weight of cleaned drums in comparison to the total weight of drums received by customers. There are two reuse rates used, the first is the reuse rate is applied at EMF.

$$Reuse\ rate\ at\ EMF\ (\%) = \frac{total\ weight\ of\ cleaned\ drums\ at\ drum\ manager\ (ton)}{total\ weight\ of\ outbound\ drums\ from\ EMF\ (ton)} \quad (4.2)$$

The second reuse rate is applied to the wholesalers to indicate the reuse in their supply chain. The wholesalers do not carry out any repair to the drums, as explained in assumption Section 4.1.

$$Reuse\ rate\ at\ Wholesaler\ (\%) = \frac{total\ weight\ of\ reusable\ drums\ at\ wholesaler\ (ton)}{total\ weight\ of\ outbound\ drums\ from\ wholesaler\ (ton)} \quad (4.3)$$

RL cycle time – P3

The RL cycle time is the period between the drums leaving and being returned to EMF inventory. As shown in Figure 4-2, there are three types of lead times (LT) constructing the RL cycle time: outbound LT, inbound LT, and processing LT. The transportation (outbound and inbound) LT is the period between a drum leaving from the origin and arriving at a destination. Outbound LT measures the lead time in the forward flow to customers. On the contrary, inbound LT is used in the reverse flow. Processing LT indicates how long does a drum is held at a location for a certain activity described in Section 6.1.4.

There are three RL cycle times measured along the chain. The first is the RL cycle time for the drums delivered to the small installers and returning to EMF, as follows:

$$RL\ cycle\ time\ (days) = EMF\ outbound\ LT\ (days) + wholesaler\ processing\ LT\ (days) + wholesaler\ outbound\ LT\ (days) + small\ installer\ processing\ LT\ (days) + small\ installer\ inbound\ LT\ (days) + drum\ manager\ processing\ LT\ (days) + transfer\ to\ EMF\ inventory\ (days) \quad (4.4)$$

The second RL cycle time is for the drums that are shipped to the large installers and returning to EMF, as follows:

$$RL\ cycle\ time\ (days) = EMF\ outbound\ LT\ (days) + large\ installer\ processing\ LT\ (days) + large\ installer\ inbound\ LT\ (days) + drum\ manager\ processing\ LT\ (days) + transfer\ to\ EMF\ inventory(days) \quad (4.5)$$

The third RL cycle time is for the drums which are circulated only between the wholesalers and small installers. In other words, this cycle time is the wholesaler's RL cycle time. The formula is as follows:

$$RL\ cycle\ time\ (days) = \ wholesaler\ outbound\ LT\ (days) + \ small\ installer\ processing\ LT\ (days) + small\ installer\ inbound\ LT\ (days)\ (4.6)$$

Mean Inventory – P4

The mean inventory at a location is calculated with the following formula, where i indicates the simulation instance. The measurement takes place at EMF, Wholesalers, Small Installers, Large Installers, and Drum Manager. The following formula is applied for every drum type:

$$Mean\ inventory(unit) = \ \frac{quantity\ in\ stock_i + quantity\ in\ stock_{i+1}}{i+1}\ (4.7)$$

Replacement ratio – P5

Replacement ratio compares between the reused and the (new) replacement drums as a result of drum shrinkage and scrapping. It may also be seen as the mix or composition of drums used by EMF to fulfill the customer demands. If the replacement ratio > 1 suggests that there are more new drums as opposed to reused drums in EMF's downstream chain, where ratio <1 suggests otherwise. If the replacement ratio equals 1, then both new and reused drums are equally used. The replacement ratio is accounted using the formula as follows:

$$Replacement\ ratio\ (\%) = \frac{sum\ of\ new\ purchased\ drums\ (unit)}{sum\ of\ reused\ drums\ (€)}\ (4.8)$$

4.3.2 Environmental Metrics

Amount of waste – E1

The amount of waste accounts for the generated waste per drum type for each material, hence it applies for the plastic and wooden drums. A drum is considered a waste once it is scrapped by the drum manager.

$$Amount\ of\ waste\ (ton)\ = \ number\ of\ scrapped\ drums\ per\ type\ (unit)\ *\ weight\ per\ type\ (kg)\ /\ 1000\ (kg)\ (4.9)$$

Inbound transport CO2 emission – E2

The inbound transport CO2 emission accounts for the emitted CO2 during the drum pickup process from the customer premises. This formula applies to inbound drums from the large and small installers.

$$Inbound\ transport\ CO2\ emission\ (ton.CO2 - eq) = \ total\ inbound\ weight\ (ton) * \ total\ travelled\ distance\ (km)\ * CO2\ generated\ (ton.CO2 - eq/ton)(4.10)$$

Disposal CO2 emission – E3

For each drum disposed to the waste collector, CO2 emission is generated for treating the waste. Hence, the formula below accounts for the CO2 emission of drum disposal:

$$Disposal\ CO2\ emission\ (ton.CO2 - eq) = \ weight\ of\ scrapped\ drums\ (ton) * CO2\ generated\ (ton.CO2 - eq/ton)(4.11)$$

Drum replacement CO2 emission – E4

To replace the lost inventory due to shrinkage and scrapping, PYNL purchases new drums from the supplier. The company acquired the drums that generate CO2 emissions during their production. The following formula accounts for the CO2 emission as a result of purchasing the drums:

$$Drum\ replacement\ CO2\ emission\ (ton.CO2 - eq) = \ order\ quantity\ from\ supplier\ (unit) * weight\ per\ drum\ type\ (kg/unit) * CO2\ generated\ (ton.CO2 - eq/ton)\ (4.12)$$

4.3.3 Customer Metrics

Service level – C1

Service level is the percentage of the total quantity demanded that was immediately satisfied from inventory on hand (i.e., no balking and back-ordering). It is also known as quantity fill rate. The following formula is applied to every drum type at every customer.

$$Service\ level\ (\%) = \frac{quantity\ demanded}{quantity\ immediately\ consumed\ from\ inventory\ on\ hand} * 100\% \quad (4.13)$$

4.3.4 Financial Metrics

Recovery value – F1

The recovery value indicates the monetary value from the reusable drum at the drum manager. A drum is reusable once it completed all maintenance process until cleaning at the drum manager Hence, the recovery value is calculated as follows:

$$Recovery\ value\ (€) = number\ of\ cleaned\ drums\ at\ the\ drum\ manager\ (unit) * drum\ price\ per\ type\ (€/unit) \quad (4.14)$$

Return logistics cost – F2

RL cost accounts for the expenditure to recover the drum from the customer's premises and the required actions for the drum become reusable. In this case, the RL cost is the sum between RL internal cost and external cost. The RL internal cost is the tangible cost that one has to pay for performing RL. On the other hand, RL external cost is the cost that emerges as a result of emitting pollutants during RL operation.

$$RL\ total\ cost = RL\ internal\ cost\ (€) + RL\ external\ cost\ (€) \quad (4.15)$$

There are two RL internal costs implemented in the RSC. The first is the RL cost for all the drums returned to EMF, which consist of the inbound transport costs and drum management cost. Drum management cost is incurred with all activities related to drum management, namely drum scrap cost, repair cost, and cleaning cost. The number of cleaned drums is the number of returned drums minus the number of scrapped drums.

$$RL\ internal\ cost\ at\ EMF (€) = inbound\ transport\ cost\ (€) + drum\ management\ cost\ (€) \quad (4.16)$$

The inbound transport costs account for the transportation of returned drums back to either the intended recipient, which may be either EMF or the wholesalers depending on the policy stated in Section 6.1.3. The following formula applies for both cases:

$$Inbound\ transport\ cost\ (€) = transported\ weight\ (ton) * transport\ distance\ (km) * transport\ unit\ cost\ (€/ton.km) \quad (4.17)$$

As mentioned in Section 4.2, each drum undergoes a set of processes before it can be reused. The costs of each activity applied to the drum are accounted in the drum management cost, which is calculated as follows:

$$Drum\ management\ cost\ (€) = number\ of\ scrapped\ drums\ (unit) * scrap\ price\ per\ drum\ type\ (€/unit) + number\ of\ repaired\ drums\ (unit) * repair\ price\ per\ drum\ type\ (€/unit) + number\ of\ cleaned\ drums\ (unit) * cleaning\ cost\ (€/unit) \quad (4.18)$$

The second RL cost applies to drums that are returned to the wholesalers. Only inbound transport cost is taken into account since no maintenance activity is carried out on the drums as explained in Section 4.2. Therefore, the RL cost at wholesaler is formulated as follows:

$$RL\ internal\ cost\ at\ wholesaler\ (€) = \ Inbound\ transport\ cost\ (€) = \ transported\ weight\ (ton) * transport\ distance\ (km) * transport\ unit\ cost\ (€/ton.km) \quad (4.19)$$

There are also two external costs, each for EMF SC and wholesalers SC. The wholesaler's external costs are applied only if there is a request from PYNL for a wholesaler to build a return flow for them. The formula used is as follows:

$$RL\ external\ cost\ at\ EMF (€) = \ total\ inbound\ weight\ (ton) * \ total\ travelled\ distance\ (km) * CO2\ generated\ (ton\ CO2\ eq/ton) * CO2\ emission\ unit\ cost\ (€/ton\ CO2\ eq \quad (4.20)$$

$$RL\ external\ cost\ at\ wholesaler\ (€) = \ total\ inbound\ weight\ (ton) * \ total\ travelled\ distance\ (km) * CO2\ generated\ (ton\ CO2\ eq/ton) * CO2\ emission\ unit\ cost\ (€/ton\ CO2\ eq \quad (4.21)$$

Recovery profitability ratio – F3

The recovery profitability ratio depicts how profitable does an operation is in terms of RL total cost and environmental costs when compared to the recovery value. The RL costs are derived by steps mentioned in the earlier paragraph. The environmental cost comprises of costs of CO2 emission generated aside from inbound transport (since already included in the RL total cost), namely incineration and new drums purchase as described in Section 4.3.2. There are two recovery profitability ratios along the chain, the first ratio belongs to EMF RSC, shown by the following equation:

$$Recovery\ profitability\ ratio\ at\ EMF\ (\%) = \frac{recovery\ value\ at\ drum\ manager\ (€)}{RL\ total\ costs\ (€) + environmental\ emission\ cost\ (€)} \quad (4.22)$$

The second ratio is implemented in the wholesalers' RSC, indicating the recovery profitability between the wholesalers and small installers.

$$Recovery\ profitability\ ratio\ at\ Wholesaler\ (\%) = \frac{recovery\ value\ at\ wholesaler\ (€)}{RL\ total\ costs\ (€) + environmental\ emission\ cost\ (€)} \quad (4.23)$$

RSC Efficiency – F4

As mentioned in Section 1.3, RSC efficiency is defined as an enterprise's attempt to recover value from retrieved RPM in a supply chain system, while simultaneously maintaining resource, cost, quality, and environmental impact. The rate takes into account the whole RSC, that is including both EMF and wholesalers' RSC operations. The RSC efficiency is calculated with the formula below:

$$RSC\ efficiency\ (\%) = \frac{recovery\ value\ at\ EMF\ (€) + \ recovery\ value\ at\ wholesaler\ (€)}{drum\ replacement\ cost\ (€) + RL\ total\ cost\ (€) + environmental\ emission\ cost\ (€)} \quad (4.24)$$

Cost-benefit ratio – F5

The cost-benefit ratio (CBR) describes the investment feasibility of the proposed improvement strategies against the cost. The following formula will be used for the developed strategies later in Chapter 5. To calculate the CBR, it is important to determine the expected benefit i.e., the net value from scenario *i* in comparison to the base scenario. Hence the net value of Scenario *i* is calculated as follows:

$$Net\ value\ Scenario\ i = \frac{Recovery\ value\ i - RL\ total\ cost\ i - Drum\ replacement\ cost\ i}{(1+r)^t} \quad (4.25)$$

The CBR is calculated using the formula below. The discount rate is represented by r, where the period of the expected benefit occurs is represented by t. A CBR >1 indicates that the investment option is profitable, whereas CBR<1 otherwise. A case where CBR = 1 is neither profitable nor lossy. The discount rate in the Netherlands for the year 2021 is set to 2% (O'Neill, 2021). It is assumed that each developed scenario will last for two years.

$$Cost - benefit\ ratio = \frac{Net\ value\ Scenario\ i - Net\ value\ Base\ Scenario}{(1+r)^t} \quad (4.26)$$

4.4 Model Implementation

The simulation uses Simio software Version 14.221.23945. The simulation is run on an Intel® Core™ i5-8250U @ 1.60 GHz (8 CPUs) computer with 8GB RAM and Intel® UHD Graphics 620 4GB graphic card. The Simio model in Figure 4-3 consists of one basic node as a supplier, followed by four servers representing distribution center, wholesaler, installer, and drum manager. At the end of the chain, a sink is placed as the final destination of scrapped drums. The detailed model is explained in Appendix 4.

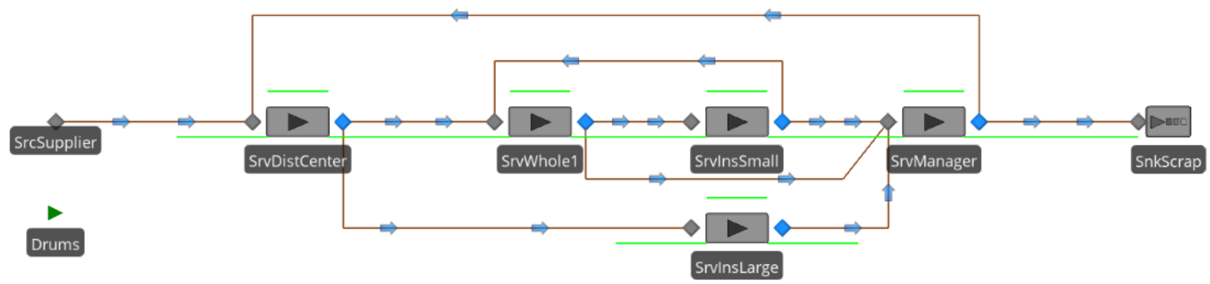

Figure 4-3 Overview of the simulation model in Simio

4.5 Conclusion

This chapter describes the model-building process and performance metrics establishment. The process involves the construction of a conceptual model and implementation in Simio simulation software. Hence, the following sub-research question can be answered:

Sub-research questions 4: How can the RSC performance be simulated and assessed?

To evaluate the logistics performance, a simulation model is built. Discrete Event Simulation (DES) is selected since it allows "what-if" analysis over complex and interrelated components in the RSC. A conceptual model consists of customer demand consumption & replenishment, EMF replenishment, outbound flow, inbound flow, and drum maintenance. The specification of shrink, scrap, and repair rate is also explained in the logic, along with lead times in the RSC.

The RSC performance can be measured from multiple perspectives: process, environmental, customer, and financial. As explained in Chapter 2, the holistic evaluation across multiple metrics can provide a better picture of the trade-off from each perspective. The process metrics measure the performance in the logistics aspect of the RSC. The environmental metrics assess the externalities of such RSC performance to the environment. The customer metrics indicate how the customers are affected by the RSC operations. The financial metrics highlight the monetary gains and losses from the RSC operations. Ultimately, RSC efficiency can be determined by estimating the recovered drum value and the resulting costs of RSC operations. RL cycle time can be defined from the time of a drum leaving and returning back to the shipper (EMF or wholesaler).

5

Strategy Development

In this chapter, a set of strategies is developed to improve the RSC in PYNL. The current state in Chapter 3 outlined the issues in PYNL RSC. Therefore, improvement strategies are necessary, derived by combining strategies from literature in Chapter 2 and expert interviews in Appendix 1. The following step will elaborate on the proposed strategy alternative, after which will be evaluated based on predefined criteria. The impacts of potential alternatives are specified, then combined to form improvement scenarios.

5.1 Developing RSC strategies

This section describes the development of RSC improvement strategies. As explained in Chapter 2, the strategies can explore from technological implementation, logistics system design, and compliance perspectives. In the following paragraphs, the abbreviation T, L, and C stand for each perspective, respectively.

T-1 Installation of RFID tags

The Root Cause Analysis in Section 3.2 highlights the lack of information sharing between stakeholders in the RSC. This limited visibility leads to uncertainty in terms of the number of drums circulating, which type, current location, and possession. As explained in Section 2.3.2, the literature suggests utilizing tracking technologies for improving SC visibility. Installation of passive UHF RFID tags and sensors is a potential option and is widely used across industries. The application extends also to RSC configurations that involve wholesalers and a variety of RPM (Nativi & Lee, 2012; Uckelmann, Hamann, & Mansfeld, 2009).

By implementing such technology, increases the SC visibility of both forward and reverse drum flow. Taking into account the variety of SKUs and the circulated volume outlined in Chapter 3, the passive RFID allows the reading capability of a large number of drums simultaneously. This solution is practical and requires less manual labor, which aligns with the requirements mentioned in the same chapter. Each tag is placed on the unique identification for each drum. The tags will be planted on the surface of the inner side of the flange as shown in Figure 5-2. This will prevent the tags to get in contact with the environment and getting damaged. Each reader costs around €2,000, and the costs of the tags are around € 0.80 each (Advanced Mobile Group, 2016; Next Points, 2018; Thrasher, 2013). The RFID cost installation cost per portal including RFID hardware, installation, and configuration ranging between €10,000-20,000 (Watson, 2013).

The passive RFID tag reader will be placed at the EMF, the drum manager, and wholesalers as shown in Figure 5-1. The RFID tags are placed by the drum supplier, where the drum manager also can reinstall the tags if found damaged or missing. The reuse and return rate can be measured for Prysmian and wholesalers' supply chain.

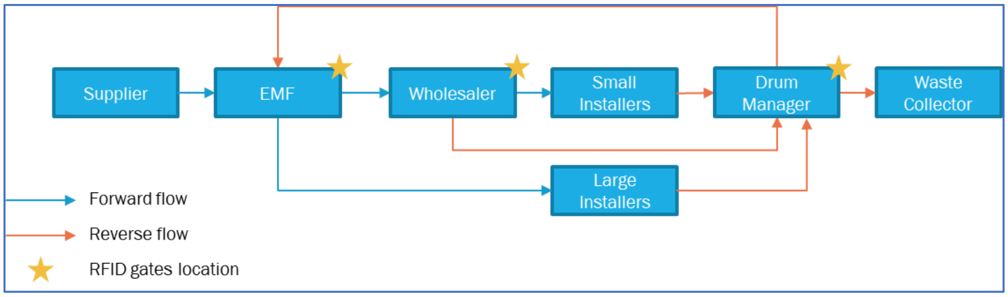

Figure 5-1 RFID implementation in PYNL RSC

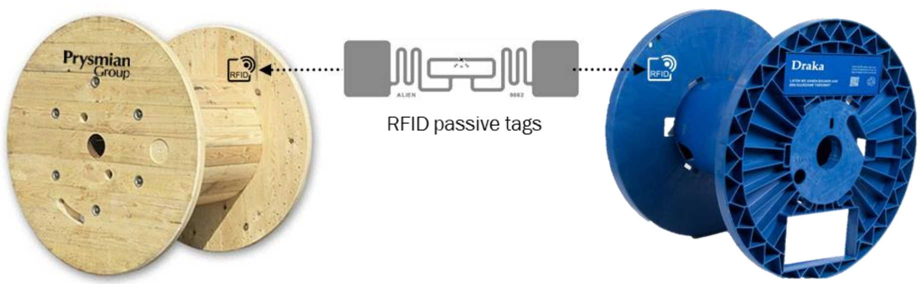

Figure 5-2 Passive RFID tag placed on a wooden and plastic drum

T-2 Installation of intelligent sensor devices

Similar to T-1, this alternative aims to increase the visibility of the supply chain by installing an intelligent sensor device on each drum. Each drum is embedded with intelligent sensors on the flange which can transmit location, the remaining cable length on the drum, environmental conditions, and motion (Alesea, 2019). The device relies on a 2G and Narrow-Band IoT (NB-IoT) connection to exchange data with the management system. It requires battery power to establish this connection which has a limited lifetime. Inclusive security features that send alerts for any theft or tampering attempts. This device, however, is only applicable for wooden drums. Based on Interviewee A in Appendix 1, this initiative has already taken place as a pilot project in PYNL. A single unit costs around [redacted].

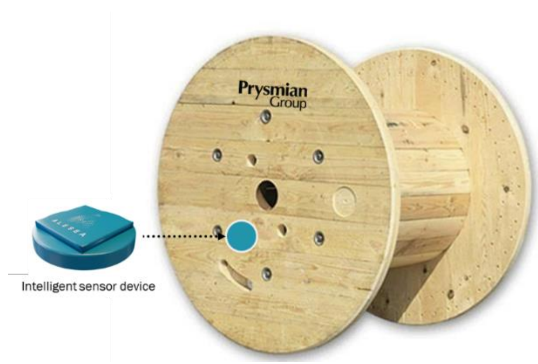

Figure 5-3 Intelligent sensor device placed on a wooden drum (Alesea, 2019)

L-1 Wholesaler reverse flow

Based on the interviews in Appendix 1, one possible solution is to instate a decentralized reverse flow for the empty drums between wholesalers and small installers. As opposed to a centralized RSC, the wholesaler can manage and arrange the returned drum in their RSC (Dominguez et al., 2021; Gobbi, 2011). After receiving an order, the wholesalers cut the cables to the requested length and use the empty drums as cable packaging before delivering to the small installers. Their cutting capabilities are limited only until a certain cable cross-section size, hence only certain types of drums are required. Based on this fact, a distinction is made based on the dimension, where drums smaller than 120 cm are returned to the wholesalers. Otherwise, the transporter picks up the empty drums and returns them to the drum manager. Figure 5-4 shows the proposed reverse flow that connects wholesalers and small installers.

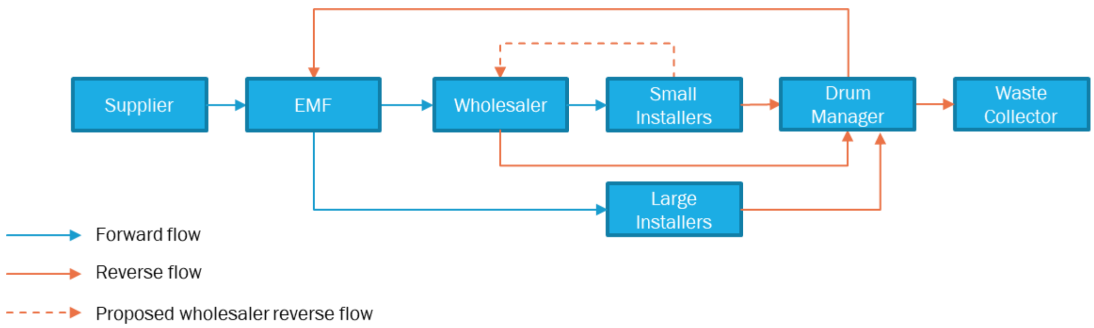

Figure 5-4 Wholesaler reverse flow

L-2 Scheduled return pickup

The introduction of a return pickup schedule promotes awareness and certainty in drum recovery from customers' premises (Nativi & Lee, 2012). PYNL informs the customers of empty drum pickup schedules in a specific interval, for instance, once every two weeks or at the end of every month. The timing and additional details are explained in the sales contract. Instead of reacting to the customer return request, this proactive approach may solve the planning issue outlined in Section 3.2. The space utilization in the pickup vehicle may become lower hence incur more costs, but the alternative offers more guarantee and awareness to the customers to return their drums. It is assumed that due to the low utilization, the drum collection cost increases by 30%.

The process starts with PYNL requesting information regarding the pickup locations to the wholesalers. Based on that information, the transporter arranges the transport to pick up from wholesalers and small installers. A simpler case for large installers, where PYNL can directly provide pickup locations to the transporter for arranging return flow.

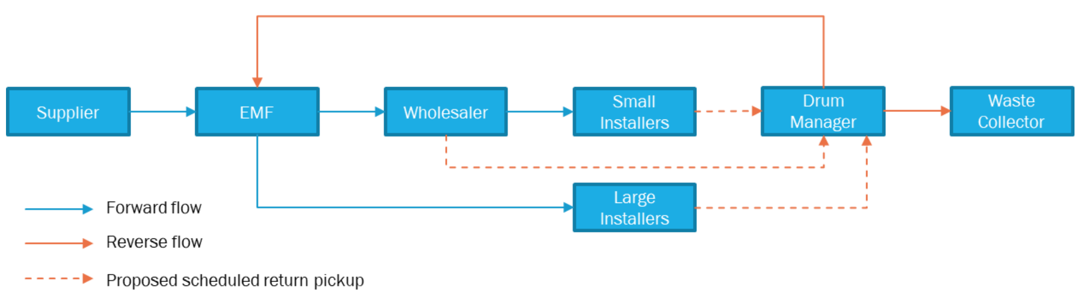

Figure 5-5 Scheduled return pickup

L-3 Outsource return management

A successful RPM management involves multiple resources and commitment, which proves not to be the case in PYNL. The lack of those elements in the organization also contributes to the low drum return as highlighted in Section 3.2. Outsourcing the drum return management to a 3PL, i.e., the current transporter can relieve PYNL responsibility on the drums and avoid allocation of resources to non-core business activities. The transporter can be awarded such tasks against a management cost, considering they currently manage the outbound and return transport. In case of drum losses or excessive drum holding time at customers, PYNL can hold the transporter accountable. According to Ullah et al. (2021), the management cost for an RTI i.e., pallets is $1, hence it is assumed at €2 unit for a single drum due to heavier and larger size.

L-4 Reinforce drum repair standard and procedure

The drum manager is responsible for assessing the drum reusability and repairs. In the current practice, there is no clear standard definition on the type of (un)repairable damage on a drum and the appropriate action to follow up such damage. The analysis in Section 3.2 also suggests that there is a lack of proper tools to repair more advanced damages. Hence, in this alternative, PYNL sets a clear and detailed standard and procedure on disposition decisions and provides the additional required tools to increase the repair capability, hence repair rate. The success of this alternative requires collaboration between production engineering, purchasing, and logistics functions.

L-5 Switch to more durable material

The drum scrap rate, particularly plastic drums are very high as shown in Section 3.2 (Oberink, 2021). Interviewee B and Interviewee J suggest a switch to more durable heavy-duty drums can improve the reusability. These changes certainly incur a higher drum cost.

C-1 Return instructions label

One possible approach to improve the return rate is to simplify the return process for customers. The current practice described in Chapter 3 has utilized a return instruction label with QR codes that can refer to a website when scanned. The proposed solution involves replacing the current QR code with unique individual QR code labels on one side of the drum flanges as shown in Figure 5-6. PYNL manages the drum identifier code for each drum. In addition to the drum return webpage (draka-haspelretour.nl), the code redirects to a mobile app for users to install. The use-case scenario is as follows:

- Users scan the QR code on the empty drum to open or install it in the user's mobile phone (if not installed yet).
- Users fill in user information regarding the time and location of return pickup
- Users scan all drums individually, similar to scanning a product in a retail store. In case a drum is double-scanned, a notification appears and the user is alerted.
- The app retrieves the data regarding drum type and size for each drum.
- The app forwards the user and drum information to the transporter for pickup arrangement. Prysmian also receives similar information for drum inventory stock planning purposes.

The label maintains most of the existing design along with the sustainability tag line and return instructions, yet with an additional pickup service level information and "do not drop" symbol. Indicating the service level guarantees that empty drums will be picked up within 5 days. Besides offering more certainty, the customers may see this alternative as an opportunity to clear up storage space in a short time at their premises. The "do not drop" symbol aims to give inform customers to handle the drums with care. The drum labels are printed at the drum supplier, where the drum manager has the capability of replacing the damaged, dirty, or missing label. The cost of redesigning the return instruction label is €0.5 per drum, whereas the cost of developing a return mobile app is around €10.000-15.000 (Gunterman, n.d.).

Figure 5-6 Return instructions for wooden (top) and plastic (bottom) drum

C-2 Reward points

This alternative suggests that a customer earns certain points based on the drum type for each drum returned in a good condition. Incentives using rewards are present in various industries (Breen, 2006). In this case, the more expensive or fragile the drum is, the higher the points are. The collected points are shared with the customers and determined in what level they rank, for example, shown in Table 5-1. To fairly distribute the rewards, the points earned are dependent upon the number of drums received and returned at a customer. This aims to balance between the customer with higher order volumes versus small customers e.g., small installers.

At the end of the year during sustainability day, PYNL invites and celebrates these achievements and awards the customers with the green labels based on their ranks. The form of reward may come in monetary or other forms. PYNL announces these achievements in external media communication to encourage customer involvement in the program.

Table 5-1 Reward points

Level rank	**Points earned**	**Rewards**
Green challenger	100-500	Reward A
Green promotor	500-1000	Reward B
Green collaborator	1000-2000	Reward C
Green champion	2000-3000	Reward D
Green leader	>3000	Reward E

C-3 Improve customer engagement

PYNL can improve the drum return and reuse by reminding customers regarding their corporate, moral, and legal responsibility. Regular contact with customers is considered one of the most effective strategies in the B2B environment (de Brito et al., 2005). Reminding of enforcing the drum return clause in the sales contract may also be an entry approach to achieve the goal. Interviewees in Appendix 1 also highlighted the importance of communication and engagement with customers to have more drum returns. This strategy does not only apply to customers, yet also to the transporter. It is expected that constant reminders of responsibilities between involved parties could lead to better results.

C-4 Non-return penalty

One of the effective options to influence return behavior is to implement a penalty (Breen, 2006). Prysmian Delft has rolled out such a penalty strategy for their RSC to a certain degree of success, as highlighted by Interviewee C & D. The main idea is that a customer receives an invoice if the drums are not returned for a certain time. This penalty policy can be inserted as a clause in sales contracts. The extent of the penalty can be stretched not only for not returning the drums but for damaged drums. It is assumed that an adaptation of the ERP system is required to implement this alternative, which costs around €10.000.

5.2 Multi-criteria analysis

To evaluate the strategic alternatives in the previous section, a multi-criteria analysis is performed. The analysis aims to narrow down the most promising strategies and filter out the less feasible ones. The selection criteria are explained in Table 5-2.

Table 5-2 Selection criteria

Criteria	Criteria	Description	Reference
1	Practicality	The required effort to carry out such alternative in daily operation	Interviewee A, Interviewee C & D, Interviewee K
2	Ease of implementation	The capability to roll out the alternative until fully operational, considering the system limitations	Interviewee C & D
3	Supportability	The level of support from key stakeholders to participate in the alternative (interview willingness)	Interviewee B, Interviewee F, Interviewee G, Interviewee H, Interviewee L & M
4	Investment	The estimated capital cost to execute the alternative	Interviewee A, Interviewee G, Interviewee H, Interviewee I, Interviewee J, Interviewee L & M,
5	Effectiveness	The likelihood of the alternative meeting the strategic objective	Interviewee I, Interviewee J
6	Continuity	The likelihood of the alternative to remain effective for a long time.	Discussion with PYNL expert

The relative importance between each criterion is scaled using Saaty's priority principle (Saaty, 2002). For a practical example, a significance ratio *k* is assigned between criterion A and criterion B to indicate that criterion A is *k* times more important than criterion B. The importance criteria scaling is shown in Table 5-3 with a scale between 1-5. The internal stakeholders across functions at PYNL will provide the weights to these criteria. However, due to the insufficient and limited timely response from PYNL experts, the scoring is filled by the author.

Table 5-3 Importance scaling between the criterion

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Sum
Criteria 1	1.00	4.00	0.33	0.33	0.50	0.33	6.50
Criteria 2	0.25	1.00	0.25	0.20	0.20	0.20	2.10
Criteria 3	3.00	3.00	1.00	3.00	0.25	0.33	10.58
Criteria 4	3.00	2.00	0.33	1.00	0.50	2.00	8.83
Criteria 5	2.00	4.00	3.00	2.00	1.00	2.00	14.00

Criteria 6	3.00	5.00	3.00	0.50	0.50	1.00	13.00

The sum of each criterion in Table 5-3 is normalized and assigned as weight in Table 5-4 for scoring the feasible strategy alternatives. PYNL customers will provide their scores towards the proposed alternatives. The score ranges between 1-10 between criteria, with larger indicating better performance in that criterion. Due to limited accessibility to PYNL customers, the scores are filled by the author.

The final results of the MCA analysis are shown in the same table. Alternative L-4 and C-2 score the lowest, therefore both are not considered. Alternative T-2 violates the constraint Section 3.4, in terms of investment cost for each drum. Alternative L-3 is filtered out due to violating the constraint of drum ownership. For alternative L-5, the plastic drum material currently in use is already heavy-duty material from the existing supplier (Axjo, 2020). Therefore, it requires a change in supplier or drum design which is not practical, according to Interviewee L & M.

Table 5-4 MCA score analysis

Criteria	**Weight**	**T-1**	**T-2**	**L-1**	**L-2**	**L-3**	**L-4**	**L-5**	**C-1**	**C-2**	**C-3**	**C-4**
Practicality	0.12	8	9	7	8	9	9	9	8	7	9	7
Ease of implementation	0.04	6	8	5	8	6	8	9	8	7	9	6
Supportability	0.19	8	8	5	6	6	8	8	7	6	8	5
Investment	0.16	7	9	6	9	9	9	9	9	9	9	5
Effectiveness	0.25	8	9	9	7	7	4	7	8	5	9	9
Continuity	0.24	9	7	9	7	8	4	5	8	5	7	8
Total score		8.00	8.30	7.36	7.29	7.56	6.32	7.35	7.97	6.15	8.34	7.00

5.3 Strategy specification

To obtain the impacts improvement strategies, the potential alternatives from previous sections have to be specified and combined. The result from the MCA score analysis in the former section filter out several infeasible alternatives, where T-1, L-1, C-1, C-3, and C-4 stands out as potential strategic alternatives as shown in Table 5-5. The magnitude of improvement from each alternative is laid out in the same table. The first row shows in which direction of impact of each alternative. A (-) sign shows that the current value in the RSC should be reduced by the magnitude of the value in Table 5-5. Otherwise, if a (+) sign is shown, then the current value should be increased by the degree stated in the same table. The impact of each alternative is linked to the shrink, scrap, and repair (SSR) rate, the customers processing lead time i.e., wholesalers, small and large installers, and the inbound transportation unit cost which is arranged between PYNL and the transporter.

The impact of RFID implementation alternative T-1 has been analyzed by Hellström (2009), where a decrease in shrinkage is expected to be around 5-15% in a retail company. Attaran (2010) argues that RFID implementation could reduce inventory shrinkage up to 11% and logistics delay up to 5%. On top of that, De Jonge (2003) states that using RFID could reduce the goods receipt process. Therefore, a decrease of 10% in shrink rate and customer process lead times are assumed. Alternative L-1 takes the approach of restructuring the logistic network, hence no effect on the SSR rate. The scheduled return pickup alternative L-2 can reduce the randomness and provide stability on the reverse flow; hence it is assumed that a 10% lead time reduction across customers takes place (Nativi & Lee, 2012). This benefit, however, entails a higher inbound transportation cost as explained in Section 5.1, thus a 30% increase in inbound unit cost is assumed to incorporate such low space utilization.

The return instruction label alternative C-1 proposed in Section 5.1, boasts a simpler return process sustainability tag line, and a new “fragile” handling logo. The new label design is expected to have impacts on SSR rates and customer process LT as indicated by Table 5-5. Customer engagement alternative C-3 is a potential solution for improving return rates, as Breen (2006) explained. Using the same approach, it is also assumed that better communication may lead to lower scrap and repair rates. Regular reminders to customers also reduce the customer processing lead time, hence the drums are returned in a shorter time. Breen (2006) also highlighted the positive impacts of the penalty on returns in the B2B environment. As mentioned in Section 5.1, a customer can be penalized if a drum is heavily damaged, but not for drums with minor damages. Hence alternative C-4 can reduce the shrink and scrap rates, but the repair rate remained unchanged. Late returns also lead to a penalty, thus reducing the customer process lead time.

Table 5-5 Improvement level of each feasible alternative

Alternative	**Description**	**Shrink rate**	**Scrap rate**	**Repair rate**	**Customers Process LT**	**Inbound Unit Cost EMF**
Impact		(-)	(-)	(-)	(-)	(+)
T-1	Installation of RFID tags	10%	-	-	10%	-
L-1	Wholesaler return flow	-	-	-	-	-
L-2	Scheduled return pickup	-	-	-	10%	30%
C-1	Return instruction label	10%	5%	5%	5%	-
C-3	Customer engagement	15%	10%	5%	5%	-
C-4	Non-return penalty	15%	15%	-	10%	-

The requirements Section 3.4 states that the proposed solution should enable visibility across the RSC, alternative T-1 will be used as a base for all developed scenarios. Hence, a set of scenarios is formed based on combinations of the six alternatives as shown by the morphological chart in Table 5-6. The magnitude of improvement is summed from each alternative, resulting in the final improvement magnitude for each scenario shown in Table 5-7. The performance of these scenarios will be evaluated later in Chapter 7.

Table 5-6 Design morphological chart

Scenario Name	Combined design alternatives	Technological implementation	Logistics system design	Compliance policy
Scenario 1	T-1 & L-1 & C-1	Passive RFID	Wholesaler return flow	Return instruction label
Scenario 2	T-1 & L-1 & C-3	Passive RFID	Wholesaler return flow	Customer engagement
Scenario 3	T-1 & L-1 & C-4	Passive RFID	Wholesaler return flow	Non-return penalty
Scenario 4	T-1 & L-2 & C-1	Passive RFID	Scheduled pickup	Return instruction label
Scenario 5	T-1 & L-2 & C-3	Passive RFID	Scheduled pickup	Customer engagement
Scenario 6	T-1 & L-2 & C-4	Passive RFID	Scheduled pickup	Non-return penalty

Table 5-7 Scenario impact specification

Scenario Name	Combined alternatives	Shrink rate	Scrap rate	Repair rate	Customers Process LT	Inbound Unit Cost EMF
Scenario 1	T-1 & L-1 & C-1	20%	5%	5%	15%	0%
Scenario 2	T-1 & L-1 & C-3	25%	10%	5%	15%	0%
Scenario 3	T-1 & L-1 & C-4	25%	15%	0%	20%	0%
Scenario 4	T-1 & L-2 & C-1	20%	5%	5%	25%	30%
Scenario 5	T-1 & L-2 & C-3	25%	10%	5%	25%	30%
Scenario 6	T-1 & L-2 & C-4	25%	15%	0%	30%	30%

5.4 Conclusion

In this chapter, the potential strategies for improving the RSC are explored. Using sources from literature in Chapter 2 and expert interviews in Appendix 1, a set of alternatives are defined. These alternatives aim to tackle issues that are outlined in Chapter 3. The development of the strategies sources from technological implementation, logistics system design, and compliance policy. Multi-criteria analysis is used to narrow down the solution space into the most feasible alternatives. The alternatives are combined into a set of scenarios of improvement strategies. Hence, the following sub-research question can be answered:

Sub-research question 5: What alternative reverse supply chain strategies can be proposed?

The RSC visibility is deemed necessary to better allocate resources and focus directly on the bottleneck. Hence, tracking technology such as RFID is mandatory for all improvement scenarios. Logistics network approaches also provide improvement opportunities for better RSC performance. This initiative involves collaboration with the wholesalers to pick up the drums and exchange information. To influence the customers' willingness in participating in drum returns, several steps can be taken. This can be achieved by simplifying and streamlining the return requests by using mobile apps. Another approach is to increase customer engagement from moral and legal aspects. Better communication is also deemed effective to improve the rate of the drums. Lastly, a penalty system may be implemented as an aggressive strategy to ensure more drums are going back to PYNL.

The RSC improvement strategies combine the alternative from technological tools, logistics system design, and compliance policy stated earlier. A set of six scenarios are formed by combining the alternatives. The impacts of each scenario are specified, by varying the shrink, scrap, repair (SSR) rate, process LT, and inbound transport unit cost.

PART V - LAUNCH THE SYSTEM

6

Model Execution

The subsequent step in the research is the **Launch the System** step. This chapter attempts to execute the simulation model described in Chapter 4. The model inputs are described also in this chapter. Further, verification and validation processes are also carried out to ensure the model correctness and degree of reality. The results of the simulation will be analyzed in upcoming Chapter 7.

6.1 Model input

As explained earlier, the input used for the model is described in the following section. The inputs consist of the average demand, replenishment policy, transportation data, station processing lead time and capacity, drum management data, and environmental data.

6.1.1 Average Demand

The average drum demand and average interarrival time (AIT) data are based on PYNL Drum consumption data in Appendix 3.3. The average interarrival time is calculated by finding the difference in the time and date two drum usage entries recorded PYNL ERP system. A distribution fitting software EasyFit is used to find out whether the recorded data follows a certain theoretical distribution function. The software features distribution fitting towards various distributions such as exponential, beta, Weibull, and gamma. To analyze whether the data indeed fits a certain theoretical distribution, the goodness of fit (GOF) tests can be performed in the software, such as Chi-square, Kolmogorov-Smirnov (KS), and Anderson-Darling (AD). The Chi-Square test is one of the GOF featured, where one can test whether the data follows a certain theoretical probability distribution. The null hypothesis is that the data follows the specified distribution. Otherwise, the alternative hypothesis states that the data do not follow the specified distribution.

The AIT for drum DP4060K and DW4116K delivered to the wholesalers and large installers are calculated. The AIT data is analyzed using EasyFit. The theoretical distributions are ranked based on the GOF of the AIT data. The results, however, show that the Chi-Square test rejects the null hypothesis for all drums going for both wholesalers and large installers, even with the theoretical distribution with the highest rank. The hypothesis rejection not only occurs in the Chi-square but also the KS and AD tests. The main reason for this is because the data in Appendix 3.3 does not capture the actual time and date of the drum consumption, yet based on the time and date of the entry on SAP which can be affected by various factors e.g., the user inputs time availability. The step of SAP data entry in the order fulfillment process is shown in Appendix 2.

To tackle this issue, an assumption on the AIT theoretical distribution is made. In the literature, the demand occurrence for an RPM follows Poisson probability distribution, in which the interarrival time is exponentially distributed (Cobb, 2016a, 2016b; Kiesmüller & van der Laan, 2001). Hence, Poisson distribution is used for the AIT in the simulation model. On the other hand, the value of AIT is still derived from the data in Appendix 3.3. The average demand for drums was also taken from the same data set.

Table 6-1 Demand Analysis

Drum Type	Average Demand (unit/year)	Average Demand (unit/day)	AIT (days)
Wholesalers			
DP4060K	25,696	70.40	0.014
DW4116K	1,742	4.77	0.204
Large Installers			
DP4060K	3,700	10.46	0.096
DW4116K	1,936	5.30	0.183

6.1.2 Replenishment policy

The replenishment process is triggered once the reorder point is triggered as explained in Section 4.2. The replenishment policy determines the quantity and the conditions in which the process is carried out. The policy applied in the model is a minimum-maximum policy. This policy places a certain reorder quantity until the maximum level is reached once the reorder point (minimum) is triggered. The reorder activity occurs after the inventory level falls below the point, followed by an order with a specific quantity, or reorder quantity. (Wagner, 2005). The minimum level, or in other words, reorder point, is calculated using the following equation:

$$Minimum\ level\ (unit) = lead\ time\ demand\ (unit)\ +\ safety\ stock\ (unit)\ (\ 6.1\ )$$

Lead time demand is the total demand between the reorder point triggered until the replenishment delivery arrives (Vermorel, 2014). The lead time demand can be determined by the following equation:

$$Lead\ time\ demand =\ [processing\ LT\ at\ the\ supplying\ station\ (days) + oubtound\ LT\ (days)]\ * \\ average\ demand\ (unit/day)\ + safety\ stock\ (unit)\ (\ 6.2\ )$$

The processing LT and outbound lead time are calculated from the supplying station from which a station sources its drums. For instance, EMF sources from the drum supplier, thus the supplier processing LT and outbound LT applies. Average demand is based on the value in Section 6.1.1. Safety stock is defined as the stock that aims to avoid disruptions from the uncertainty of production lead times, transport lead times, and customer demand (Wagner, 2005). The safety stock is determined using the following equation (King, 2011):

$$Safety\ stock\ =\ Z\ *\ standard\ deviation\ of\ lead\ time\ (days)\ *\ average\ demand\ (unit/day)\ (\ 6.3\ )$$

The service level of the drums is based on the data provided by Interviewee F in Appendix 1. Both drum types are categorized as A-type drum which is fast-moving products, hence the service level is 97,6%. It is also indicated by the small value of AIT in the previous section. The relationship between the Z score and the service level is shown in Figure 6-1. Based on the current service level, the Z-score of 2 is selected.

Desired cycle service level	Z-score
84	1
85	1.04
90	1.28
95	1.65
97	1.88
98	2.05
99	2.33
99.9	3.09

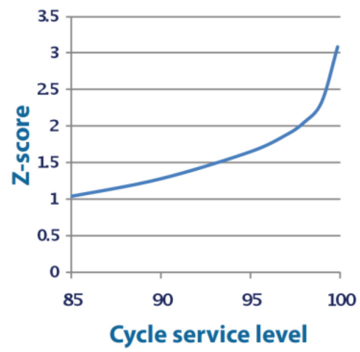

Figure 6-1 Z-score and cycle service level (King, 2011)

The standard deviation of lead times takes the processing time deviation in the supplying (previous) station. Since the processing time distribution in 6.1.4 is assumed to follow triangular distribution, hence the standard deviation is calculated below (Petty & Dye, 2013). The triangular distribution minimum, mode, and maximum days are represented by a, b, and c in the formula.

$$Standard\ deviation\ (days) = \sqrt{\frac{(a^2+b^2+c^2-ab-ac-bc)}{18}} \quad (6.4)$$

The reorder quantity is calculated using the following equation:

$$Reorder\ quantity\ (unit) = [expected\ inventory\ stock\ days\ (days) * average\ demand\ (unit/day)] - current\ stock\ (unit) \quad (6.5)$$

The expected inventory stock days for all station is assumed to be 14 days. The current stock unit is assumed to be equal to the reorder point since the reorder only occurs only after the stock level reaches the reorder point. The lead times used for the above equations can be found in Section 6.1.4. The average demand for each station is explained in Section 6.1.1. Table 6-2 and Table 6-3 states the replenishment details for all stations. The initial quantity used is the maximum stock level. The supplier and drum manager do not have any replenishment policy. The small installer also does not replenish, based on the assumption made in Section 4.1.

Hence the maximum level is defined as follows:

$$Maximum\ stock\ level\ \ (unit) = reorder\ point\ (unit) + reorder\ quantity\ (unit) \quad (6.6)$$

Table 6-2 Replenishment details for DP4060K

Station	Reorder Policy	Initial Quantity (unit)	Minimum level (unit)	Maximum level (unit/order)	Service Level (%)
Supplier	None	-	-	-	-
EMF	Minimum/maximum	4,190	3,062	4,190	97.6%
Wholesaler	Minimum/maximum	1,376	390	1,376	97.6%
Small Installer	None	-	-	-	-
Large Installer	Minimum/maximum	198	56	198	97.6%
Drum Manager	None	-	-	-	-

Table 6-3 Replenishment details for DW4116K

Station	Reorder Policy	Initial Quantity (unit)	Minimum level (unit)	Maximum level (unit/order)	Service Level (%)
Supplier	None	-	-	-	-
EMF	Reorder point/quantity	526	384	526	97.6%
Wholesaler	Reorder point/quantity	94	27	94	97.6%
Small Installer	None	-	-	-	-
Large Installer	Reorder point/quantity	105	30	105	97.6%
Drum Manager	None	-	-	-	-

6.1.3 Transportation data

The distance between each station is described in Table 6-4. The average distance from EMF to the wholesalers and large installers is calculated based on Transportation data in Appendix 3. The drum supplier is located in Schwerin, Germany as shown in Figure 6-2. The drum manager is located next to PYNL. The wholesaler is assumed to serve small installers across the Netherlands within a radius of ≤150 km since the extent of the Netherlands is around 300 km (Nations Encyclopedia, 2021). The distance between EMF and customers is calculated with a weighted average based on the number of drums sent to the customers in Appendix 3.3

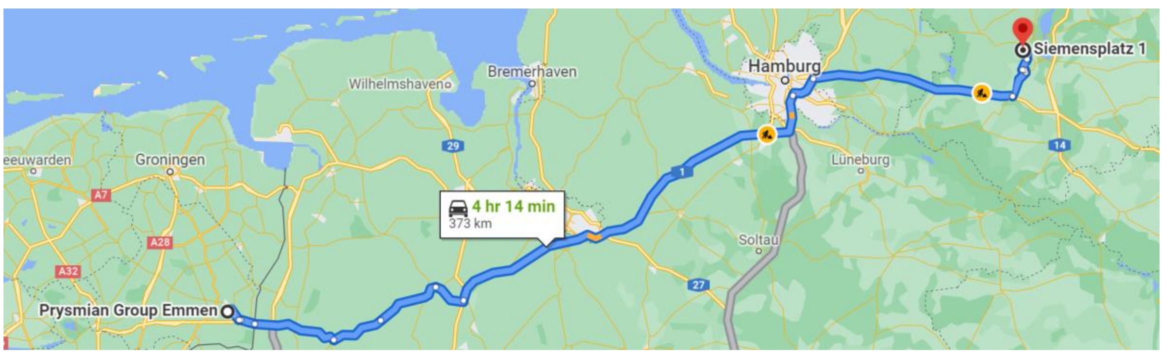

Figure 6-2 Distance between EMF to the drum supplier

Table 6-4 The origin-destination matrix

Station (in km)	Supplier	EMF	Wholesaler	Small Installer	Large Installer	Drum Manager
Supplier	-	373	-	-	-	-
EMF	-	-	174	-	146	-
Wholesaler	-	174	-	150	-	174
Small Installer	-	-	150	-	-	146
Large Installer	-	-	-	-	-	146
Drum Manager	-	0.5	-	-	-	-

The transportation unit cost is shown in Table 6-5. For transporting drums between EMF and its customers (wholesalers and large installers), a truck trailer is used. On the other hand, a box truck is used for transporting between wholesalers and small installers. The illustration of both types of trucks is shown in Figure 6-3. Since the unit cost for the transportation between wholesalers and small installers are unavailable, therefore the value follows the study by Meulen et al. (2020).

Figure 6-3 Truck Trailer and Box Truck
(Source: www.truckstar.nl)

The outbound and inbound transportation unit costs are based on the data in Appendix 3.5. The shipper and consignee locations are filtered for transportation in The Netherlands. A trip is considered outbound if the shipper loading address is PYNL and the unloading address is other than PYNL. On the other hand, inbound trips are all trips going to the drum manager. A transportation unit cost (in €/ton.km) is determined by dividing the charged transport cost against the traveled distance and transported weight. To arrive at a final outbound unit cost, the transportation unit costs are averaged between all outbound trips. A similar approach also applies to the inbound unit cost.

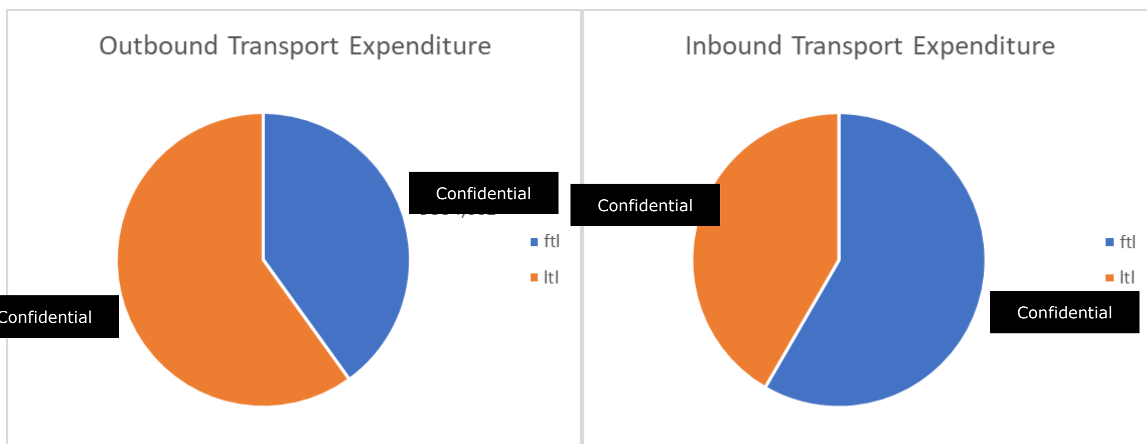

Figure 6-4 Outbound and inbound transport expenditure

It can be seen in Figure 6-4 that the less-than-truckload (LTL) is more dominant in outbound transport expenditure, rather than the full-truck-load (FTL) shipments. In general, an FTL shipment costs less than LTL. Hence, the unit cost for outbound is higher compared to the and inbound, which are €[redacted] and €[redacted] per ton.km, respectively.

Table 6-5 Transportation unit cost

Parameter	Unit	Truck Trailer	Box Truck	Source
Average Speed	(km/h)	60	60	T&M Leuven (2013)
EMF Outbound	(€/ton.km)	Confidential	-	PYNL Data Appendix 3
EMF Inbound	(€/ton.km)		-	PYNL Data Appendix 3

Wholesaler Outbound	(€/ton.km)	-	0.348	Meulen et al. (2020).
Wholesaler Inbound	(€/ton.km)	-	0.348	Meulen et al. (2020).

6.1.4 Station processing lead time

In this section, the processing time at each station is explained. The processing LT at the supplier and EMF accounts average the period between the replenishment order received until the delivery pickup arrives. The processing LT at wholesalers, large, and small installers represent the average period between a full drum received (drum with cables), then fully consumed (empty drum), until delivery pickup arrives (if returned). The processing LT at the drum manager starts when the drum is received, then repaired (if necessary) and cleaned, until it is ready for transfer to EMF storage.

Table 6-6 shows the processing LT distribution at each station, written in the format of *distribution (min, mode, max)*. The triangular distribution is selected since there is no historical time data available for this purpose (Law, 2015). The values are validated with two PYNL experts, Interviewee I and Interviewee C.

Table 6-6 Processing time distribution

Station	Processing LT distribution (days)	Description
Supplier	Triangular (21,30,40)	Time to process an order and prepare drums
EMF	Triangular (0.5, 1, 1.5)	Time to process an order and prepare drums
Wholesalers	Triangular (10,20,30)	Consumption and holding time
Small Installer	Triangular (3,7,14)	Consumption and holding time
Large Installer	Triangular (10,25,30)	Consumption and holding time
Drum Manager	Triangular (0.5,1,1.5)	Time to check, repair, and clean drum

6.1.5 Station processing capacity

The processing capacity at each station determines how many drums it can process at one time. To process one drum, a station seizes one capacity from its total capacity. Thus, the values stated in Table 6-7 show the maximum capacity to simultaneously process drums at each station. The supplier is assumed to have infinite capacity since PYNL has multiple suppliers that can provide the drums. The small and large installers are aggregated end customers; therefore, it is assumed that every customer does not have any limiting processing capacity when they receive the drums.

The processing capacities of EMF and wholesalers are calculated using the following formula:

$$Processing\ capacity\ (unit) = \ maximum\ level\ for\ drum\ DW4116K + maximum\ level\ for\ DP4060K \quad (6.7)$$

The processing capacity of the drum manager is assumed to be the same as EMF.

Table 6-7 Maximum processing capacity

Processing Capacity	DP4060K (unit)	DW4116K (unit)	Total Capacity
Supplier	Infinity	Infinity	Infinity
EMF	4,190	526	4,716

Wholesaler	1,376	94	1,470
Small Installer	Infinity	Infinity	Infinity
Large Installer	Infinity	Infinity	Infinity
Drum manager	4,190	526	4,716

6.1.6 Drum management data

Drum shrink rate represents how many drums are not returned after being delivered to the customers. The rate is derived by comparing the outbound drums from PYNL Drum consumption data and for inbound drums from the Drum manager annual report in Appendix 3. Due to limited data of the inbound drum details, it is not possible to distinguish how many drums come from which customers. Therefore, the shrink rates for both small and large installers are the same. The scrap and repair rate follows the Drum manager annual report in Appendix 3, mentioning the values for every drum type. The drum-related price, i.e., purchase, scrapping, repair, cleaning price also can be found in the same section of Appendix 3. In contrast to wooden drums, plastics drums are unrepairable. Therefore, the repair rate and price for plastic drums are set to zero.

Table 6-8 Drum shrink, scrap, and repair rate

Drum Type	Shrink Rate Small Installer	Shrink Rate Large Installer	Scrap rate	Repair Rate	Default Return to
DP4060K	0.521	0.521	0.979	0.000	Drum Manager
DW4116K	0.343	0.343	0.151	0.241	Drum Manager

Table 6-9 Drum management unit price

Drum Type	Purchase Price (€/unit)	Scrapping Price (€/unit)	Repair Price (€/unit)	Cleaning Price (€/unit)
DP4060K	[redacted] Confidential			
DW4116K				

6.1.7 Environmental data

The following explains the steps to obtain the environmental impacts. In Table 6-10, the CO2 generated unit from producing and disposal of both plastic and wooden cable drum is shown.

Table 6-10 CO2 generation unit

Drum Type	Wood (ton CO_2-eq/ton)	Plastic (ton CO_2-eq/ton)	Source
Production	0.057	0.122	(Takahashi et al., 2001)
Disposal	0.008	0.008	(Takahashi et al., 2001)

The replacement CO2 emission evaluates how many CO2 emissions are generated from drum production. It is assumed that every time PYNL purchases a drum, there will be environmental impacts generated. The amount of CO2 emission from such purchases is calculated with the below formula:

$$Replacement\ CO2\ emission\ generated\ (ton\ CO2-eq) = \ total\ weight\ of\ new\ purchased\ \ drums\ (ton) * CO2\ generation\ unit\ \ for\ production\ (ton\ CO2-eq/ton)\ (6.8)$$

The impact from the above emission is converted to monetary value, with the following formula using the CO2 emission unit cost from Table 6-11:

$$Replacement\ CO2\ emission\ cost\ (€) = \ Replacement\ CO2\ emission\ \ (ton\ CO2-eq) * CO2\ emission\ unit\ cost\ (€/ton\ CO2-eq)(6.9)$$

Each time a damaged drum is scraped, it will be disposed of by a waste collection company. The estimated CO2 generated from such activity along with the monetary cost to the environment is calculated using the below formulas. The CO2 emission cost refers to the CO2 emission unit cost from Table 6-11

$$Disposal\ CO2\ emission\ \ generated\ (ton\ CO2-eq) = \ total\ weight\ of\ disposed\ drums\ (ton) * CO2\ generation\ for\ disposal\ (ton\ CO2-eq/ton)\ (6.10)$$

$$Disposal\ CO2\ emission\ \ generated\ (€) = disposal\ CO2\ emission\ \ generated\ (ton\ CO2-eq) * CO2\ emission\ unit\ cost\ (€/ton\ CO2-eq)\ (6.11)$$

A higher drum return leads to a higher drum pickup trip going inbound. This results also in higher transportation emissions by the trucks. The generated CO2 along with the CO2 emission unit cost is shown in Table 6-11.

Table 6-11 Transportation emission unit cost

Description	Unit	Truck	Box truck	Source
CO_2 generated	(ton/ton.km)	0.000104	0.000104	(Sieber et al., 2018)
CO_2 emission unit cost	(€/ton CO2-eq)	80	80	(Sieber et al., 2018)

The following formula is used to calculate the generated CO2 and the environmental cost. The formula is applicable for the inbound drums going to EMF and the wholesaler.

$$Inbound\ transport\ CO2\ emission\ generated\ \ (ton\ CO2-eq) = \ total\ weight\ of\ inbound\ drums\ (ton) * total\ travelled\ distance\ (km) * \ CO2\ generation\ for\ inbound\ transport\ (ton\ CO2-eq/ton)\ (6.12)$$

6.2 Verification

In the following section, the verification tests are carried out to ensure that the model is built correctly (Sargent, 2013). Aside from model tracing and balance checks that were carried out during the model building process, verification tests are required for final checks. The result and scenarios for the verification tests are outlined in Table 6-12.

Table 6-12 Scenarios for verification tests

Scenario	Description	Expectation	Result	Pass/Fail
0	-	-	Return rate = 61%	
0	-	-	Reuse rate = 17%	
0	-	-	RL cost for EMF = €37,093	
0	Process LT at Small Installer – Triangular (3,7,14) days	-	RL cycle time via Small Installer = 42.1 days	
0	Process LT at Large Installer – Triangular (10,25,30) days	-	RL cycle time via Large Installer = 24.9 days	

1	Shrink Rate set to 0	Return rate > 61%	Return rate = 100%	Pass
2	Shrink Rate set to 1	Return rate < 61%	Return rate = 0%	Pass
3	Scrap Rate set to 0	Reuse rate > 17 %	Reuse rate = 35%	Pass
4	Scrap Rate set to 1	Reuse rate < 17 %	Reuse rate = 0%	Pass
5	Repair Rate set to 0	RL cost for EMF < €37,093	RL cost for EMF = €26,940	Pass
6	Repair rate set to 1	RL cost for EMF > €37,093	RL cost for EMF = €69,989	Pass
7	Decrease Process LT at Small Installer – Triangular (1,3,7) days	RL cycle time via Small Installer < 42.1 days	RL cycle time via Small Installer = 39.7 days	Pass
8	Increase Process LT at Small Installer – Triangular (10,14,20) days	RL cycle time via Small Installer > 42.1 days	RL cycle time via Small Installer = 49.6 days	Pass
9	Decrease Process LT at Large Installer – Triangular (5,12,10) days	RL cycle time via Large Installer < 24.9 days	RL cycle time via Large Installer = 15.9 days	Pass
10	Increase Process LT at Large Installer – Triangular (14,20,40) days	RL cycle time via Large Installer > 24.9 days	RL cycle time via Large Installer = 27.9 days	Pass

6.3 Validation

To ensure the model sufficiently represent the real world and meets the simulation objective, model validation is performed. Since having a model that perfectly resembles the real world is impossible, then the focus should be whether any significant differences prevent any conclusions derived from the model (Law, 2015). Hence, the main objective is to be confident that the model sufficiently meets the intended purpose. The method used for validation is face validation. This method requires the judgment of experts to assess the sufficiency of the model.

Two experts of PYNL were contacted for the model validation step. The first expert is Interviewee I as the Warehouse Manager and the second expert is Interviewee C as Supply Chain Manager. The conceptual model in Section 4.2 is presented to the experts and they have agreed that the model behavior is sufficient for achieving the simulation objective. The performance metrics in Section 4.3 are discussed with Interviewee C. The model inputs in Section 6.1 were also validated by both experts.

Data validation is also carried out towards the simulation results. Table 6-13 shows the service level at wholesalers and large installers, with the average, minimum, and maximum results from the simulation. The result is compared to the input from the case study in Section 6.1.2. Similarly, the total demand from the simulation results is shown in

Table 6-14. It is compared to the demand from the case study in Section 6.1.1. Both results show a difference under 5% for the average outputs if compared to the case study inputs.

Table 6-13 Service level validation

Station	Drum	Average	Minimum	Maximum	Case	Difference
Wholesaler	DP4060K	97.8%	94.5%	99.0%	97.6%	0%
	DW4116K	98.1%	95.8%	99.5%	97.6%	1%
Large Installers	DP4060K	97.8%	95.5%	99.4%	97.6%	0%
	DW4116K	98.1%	95.4%	100.0%	97.6%	0%

Table 6-14 Demand quantity validation

	Drum	Average	Minimum	Maximum	Case	Difference
Wholesaler	DP4060K	26,420	25,308	27,060	25,696	3%
	DW4116K	1,774	1,663	1,893	1,742	2%
Large Installers	DP4060K	3,788	3,580	3,944	3,700	2%
	DW4116K	1,972	1,820	2,116	1,936	2%

PART VI - ASSESS PERFORMANCE

7

Results

In this chapter of **Assess Performance** research step, the experimental plan and model results are explained. After the model is verified and validated in Chapter 6, the six scenarios developed in Chapter 5 are executed based on the experimental configurations stated below. The model outputs are shown in the upcoming part of this chapter. Finally, a sensitivity analysis takes place to test the robustness of the outputs.

7.1 Experimental plan

In this section, the simulation configurations are set, namely the warm-up period, simulation runs, and the number of replications.

7.1.1 Warm-up period

The warm-up period is the period when the simulation results are not recorded or cleared. The main purpose of this is to remove the divergent or atypical system behavior. At the start of the simulation, the quantity in stock shown in Figure 7-1 behaves erratically until the first 4 weeks. Hence, a warm-up period of 4 weeks is set for the experiment.

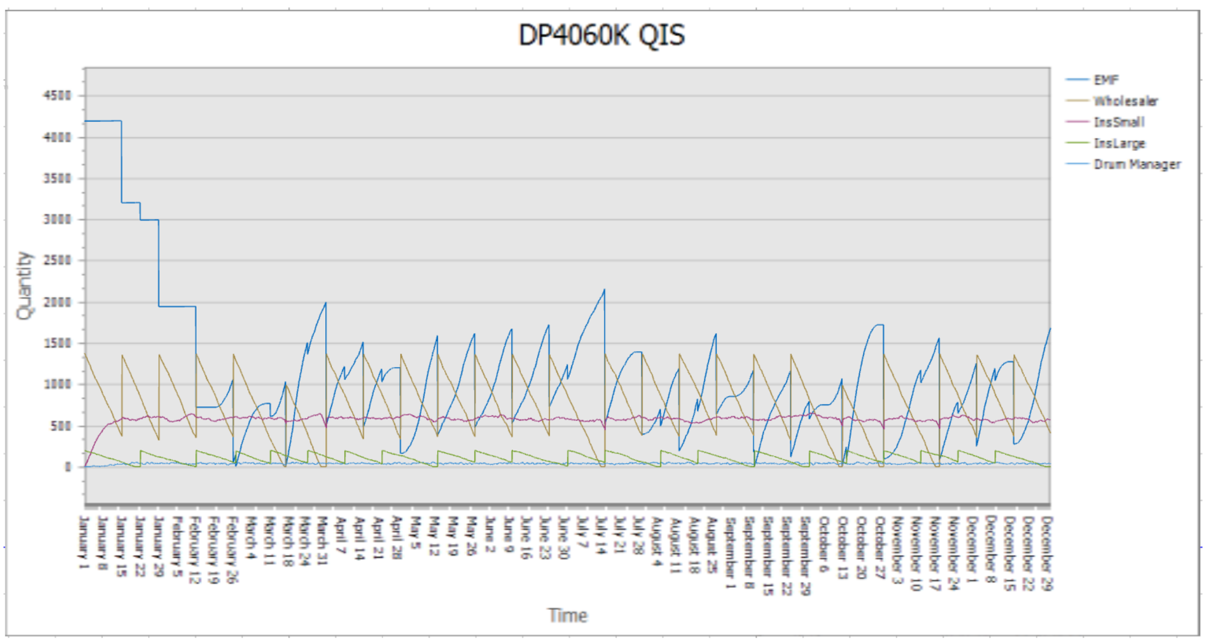

Figure 7-1 Drum quantity in stock

7.1.2 Simulation runs and replications

The simulation run is set to 52 weeks, to analyze the RSC operations in one year. The replication in each experiment is based on the error margin or half-width. The half-width of each performance metrics stated in Section 4.3 should be less than 5% (Munsters, 2018). The confidence level of the experiments is set to 95%, with the upper and lower percentile of 75% and 25% respectively. After evaluating the model output, it shows that replication of 70 times is sufficient to obtain less than 5% of half-width. The boxplot in Figure 7-2 shows the simulation response of RSC efficiency.

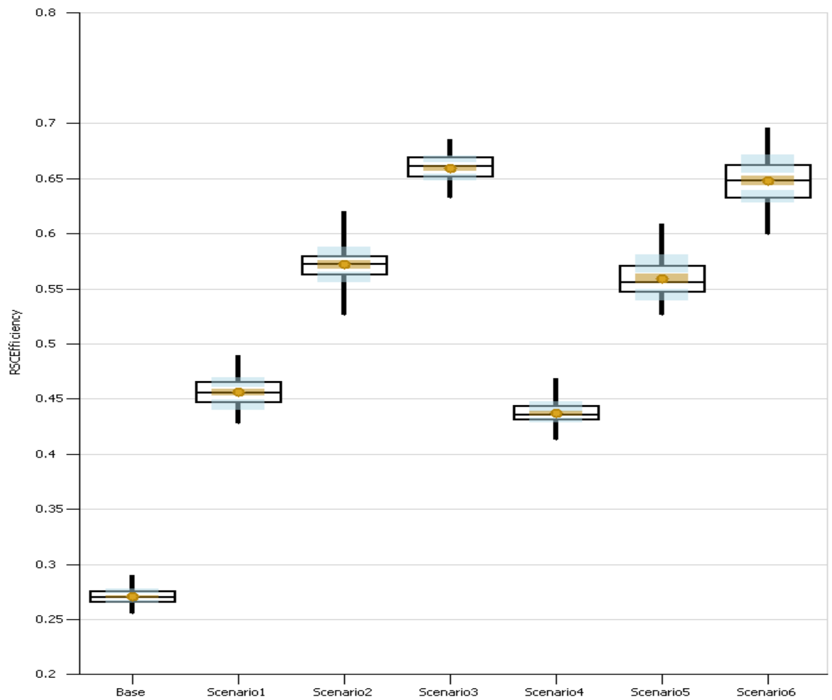

Figure 7-2 Boxplot of RSC simulation results for all scenarios

7.2 Model Output

The simulation experiments in Section 7.1 generate the performance of six scenarios developed in Chapter 5. The discussion is grouped into four sections, starting with process performance, environmental performance, customer performance, and financial performance. The key two metrics as mentioned in the main research question in Chapter 1 are RL cycle time and RSC efficiency. Both are discussed in the process and financial performance, respectively.

Process performance

The process performances are outlined in this part, evaluating the return rate, reuse rate, replacement ratio, and mean inventory level at customers. The return rate indicates how many drums are returned to EMF in comparison to the number of drums delivered to customers. The reuse rate further measures the number of reusable drums available for cable packaging, at EMF and in certain scenarios, also the wholesalers. The return and reuse rates from the base and six improvement scenarios are shown in Figure 7-3. It can be seen that all of the strategies developed in Chapter 5 do have an impact on both rates. Scenarios 2, 4, 5, and 6 excel in terms of return rates by 86%, compared to 60% in the base scenario. The reason behind this is these four scenarios experience a similar shrink rate improvement of 25%. It implies that more drums are returning to EMF.

The reuse rates also increased, however, not in the same magnitude as the return rate. The result shows that the improvement is between 24-31%. It is noteworthy that in Scenario 1-3, the wholesaler receives the empty plastic drums. The reuse rate at the wholesaler is still considerably low since only a fraction of plastic drums is reusable in the current state. Therefore, the improvement offered cannot compensate for the scrap rate on this scale. In addition, the specific reuse rates defined at EMF and wholesaler enable individual evaluation of the reuse performance. The highest reuse rate is achieved by Scenario 6, where scheduled return pickup and penalty policy are introduced. Nonetheless, in a case where the reuse rates at EMF and wholesaler are combined, Scenario 3 turns out to be the best performing scenario (28%+6%).

The increase in reuse rate also affects the mean inventory level at EMF shown by Figure 5-1 in Appendix 5. The growth is experienced in all of the scenarios. It means that more reused drums available for placement of new cable products. This argument is also supported by Figure 5-2 in the same section, which indicates a lower drum replacement ratio. This emphasizes that there are more reused drums used in the EMF downstream chain instead of newly purchased drums.

The first key metric in this study is the RL cycle time, shown in Figure 7-4. RFID implementation provides better visibility across RSC, therefore the RL cycle time decreases in all scenarios. The regular pickup schedule solved the return uncertainty issue; hence in overall, Scenario 3-6 performs better than Scenario 1-3. The non-return penalty in Scenario 6 suggests its effectiveness in minimizing the RL cycle time. It requires 21 days after dispatch from EMF until it returns, after being held at the wholesalers and small installers. For the flow going through the large installers, it takes 16 days. The worst performing scenario is claimed by Scenarios 1 and 2. In Scenario 1, PYNL relies on the customer's willingness to submit a return request via the QR code and mobile app. Improving engagement with the customer takes place in Scenario 2, where only modest improvement is expected when compared to other scenarios. Moreover, shorter RL cycle time also influences the mean inventory level Figure 5-1 Appendix 5, with Scenario 5 and 6 having more drums in stock at EMF among all scenarios. The detailed outputs can be seen in Table 7-1.

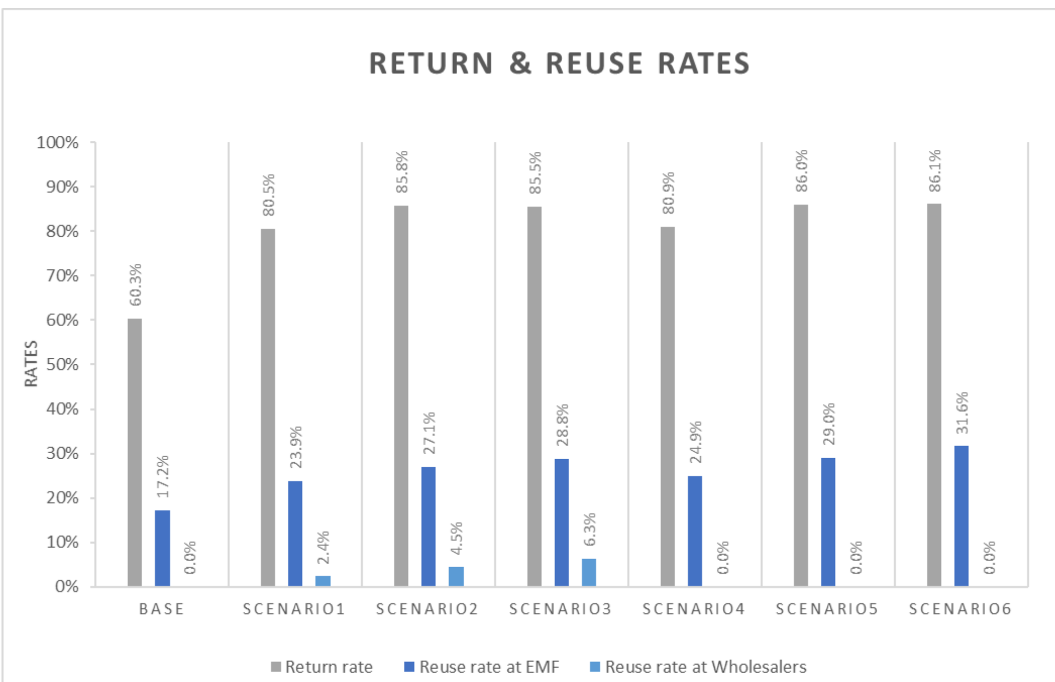

Figure 7-3 Return and reuse rates

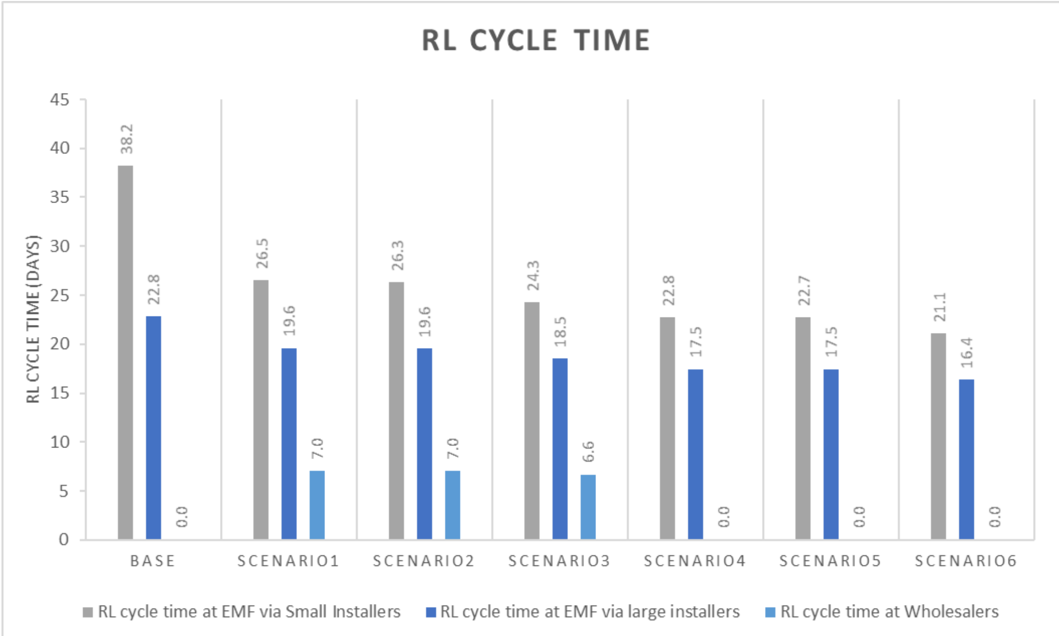

Figure 7-4 RL cycle time

Table 7-1 Impacts of scenarios on RL cycle time

Return flow owner	**EMF**	**EMF**	**Wholesaler**	**EMF**	**EMF**	**Wholesaler**
Via	Small Installers	Large Installers	Small Installers	Small Installers	Large Installers	Small Installers
Unit	days	days	days	Δ Difference	Δ Difference	Δ Difference
Scenario Name						
Base	38.2	22.8	-	-	-	-
Scenario1	26.5	19.6	7.0	-31%	-14%	-
Scenario2	26.3	19.6	7.0	-31%	-14%	-
Scenario3	24.3	18.5	6.6	-36%	-19%	-
Scenario4	22.8	17.5	-	-40%	-24%	-
Scenario5	22.7	17.5	-	-40%	-24%	-
Scenario6	21.1	16.4	-	-45%	-28%	-

Environmental performance

The assessment of environmental aspects is carried out based on the amount of waste and CO2 emissions generated from the RSC operations. It turns out that a better return rate does not necessarily lead to less waste if there are no effective measures in increasing the reuse rate. The amount of waste generated due to scrapped drums is shown in Figure 5-3 in Appendix 5. The figure indicates that the number of plastic drum wastes increases in all scenarios in comparison to the base. Higher drum returns without any actions on the scrap rate only lead to transporting damaged drum wastes between EMF and their customer. The fact that plastic drums are unrepairable also adds up to the issue. This argument is also supported by Scenario 3 and 6 where a higher return rate is complemented with a lower scrap rate, resulting in the lowest plastic wastes. Substantial reduction is found on wood wastes in both scenarios. It can be accomplished by enforcing non-return penalties to customers; hence drum condition is maintained.

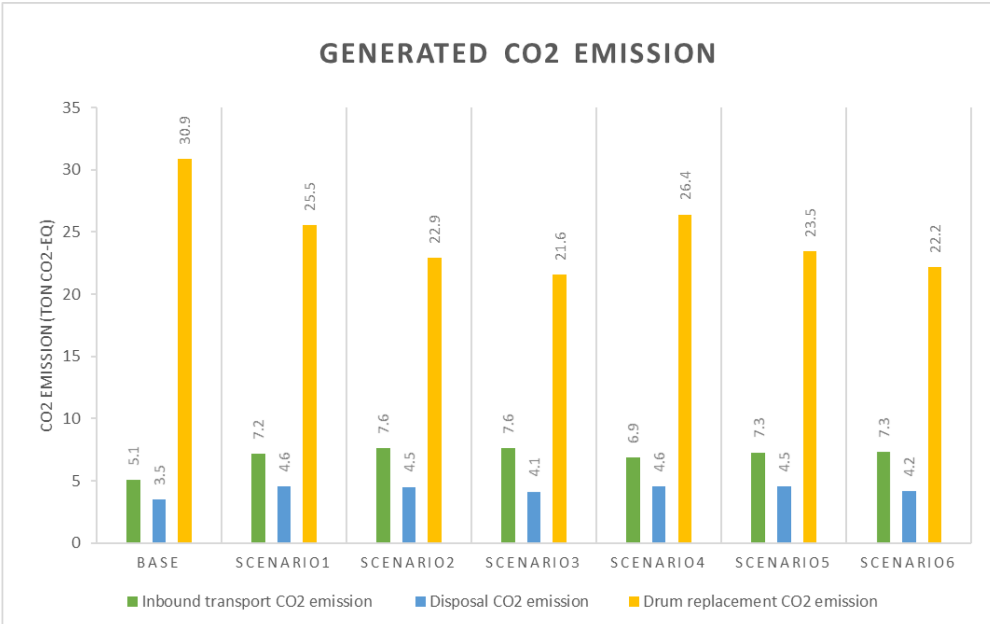

Figure 7-5 Generated CO2 emission

The produced wastes from scrapping drums are treated by the waste-collecting company. Figure 7-5 illustrates the estimated CO2 emissions from PYNL RSC operations. Scenarios 3 and 6, again, come out as the lowest CO2 producing scenarios at approximately 4 tons CO2-eq. The emission from inbound transportation in all scenarios is higher than the base scenario, due to more truck movements. The emissions generated from the disposal activities, however, do not stand in the same magnitude if compared to those generated from drum replacement. A similar observation is found for the inbound transport CO2. Furthermore, a better reuse rate entails a lower replacement ratio in the process performance, contributing to the reduction of CO2 emission generated from purchasing new drums. This argument is supported by Scenario 3 and 6, with approximately 22 tons of CO2-eq.

Customer performance

In customer performance, the service level is used to measure how many orders a customer can satisfy directly from their inventory on hand. Figure 7-6 illustrates the service level in the wholesaler and large installers. The small installer is excluded since it is the indirect customer of PYNL. In the figure, Scenario 1 accounts for the lowest service level at the wholesalers at 97.2%, even if compared to the base scenario. As explained previously, increasing the return rate without adequate actions on scrap rate results in a new problem. Since Scenario 1 assigned the plastic drums to be returned to the wholesalers, it leads to only damaged drums arriving at the wholesalers. Therefore, the wholesalers miscalculate their future inventory stock, hence requiring replenishment from EMF. The replenishment process takes time, thus there is a risk of stockouts at the wholesaler. On the contrary, Scenario 3 provides an example to support this argument. This scenario offers 25% and 15% reductions on shrink and scrap rates, leading to the highest service level at 98.9%. In addition, only marginal changes occur in large installers, since PYNL serves them directly and thus can be more responsive for fluctuations in the RSC.

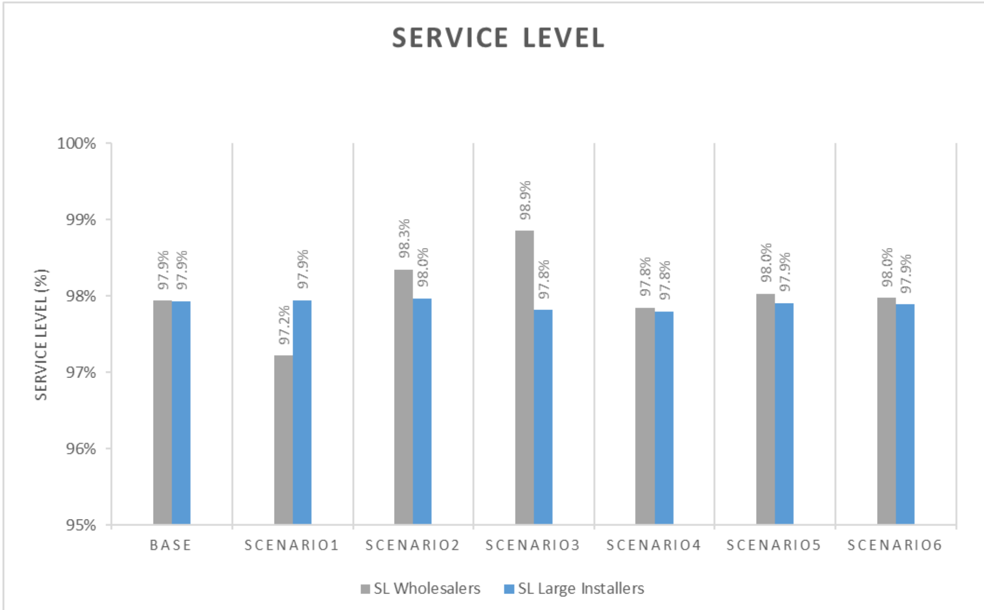

Figure 7-6 Service level at customers

Financial performance

The financial performance is the final assessment, incorporating recovery value, RL costs, recovery profitability ratio, RSC efficiency, and cost-benefit ratio. In Figure 7-7, the recovery value improves significantly in all scenarios. Scenario 3 and 6 generate the most recovery value at around €408.000, due to less scrap and more reusable drums available in stock. As explained earlier, a higher return rate and lower reuse rate does not generate the intended results. This is shown by Scenario 1 and 4, where the new return label instruction design is deemed not too effective to prevent drum mishandling. Only €311.000 can be recovered using these scenarios.

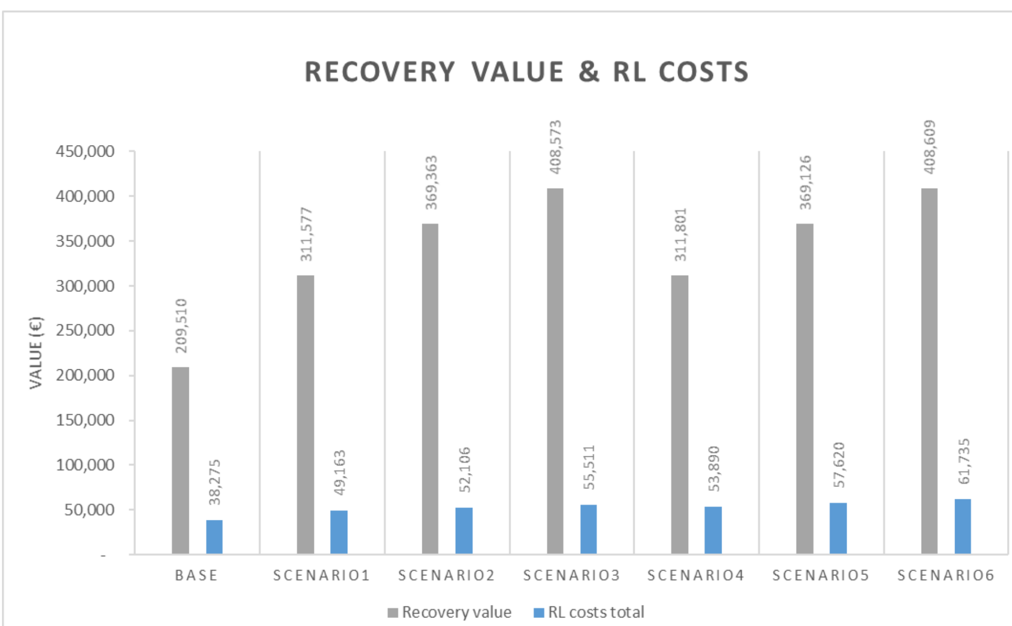

Figure 7-7 Comparison between recovery value, RL costs, and remaining value

Furthermore, the RL costs increase in all scenarios if compared to the base. The main reason behind this is more transportation requests for picking up the empty drums at customers' premises as the return rate grows higher. The increase in return rate also leads to higher drum management costs (for scraping, repairing, and cleaning), and environmental costs (inbound transport CO2 emission). As expected, introducing scheduled drum pickup at customers costs more than transferring the return flow responsibility to the wholesalers. Therefore, RL costs in Scenario 4-6 are higher than Scenario 1-3, where the wholesalers arrange the return flow in the latter. The highest RL cost is obtained by Scenario 6 at €61.000, whereas Scenario 1 yields the lowest with €49.000.

If compared, the recovery value from all scenarios outweighs the RL cost, including in the base scenario. It means that the drum recovery operations return positive monetary benefit to PYNL, in a considerable magnitude. The recovery profitability ratio is shown in Figure 5-4 in Appendix 5 also supports this notion. Even after taking into account the transportation costs, drum management costs, and environmental costs, this ratio still results in a value of more than 1. It suggests that a recovery operation is more than a break-even activity that promised a high potential of financial benefits. Moreover, Scenario 1 and 4 are responsible for the two lowest profitability ratios. As explained in previous sections, this is due to the lower scrap rate improvement in comparison to the rest of the proposed scenarios.

The drum purchase price in Table 6-9 Chapter 6, shows that the range of the drum prices is not comparable with the typical RPM in other applications. Drum DP4060K and DW4116K cost €[redacted] and €[redacted], respectively. Furthermore, the drums owned by PYNL range between €[redacted] based on the data in Appendix 3.2. In contrast, Limbourg et al (2016) in their research mention that the range of wooden pallets, plastic pallets, plastic boxes, and polystyrene box is between €9-36. In line with Gobbi (2011), a product with a high residual (financial) value, or drums, in this case, are worthy to be reconditioned and reuse. Therefore, RL costs do not hinder the appeal to recover the drums from customers since the recovery profitability shown in Figure 5-4 in Appendix 5 is at least threefold.

Ultimately, the second key metric in the study is the RSC efficiency shown in Figure 7-8. The RSC efficiency considers the recovery value at both EMF and wholesalers, in comparison to the RL costs, drum replacement costs, and environmental costs of the RSC. The top two best RSC efficiencies are accounted for in Scenario 3 and Scenario 6. An outstanding increase in RSC efficiency is related to managing the scrap rate in the RSC. This signifies the importance of the returned drum condition in which both scenarios have addressed better than the others. These findings align with the study of Kim et al (2014), where the return rate has to be complemented with the serviceability of the RPM.

All improvement scenarios, however, result in higher inbound transportation emissions of CO2, as explained in the environmental performance previously in Figure 7-5. It is a trade-off that has to be made according to Beiler et al (2020), as one cannot satisfy economic and environmental simultaneously. Nonetheless, looking further at the formulation of the RSC efficiency, it has accounted these externalities into monetary value. This made the evaluation of strategies much simpler with the ultimate measurement is shown in one dimension as RSC efficiency.

A non-return penalty helps not only to have more returns but ensuring the drums are well handled by the customers. Moreover, the different logistics configuration only shows marginal differences between both scenarios. It shows that either centralized return management with EMF, or decentralized management involving wholesalers, do not have a substantial effect on the RSC efficiency. The bottom two efficiencies are claimed by Scenario 1 and 4 with improvements only by placing a “do not drop” symbol in the drum label. It is not as effective as other measures as it depends on the user’s awareness to handle the drums with caution.

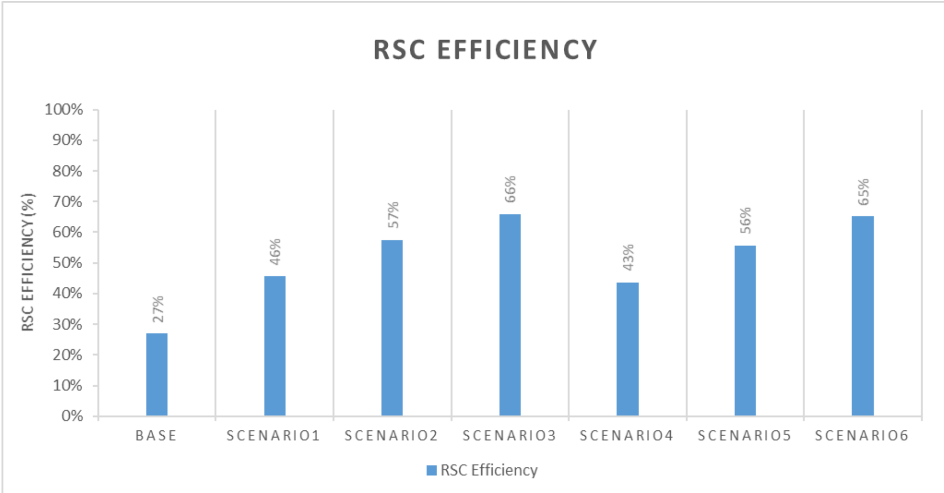

Figure 7-8 RSC efficiency

The improvement strategies developed in Chapter 5 prove to have significant impacts on the RSC efficiency as indicated in Table 7-2. The best strategy is achieved by Scenario 3 at 66%, a 144% increase in RSC efficiency compared to the base scenario. This strategy proposes RFID implementation at EMF and wholesalers, decentralized return flow involving the wholesalers, and a penalty system for non-returned and heavily damaged drums. The lowest improvement is claimed by Scenario 4 at 46%, utilizing RFID implementation, centralized return management flow by EMF, and a new return label design.

To assess the financial feasibility of implementing the strategies, a cost-benefit analysis is carried out in Appendix 6. The final result of the cost and benefit ratio (CBR) is shown in Table 7-3. All scenarios offer a positive CBR implying that all proposed strategies outweigh the investment costs. Scenario 3 claims the highest CBR, followed by Scenario 6. Scenario 4 is the lowest due to scheduled return pickup and leads to higher RL costs. The estimated benefit can be gained annually as long as the scrap, shrink, and return rates are maintained at the same level.

Table 7-2 Impact of scenarios on RSC efficiency

Scenario Name	Value	Δ Difference
Base	27%	-
Scenario 1	27%	68%
Scenario 2	46%	111%
Scenario 3	57%	144%
Scenario 4	66%	62%
Scenario 5	44%	107%
Scenario 6	56%	139%

Table 7-3 Cost benefit ratio

Scenario Name	CBR
Scenario 1	1.9
Scenario 2	3.2
Scenario 3	3.7
Scenario 4	1.6
Scenario 5	3.0
Scenario 6	3.6

Based on the results on RSC efficiency Scenario 3 seems to be the best strategy to implement in PYNL RSC, closely followed by Scenario 4. Even though there is a shorter RL cycle time in Scenario 4, the results imply that decentralized return management flow with the wholesalers outperforms the benefits of reducing customers processing LT. The difference, however, is not too significant by only 1% higher efficiency. Moreover, the CBR also shows that Scenario 3 returns the most benefits among the scenarios, again, followed by Scenario 6. Even though Scenario 1 and 4 only show modest improvement, the QR code and mobile app enhancements in both scenarios may feature better drum inventory forecasting.

Once the users scan the drum, a real-time update on inbound drums can be estimated at EMF. Nonetheless, the expected impact of this feature is outside the scope of this research.

7.3 Sensitivity analysis

The dynamics in the RSC operations always consist of a certain amount of uncertainty. To test the robustness of the potential improvement from the proposed strategies, a sensitivity analysis of RSC efficiency is carried out. The varying parameters used in the analysis are shrink rate, scrap rate, repair rate, customer process LT, and inbound transportation unit cost. In the figures below, five input parameters are tested, using a variation of +/- 10% from the specified improvement value in Table 5-7 in Chapter 5.

The first three scenarios propose a decentralized return management flow involving the wholesalers. Scenario 1 in Figure 7-9, shows that reducing the scrap rate has a higher magnitude of impact towards RSC efficiency at 8%, compared to increasing the scrap rate at -6%. This is a reasonable outcome because there is less scrap adding up to the RL costs. The effect of varying shrink rate almost has a similar size of the impact on the RSC efficiency at 1.5% yet in opposite direction. The repair, customer process LT, and inbound transportation unit cost only affect to a smaller extent. It also indicates that the fluctuation of RL cycle time does not greatly affect the RSC efficiency, given the large scrap rate. The dynamics in the improved repair rate for this scenario (5%) do not lead to a notable effect.

In Scenario 2 (Figure 7-10), changing the scrap rate by +/- 10% results in -8% and 9% on the RSC efficiency. It has a higher impact on efficiency than Scenarios 1. The main reason is that this scenario provides a larger scrap rate improvement than the previous scenario (10% instead of 5%), hence any fluctuation in the scrap rate is magnified. Similar to Scenario 1, the changes in shrink rate contribute to RSC efficiency at approximately 1% in opposite direction. The repair, process LT, and repair rate barely affect the efficiency.

The RSC response towards the fluctuation of scrap rate in Scenario 3 (Figure 7-11) has similarities with those in Scenario 2. Lowering the scrap rate leads to 10% RSC efficiency improvement, in contrast to -8% for upping the rate. A consistent explanation also applies for this and Scenario 2, accounting for the effect of higher scrap rate improvement (15% vs 10%). The increase and decrease in shrink rate result in 1% changes in both directions.

The last three scenarios incorporate scheduled empty drum pickup for the logistics configuration. Scenario 4 in Figure 7-12 shows an observable difference when varying the scrap rate by +/-10%. Because the scenario scrap rate improvement is rather small (5%), hence further reducing the scrap rate increases the RSC efficiency by 9%. Similar results Marginal effects can be observed for changes in repair rate, customer process LT, and inbound unit cost.

Figure 7-13 and Figure 7-14 show the sensitivity of Scenario 5 and 6 respectively. A similar phenomenon can be observed for impacts in varying the scrap rate, where reducing scrap rates returns better RSC efficiency. The impact of shrink rate, particularly in Scenario 6, is the highest among all scenarios at 2% in both directions. This is because the scenario offers the highest improvements in terms of return rate (25%) and shorter customer LT (30%). Therefore, any fluctuation in the scenario is magnified.

Useful insights from the sensitivity analysis are: first, all scenarios are most sensitive towards fluctuation in scrap rate. Therefore, it is rational to focus on reducing the scrap rate as an immediate response. This is also consistent with the performance discussion in the earlier section. Second, RL cycle time only has a marginal effect on RSC efficiency. This might be caused by the scrap rate overpowering the benefits of a shorter lead time. As specified in Table 5-5 in Chapter 5, the logistics configuration for Scenario 4-6 offers shorter customer process LT by 10% if compared to the wholesaler return flow logistics design in Scenario 1-3. The sensitivity analysis shows that even with further reduction in RL cycle time, no substantial improvement is found.

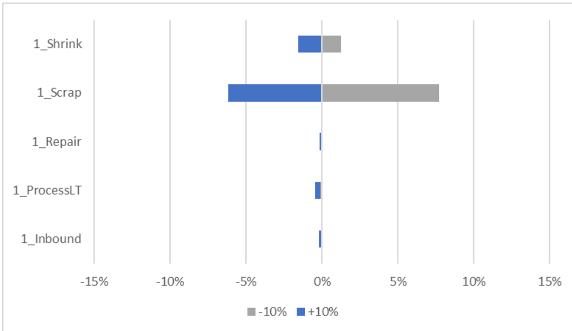

Figure 7-9 Sensitivity of RSC efficiency Scenario 1

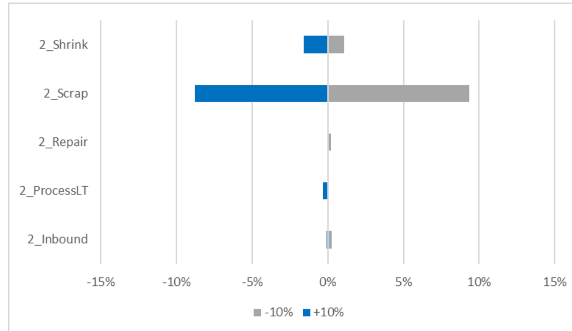

Figure 7-10 Sensitivity of RSC efficiency Scenario 2

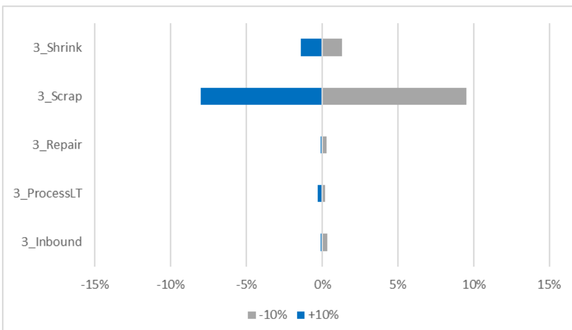

Figure 7-11 Sensitivity of RSC efficiency Scenario 3

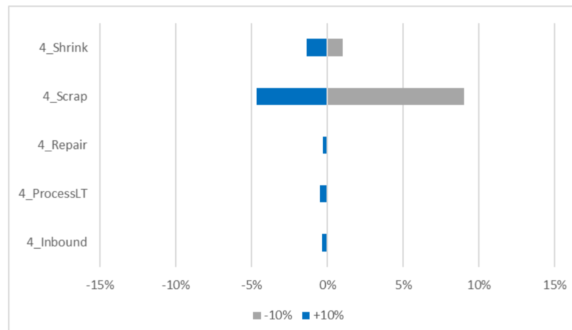

Figure 7-12 Sensitivity of RSC efficiency Scenario 4

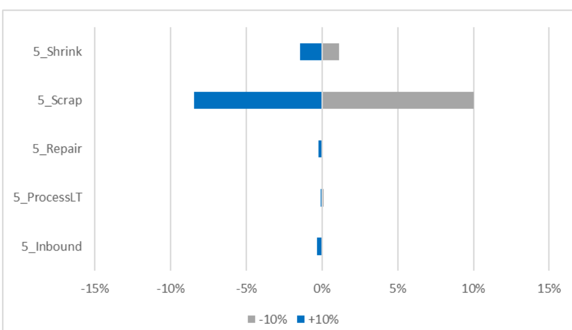

Figure 7-13 Sensitivity of RSC efficiency Scenario 5

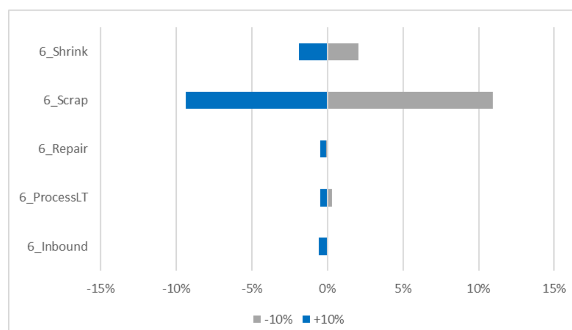

Figure 7-14 Sensitivity of RSC efficiency Scenario 6

7.4 Conclusion

In this chapter, simulation experiments are performed. The simulation is based on the model inputs presented in Chapter 6. The scenarios from Chapter 5 are examined in this section, with specific simulation configurations stated in Section 7.1 above. Final simulation outputs are then obtained from these processes. Thus, the following sub-research question can be answered:

How do the proposed strategies perform in terms of the transport logistics performance of the RSC?

The proposed strategies are examined in six scenarios. The key two metrics are RSC efficiency and RL cycle time, as stated in the main research question. Each scenario incorporates an RFID implementation, that can increase visibility in the RSC to the item level. RFID implementation provides better visibility across RSC, therefore the RL cycle time decreases in all scenarios. The regular pickup schedule solved the return uncertainty issue against a higher RL cost. The non-return penalty proves its effectiveness in minimizing the RL cycle time. It requires 21 days after dispatch from EMF until it returns, after being held at the wholesalers and small installers. On the other hand, it takes 16 days for the cycle via the large installers. The worst performing scenario is claimed by Scenarios 1 and 2. In Scenario 1, PYNL relies on the customer's willingness to submit a return request via the QR code and mobile app. Improving engagement with the customer takes place in Scenario 2, where only modest improvement is expected. Moreover, shorter RL cycle time also influences the mean inventory level with Scenario 5 and 6 to have more drums in stock at EMF among all scenarios.

The improvement strategies have substantial impacts on the RSC efficiency. The best strategy is achieved by Scenario 3 at 66%, a 144% increase in RSC efficiency compared to the base scenario. This strategy utilizes RFID implementation at EMF and wholesalers, decentralized return flow involving the wholesalers, and a penalty system for non-returned and heavily damaged drums. The lowest improvement is claimed by Scenario 4 with RFID implementation, centralized return management flow by EMF, and a new return label design. The cost-benefit analysis shows that Scenario 3 has the highest CBR rate at 3.7.

PART VII - RE-EVALUATE

8

Conclusion & Recommendation

8.1 Main Conclusion

This chapter provides the main conclusion and recommendations for the research. The answer to the main research question will be elaborated in the sub-research questions below:

1) How does literature describe returnable packaging material in the context of the reverse supply chain?

The review of the relevant literature suggests that economical and logistical aspects are dominating in RSC evaluation, despite the increasing demand on incorporating sustainability aspects. Moreover, the RSC encourages the returns of RPM, thus it differs from RSC for non-returnable products. The residual value of an RPM determines the feasibility of RSC and the recovery options. The increasing raw material price for cable drums makes the reuse of this RPM an imperative task.

The approach to developing RSC strategies may be rooted in logistics system design, technological implementation, or compliance strategy. Even though a successful RSC operation demands both technical improvement and proper management actions, these studies typically examine the strategies only from one of the approaches. Therefore, compliance strategy takes a different step by getting into a more managerial approach. It aims to encourage return behaviors from customers.

2) How can reverse supply chain performance be measured and evaluated?

The RSC performance can be measured by evaluating through multi-dimensional aspects. Trade-offs that reflect real human behavior can only be reflected if assessed through various perspectives. The proposed metrics incorporate financial, process, customer, and environmental perspectives. This approach can help related stakeholders evaluate the feasibility of potential improvement strategies. Furthermore, simulation methods allow evaluation from multiple perspectives in RSC performance.

3) How is the current supply chain structured and performed?

PYNL uses cable drums as transport packaging. In the current state, there is an imbalance between the outbound and return flow. This implies a financial loss from the low return and reuse of the drums shipped to the customers. The current wooden and plastic drums return rates are 40% and 29%, respectively. On the other hand, the reuse rates of wooden and plastic drums are 31% and 0.6%, respectively. Hence, PYNL has to replace the shortage of drums which leads up to a significant cost. The drums with the highest shrink and scrap value are wooden drum DW4116K and plastic drum DP4060K.

Furthermore, the empty drum recovery operations promise positive financial returns. However, only PYNL will reap such benefits since it is not shared equally across stakeholders. The challenges in the current operations are RSC visibility among related stakeholders and customers’ willingness. The latter may be caused by unequal benefits distribution mentioned earlier.

4) How can the RSC performance be simulated and assessed?

A simulation model is built to assess the impact of RSC improvement strategies. Discrete Event Simulation (DES) is used to perform "what-if" analysis over complex and interrelated components in the RSC. The RSC performance can be measured from multiple perspectives: process, environmental, customer, and financial. This holistic evaluation can provide a better picture in terms of trade-offs. The process metrics measure the performance in the logistics aspect of the RSC. The environmental metrics assess the externalities of such RSC performance to the environment. The customer metrics indicate how the customers are affected by the RSC operations. The financial metrics highlight the monetary gains and losses from the RSC operations. Ultimately, RSC efficiency can be determined by estimating the recovered drum value and the resulting costs of RSC operations. RL cycle time can be defined from the time of a drum leaving and returning to the shipper.

5) What alternative reverse supply chain strategies can be proposed?

RSC improvement strategies may branch from three approaches: technological implementation, logistics system design, and compliance policy. Tracking technology such as RFID is mandatory to improve visibility in the RSC. Logistics network design aims to increase RSC performance by sharing the return management responsibilities with the wholesalers. A regular pickup schedule may be the potential to reduce the uncertainty in return and increase customer awareness. To influence the customers' willingness in participating in drum returns, several steps can be taken. This can be achieved by simplifying and streamlining the return requests by using mobile apps. Another approach is to increase customer engagement from moral and legal aspects. Better communication is also deemed effective to improve the rate of the drums. Lastly, a penalty system may be implemented as an aggressive strategy to ensure more drums are going back to PYNL. The developed strategies are considered to have impacts on the shrink, scrap, repair (SSR) rate, process LT, and inbound transport unit cost.

6) How do the proposed strategies perform in terms of the transport logistics performance of the RSC?

Each scenario incorporates an RFID implementation, that can increase visibility in the RSC to the item level. RFID implementation provides better visibility across RSC, therefore the RL cycle time decreases in all scenarios. The regular pickup schedule solved the return uncertainty issue against a higher RL cost. The non-return penalty proves its effectiveness in minimizing the RL cycle time. It requires 21 days after dispatch from EMF until it returns, after being held at the wholesalers and small installers. On the other hand, it takes 16 days for the cycle via the large installers. The worst performing scenario is claimed by scenarios using QR codes and mobile app. In this scenario, PYNL relies on the customer's willingness to submit a return request via the QR code and mobile app. A better customers engagement offers modest improvement if compared to other strategies. Moreover, shorter RL cycle time also influences the mean inventory level in terms of stock at EMF.

The improvement strategies have substantial impacts on the RSC efficiency. The best strategy is achieved by Scenario 3 at 66%. This strategy utilizes RFID implementation at EMF and wholesalers, decentralized return flow involving the wholesalers, and a penalty system for non-returned and heavily damaged drums. The lowest improvement is claimed by Scenario 4 with RFID implementation, centralized return management flow by EMF, and a new return label design. The cost-benefit analysis shows that scenario 3 has the highest CBR rate at 3.7.

7) How can the returnable packaging material in a reverse supply chain be improved in terms of RSC efficiency and return cycle time?

The research suggests that improving the return and reuse rate leads to a higher recovery profitability ratio, i.e., financial benefits. This is more promising if the RPM has a high residual value such as cable drums where it can be reconditioned and reused. Therefore, the costs from RL activities do not discourage the attractiveness to recover the drums from customers. An increase in inbound transportation costs also does not have any considerable effect.

In terms of improving RSC efficiency, it can be said maintaining an RPM condition has the utmost importance. Recovering damaged drums from customers only leads to pure cost from transportation and scrap activities. This also should be considered when setting up a return flow in the wholesalers' supply chain. Failure to ensure drum integrity from end customers incur bigger financial impacts from setting up the return flow, in addition to the scrap cost. The sensitivity analysis also suggests that RSC efficiency is highly sensitive to changes in scrap rate. On top of that, the drum service level at the wholesalers will be lower, since they receive damaged and unusable drums instead of directly reusable drums. It can also lead to stockouts due to miscalculation of future inventory stock. The impact of the improvement scenarios can be found in Table 8-1.

Increasing the return and reuse rate results in higher CO_2 emissions. The increase in CO_2 emission from inbound transportation is a consequence of a higher return rate. This trade-off is inevitable as one cannot satisfy economic and environmental at the same time. However, considering the way RSC is formulated, the externalities are already accounted for as monetary value. This allows easier judgment on which scenario performs better overall.

In addition, shorter RL cycle time only has a marginal effect on RSC efficiency. This might be caused by the scrap rate overpowering the benefits of a shorter lead time. The sensitivity analysis shows that even with further reduction in RL cycle time, no substantial improvement occurs. The improvement in RL cycle time can be seen in Table 8-2.

The RPM management in an RSC can be improved with strategies branching from technological implementation, logistics system design, and compliance policy. The use of RFID can increase RSC visibility, allowing resource allocation to focus on specific customers and better stock accuracy. The decentralized return management flow involving the wholesalers does not provide substantial advantages in comparison to centralized management by PYNL. The QR code and mobile app enhancements perform the worst in comparison to other strategies due to their dependency on customers participation. However, they could upgrade the drum inventory forecasting by real-time stock calculation. Aside from their promising benefits, the strategy using non-return may impose a business risk where the customers can get discouraged from such policy and switch to another brand.

Table 8-1 Improvements in RSC efficiency

Scenario Name	Value	Δ Difference
Base	27%	-
Scenario 1	46%	69.5%
Scenario 2	57%	113.5%
Scenario 3	66%	145.0%
Scenario 4	43%	61.8%
Scenario 5	56%	106.6%
Scenario 6	65%	142.2%

Table 8-2 Improvements in RL cycle time

Return flow owner	EMF	EMF	Wholesaler	EMF	EMF	Wholesaler
Via	Small Installers	Large Installers	Small Installers	Small Installers	Large Installers	Small Installers
Unit	days	days	days	Δ Difference	Δ Difference	Δ Difference
Scenario Name						
Base	38.2	22.8	-	-	-	-
Scenario1	26.5	19.6	7.0	-31%	-14%	-
Scenario2	26.3	19.6	7.0	-31%	-14%	-
Scenario3	24.3	18.5	6.6	-36%	-19%	-
Scenario4	22.8	17.5	-	-40%	-24%	-
Scenario5	22.7	17.5	-	-40%	-24%	-
Scenario6	21.1	16.4	-	-45%	-28%	-

8.2 Recommendations

The following recommendations serve two purposes: practical recommendations for Prysmian Netherlands and scientific recommendations for future research.

8.2.1 Recommendation for Prysmian Netherlands

- Efforts should be made first to address the reuse rate, then followed instead of more returns. Failing to acknowledge the role of scrap rate will result in pure losses from inbound transportation and scrap activities. The same consideration should be taken into account when setting up a return flow for wholesalers, ensuring that all the drums' conditions are maintained.
- Increased RSC visibility through RFID implementation has to be followed up with tangible actions. PYNL can start with better customer engagement, thus avoiding huge financial investment ahead.
- The financial benefits generated in this research are aimed at PYNL. Hence, the company can consider implementing a policy sharing the benefits, and possibly also the cost of investment with the stakeholders to attract their participation.
- If PYNL is considering replacing the existing drums with more robust materials, then further analysis has to be done to understand how tough the drums are compared to the current. This will determine whether the scrap rate indeed improved.
- The investment costs in the cost and benefit analysis are based on available literature and estimations. Hence, further analysis should take place to ensure CBR validity.
- The information exchange between the shipper, transporter, and Prysmian should be improved. The management of transportation data is currently considered as the responsibility of the transporter. Therefore, the quality of input data relies on the transporter.
- During the interviews with stakeholders, it is found that return activities are not monitored continuously. Measuring such rates is important to improve the RSC, hence sufficient resources and focus should be allocated.

8.2.2 Limitation and recommendation for future research

- The MCA analysis and strategy selection could be improved by involving customers and key stakeholders directly. By doing so, it can result in higher validity in capturing the real behavior of key stakeholders.

- The impacts of managerial and organizational initiatives are based on limited literature and assumptions. Hence, a more accurate impact estimation can improve the accuracy of the proposed strategies.
- The product demand from the customers is assumed to follow a Poisson probability distribution due to data limitations. Hence, a distribution that is based on well-structured data can provide more accuracy in estimating the RL cycle time.
- The research only examines one wooden drum and one plastic drum in the year 2020. Therefore, it is recommended to use bigger data sets with a wider time range. This allows a general overview of the whole RSC performance; hence, more representative outputs can be derived.
- All suggested improvement scenarios utilize the RFID technology. Any firm certainly requires a certain amount of time for tagging the existing RPM circulating along its supply chain. Therefore, it is interesting to find out how to manage the RPMs during this transition period.
- Improved visibility through RFID generates a lot of data in terms of time and location. One can use these data sources to forecast the return rate of the RPM in the future.

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Appendix 1

Interview Results

1.1 Interviewee A

Job title: Director of Commercial Trade & Installers, Prysmian NL

22nd June 2021 15.00 CET

Functional Overview Appendix

1. **Could you tell me about your function and its goal?**
   The function comprises the sales team, customer care, product management, and marketing. There are 5 business managers involved. We are responsible for brands: Draka (low voltage) and Prysmian (medium voltage) in NL to markets such as wind parks and solar parks. 80% of the business is coming from Emmen via the wholesalers.
   Currently, the wholesalers receive cables in bulk form. For big cable drums, the wholesalers are [redacted] (part of [redacted], the biggest wholesaler globally), [redacted], [redacted], where [redacted] and [redacted] handle smaller cable drums. Prysmian owns the drums and they have to be returned after use.

   Draka markets are low voltage installers (e.g., houses, large construction areas) where 95% of products are sold via wholesale and 5% sold direct using FTL shipment. We sometimes drop ship our products directly to installers who are ordered via the wholesalers due to size.
   The wholesalers can wind and cut cable they receive as stocks from Emmen. For example, [redacted] receives thousands of items from Draka in stock and cuts the cables into smaller lengths based on customer requests. The wholesalers can make 1500 cuts per day.

2. **What factors do you focus on in your function?**
   Sales, contribution margin, sustainability, key customers, and the number of projects acquired. The function is also concerned with planning in combining orders via the wholesalers.

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI).**
   We measure how many people are using, how many new users (based on the sales system). We work together with the wholesalers to know which and how many products we sell to which customers. In general: market share, costs, sales volumes, contribute to margin.

4. **What kind of information do you collect and manage for that performance measurement?**
   We collect Internal costs, volumes, margins. An external organization publishes "Marktmeter" regarding the market share based on figures from the wholesaler.

Drum return process

5. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**

Information regarding how many drums do we buy, how many loaded drums do we sell, and how many drums we send out for free, and how many returned. The information is mainly exchanged internally, yet sometimes for external purposes with wholesalers if drum return is low.
The cost ratio of drums depends on the type of cables and drums. Some items cost between [redacted] some cost as little as [redacted]

6. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have? What difficulties you are likely to face?**
   We are very interested since we have to recycle more for sustainability reasons. We purchase fewer new drums, less volatile towards the wood price, thus cost wise it's interesting. We don't have to send the wholesalers trucks loaded with new empty drums. We want to have green images as a company, which is regularly discussed with wholesalers and installers.

7. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines)**
   Because many drums are going back to the wholesale and often it's too difficult to send it back. Sometimes installers are collecting them for a project if only there are many empty drums in the area. On another hand, it's easier to neglect only 2 drums (even if it's big drums) rather than arranging transport for drum return. Accessibility to pick up the drums is also an issue (e.g., if it's located in the city center).
   Wholesalers were not so receptive back in the days, since the trucks has limited capacity for an extra empty drum pickup. There are [redacted] customers of which one-third are small installers.
   For example, in one local installer, they collect the drums but we're not motivated to arrange the pickup.

Solution and requirements

8. **What kind of strategy do you think might work, from your function's perspective?**
   It should increase the awareness among the customers to not throw them away. Another strategy should make arranging drum returns much easier and simpler. Crowd shipping apps for empty hauling trucks could be useful. In addition, QR-coded plastic drums return more often than other drum types. Thus, the wholesalers require fewer new drums.
   Currently, wood supply is hard, prices go up, thus higher drum return rate is important. Initiatives such as "Haspel Retour" involve QR code scanning to notify between 5 wholesalers to pick them up from the installer. They can pick up small to big drums.

   There is a running pilot project called "De Groene Boog" on the medium voltage drums coming from Delft. Due to the high copper price, the customers are afraid someone will steal the drums. They placed a sensor device from Alesea (www.alesea.com) to 3 big drums out for several months. The sensors can track location, activities, cable usage, temperature, and other intelligent features. However, the device costs [redacted] that proves too expensive for smaller Draka drums in Emmen, which costs around [redacted].

9. **What kind of strategy/initiative you can contribute to your function?**
   There was a deposit system that we implemented on thousands of drums. The administration tracking is complicated. Determining the fair deposit cost is also difficult.

10. **To what extent do you support the drum return initiative?**
    We will always support this initiative since it's a part of our business model. It's included in the annual KPI to improve the drums returned, also to send fewer new empty drums to the wholesalers.

1.2 Interviewee B

Job title: Purchasing Manager Metals and Transport, Prysmian NL

23rd June 2021 14.00 CET

Functional Overview

1. **Could you tell me about your function/department and its goal?**
   I am a member of the purchasing department and responsible for base metals (the most expensive part of the cable), steel drums, and also transportation (approximately €9.5 million, mostly for Emmen). The goal is to purchase goods as economically as possible in the best quality and in a sustainable way.
   The sustainable supplier is selected through a tender followed by approved suppliers in which they have to satisfy certain requirements. In the transport world, there is a green and clean star which shows how the company follows sustainable practices. A company should meet some requirements to get a star. The transporter, as the trucking company, aims to obtain its third star next year. The third star requires collaboration with the customers (i.e., Prysmian).

2. **What factors do you focus on in your function?**
   We focus on cost, quality, sustainability. For transport, we focus delivery time in full. We measure this on monthly review to our suppliers. For [redacted], we have weekly targets in terms of delivery time, missing goods (manco), regular delivery performance in 24/48 hours, special delivery performance (with an additional surcharge), empty drum timely performance, and return flow (non-conformity due to damage/reject).

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI)**
   Spot savings (non-recurring negotiation) typically for projects, thus tender only in the beginning. In addition, recurring savings and report per purchasing.
   For transportation: delivery time, missing goods, regular delivery performance in 24/48 hours, special delivery performance (with an additional surcharge), empty drum timely performance, and return flow (due to damage/reject).

4. **What kind of data do you collect for that performance measurement?**
   Purchases for recurring and non-recurring projects. There is also an annual savings target.

Drum return process

5. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**
   We arrange transportation with [redacted] for the return drums. The warehouse logistics place an order for drum return transport. We manage the contract regarding the transport costs. [redacted] has been our partner for the last 5-6 years. They have special trucks with cranes, trailers and there are limited trucking companies with such capacity. [redacted] is closely located and have a storage facility on their premises.

6. **How hard is it to get the transporter on board on new initiatives?**
   It was very difficult; it took 8 months to complete. We have to ensure they satisfy all of the tender requirements one by one. [redacted] currently hires additional trucks to serve Prysmian, since the load is very high.
   The lack of shared information also becomes an issue. [redacted] demands shipment data before the pickup, in which Prysmian hasn't been able to provide direct access to the company's database. EDI connection is preferred, but for the last 5 years, we use only TXT data. They require this information for the "biggest" list between 16.00-19.30, and for an additional (second) list before 22.00. [redacted]

labels the drums before shipment.

7. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
   It's not due to transport reasons as shown by the KPIs and graph. Lots of wooden and plastic drums are returned but damaged. Thus, we buy much more than what is returned.
   Our function supports this initiative because more return means better sustainability and cost savings. Plastic drums are recycled easily since it's PP plastics, but wooden drums can either be recycled or incinerated. The drums are no longer used if they don't comply with our specifications or are severely damaged. The transportation company has to ensure the safety of the drums during shipment.

8. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines)**
   Material durability for plastic drums is not for heavy-duty purposes. However, the cost of using heavy-duty vs standard plastic drums is not yet calculated.

Solution and requirements

9. **What kind of strategy do you think might work, from your function's perspective?**
   I am not involved in the process; thus, we do not have any suggestions. If using a deposit scheme, then each drum has to have a unique ID code. Using a GPS tracker also can be useful for bigger drums. Bigger customers are also against the deposit scheme.

10. **What kind of strategy/initiative that your function can contribute?**
    I am not involved in the process; thus, we do not have any suggestions.

11. **To what extent do you support the drum return initiative? (CO2 examples).**
    We're supportive of the initiative, but since I am too far out in the process, we don't have a limitation as such.

1.3 Interviewee C & D

Job title: Supply Chain Manager (C) & Logistics Manager Delft (D), Prysmian NL

28th June 2021 16.30 CET

Functional Overview

1. **Could you tell me about your function and its goal?**
   There are two specific areas, the first is related to the central logistics (demand and supply planning) for NL and abroad, and the second deals with internal logistics within the factory. The central logistics deals with the sales dept and customer to translate the market demand into volumes that the plants have to produce. The production stars are based on the customer-requested lead time.

   The internal logistics manages the 3 factories in NL, Delft, Nieuwe-Bergen, and Emmen. The function is responsible for the end-to-end supply chain including sourcing raw material (within production frame), catering for the production in the factory, and storage of finished goods. Three pillars of internal logistics consist of material management, planning and execution, and physical distribution.

2. **What factors do you focus on in your function?**
   The internal logistics aim to have a helicopter view over 3 different aspects (material management, planning and execution, and physical distribution). The connection between the departments is also maintained to have an effective production flow. We aim to provide the right cable at the right time for the customers, and efficiency. We are always involved in the discussions.

   The central logistics focus on service level and control of the factories to ensure reliable output from the factories.

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI)**
   The SC department measures on-time delivery and compliance to wish date. On-time delivery in full (OTIF) based on the confirmed dates wish date (what the customer is requesting). The wish date is typically earlier than the confirmed dates. Other KPIs such as the order book, the order intake, future performances of recurring orders (ensure customer retention). The future purchase performance information is used to determine the planning of sourcing, production, and resources. Inventory value and the number of inventory days also become targets for the function that needs to be monitored. The drum return is recently added, measured based on how many drums have been returned and how many drums we have reused in the factory.

   The internal logistics monitors demand, supply, and inventory levels. For example, the number of drums on stock and the remaining storage capacity in the factory. We focus more on operational KPIs and report it on a month to date (MTD) which includes production, sales, and inventory development in a certain period. Material balance is also monitored (raw material, finished goods).

Drum return process

4. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**
   The MTD report is shared internally with the operational team and the management. The information covers the progress of production, sales, and inventory.

   For central logistics, that depends on which factory. In Delft, the number of drums circulated is lower, mainly wooden and steel drums. We have a contractual agreement for the drums either to be picked up or shipped back to the factory. RFID tags are placed on drums that can record specific drum locations and update the status in SAP. The drums are scanned again once they are returned and become stock in the factory.

An invoice will be issued if the customers don't return the drums within one year. This is possible since there is a specific drum number on the drums (thus it's traceable). The drum size in Delft doesn't vary that much, only between 2.00-2.80 m. The customers' portfolio is also not as complex as Emmen's. The cost of each tag is around [redacted].

5. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
   We have a very high interest in which we include the drum return in the performance appraisal process and sustainability target. Some obstacles noted are unwilling/unmotivated customers to participate since they perceive differently than us. Currently, they're more focused more in green transportation, but haven't explored the impact of returned drums on sustainability.

   It's in the interest of everyone to maximize the return. We need to get the customers and suppliers on board with sustainability initiatives and convince them.

6. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines).**
   We need to put more focus, commitment, and resources on this issue. Additional tools need to be developed (e.g., QR code). Streamlined mechanisms and processes are key. Other variables impacting the drums' return might be customers' behavior towards the drums. Customer's drawing marks and installation messages can be avoided by good communication. In the past, we can ask them to clean the drums before returning.

   We also have to communicate with the drum manager to scrap less and more repair, so that they're more careful with drums received.

Solution and requirements

7. **What kind of strategy do you think might work, from your function's perspective? And What can you contribute to your function?**
   The commitment, the focus, the process, and the system for the drum return in Delft are quite good. The system uses RFID proved to be successful. The cascading from the management to the operational level showed the focus of the company. The point of improvement could be the quality of the drum returns.
   A streamlined internal process will improve the return. Launching an effective campaign to involve them and show to customers how big an impact they can make by doing so little. An average of [redacted] per drum can be billed, sometimes charged up to [redacted] A successful campaign in the past (from the T&I segment) involved the wholesalers. We used a camera can read the QR codes and took almost no time for the drums can be picked up.

   With higher drum returns, we can optimize trucks usage only for domestic transport in NL, not from abroad. Thus, we can achieve more sustainable practices.

8. **What difficulties you are expecting if we increase the drum return rate?**
   We may face difficulties from unreliable customer sales forecasts. If they're overordering in one period, we will receive lots of stock in the factory. A reliable baseline of customer forecast is important. Storage issues may appear but only temporarily since the drums will be sent out again. Workload could be a potential issue in The drum manager since they require more resources.

9. **To what extent do you support the drum return initiative?**
   Customers are all willing to participate and collaborate as long as it doesn't interrupt their daily activities. The return flow has to be very smooth and requires zero/minimum effort.

1.4 Interviewee E

Job title: Branch Manager Remondis BV

29th June 2021 11.00 CET

Company and Functional Overview

1. **Could you tell me about your company and the goal?**
   Remondis is a waste collection and recycling company, part of the Redman group. The facility is situated in Ermelo. The goal of the company is to be more sustainable by promoting the reuse of materials and recycling wastes.

2. **What main factors affect your company business?**
   Macroeconomic factors in the Netherlands, amount of waste available, quality of the employee, the trucks and drivers available, law and regulations, and the quality of the wastes.

3. **How currently does Prysmian respond to your campaign/initiative?**
   It depends on the case. Prysmian has responded well so far in initiatives that align with their interests. It's not that easy to ask for a change (e.g., in the process) since we don't know the impacts on their customers, employee, etc.

4. **What kind of information do you collect and manage during performance measurement?**
   The amount and type of waste (PP or wood), the price of collection and recycling, number of trucks used.

Drum return process

5. **Could you explain the processes you have that are related to the drums? And if you can also tell me what information you share with whom during the processes?**
   There are three types of wastes, both for wooden or plastic drums:

   - A-type: This type of waste has the best quality i.e., no paint and no impregnation against rain or sunlight. The options for A-type wooden waste are: a) bring to biomass center to be incinerated for power generation, or b) recycled into stamplaat, MDF, or pellets.
   - B-type: This type of waste has paint on it, or was made of multiple wood (stamplaat). The options are a) recycle into reused wood or b) incinerate in a special-licensed biomass center
   - C-type: This is the lowest quality of waste. The only option is only to incinerate in a biomass center specialized for C-type waste.
   - The treatment for all A, B, and C-type PP plastics is to break them down into small pieces (granulates) and recycle them into reused plastics. XLPE (cross-linked polyethylene) plastics can only be incinerated.

   In Emmen, there are only A or B-type wastes generated. The process starts from knocking down the drums into smaller pieces in The drum manager, before delivery to Remondis. Prysmian categorizes in which type these wastes fall. Prysmian then sends information regarding the amount and type of waste (PP or wood). Remondis sends the truck with empty waste containers and exchanges them with the loaded containers at Emmen. The wastes are sent to a recycling plant and Remondis issues an invoice and reports to Prysmian.

   On the other hand, plastic drums are broken down into pieces of granulates, before being tested for quality. Prysmian then is informed about the results and sold the granules to Remondis as an intermediary to the recycling market. Recycling plants buy these reused plastic granulates. Unlike wooden waste treatment, Prysmian receives income from selling the plastics.

   To collect the drum waste, there are special trucks for pick up. Currently, there are 40 trucks available. The wastes are picked up using containers for wood, plastics, or paper (burrows, press, or 40 cbm containers).

6. **How are the conditions when you receive the drums?**
There are wooden drums that contain metal on them, thus requiring segregation later on. Some drums still have cables on them during pickup. Most of them are A or B-type waste. The form factor (dimension) of the drums is also important (should be less than 2.20 m) unless it'll be an issue for transportation.

7. **What do you think of the Prysmian initiative to increase the drum return? How interested are you? Would it be good or bad for your company?**
It's a good initiative, we support the effort to be more sustainable. However, we are a waste collection company, thus we are driven by the amount of waste available in the market. Since the drums are used internally by Prysmian, we are too far out and our contribution is limited in the drum return.

8. **How much capacity is used for serving drum waste? Scraping and incinerating?**
Prysmian currently delivers 300 tons/year of wood and 285 tons/year of PP. With this amount, we do not have any capacity problem, even if the demand is doubled/tripled.

9. **What factors affect the number of drums sent to your company? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines).**
We are too far out in the process.

Solution and requirements

10. **Do you have any ideas that might work for both Prysmian and Remondis to be more sustainable, in terms of usage of drums?**
We can consider to:
    - Maintain the purity/quality of the waste by not mixing the material.
    - Reuse the drums more frequently in the internal chain
    - Repair more drums
    - Use more recyclable material, (i.e., use PP more instead of XLPE plastic)
    - Prysmian can use the Ladder van Lansink approach so that fewer drums are used if possible.
    - The dimensions of the waste should fit with the incineration plant requirements. Plastics that are too big couldn't be fully incinerated and leave solid residues.

11. **What factors matter to you to participate with new initiatives from Prysmian?**
Sustainability. Prysmian should maintain high-quality waste by not mixing all types of wastes. Therefore, maintaining quality is important.

1.5 Interviewee F

Job title: Business Manager Wholesale

30th June 2021 15.00 CET

Functional Overview

1. **Could you tell me about your function and its goal?**
   We are a sales department who are responsible for sales, including Draka brand for traders and installers. There are a lot of business units, where 90% is dominated with Traders and Installers (T&I) business. The goal is to ensure sufficient products on stock at the agreed stock level at wholesalers, thus no need for rush orders, extra handling, cutting, and cost. In general, we aim for better performance at the wholesalers.

   We manage the wholesalers in terms of negotiating purchase prices and product portfolio in the wholesalers (items that should be on stock). We collaborate with every customer care, sales team, and logistics. We ensure the demand forecast from the wholesalers is in place in the production so that the stock position will be fully in line. In supplying the wholesalers, there is currently around 40% direct cutting sent from Emmen and 60% of cutting is done at the wholesalers.

2. **What factors do you focus on in your function?**
   We focus on product stock levels at wholesalers, smooth operation, less cost due to direct cutting and rush delivery. Currently, the agreed on-time delivery (OTD) with the wholesalers is 98%, aggregated from various product categories (Category A-F, N, Rest) as shown in the table below. The table is the dashboard between [redacted] and Prysmian.

   Class A, B, and C products are runner type (MTS) that must always be available in the wholesalers. Class D and E products are runner types for Prysmian but are considered custom orders by the wholesalers. The F, N, and rest product classes are custom orders.

Product Class	**Service Level**	**Target**
A	97.6	99
B	[redacted]	
C		
D		
E		
F		
N		
Rest		

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI)**
   We based the performance on our compliance towards the customer delivery wish date (e.g., for MTS product: 2 days lead time + 3 days delivery).

   The wholesalers have a KPI dashboard for Prysmian which consist of:
   - Purchases realization from Prysmian (MTD and YTD 114%)
   - Selling realization to customer (MTD and YTD 123%).
   - Delivery reliability (too early, on time, and too late) for on-stock (MTS) and non-stock items.
   - Agreed vs actual delivery volumes in the wholesalers.
   - Service level for the past 12 months and 35 days

- Number of orders per order method (EDI, email, print, voice call)
- Monthly forecast for the next 3 months
- Number of unsold items for the last 3 months
- Value of backorders
- Rush delivery for stock items
- Sales based on last year, 3-months sales, and seasonal pattern

Drum return process

4. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**
   Sales forecast information (volume and type) is passed on to the production and logistics. This gives an estimate for resource allocation.

   For the drum return, it started 2 years ago. There is a website (www.draka-haspelretour.nl) where customers can order pick up and fill in the information for drum return. The information regarding the number of drums, sizes, is sent the transporter. The drums less than 120 cm will be picked up by the wholesalers with their transportation, and the bigger drums are picked up by [redacted]. If the wholesalers do not have enough empty drums after they cut the cables, Prysmian will send empty drums to them.

   The current return rate for the big drums is 40%. Most of the smaller drums are made of plastics.

5. **Why does the return rate for certain drums are higher (up to 3 times) than the other?**
   The return rates for specific types are higher because they are used by specific customers who require specific cables. Because these customers are responsible for the drums. Thus, bigger drums have higher return rates than smaller drums.

6. **How about your competitor, do they collect drums and face the same issue with the drums?**
   Our competitors do not manage the drum return, and indeed, they eventually have to account for the cost of lost drums in their margin calculation. They also experience a shortage of drums and an increasing wood price.

7. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
   We are supporting the drum return. Our concern is that the wholesalers bear the cost of the return flow. It can reach [redacted] for managing the drums. The increasing wood price leads to an increase in drum price. Even in this condition, Prysmian is sending free empty drums to the wholesalers.

8. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines).**
   Last year, there are [redacted] drums sent out valued at [redacted], consisting of [redacted] loaded drums valued at [redacted], and 14.550 empty drums valued at [redacted] to the customer. Thus, at least a 20% increase (from 14.550/57.296 = 25%) in return rate must be achieved. The transportation cost is not yet included.

   We do not have any information on how many drums we have, how many are in the customers and wholesalers, and how many are returned to the wholesalers. We only know how many we receive and send to the wholesalers. In the past, the wholesalers are not accepting return from the end customers. This is quite strange behavior. The wholesalers also didn’t have any return flow two years ago.

9. **How do the different customers impact the drum return? For small and big drums?**
   The contract for the drums is made between Draka and the wholesalers or Draka and the end customers. So different actor is held accountable in a different market.

10. **How long do the drums stay out in the site project?**
   We do not have this information. The wholesalers' current system does not allow data sharing with Prysmian.

Solution and requirements

11. **What kind of strategy do you think might work, from your function's perspective?**
   There could be several strategies:
   - Improve drum visibility regarding the location so that the company can act on it.
   - Change the wholesalers' and customers' behavior. This can be achieved by demanding them to do something or helping them to behave in a certain way. A loyalty campaign is an option to increase their awareness in returning the drums.
   - Help the wholesalers to build the return flow in their operation
   - Encourage end-customers to return the drums
   - Emphasize sustainability and cost-effectiveness as the main entry point to convince the customers.

   The deposit system didn't work in the past because drums are considered a service and corporate branding tool for Prysmian. A refund system might work but it will leave a negative impression on the customers.

   Currently, there is a solution being developed by using an API system that can track how many drums are sent from Emmen to the wholesalers, and from wholesalers to the end customer. End customers with legacy systems (no API) can use a scanner (mobile device) to input the data.

12. **What kind of strategy/initiative you can contribute to your function?**
   This year, there are new internal KPIs introduced to measure Prysmian performance towards the wholesalers. The KPIs are linked with financial incentives to the responsible employees. The aim is to have more cable cutting in the wholesalers (instead of in Emmen), thus empty drums are needed in their location.

13. **How hard is it to get the customers on board?**
   When this return drums issue is brought up with the customers, none of them disagree with the idea. In the past, the customers are willing to send the drums back, however, the wholesalers won't allow it.

14. **To what extent do you support the drum return initiative?**
   The initiative should not leave a negative impression on the customer.

1.6 Interviewee G

Job title: Branch Manager (Transporter)

1st July 2021 10.00 CET

Company and Functional Overview

1. **Could you tell me about your company, your function, and the goal?**
   Our company is a transportation and warehousing company operating in the Netherlands and the EU. Prysmian is one of our big clients. We manage raw materials, finished goods, also custom clearance for import/export. We use trucks with cranes for drums transportation for (un)load in the project site. We offer LTL and FTL services in the Benelux.

2. **What main factors are important for your company's business?**
   It's important to have reliable partners in the country where we are operating. We currently own 300 trucks of which 90% operate in Benelux, and for operations abroad, we have daily agreements with our partners. The demand is currently high in the Netherlands, we have to rent an additional capacity of 30-50 trucks.

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI)**
   Weekly report and month-to-date report. We record deliveries which are too late, on time, and too early. Damaged and missing goods are also recorded.

Drum return process

4. **Could you explain the processes you have that are related to the drums? And if you can also tell me what information you share with whom during the processes?**

   The information shared is also incomplete or inaccurate both from Prysmian or customers i.e., the number of drums to be picked up, the dimensions, the picking location, and condition.

   We receive pick-up orders in the system (or email) from Prysmian, then we register a plan for the pickup. We contact the customer for detailed information (the number of drums, the brand, dimensions). We wait for two days for customer response and they inform the volume and the pickup location. Then we determine the capacity and the type of trucks used. Any additional capacity is determined one day before. We contact Prysmian about the destination (The drum manager or Emmen) and then unload the drums at the agreed location.

   If there's no response, we send a reminder and wait for another two days. If still no response, we inform Prysmian, then forwarded to the sales department to reach directly to the customer.

   No EDI is involved currently, even though it's preferred.

5. **How are the conditions when you receive the drums? How do you handle them? What problems do you have when picking up?**
   Most of the pickup location allows a simple pickup process. However, sometimes the pickup location is remote, in harsh conditions (e.g., mud). Also, quite often they are stored in different areas in the project location.

   We pick up wooden drums most of the time, but sometimes plastic drums.

6. **What do you think of the Prysmian initiative to increase the drum return? How interested are you? Would it be good or bad for your company?**
   It's good for the environment to always return the drums. The existing web page helped us to plan, but if more specific information (i.e., the dimension of each drum) is given, we can plan the truck

capacity better. Maybe there are occasions that Prysmian can inform us earlier while serving their customer in parallel.

7. **How much capacity is used for serving Prysmian currently?**
   It's should not be a problem. The key is that if we receive sufficient and complete information in time, we can be flexible for changes.

8. **How long does it take usually to pick up the drums?**
   It depends on the location.

9. **What factors affect your capability to serve Prysmian? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines).**
   Information sharing at the right time, so we can act on it in a normal way. However, we understand how Prysmian operates, so we sometimes just plan based on what information we have.

   Unstable demand and minimum reaction time caused the planning difficulty. Customer orders are coming into Prysmian until 17.00, where the cables have to be cut. Thus, we have a small window to plan and act on such short notice. This issue occurs daily between Prysmian and the transporter, including rush deliveries. The ideal situation is to have the planning one day earlier.

Solution and requirements

10. **Do you have any ideas that might work for both Prysmian and the transporter to be more sustainable, in terms of drum return?**
    Improve information flow (more accurate and complete). We are also looking forward to using electric trucks if the technology is already capable to pick up such heavy loads.

11. **What factors matter to you to participate with new initiatives from Prysmian?**
    We always look for innovation, including with Prysmian. We have the financial stability to participate, however, it also depends on the return of investment (ROI) of the initiative.

12. **Will you face any difficulty if we increase the drum return rate?**
    We don't think so since we have sufficient capacity.

1.7 Interviewee H

Job title: Business Manager Installers

5th July 2021 10.00 CET

Functional Overview

1. **Could you tell me about your function and its goal?**
   Our function manages sales representatives to visit installers and wholesale branches, creating push-pull demand for Draka products. The visit includes promotions to convince customers in choosing Draka products. We account for €100 million in sales in the Netherlands where 90% comes from wholesale (indirect business).

   The wholesalers receive master cable drums with 2 km cable length, then cut them into individual lengths based on customer orders in their distribution center. Thus, it's important to have empty drums returned to the wholesalers and measure these return rates, instead of Emmen. This is also because the wholesalers have a higher cutting capacity (1.500 cuts per day at TU) than in Emmen.

2. **When do you have direct business with customers?**
   If there is a big customer in a specific business.

3. **Why do you choose the wholesale approach instead of direct?**
   Because customers prefer to have a complete product portfolio for their project, not only limited to cables. Wholesalers can offer various types of products (including our competitor products). The wholesalers also bear the financial risk from the customer. In addition, we can save money by sending FTL delivery to the wholesales.

4. **What factors do you focus on in your function?**
   We focus on a sales level, market share, and margin contribution. We try to be cost-effective and efficient since prices are increasing. However, since our competitors are situated also in Europe, we have the same level playing field.

5. **How competitive are your products compared to the others?**
   We are the market leader in the business. As long as we serve the customer well (in-time, cut well), they are willing to spend more for these added values. Our brand is more expensive than other brands but customers demand good products and services.

6. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI)**
   We measure the daily performance of our wholesalers in terms of delivery, based on product classification. The behavior between customers and wholesalers is also measured. Service levels are also used. The performance dashboard only accounts for the loaded drums, thus empty/returned drums are not counted.

7. **What kind of information do you collect and manage for that performance measurement?**
   We collect information about the stock and non-stock items, delivery time between orders, and actual delivery date. The wholesalers also measure our performance.

8. **What is the difference in the market between selling direct to customers and via wholesalers?**
   In direct business, we require more resources to serve the customer. We have to arrange the logistics, customer care, and bear the financial risk. Not to mention that we have to have the equipment (trucks with cranes) and delivery between the time slots.

9. **Could you explain more about the installer's place orders? How is it different between big and small installers (collective agreement)?**
Smaller installers use smaller cable cross-sections; thus, the drums are smaller and vice versa. Some smaller installers purchase collectively through a purchase organization in which they receive a rebate in return. No difference in the delivery process or buying behavior for this kind of practice. They only aim for bigger negotiating power.

Drum return process

10. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**
During the order process, the customer chooses the cable lengths they wish, which correspond to the type of storage medium (box or drums) given with the cable. The wholesalers cut the cable based on the order and put it on the Draka drums. The drums returned from customers can be reused for the newly cut cables. If there are not enough drums, Prysmian will send empty drums to the wholesalers.

    If the drums are coming back to Emmen, then the cutting is done in Emmen which requires more resources (labor and capacity).

11. **If we push all the activities (storage of master drums and cutting) to the wholesaler, would there be a (capacity) problem?**
We're currently doing it now in Solar Park, but for smaller cable cross-sections. For larger cross-sections, they have equipment limitations to do the cutting. This is where Emmen should take part, also for direct order deliveries.

12. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
We support the initiative to increase the drum return due to efficiency and sustainability reasons. It's easier if we know how many drums returning to the wholesalers. Cooperation along the supply chain is important, including Prysmian, Draka, the wholesalers, also our competitor.

13. **Do you think other competitors have the problems?**
Yes, the same problem.

14. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines).**
Customers (installers) have to wait for a long time before it's being picked up, sometimes the truck is not coming. If the pickup takes too long, the installers will throw the drums away. Maybe because the wholesalers are good at delivering, but were not built for taking returns. The process also has to be easier and based on data.

    Sometimes the pickup demand and the truck capacity do not match e.g., a few drums picked up by large trucks and vice versa. It's not good for sustainability and economic reasons.

15. **How long do the drums stay out in the site project?**
We guess that for smaller drums, possibly one month, and larger drums may be longer. We don't have enough information for this. For the pickup process itself, it sometimes takes a week for [redacted].

Solution and requirements

16. **What kind of strategy do you think might work, from your function's perspective?**

We can develop a good return program with wholesalers, with clear responsibilities. Our function can push the wholesalers to act on customers' pickup requests if needed.

To make the process simpler, we can also, for instance, scan a QR code and identify the drum type/dimensions, then the system can determine whether the drum should return to wholesalers or Emmen.

Currently, [redacted] has daily delivery to wholesalers (Solar Park). So, if they can pick up the drums for the backhaul, it'll be more efficient. Coordination is key in this issue.

17. **How hard is it to get the customers (i.e., installers) onboard?**
If the process is simple, customers will participate. An effective campaign is also needed to educate the customers. The service level (i.e., picking up on time) of the empty drums should also be maintained.

18. **What difficulties you are likely to face if we increase the drum return rate?**
We have enough capacity in wholesalers.

19. **To what extent do you support the drum return initiative?**
It should not cost us too much time, resources (e.g., labor), do not interfere with our current operations.

1.8 Interviewee I

Job title: Warehouse Manager

6th July 15.00 CET

Functional overview

1. **Could you tell me about your function and its goal?**
   As the warehouse manager, I am responsible for the physical inbound flow, storage, and outbound flow. The goal is to deliver goods at the right time, quality, requirements, to the right customers. Our team consists of 45 personnel, 6 people in inbound flow, and the rest are outbound. They are responsible for bringing the drums to the production, storing, counting, ad everything related to the drums. We also establish the minimum and maximum stock level and mitigate this with the suppliers.

2. **What factors do you focus on in your function?**
   The main focus is tracking customer demands and on-time delivery. The other focus is safety, the number of claims, the resource (i.e., labor), the stock level, and the right numbers of the right drums in stock (including the loaded and empty drums).

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI).**
   We measure backlog (wish vs actual delivery date). In the S&OP chain, we plan the resource (labor) for future deliveries.

4. **What kind of information do you collect and manage for that performance measurement?**
   We derive information from SAP which provides delivery information (on-time delivery and backlogs). The workload forecast can also be derived.

Drum return process

5. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**
   We only have data about the number of outbound and inbound drums and the stock level. With this information, we calculate the return rate and the safety cost. Weekly stock counting of empty drums and sharing with the suppliers (ensure the minimum stock level is satisfied). We sometimes share also this information with the sales department, probably due to the lack of certain types of drums. The goal is to ask the customers to return those drums.

6. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
   We introduced the QR code on plastic drums and considered tagging the wooden drums. However, some drums are sent directly from production to the customers. Therefore, in the existing machinery, it's not possible to tag the drum with a QR code right after production. Manual tagging by labor will cost money and time.
   We are also in contact with Oegema and put a KPI of 5 days to return the drums.
   Our drum manager follows a drum specification guideline to determine which drums can be reused. Lowering the standard could easily increase the return rate, however, it leads to a higher rejection rate.

7. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines)**
   Around one thousand drums are going out of the warehouse daily, most of them are small drums (around 60 cm). The value of the drums is not that high, thus the pressure to return the drum is low.

Plastics drums are not handled well, whether it's on the project site or during transport. People see the drums as durable so they can throw the drums, while in fact, it's not.

Solution and requirements

8. **What kind of strategy do you think might work, from your function's perspective?**
   The usage of RFID (as presented by Stenden) could be a solution for the small drums. The simplicity of remote scanning multiple barcodes at once could solve the problem. For big drums, we can scan using QR codes since there are not so many of them. But we have to know how it will cost us and ensure how many drums will return if we implement such technology.

9. **What is the specification of the drums that can be reused?**
   Based on the flange condition. One flange consists of six wooden beams. If one beam is damaged, it's replaced right away. But for two or three damaged beams, we don't know what the drum manager will do about it. We do not get the information about the reasons for scrapping, whether it's completely or partially damaged, or maybe only on the flanges. For the repair process, it'll take a maximum of 30 minutes for one drum.

10. **What difficulties you are likely to face if we increase the drum return rate?**
    It will be a problem if we do not know how many drums will be returned, thus we can't calculate the required new drums from the suppliers. The drum manager capacity will be a problem if the return increases in terms of space.

11. **If we collect the returned drums in the wholesalers instead of Emmen, what will be the issue?**
    Emmen will lose a part of the return rate, thus we have to buy more drums and more cost. The empty drum stock on the wholesalers may also be unbalanced (too high at one wholesaler, low at the other). We also need a digital system that can measure return levels in the wholesalers and Emmen at the same time.

12. **Who picks up the drums coming from the website? And what if they do not use the website?**
    Oegema picks up the order coming from the website. Manual orders are not welcomed and returned to the customers. The pickup orders coming to the wholesalers will be fulfilled by their transport.

13. **Could you tell me more about the VMI system in Emmen?**
    The Vendor-managed inventory (VMI) system allows the drum supplier to assemble the drums in Emmen with less space. Prysmian can use it at the time the drums are needed. Aside from its advantages, VMI is not applied in Emmen due to the risk of having a single supplier for production.

1.9 Interviewee J

Job title: Sustainability Officer, Prysmian NL

8th July 2021 11.00 CET

Functional Overview

1. **Could you tell me about your function and its goal?**
   I am the Sustainability Officer for Prysmian Netherlands and North-Europe region, reporting for issues related to Quality, Health, Safety, and Environment (QHSE). The main activity is to connect the different internal and external con for sustainability activities that have an impact. The importance of sustainability coming from employee intrinsic motivation, customers' demand, and government regulation drive us to embed sustainability into our organization. To achieve such a purpose, we have a corporate strategy including KPIs and targets in sustainability, customer-specific requests for sustainable practices, and incentives for sustainability performance, as examples.

   We have experience and knowledge about cable production and research R&D, also leveraging those from our colleagues. People and society.

2. **What factors do you focus on in your function?**
   We focus on improvement strategy which has measured impact on sustainability scorecard. We also put focus on the customer where it may differ between countries.

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI)**
   We have set targets to carry out Plan Do Check Action (PDCA) approach for QHSE issues, instead of only reporting. This demands a complete understanding of the numbers in the report, and follow-up actions. The main aim of this year is to change QHSE managers' attitudes towards QHSE topics to be more concrete.

   There are four functional targets:
   - Support North-Europe plant managers with green manufacturing practice workshops
   - PDCA cycle with HSE managers and linking to with plant managers.
   - Support sales from a customer perspective in sustainability, including ecological footprints of products, plants, manufacturing sites, company policy in sustainability, and other sustainability-specific requirements. There is an increase in this type of request, together with its importance among customers.
   - Support PYNL procurement department in the waste tender. Support sales when the customer has sustainability issue and support marketing on sustainability branding of the company

4. **What kind of information do you collect and manage for that performance measurement?**
   There is a report that records whether the actions have been done or not (i.e., the QHSE manager's actions, discussions frequency). For the Netherlands scope, there is a management review that indicates a sustainability scorecard.

Drum return process

5. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**
   We do not have a direct process in the drum return process. However, there is a corporate target in sustainability involving the drum return. Previous studies suggested that the return rate can still be improved. We create a team from logistics, sales, and procurement to carry this as a continuous project.

6. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
   We are very interested in the initiative. Our concern is the supply chain complex will be challenging. Currently, there are more people interested in this initiative.

7. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines)**
   Because people do not share the value of drums, thus it's more a behavioral issue. We are not responsive enough in answering customer requests, including at the wholesalers. In the past, it's considered an administrative nuisance because sometimes the customers do not acknowledge the drums are in their possession.

Solution and requirements

8. **What is the existing solution to increase the drum return?**
   Ensure good communication and information sharing. Last year, we attempt to grind the drums with graffiti on wooden drums in the Delft plant. This leads to an increase in the reuse rate with the additional repair cost. The plastic return rate is around the same as the wooden drums, but the scrap rate is higher. Some possible solutions are to have more durable drums, train the installers to better handle the valuable drums, or focus more on the recycling of the damaged plastic drums and reap from that. The existing QR code placed in the plastic drums is claimed to have a better return rate.

9. **Do you know the return rate in the wholesalers?**
   It's possible to measure the return rate through the new website (Draka Haspel Retour). There is also a discussion with Return Transport Items (RTI) using blockchain technology to manage the drum returns. It allows related stakeholders in the supply chain to participate in the system, including the introduction of an incentive system.

10. **What kind of strategy do you think might work, from your function's perspective?**
    We currently do not have any suggestions for this.

11. **What difficulties you are likely to face if we increase the drum return rate?**
    We will not face any difficulty of the increase. We might have a high cost of repair but eventually, less cost for replenishment.

12. **To what extent do you support the drum return initiative?**
    It should be a balance between the effort and the expected impact. An increase of 10% return rate in Emmen, should be sufficient.

1.10 Interviewee K

Job title: Manager Customer Care, Prysmian NL

14th July 2021 09.00 CET

Functional Overview

1. **Could you tell me about your function, your department, and its goal?**
   I am the manager for Customer Care department who is responsible for inside sales in the telecom, low voltage, and medium voltage business. The goal of the department is to ensure maximum customer satisfaction. This goal can be met by managing a good relationship with the customers, product management, project management, and keeping customers updated on product stock level, order, and delivery status. In addition, our department sends commercial quotations for our products based on the set price in the BPL. The offered product prices are always updated with the copper price index. There is a short clause for drum return included in the quotation, stating that the drums are free of charge and we pick them up. The department consists of 14 people.

   There is a difference between managing wholesalers and project-based customers. We engage more intensively with project-based customers, in terms of the delivery time, while for the wholesalers, we focus on replenishment. We also receive direct delivery orders coming from the wholesalers for a project, yet only from a small percentage of wholesalers.

2. **Could you explain more about your function process to achieve your goals?**
   In managing complaints, we receive these complaints via email or phone calls. The complaints can be accepted, rejected, or further investigated. We categorize the complaints into three categories: commercial, quality (defected or wrong product), and logistics (other than defected or wrong product). The complaints are forwarded to the responsible department and the status stays open until resolved.

   We act as a communication point between customers and the internal department. If any issue occurs in the production or logistics, for example, we try to come up with solutions together with related parties before it escalates any further.

   In managing inside sales, customers place a request for a quotation (RFQ) and we respond with a quotation. We act on an accepted quotation by placing orders to the system for the production and/or logistics to follow up. Negotiation is under the Account Manager (Johan Meinen) or Business Managers domain.

3. **What factors do you focus on in your function? How do you measure your performance towards the goal you've mentioned? (e.g., KPI)**
   Our KPIs are the amount of carried out projects, number of complaints, the throughput time of the complaints, number of phone calls responded, and the number of quotations, make offers. There is no segmentation in the type of phone calls, it could be both a good and bad indicator for the company (e.g., increased product demand, customer interests, complaints).

   - Number of complaints received
   - Number of open complaints
   - Monetary values of each complaint
   - Throughput time per complaint
   - Complaint age days

4. **What kind of information do you collect and manage for that performance measurement?**

We derive most of the information from SAP as the basis of our customer care dashboard. This includes the number of complaints and the number of quotations sent. There is also a phone system to report incoming and outgoing calls.

Drum return process

5. **What processes do you have that relate to the drum return? If you can also tell me the type of information and with whom do you send/receive that information?**
   Our department has no direct process with the drum return. The only process we have is when the customers put drum pickup orders on the Draka website, we receive a notification from the system. We do receive complaints about the drum returns, most of the time because they are not being picked up or late. The 5-days pickup time window given to the transporter (Oegema) sometimes is not met and customers are not happy that the agreement can't be kept. In the past, we receive these complaints almost daily, yet currently, we receive around three complaints of this type in a month.

6. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
   We support the initiative because it's a good practice to reuse plastics or wooden drums. However, if we ask customers to return drums, we also have to pick them up as promised. Putting more focus on customers should make this initiative successful.

7. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines).**
   The issue is that we do not have the overall visibility of the supply chain. For example, we do not know how many drums returning to wholesalers if at all. We assume that after the wholesalers deliver our products, 9 out of 10 times they also pick up the empty drums. Another reason is that there is not enough focus to return the drums to customers. It's easier to dispose of rather than to return.

Solution and requirements

8. **What kind of strategy do you think might work, from your function's perspective?**
   We can proactively check with customers to file the drum return request, particularly when a project is finished. In addition, we can communicate the initiatives to customers since we are their first point of contact. Inserting a drum return clause in the sales contract may also work, which requires them to return in a specific time window.

9. **What role do you have when Prysmian has a new project involving the customers?**
   We try to manage the potential risks perceived by the customers by helping with their delivery planning/scheduling. In another case, we try to get information regarding the customers (practical) requirements for the project (e.g., clearance to enter their premises)

10. **How hard is it to get the customers (i.e., wholesalers) onboard? What factors are important for customers before they agree to join new initiatives?**
    We have to ensure what benefits the new initiatives will bring. It should be simple so that the customers do not put too much effort (and time) into it.

11. **What difficulties you are likely to face if we increase the drum return rate?**
    We do not have one. On the contrary, we will have fewer complaints.

12. **To what extent do you support the drum return initiative?**
    We fully support this initiative.

1.11 Interviewee L & M

Job title: Purchaser Raw Material (L & M), Prysmian NL

29th July 2021 14.00 CET

Functional Overview

1. **Could you tell me about your function and its goal?**
   I am responsible for the purchase of raw and non-raw materials, including the purchase of new drums and pallets. Our function manages the contracts for new drums with the suppliers. In addition, we manage the partnership with the drum manager for drum maintenance. The drum manager is under our function's supervision.

2. **What factors do you focus on in your function?**
   We focus on ensuring the new drums arrive in time and return as fast as possible and the associated cost. The negotiation for the drums is currently handled by Prysmian HQ in Italy.

3. **How do you measure your performance towards the goal you've mentioned? (e.g., KPI).**
   We do not have any KPI, both for our function in general and the drum return.

4. **What kind of information do you collect and manage for that performance measurement?**
   We do not have any KPI, both for our function in general and the drum return.

Drum return process

5. **What processes do you have that relate to the drum return? I understand that there are two processes under your function: the wooden and plastics drums purchase and the reuse drum process with the drum manager. If you can also tell me the type of information and with whom do you send/receive that information?**
   Annually, we purchase around 40.000 units of drums. Our function ensures that the system indicates the right drum prices. If there are insufficient drums, the logistics function then requests the drum they need. The logistics can directly make purchase orders/delivery requests to the suppliers based on the min-max stock level.

   In terms of the reuse process, our function makes a contract agreement regarding the service price (clean, repair, and scrap price) with The drum manager at the start of every year. The request for quotation (RFQ) process is done during that process which states the prices for a certain period.

   After drums are received, The drum manager will look for any physical damage on the drums. They also test the drum stability and fasten the tie rods if necessary. To clean a drum, the nails and sheet on the drum have to be removed so the final product is smooth for reuse. For damaged drums, it is considered reusable if there are a maximum of 3 damaged batons on the flanges (were previously up to one baton). There is currently no fixed standard for this specification.

   Since the drum cost is very high recently, repairing drums is more economically effective. The cleaning cost is [redacted] per drum, repairing is [redacted] (depending on the diameter), and for scrap is around [redacted] (also depending on the type).

   In the scrap process, a wooden drum is fully disassembled by removing the tie rods until it falls apart.
   The removed tie rods are usually very rusted; thus, the drum suppliers won't accept them for reuse. For plastic drums, The drum manager cuts the plastic drums in half and disposes them into the waste container. This practice leads to low space utilization in the containers. Unlike plastic wastes,

Prysmian does not receive any returns from the wooden drums waste. However, considering the high price of wood, this might change.

6. **How do you test the plastics and wooden drums? Who is responsible for the test specifications? How do you formulate it? Does The drum manager have the final say on which drums can be reused? Do you have any record about the test i.e., how many drums failed at each step?**
   The drum manager is responsible for the test and determines which drums can be reused. There is no test carried out for the drums unless it's a new drum. Thus, there is no report for the test and the type of damage that each drum has.

7. **What do you think of the initiative to increase the drum return? How interested are you? What concerns do you have?**
   We are very interested in the initiative and that's why we are working on it. The reuse rate of wooden drums is better (80%) than plastics drums (2%). Thus, using higher quality drums can increase the return rate.

8. **In your opinion, why do you think the return drum rate is low? (You can think of it from various factors: measurement, materials, methods, environment, manpower, machines)**
   The quality, the handling, and the drum manager's repair facility. The quality of the drum at this moment is for a single use purpose, thus it's not intended for reuse purposes. The customer/transporter throws the drums to the trucks instead of handling with care or packing them in the pallet. Recently, the drum manager receive the returned drums in terrible condition with garbage inside them.
   The drum manager can't repair more complex drum damages due to equipment limitation, which is caused by a) most repairs are done by hand, and b) repair on a plastic drum requires special tools (mold).

Solution and requirements

9. **What kind of strategy do you think might work, from your function's perspective?**
   - Increasing the drum reuse rate by improving the quality, however, is not simple. Maintaining the drum dimension while drum quality is increased will be the issue. If we request for tougher drum, it can also require the drum producer to change the mold, which is costly. Changing drum suppliers can be an option, but we have to make sure that their product matches the current drum dimensions. We don't know how much it will cost if we ask for better quality drums.
   - Better agreement on the sales side to return more drums
   - Better communication on how to handle the drums
   - Use a waste compactor machine for drums before dumping in the waste container, therefore more waste can fit in the container.

10. **I understand that the plastic drums have QR codes from the supplier. Could you tell me more about this program?**
    I am not familiar with this. I understand that there is a program with Axjo, the plastics drums supplier, to place a QR code on the drum flange. But until now, I haven't seen it.

11. **What if we ask the suppliers to place a tag or code (either QR or RFID tag) on the drums before delivery to the Prysmian? Can the supplier do that? And how much would that cost?**
    It is possible to ask the supplier to place a tag/code on the drums. It should not cost that much because it will require them presumably one additional handling. The drum suppliers start the production first with the flanges, so adding a tag is possible. However, this tagging is effective if the drums are durable enough for multiple reuses. In case of damages, these tags can indicate which

customers/installers poorly handled the drums. When supported with a good system, these tags can be useful.

12. **What difficulties you are likely to face if we increase the drum return rate?**
    The only issue is on the storage space at The drum manager and Prysmian, as we already have it at the time being. There is no issue to increase the labor quantity and production capacity at The drum manager.

13. **To what extent do you support the drum return initiative?**
    We fully support the initiative and do not have any limitations. We want to receive as many drums as possible at the factory.

Appendix 2

Swimlane Analysis

A swimlane diagram is a visualization tool that can be used to identify the steps in a business process and the assignment of responsibilities. This diagram can help to clarify where delays and bottlenecks may occur along the process. In this way, cross-functional collaboration can be improved by identifying gaps in responsibility and communication (Ezeonwumelu et al., 2016).

The processes related to the drums are new drum purchase, order fulfillment, empty drum return, and waste treatment process. These processes are visualized by the swimlane diagram shown in Figure 2-1, Figure 2-2, Figure 2-3, Figure 2-4, respectively. In these diagrams, notes in the yellow hexagonal shape are assigned, indicating where the root causes mentioned in the Figure 3-10 of Chapter 3 occur in the respective process.

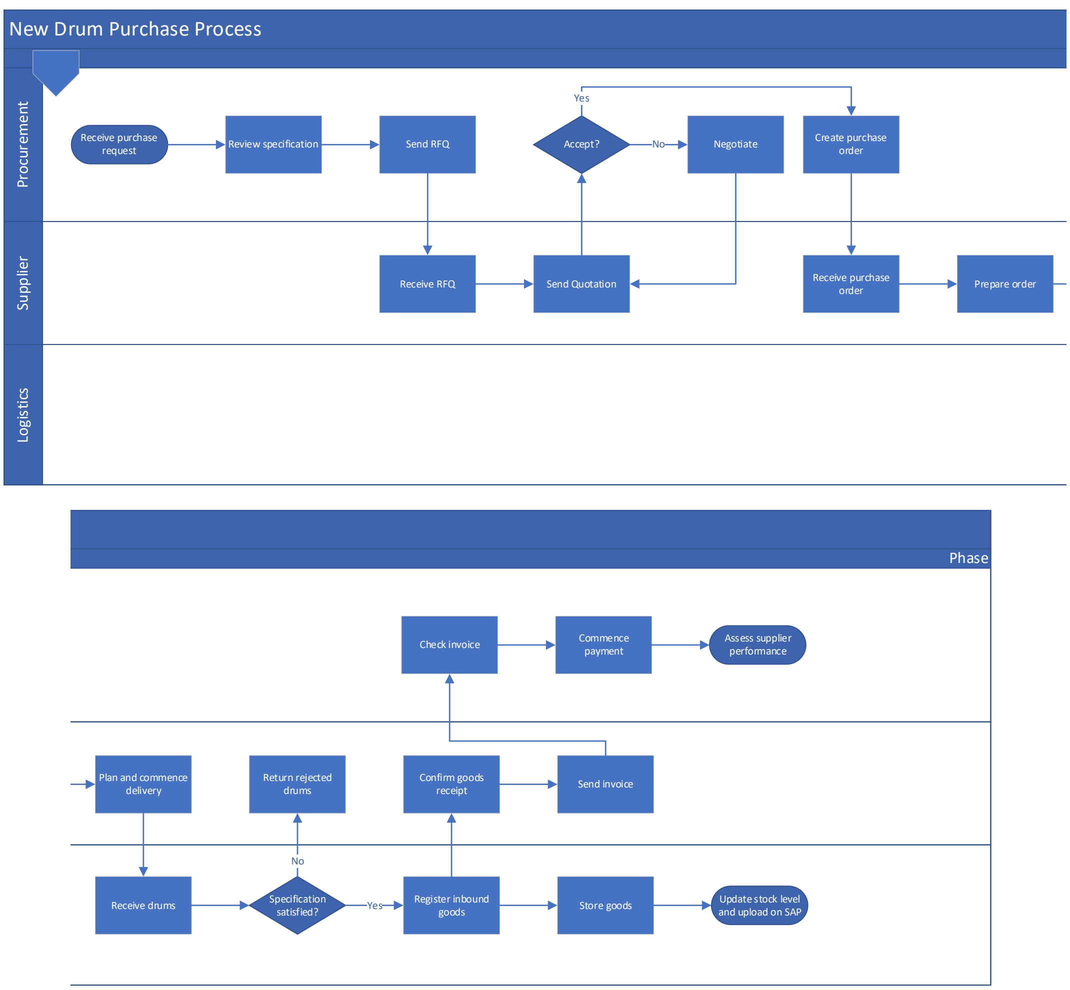
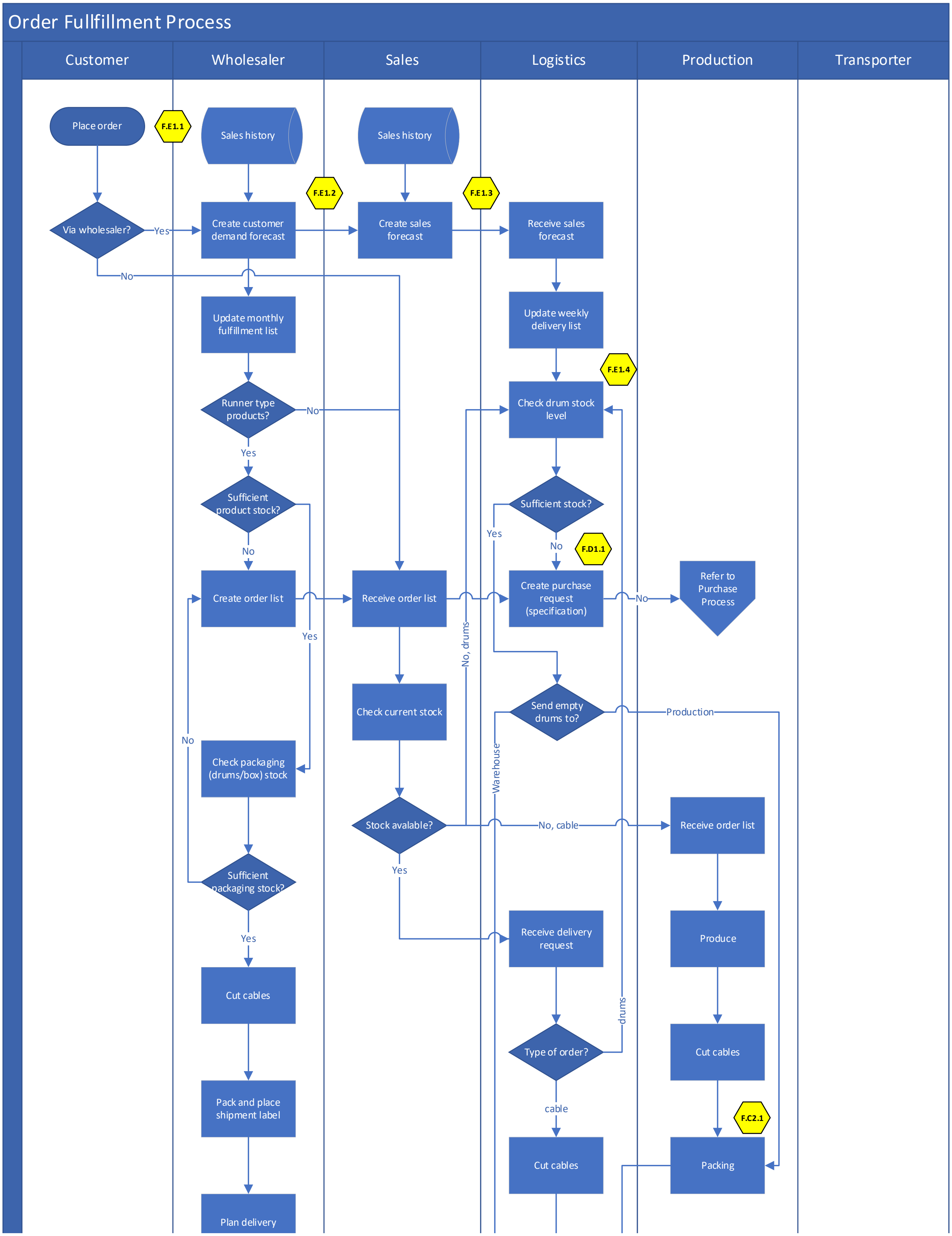


Figure 2-1 New Drum Purchase Process



Order Fullfillment Process
Customer
Wholesaler
Sales
Logistics
Production
Transporter
Place order
F.E1.1
Sales history
Sales history
F.E1.2
F.E1.3
Via wholesaler?
Yes
Create customer demand forecast
Create sales forecast
Receive sales forecast
No
Update monthly fulfillment list
Update weekly delivery list
F.E1.4
Runner type products?
No
Check drum stock level
Yes
Sufficient product stock?
Sufficient stock?
Yes
No
No
F.D1.1
Create order list
Receive order list
Create purchase request (specification)
No
Refer to Purchase Process
Yes
No, drums
Check current stock
Send empty drums to?
Production
No
Check packaging (drums/box) stock
Warehouse
Stock avalable?
No, cable
Receive order list
Sufficient packaging stock?
Yes
Yes
Receive delivery request
Produce
drums
Cut cables
Type of order?
Cut cables
Pack and place shipment label
cable
F.C2.1
Cut cables
Packing
Plan delivery

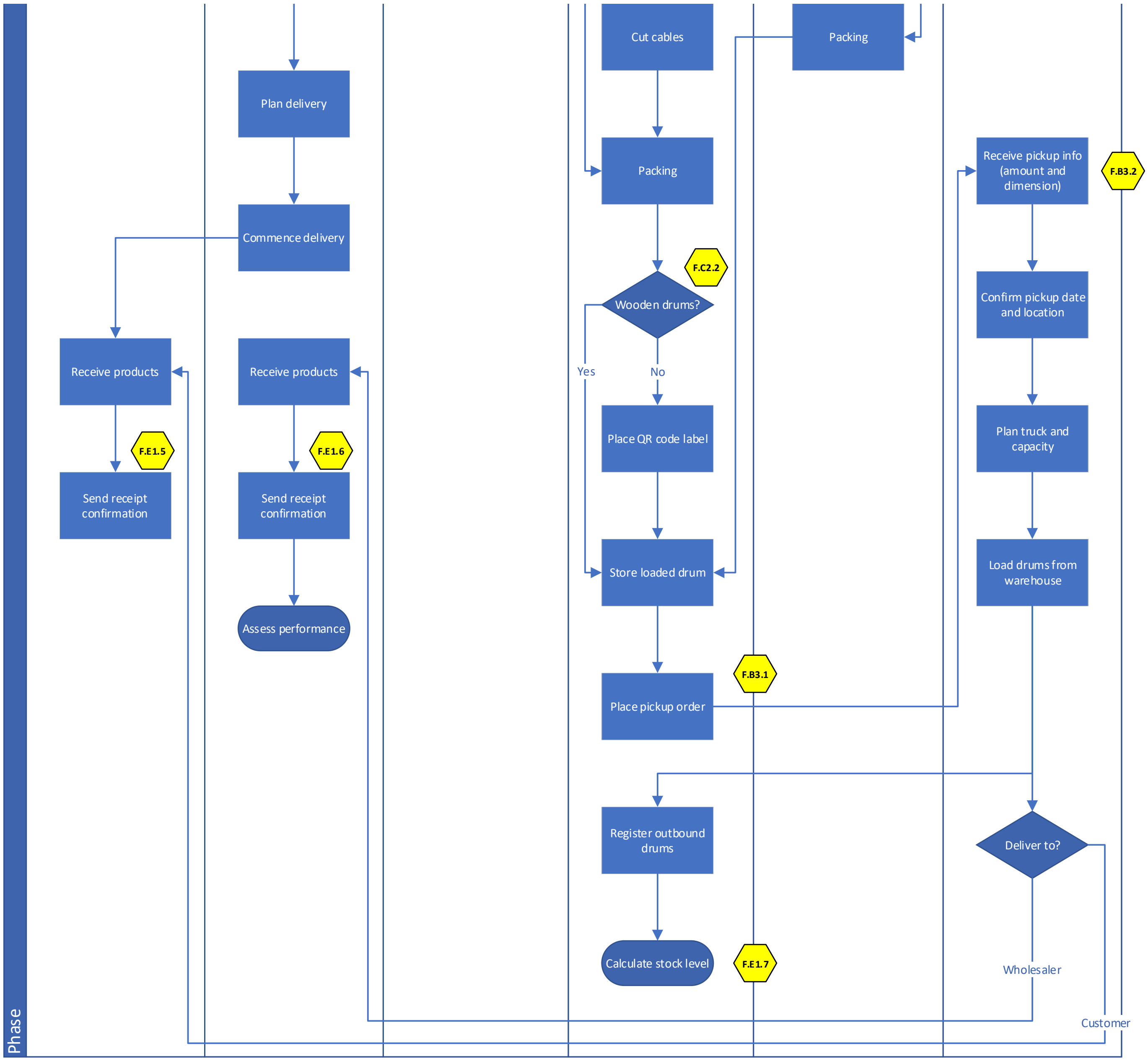
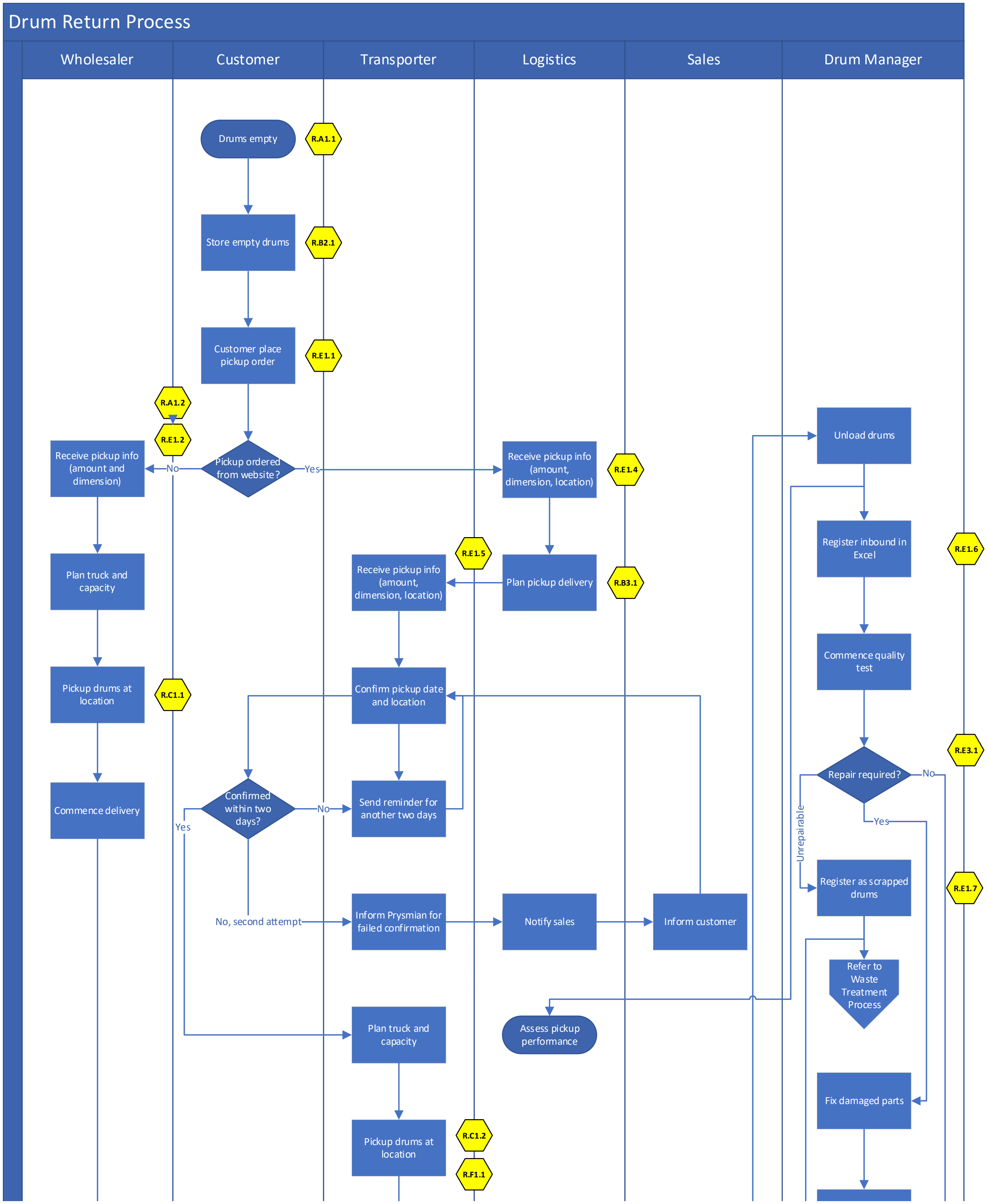


Figure 2-2 Order Fulfillment Process



Drum Return Process
Wholesaler
Customer
Transporter
Logistics
Sales
Drum Manager
Drums empty
R.A1.1
Store empty drums
R.B2.1
Customer place pickup order
R.E1.1
R.A1.2
R.E1.2
Receive pickup info (amount and dimension)
No
Pickup ordered from website?
Yes
Receive pickup info (amount, dimension, location)
R.E1.4
Unload drums
Plan truck and capacity
R.E1.5
Receive pickup info (amount, dimension, location)
Plan pickup delivery
R.B3.1
Register inbound in Excel
R.E1.6
Pickup drums at location
R.C1.1
Confirm pickup date and location
Commence quality test
Commence delivery
Confirmed within two days?
No
Send reminder for another two days
Yes
Repair required?
No
R.E3.1
Unrepairable
Yes
Register as scrapped drums
R.E1.7
No, second attempt
Inform Prysmian for failed confirmation
Notify sales
Inform customer
Refer to Waste Treatment Process
Plan truck and capacity
Assess pickup performance
Fix damaged parts
Pickup drums at location
R.C1.2
R.F1.1

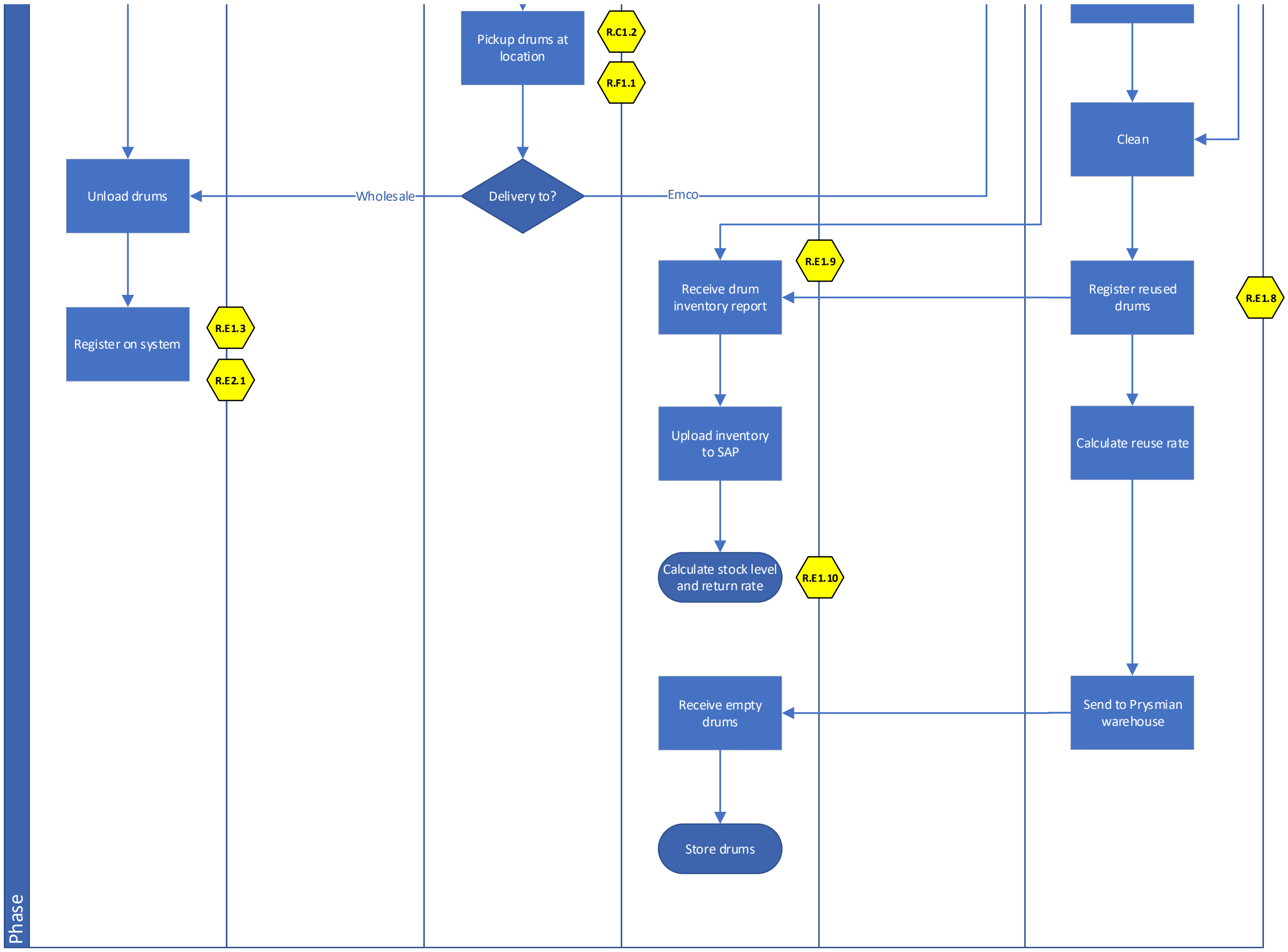
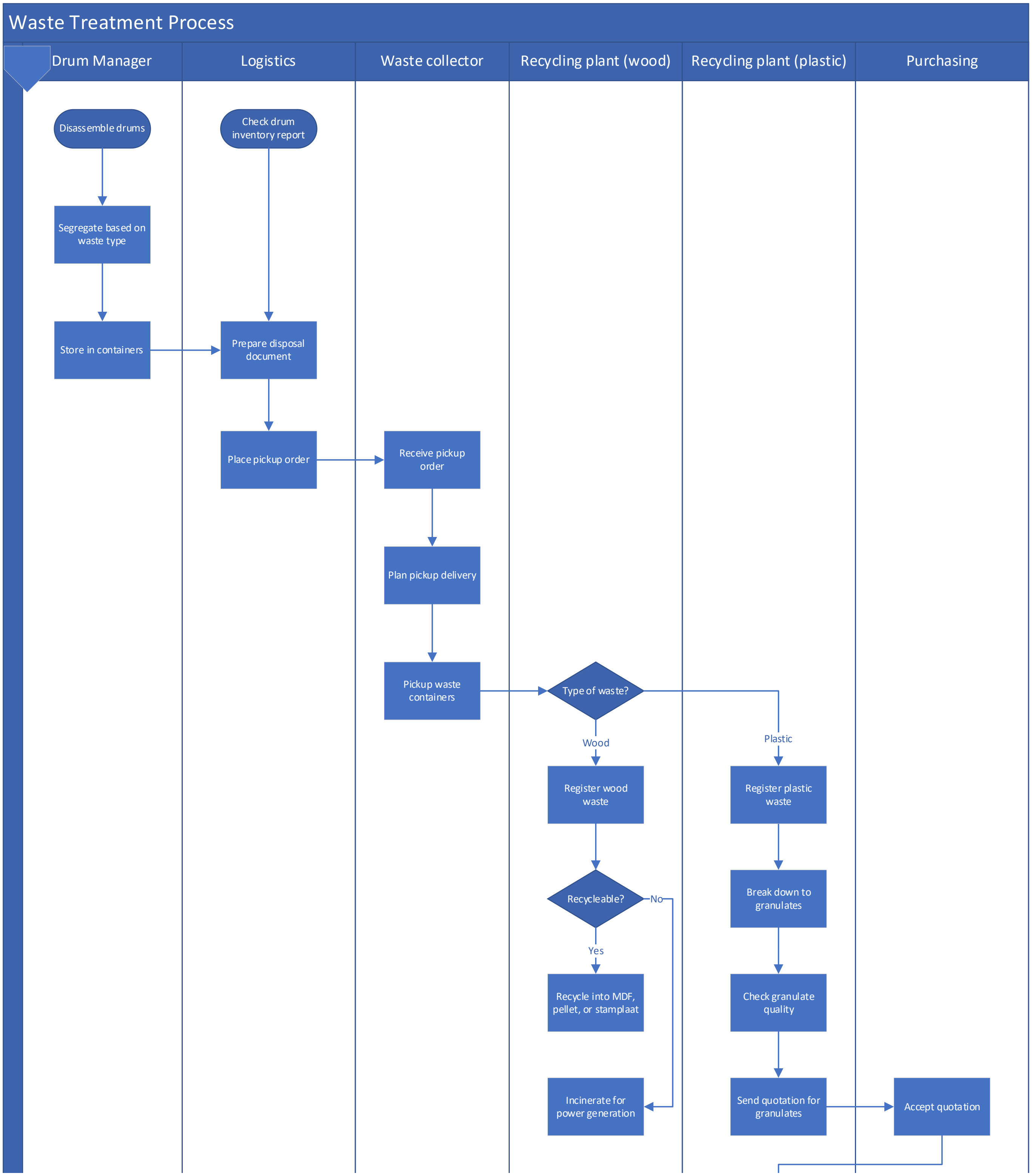


Figure 2-3 Drum Return Process


Waste Treatment Process
Drum Manager
Logistics
Waste collector
Recycling plant (wood)
Recycling plant (plastic)
Purchasing
Disassemble drums
Check drum inventory report
Segregate based on waste type
Store in containers
Prepare disposal document
Place pickup order
Receive pickup order
Plan pickup delivery
Pickup waste containers
Type of waste?
Wood
Plastic
Register wood waste
Register plastic waste
Recycleable?
No
Yes
Break down to granulates
Recycle into MDF, pellet, or stamplaat
Check granulate quality
Incinerate for power generation
Send quotation for granulates
Accept quotation

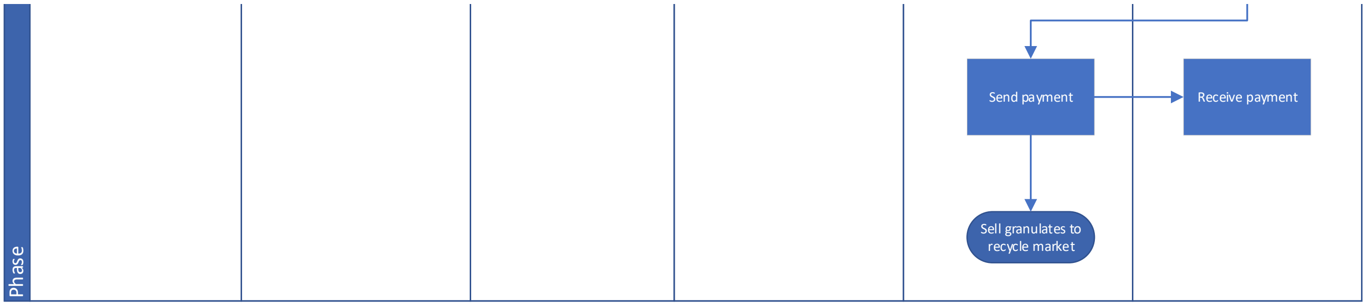


Figure 2-4 Waste Treatment Process

Appendix 3

Data

The data provided by PYNL for case study purposes is explained in this section. Since not all of the available data is utilized, hence the following explanation will exclude the data (columns) that are not used.

3.1 Drum management data

The Warehouse function updates the drum management data usage every week (as shown in the process by Figure 2-2 and Figure 2-3). The data is shown as a dashboard table which consists of several columns, updated based on the inbound and outbound flow. The inputs to this dashboard are newly purchased drums, returned drums, and outbound drums.

The first and second column shows the supplier and code name in the SAP system. The third, fourth, and fifth columns recorded the current stock, minimum, and maximum allowable stock units in EMF. The drum returns are logged in the sixth column.

3.2 Drum specification data

The drum specification data is derived from two separate sources. The first source obtained from the QHSE function describes the dimension in terms of flange diameter, width, and empty weight for each drum type. The second source obtained from the Warehouse function mentions the purchasing price for each drum type.

3.3 Drum consumption data

In the SAP system, the Sales and Warehouse functions share the drum consumption data. Each time the Sales function requests drums, the system records such requests. The Warehouse function uses this data for tracking the number of outbound drums. The data provided is for the year 2020, starting from the 1st January to 31st December 2020.

The first column mentions the drum type. The second column shows the customer code who requested the drum. The third column shows the quantity requested for the customer in question. The date of entry is shown in the fourth column, which indicates the date that the drum request is entered on SAP.

3.4 Drum manager annual report

The drum manager records the inbound drums and reports to PYNL every week via email. The consolidated report is created only at the end of each calendar year, as described by Figure 2-3. The first column shows the treatment applied to each drum type, followed by the drum material in the second column. The third column indicates the price for the year 2020 for each type of activity: scrapping, repairing, and cleaning. The third until the fourteenth column logged the number of activities carried out on each drum type per month for 12 months. The fifteenth until the seventeenth column aggregates the costs for cleaning, repairing, and scrapping, respectively. The eighteenth until the twentieth column aggregates the number of drums that are cleaned, repaired, and scrapped, in that order.

3.5 Transportation data

The transportation data is collected by the transporter, then reported to the Purchasing function. The Purchasing function receives this report weekly, which tracks the transport activities between PYNL and related parties. The transportation data obtained from PYNL is for weeks 24 and 29 in the year 2021. The first two columns show the shipper details: name and departure city. The following two columns show the consignee details: name and arrival city. In the fifth column, the chargeable weight is shown. This is the assumed weight to be charged to PYNL. The shipment type in the sixth column indicates whether the transport is a full-truckload (FTL) or a less-than-a-truck load (LTL). The invoice amount for that specific distance and weight is shown in the seventh column.

3.6 Customer data

The customer data is derived from the SAP system which contains four columns: the customer code, customer name, the address zip code, and city. Based on the latitude and longitude data of each zip code (Kraijesteijn, n.d.) and customers' zip code, the Euclidian distance between EMF and the customers can be determined.

Appendix 4

Simio Model

This chapter describes the process of model building in Simio software. It includes the model overview, model controls, processes, and model inputs.

4.1 Simio model overview

The simulation model in Simio consists of 8 objects as shown in Figure 4-1. All objects are connected by paths except the connection between F to C which is linked by a connector. The path allows specifying distance input between objects; hence an entity travel speed. There is one model entity named "Drums" that is used to model the drum. The aliases used in Simio are shown in Table 4-1. The model control properties in Figure 4-2 are used to change the values for the experiments stated in Chapter 7.

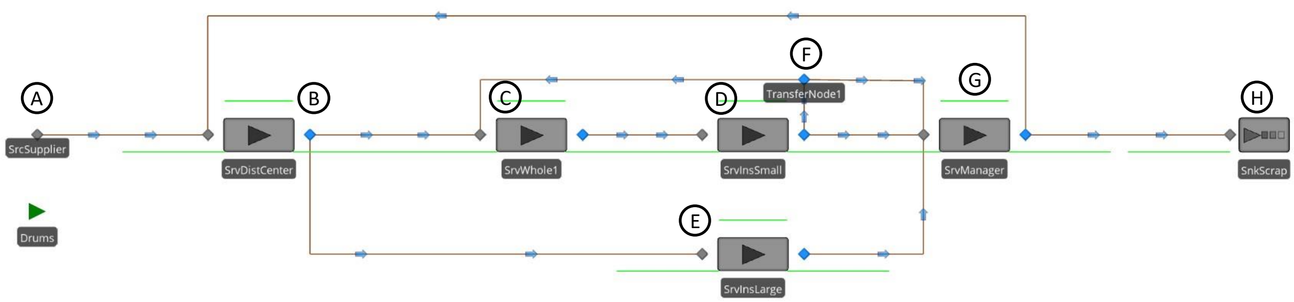


Figure 4-1 Model overview in Simio

Table 4-1 Station aliases in Simio

Symbol	Station	Object Name
A	Drum Supplier	SrcSupplier
B	EMF	SrvDistCenter
C	Wholesalers	SrvWhole1
D	Small Installers	SrvInsSmall
E	Large Installers	SrvInsLarge
F	Wholesalers transfer area	TransferNode1
G	Drum Manager	SrvManager
H	Waste Collector	SnkScrap

Properties: BaseModelMinMax (Fixed Model)

Controls	
General	
DW4116K_ShrinkRate_InsSmall	0.343
DW4116K_ShrinkRate_InsLarge	0.343
DW4116K_ScrapRate	0.151
DW4116K_RepairRate	0.241
DP4060K_ShrinkRate_InsSmall	0.521
DP4060K_ShrinkRate_InsLarge	0.521
DP4060K_ScrapRate	0.979
DP4060K_RepairRate	0.0
DW4116K_ReturnToManager	1
DP4060K_ReturnToManager	0
DW4116K_ScrapPrice	Confidential
DP4060K_ScrapPrice	
ProcTimeProp_InsSmall	Random.Triangular(3,7,14)
Units	Days
ProcTimeProp_InsLarge	Random.Triangular(10,25,30)
Units	Days
OutboundCost_DC_Inc	Confidential
InboundCost_DC_Inc	
OutboundCost_Whole1_Inc	
InboundCost_Whole1_Inc	
ProcTimeProp_Whole1	Random.Triangular(10,20,30)
Units	Days

Figure 4-2 Model control properties

4.2 Simio model input

The model inputs outlined in Chapter 6 are specified in this section. Two drum types are shown in Figure 4-3. Figure 4-4 shows the link between replenishment policy and drum input data, including the sourcing location of each station, the min/max quantity, where to send the drums i.e., destination node, and the process name to perform if replenishment is required.

Inventories | Materials | Demand | Sites | Transport

	Material Name	Material List	Purchase Price	Cleaning Price	Repair Price	Weight (Kilograms)
1	DW4116K	Wood	Confidential			
2	DP4060K	Plastic				
*						

Figure 4-3 Drum input data

Inventories | Materials | Demand | Sites | Transport

	Inventory Name	Material Name	Source Site Object Name	Initial Quantity	Replenishment Policy	Reorder Quantity Or Up To Level	Reorder Point Or Condition	Destination Node	On Replenishment Order
1	INV_DW4116K_DC	DW4116K	SrcSupplier	526	Min/Max	526	384	Input@SrvDistCenter	4_OnReplenishmentOrder_DC
2	INV_DW4116K_WH1	DW4116K	SrvDistCenter	94	Min/Max	94	27	Input@SrvWhole1	3_OnReplenishmentOrder_AllCustomer
3	INV_DW4116K_MAN	DW4116K	null	0	None	0.0	0.0	Input@SrvManager	
4	INV_DW4116K_SUP	DW4116K	null	Infinity	None	0.0	0.0	null	
5	INV_DW4116K_INL	DW4116K	SrvDistCenter	105	Min/Max	105	30	Input@SrvInsLarge	3_OnReplenishmentOrder_AllCustomer
6	INV_DW4116K_INS	DW4116K	null	0	None	0.0	0.0	Input@SrvInsSmall	
7	INV_DP4060K_DC	DP4060K	SrcSupplier	4190	Min/Max	4190	3062	Input@SrvDistCenter	4_OnReplenishmentOrder_DC
8	INV_DP4060K_WH1	DP4060K	SrvDistCenter	1376	Min/Max	1376	390	Input@SrvWhole1	3_OnReplenishmentOrder_AllCustomer
9	INV_DP4060K_MAN	DP4060K	null	0	None	0.0	0.0	Input@SrvManager	
10	INV_DP4060K_SUP	DP4060K	null	Infinity	None	0.0	0.0	null	
11	INV_DP4060K_INL	DP4060K	SrvDistCenter	198	Min/Max	198	56	Input@SrvInsLarge	3_OnReplenishmentOrder_AllCustomer
12	INV_DP4060K_INS	DP4060K	null	0	None	0.0	0.0	Input@SrvInsSmall	
*									

Figure 4-4 Replenishment policy and data

4.3 Simulation objects and processes

The objects and processes of the Simio simulation are outlined in this section. The simulation starts with process *1_OnCustomerOrder* that is also a timed event shown in Figure 4-6. The process starts on 01-01-2020 at 00.00 hours and loops infinitely until the simulation run length is met for 52 weeks, as mentioned in Sections 4.1 and 7.1.2. Each loop executes process *2_DrumConsumption.*

Each time *2_DrumConsumption* is executed, specific drum types are consumed at respective stations based on the information indicated in Figure 4-5. One drum is consumed in each loop with an average interarrival time (AIT) between orders stated in the same figure. The *Delay* step given by the *TimeBetweenOrder* in Figure 4-6 ensures the AIT between one order and another. Once consumed, the quantity in stock at the respective stations decreases, and drum entities are created. The created drum entities at SrvWhole1 are considered full drums, meanwhile, those created at SrvInsLarge are considered empty drums. The created drums are sent to the destination stated in the *Destination Node* column in Figure 4-4.

Inventories | Materials | **Demand** | Sites | Transport

	Order Time	Quantity	Material Name	Site Object Name	Occurences	TimeBetweenOrders (Days)
1	01-Jan-20 00:00:00	1	DW4116K	SrvWhole1	Infinity	Demand_DW4116K_Whole1
2	01-Jan-20 00:00:00	1	DW4116K	SrvInsLarge	Infinity	Demand_DW4116K_InsLarge
3	01-Jan-20 00:00:00	1	DP4060K	SrvWhole1	Infinity	Demand_DP4060K_Whole1
4	01-Jan-20 00:00:00	1	DP4060K	SrvInsLarge	Infinity	Demand_DP4060K_InsLarge
*						

Properties: Demand_DW4116K_Whole1 (Distribution Input Parameter)

Value	
Distribution Type	**Exponential**
Mean	**0.2044787**
Units	**Days**
Unit Type	**Time**

Properties: Demand_DW4116K_InsLarge (Distribution Input Parameter)

Value	
Distribution Type	**Exponential**
Mean	**0.1834982**
Units	**Days**
Unit Type	**Time**

Properties: Demand_DP4060K_Whole1 (Distribution Input Parameter)

Value	
Distribution Type	**Exponential**
Mean	**0.0138624**
Units	**Days**
Unit Type	**Time**

Properties: Demand_DP4060K_InsLarge (Distribution Input Parameter)

Value	
Distribution Type	**Exponential**
Mean	**0.096**
Units	**Days**
Unit Type	**Time**

Figure 4-5 Demand input detail

As mentioned, each drum consumption reduces the quantity in stock at each station. Once a reorder point is reached, the respective station will perform an order replenishment process as stated in the *On Replenishment Order* column in Figure 4-4. There are two types of order replenishment processes: *3_OrderReplenishmentOrder_AllCustomer* for SrvWhole1 and SrvInsLarge, and *4_OrderReplenishmentOrder_DC* for SrvDistCenter as shown Figure 4-6. The requested station records the order quantity and delivers the drums to the requesting station. The changes in state variables for SrcSupplier are recorded as shown in Figure 4-7.

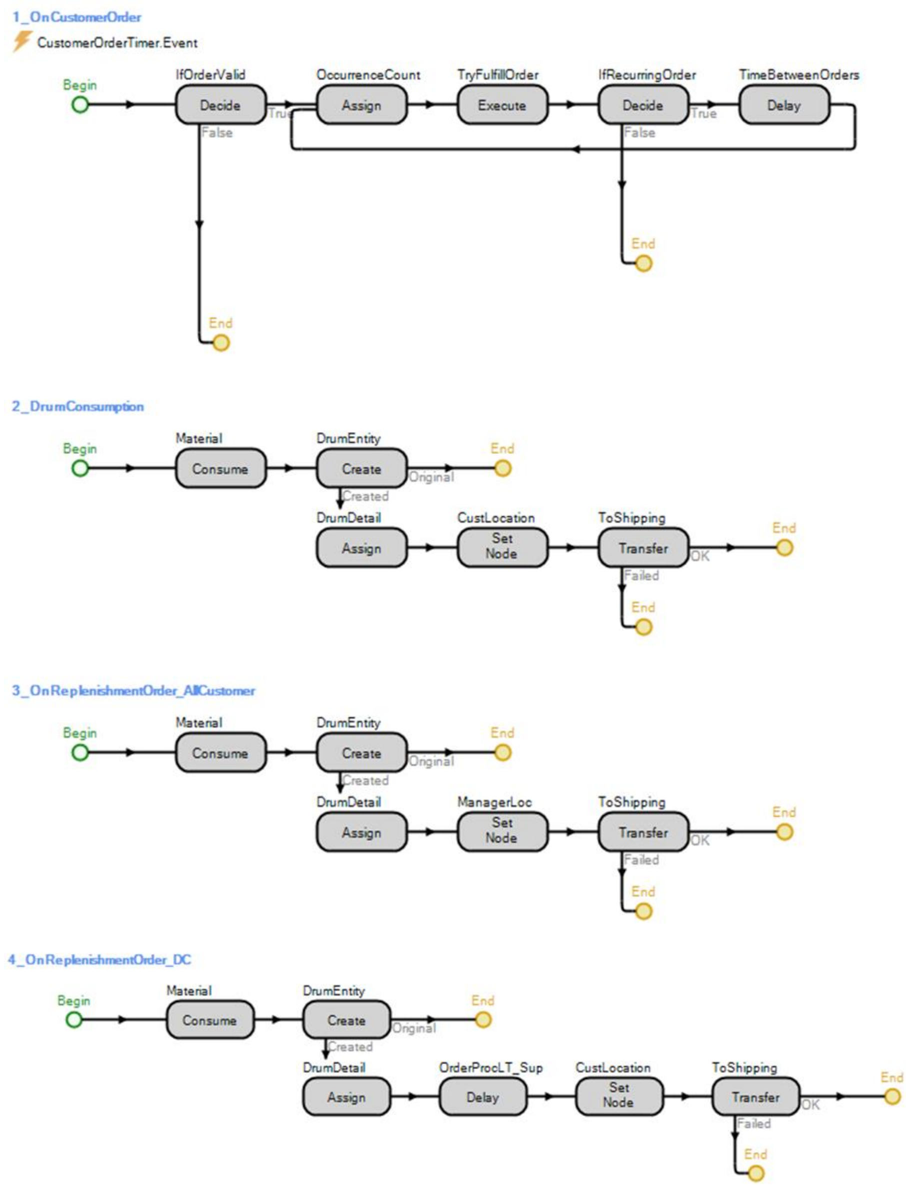


Figure 4-6 Customer order processes

```
ModelEntity.OrderQuantity, 1,
ModelEntity.ReplenishLT_OrderPlacedSupplier, TimeNow,
ModelEntity.TransportSize, Materials.Weight,
Stat_InboundWeight_DC, Stat_InboundWeight_DC + ModelEntity.TransportSize,
PurchaseCost.Cost, PurchaseCost.Cost + Materials.PurchasePrice,
ModelEntity.Picture, Materials.ColorCode,
```

Figure 4-7 State assignments for purchased drums at SrcSupplier

4.3.1 Drum Supplier (SrcSupplier)

SrcSupplier is constructed as a basic node that supplies SrvDistCenter for drums. The related process with SrcSupplier is *4_OrderReplenishmentOrder_DC* shown in Figure 4-6. It is only involved when a replenishment order from SrvDistCenter is placed. Drum entities are created then sent to SrvDistCenter.

The process follows process 4_OnReplenishmentOrder_DC in Figure 4-6 as explained in the previous section.

4.3.2 EMF (SrvDistCenter)

SrvDistCenter has three connections that allow: a) receiving purchased drums from SrcSupplier b) receiving empty drums from SrvManager, b) delivering the ordered full drums to SrvWhole1, and SrvInsLarge. The SrvDistCenter is constructed as a server that has three processes at the input buffer, server, and output buffer respectively shown in Figure 4-8. Process *1_Input_SrvDistCenter_Entered* is executed when a drum entity enters it. A drum entity arrival time is recorded once entered to measure the time spent in this server. If the drum entity is a returned drum, then a return lead time is measured. If not, then it will count the number and weight of plastic and drums entering this station.

Process *2_ShipmentReceivingLogic_DistCenter* ensures if SrvDistCenter is the intended destination of an incoming drum entity. If it is true, then the *Produce* step reads the drum details i.e., drum-type, and adds it as an inventory stock in this station. Process *3_Output_SrvDistCenter_Entered* segregate between the returned drums from SrvManager, the replenishment drums from SrcSupplier, or the replenishment drums intended for delivery to customers (SrvWhole1 or SrvInsLarge). The number and weight of the replenishment drums for customers are measured before exit. The processing lead time at SrvDistCenter is tallied for returned drums and replenishment drums, then they are destroyed.

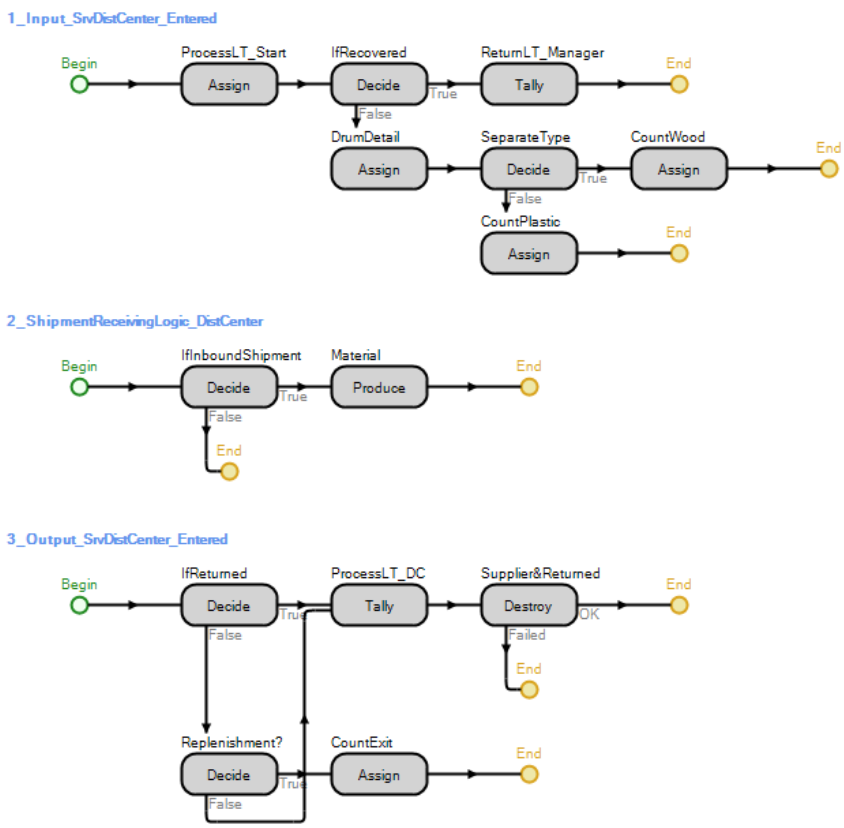


Figure 4-8 EMF station process

4.3.3 Wholesaler (SrvWhole1)

The wholesaler has three connections that allow: a) receiving full drums replenishment from SrvDistCenter, b) receiving empty drums from SrvInsSmall via TransferNode1, c) delivering full drums to SrvInsSmall. The wholesalers i.e., SrvWhole1 are constructed as a server that has three processes at input buffer, server, and output buffer, respectively shown in Figure 4-9. Process *1_Input_SrvWhole1_Entered* is triggered when a drum entity enters the SrvWhole1 station.

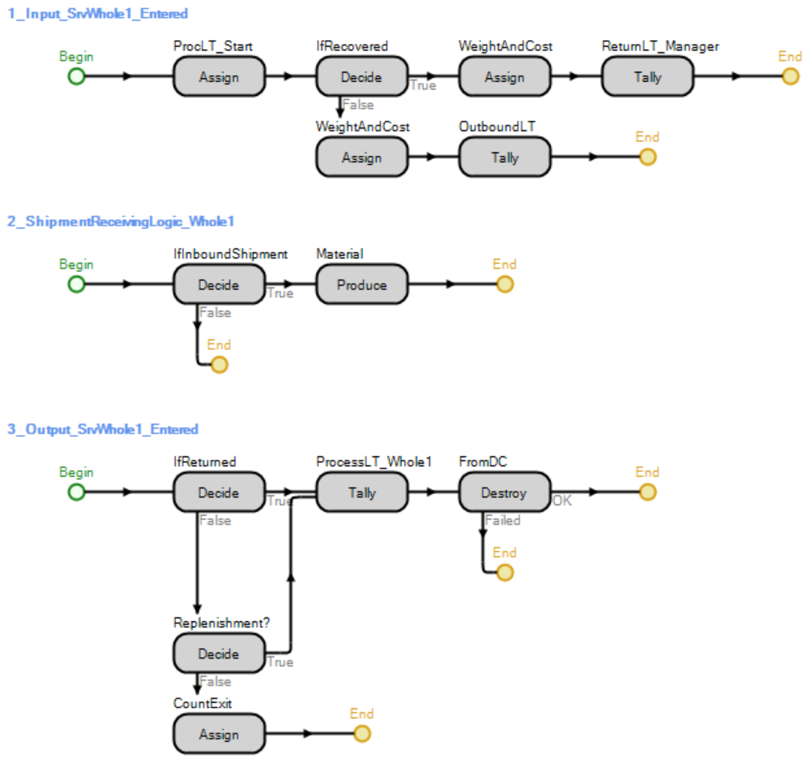


Figure 4-9 Wholesaler station processes

For a returned drum, the *Assign* step changes the variable states as indicated below in Figure 4-10.

Stat_NumReused_InsSmall, Stat_NumReused_InsSmall + 1,
Stat_InboundWeight_InsSmallToWhole, Stat_InboundWeight_InsSmallToWhole + ModelEntity.TransportSize,
Stat_ReusedWeight_Whole1, Stat_ReusedWeight_Whole1 + ModelEntity.TransportSize,
InboundCost_Whole.Cost, InboundCost_Whole.Cost + (ModelEntity.TransportSize * (InsSmallToWhole1.LogicalLength / 1000) * Materials.InboundUnitCost_Whole),
Stat_RecoveryValue_Whole, Stat_RecoveryValue_Whole + Materials.PurchasePrice,
Stat_ReuseRate_Whole1, Stat_ReusedWeight_Whole1 / Stat_OutboundWeight_InsSmall,

Figure 4-10 State assignments for returned drums at input buffer SrvWhole1

For a non-returned drum i.e., replenishment drum the *Assign* step changes the variable state shown by Figure 4-11.

Stat_OutboundWeight_Whole1, Stat_OutboundWeight_Whole1 + ModelEntity.TransportSize,
OutboundCost_DC.Cost, OutboundCost_DC.Cost + (ModelEntity.TransportSize * (DCToWhole1.LogicalLength/1000) * Materials.OutboundUnitCost_DC),
ModelEntity.Picture, Materials.ColorCode,

Figure 4-11 State assignments for replenishment drums at input buffer SrvWhole1

Process *2_ShipmentReceivingLogic_Whole1* ensures if SrvWhole1 is the intended final destination of an incoming drum entity. If it is true, then the *Produce* step reads the drum details i.e., drum-type, and adds it as an inventory stock in this station.

Process *3_Output_SrvWhole1_Entered* separates the returned drum from SrvInsSmall, replenishment drum from SrvDistCenter, or the replenishment drums intended for delivery to SrvInsSmall. The number and weight of the replenishment drums for customers are measured before exit. The processing lead time at SrvWhole1 is tallied for returned drums and replenishment drums, then they are destroyed.

4.3.4 Small Installers (SrvInsSmall)

SrvInsSmall has three connections that allow: a) receiving full drums replenishment from SrvWhole1, b) returning empty drum to SrvWhole1 via TransferNode1, and c) returning empty drums directly to SrvManager. SrvInsSmall is constructed as a server that has three processes at input buffer, server, and output buffer as shown in Figure 4-12. Process *1_Input_SrvInsSmall_Entered* is triggered when a drum entity enters the SrvInsSmall station.

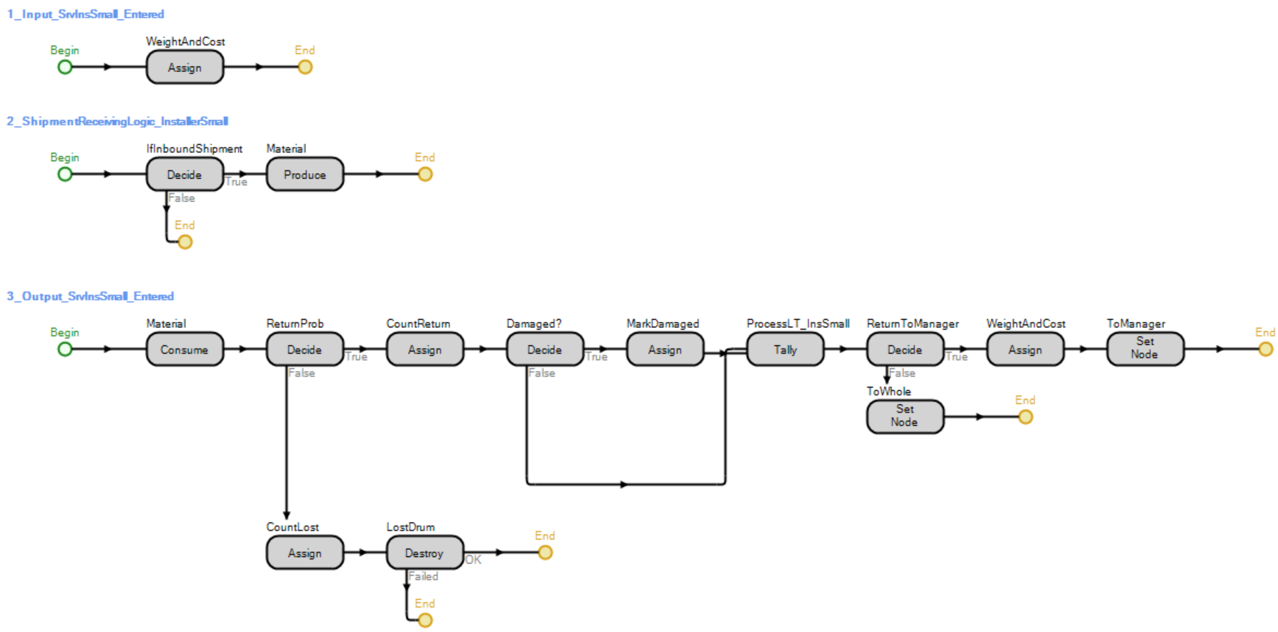


Figure 4-12 Small Installer station process

Process *1_Input_SrvInsSmall_Entered* is triggered when a drum entity enters the SrvInsSmall station. The *Assign* step records the state variable changes as indicated in Figure 4-13.

ModelEntity.TransportSize, Materials.Weight,
Stat_OutboundWeight_InsSmall, Stat_OutboundWeight_InsSmall + ModelEntity.TransportSize,
OutboundCost_Whole.Cost, OutboundCost_Whole.Cost + (ModelEntity.TransportSize * (Whole1ToInsSmall.LogicalLength / 1000) * Materials.OutboundUnitCost_Whole),
Stat_InboundQtyAtInsSmall, Stat_InboundQtyAtInsSmall+1,

Figure 4-13 State assignments for drum replenishment at SrvInsSmall

Process *2_ShipmentReceivingLogic_InsSmall* ensures if SrvInsSmall is the intended final destination of an incoming drum entity. If it is true, then the *Produce* step reads the drum details i.e., drum-type, and adds it as an inventory stock in this station.

Process *3_Output_SrvInsSmall_Entered* indicates the steps that a drum entity experiences if it enters the output buffer. The drum quantity in stock at SrvInsSmall should decrease after a drum entity exits that server, hence a *Consume* step is required. The shrink rate determines how many drums are returned, specified by the syntax shown in Figure 4-14. The number of damaged/scrap drums is also determined and marked. The processing LT at this server is tallied, then the return destination is set for each drum. The shrink rate, scrap rate, and return destination are specified in the control properties in Figure 4-2.

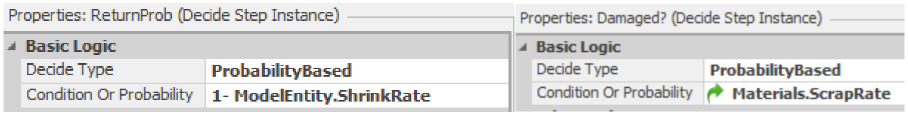


Figure 4-14 Shrink and scrap rate syntax

Before exiting the SrvInsSmall output buffer, an *Assign* step registers the state variable changes as shown in Figure 4-15.

```
Stat_InboundWeight_InsSmallToMan, Stat_InboundWeight_InsSmallToMan + ModelEntity.TransportSize,
InboundCost_DC.Cost, InboundCost_DC.Cost + (ModelEntity.TransportSize * (InsSmallToManager.LogicalLength / 1000) * Materials.InboundUnitCost_DC),
ModelEntity.Picture, Materials.ColorCode,
ModelEntity.OriginObject, 1,
```

Figure 4-15 State assignments for returned drums at SrvInsSmall output buffer

4.3.5 Wholesaler transfer area (TransferNode1)

All drums returned from SrvInsSmall to SrvWhole1 will be directed to the wholesaler transfer area (TransferNode1). This aims to ensure the returned drums are still reusable, otherwise returned to the drum manager. TransferNode1 has three connections that allow: a) receiving empty drums from SrvInsSmall heading to SrvWhole1, b) putting the reusable drums to SrvWhole1 inventory, and c) returning the empty drums to SrvManager if marked as damaged.

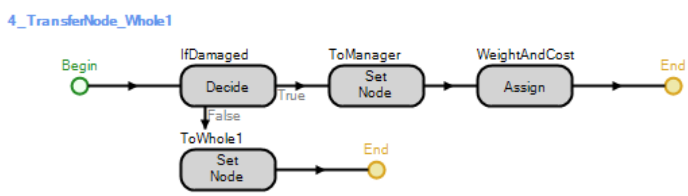


Figure 4-16 Wholesaler transfer area process

For the drums returned to SrvManager, an *Assign* step records the state variable changes as shown in Figure 4-17.

```
Stat_InboundWeight_Whole1, Stat_InboundWeight_Whole1 + ModelEntity.TransportSize,
InboundCost_DC.Cost, InboundCost_DC.Cost + (ModelEntity.TransportSize * (Whole1ToManager.LogicalLength / 1000) * Materials.InboundUnitCost_DC),
ModelEntity.Picture, Materials.ColorCode,
ModelEntity.OriginObject, 0,
```

Figure 4-17 State assignment for returned drums at TransferNode1

4.3.6 Large Installers (SrvInsLarge)

The large installers i.e., SrvInsLarge has two connections that allow: a) receiving full drums replenishment from SrvDistCenter, and b) returning empty drums to SrvManager. SrvInsLarge is constructed as a server that has three processes at input buffer, server, and output buffer, respectively shown in Figure 4-18. Process *1_SrvInsLarge_Entered* starts when a drum entity enters the SrvInsLarge station. For the full drums entering the SrvInsLarge from SrvWhole1, an *Assign* step records the state variable changes as shown in Figure 4-19.

Process *2_ShipmentReceivingLogic_InsLarge* ensures if SrvInsLarge is the intended final destination of an incoming drum entity. If it is true, then the *Produce* step reads the drum details i.e., drum types, and adds them as an inventory stock in this station.

When a drum entity enters the output buffer of SrvInsLarge, process *3_Output_SrvInsLarge_Entered* is executed. For replenishment drums received from the SrvWhole1, the processing LT at SrvInsLarge is measured, then destroyed. For non-replenishment drums i.e., returned drums, the shrink rate is applied. The *Decide* step *ReturnProb* determines the shrink rate and *Damaged?* determines the damaged/scrap rate at SrvInsSmall, using a similar syntax as SrvInsLarge in Figure 4-14. The shrink and scrap rates are specified in the control properties in Figure 4-2.

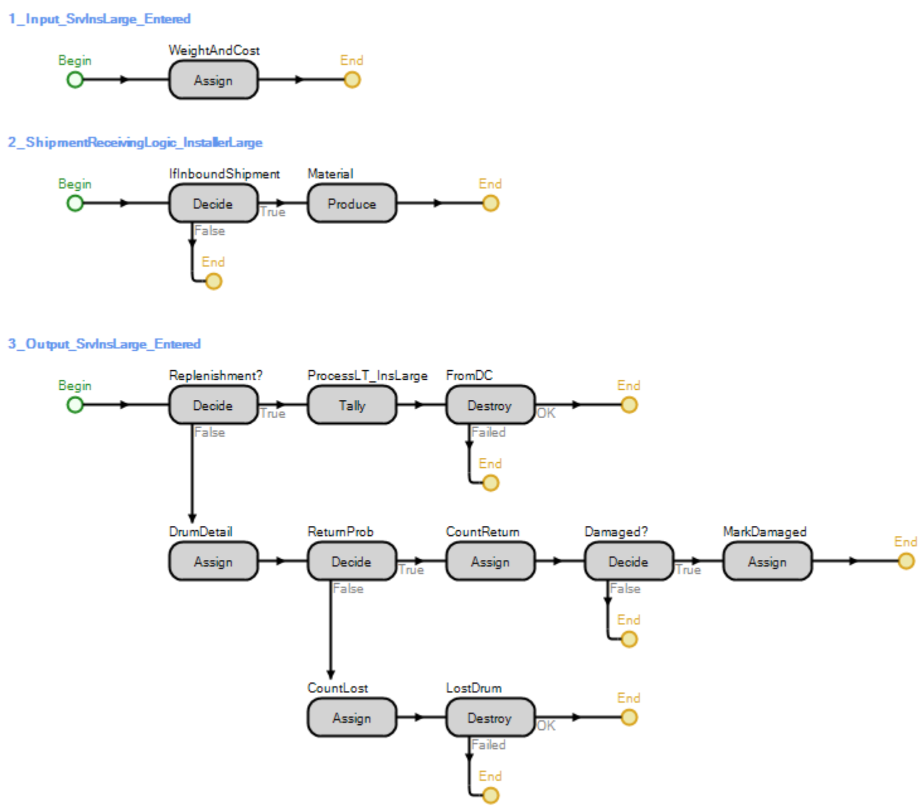


Figure 4-18 Large Installers station processes

```
ModelEntity.TransportSize, Materials.Weight,
Stat_OutboundWeight_InsLarge, Stat_OutboundWeight_InsLarge + ModelEntity.TransportSize,
OutboundCost_DC.Cost, OutboundCost_DC.Cost + (ModelEntity.TransportSize * (DCToInsLarge.LogicalLength/1000) * Materials.OutboundUnitCost_DC),
ModelEntity.ArrivalAtInsLarge, TimeNow,
Stat_InboundQtyAtInsLarge, Stat_InboundQtyAtInsLarge+1,
```

Figure 4-19 State assignments for full drums at SrvInsLarge

4.3.7 Drum manager (SrvManager)

The drum manager has five connections that allow: a) receiving empty drums from SrvInsSmall, b) receiving empty drums from SrvInsLarge, c) receiving damaged empty drums from SrvWhole1, d) delivering cleaned drums to SrvDistCenter for further reuse, and e) delivering scrapped drums to SnkScrap. SrvManager is constructed as a server that has four processes: one at the input buffer, two at the server, and one at the output buffer. Process *1_Input_SrvManager_Entered* begins when a drum entity enters SrvManager input buffer. It measures the inbound transport LT from SrvInsSmall, SrvInsLarge, and SrvWhole1.

Process *2_ShipmentReceivingLogic_InsLarge* ensures if SrvManager is the intended final destination of an incoming drum entity. If it is true, then the *Produce* step reads the drum details i.e., drum types, and adds them as an inventory stock in this station. The return rate calculation in Figure 4-20 considers the number of drums received at SrvManager in comparison to the outbound drums sent from SrvDistCenter to the customers.

Properties: CountReturnRate (Assign Step Instance)

Basic Logic	
State Variable Name	**Stat_ReturnRate**
New Value	**Math.min((Stat_InboundWeight_InsLarge+Stat_InboundWeight_InsSmallToMan+Stat_InboundWeight_Whole1) / (Stat_OutboundWeight_Whole1+Stat_OutboundWeight_InsLarge+1),1)**
Assignments (More)	0 Rows

Figure 4-20 Return rate calculation at SrvManager

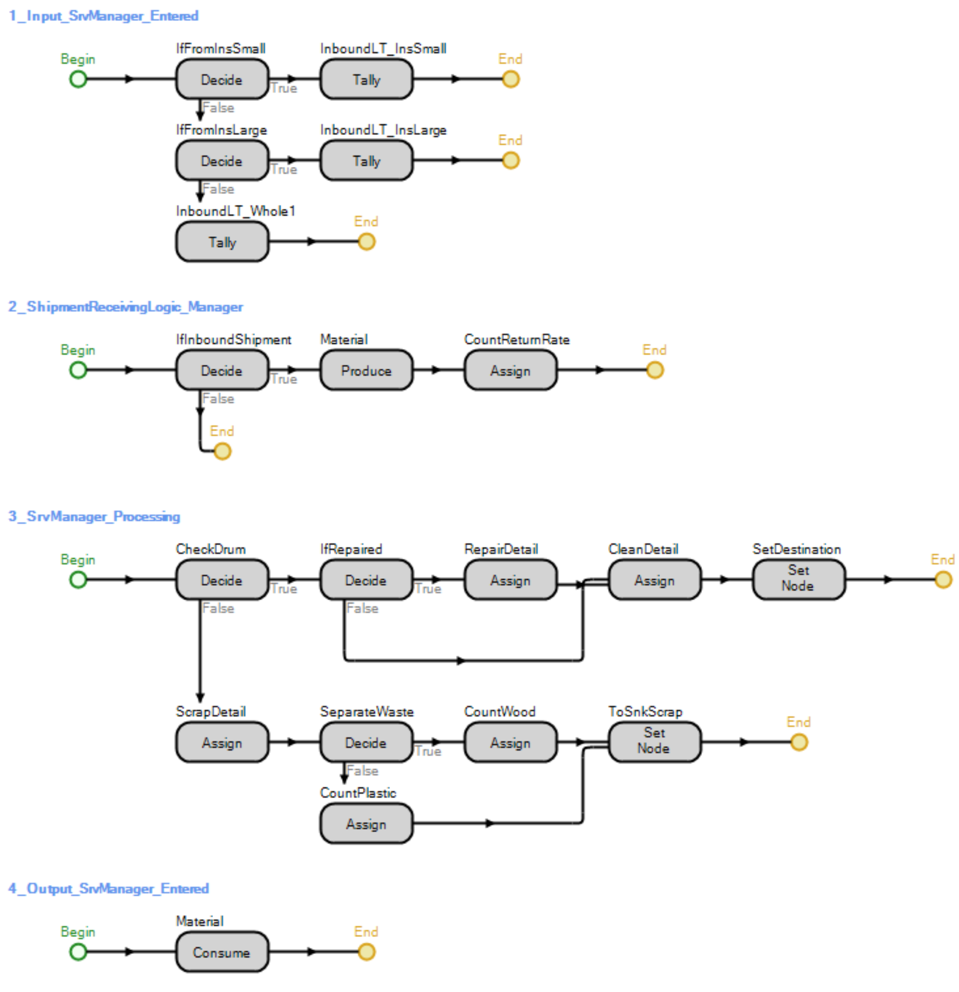
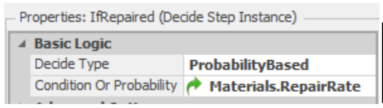


Figure 4-21 Drum Manager station processes

Process 3_SrvManager_Processing checks the incoming drum if it is marked as damaged or not. Drums that are still in good condition may undergo a repair or not based on a probability as specified in Figure 4-22. The repair rate is specified in the control properties in Figure 4-2. The *Assign* step in the *RepairDetail* in Figure 4-22 records the state variable changes. Another *Assign* step named *CleanDetail* also registers the state variable changes stated in Figure 4-23.




```
ModelEntity.RepairedMaterial, ModelEntity.Material,
Stat_NumRepaired, Stat_NumRepaired + 1,
RepairCost.Cost, RepairCost.Cost + Materials.RepairPrice,
```

Figure 4-22 Repair rate specification and state assignments for repaired drums at SrvManager

```
CleaningCost.Cost, CleaningCost.Cost + Materials.CleaningPrice,
Stat_NumCleaned_Manager, Stat_NumCleaned_Manager + 1,
Stat_ReusedWeight_DC, Stat_ReusedWeight_DC + ModelEntity.TransportSize,
Stat_RecoveryValue_DC, Stat_RecoveryValue_DC + Materials.PurchasePrice,
Stat_RepairSuccess, Stat_NumCleaned_Manager / (Stat_NumCleaned_Manager + Stat_NumScrapped_Wood),
Stat_ReuseRate_DC, Stat_ReusedWeight_DC / (Stat_OutboundWeight_InsLarge + Stat_OutboundWeight_Whole1 + 1),
```

Figure 4-23 State assignments for cleaned drums at SrvManager

Damaged drums will be scrapped. Each scrap drum is counted and weighted based on the material types (wood or plastic). The scrapped drums are then sent to the SnkScrap as a waste collector. The drum quantity in stock at SrvManager should decrease after a drum entity exits that server, hence a *Consume* step is required in process *4_Output_SrvManager_Entered.*

Appendix 5

Simulation Results

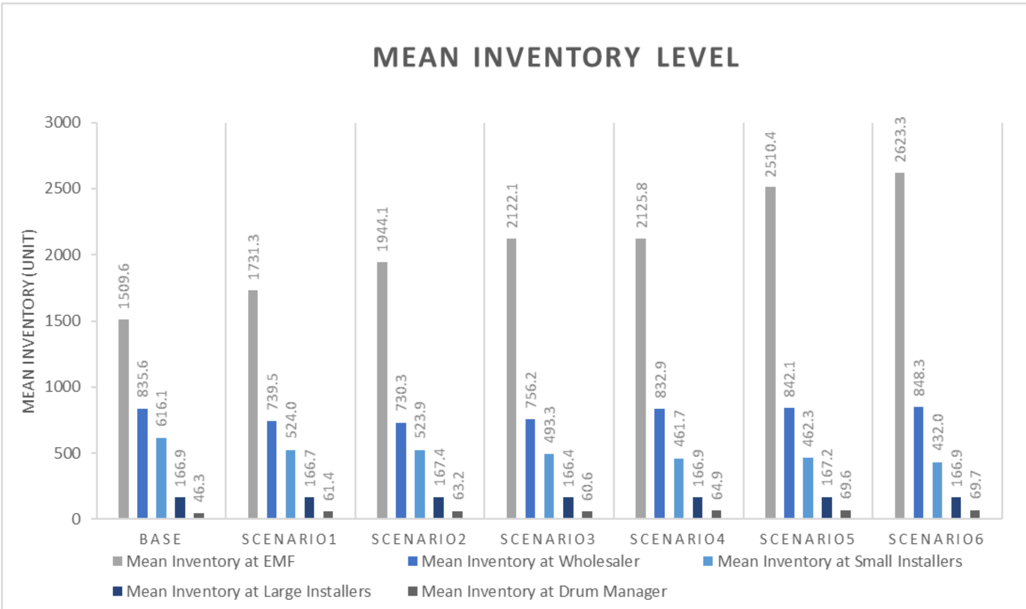


Figure 5-1 Mean inventory level

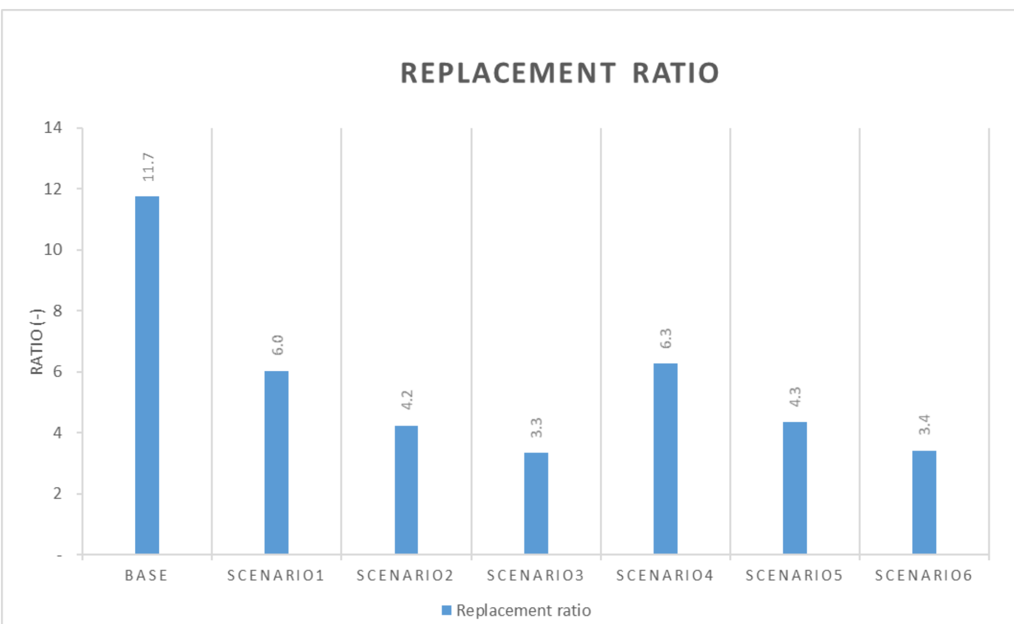


Figure 5-2 Replacement ratio

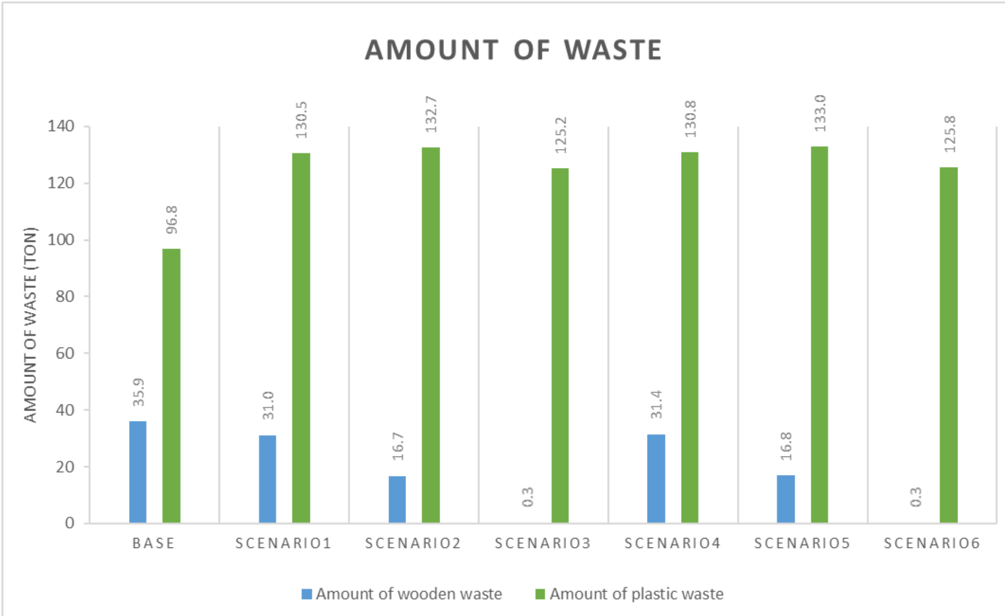


Figure 5-3 Amount of generated waste

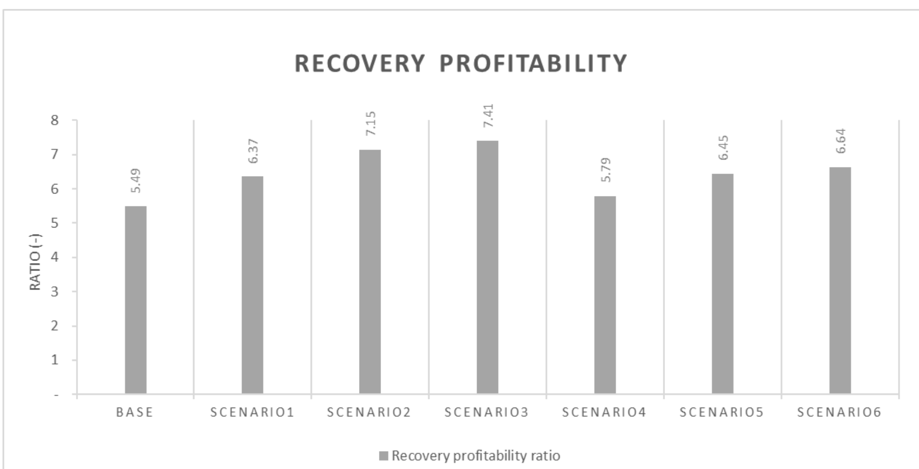


Figure 5-4 Recovery profitability

Appendix 6

Simulation Results

In this section, the results from the base and developed scenarios are presented. Table 6-1 shows the absolute values generated from the simulations. In Table 6-2, the difference between the developed and base scenarios are presented in percentage.

Table 6-1 Absolute values generated from scenario simulation

Code	Parameter	Unit	Base	Scenario1	Scenario2	Scenario3	Scenario4	Scenario5	Scenario6
P1	Return rate	%	60.3%	80.5%	85.8%	85.5%	80.9%	86.0%	86.1%
P2	Reuse rate (EMF & Wholesaler)	%	17.2%	26.3%	31.5%	35.1%	24.9%	29.0%	31.6%
P2.1	Reuse rate at EMF	%	17.2%	23.9%	27.1%	28.8%	24.9%	29.0%	31.6%
P2.2	Reuse rate at Wholesalers	%	0.0%	2.4%	4.5%	6.3%	0.0%	0.0%	0.0%
P3.1	RL cycle time at EMF via Small Installers	days	38.2	26.5	26.3	24.3	22.8	22.7	21.1
P3.2	RL cycle time at EMF via large installers	days	22.8	19.6	19.6	18.5	17.5	17.5	16.4
P3.3	RL cycle time at Wholesalers	days	0.0	7.0	7.0	6.6	0.0	0.0	0.0
P4	Mean Inventory	unit	3174.4	3223.0	3429.0	3598.6	3652.2	4051.5	4140.3
P4.1	Mean Inventory at EMF	unit	1509.6	1731.3	1944.1	2122.1	2125.8	2510.4	2623.3
P4.2	Mean Inventory at Wholesaler	unit	835.6	739.5	730.3	756.2	832.9	842.1	848.3
P4.3	Mean Inventory at Small Installers	unit	616.1	524.0	523.9	493.3	461.7	462.3	432.0
P4.4	Mean Inventory at Large Installers	unit	166.9	166.7	167.4	166.4	166.9	167.2	166.9
P4.4	Mean Inventory at Drum Manager	unit	46.3	61.4	63.2	60.6	64.9	69.6	69.7
P5	Replacement ratio	-	11.7	6.0	4.2	3.3	6.3	4.3	3.4
E1	Amount of waste (E1.1+E1.2)	ton	132.6	161.5	149.4	125.5	162.2	149.8	126.1
E1.1	Amount of wooden waste	ton	35.9	31.0	16.7	0.3	31.4	16.8	0.3
E1.2	Amount of plastic waste	ton	96.8	130.5	132.7	125.2	130.8	133.0	125.8
E2	Inbound transport CO2 emission	ton CO2-eq	5.1	7.2	7.6	7.6	6.9	7.3	7.3

E3	Disposal CO2 emission	ton CO2-eq	3.5	4.6	4.5	4.1	4.6	4.5	4.2
E4	New purchase CO2 emission	ton CO2-eq	30.9	25.5	22.9	21.6	26.4	23.5	22.2
C1.1	SL Wholesalers	%	97.9%	97.2%	98.3%	98.9%	97.8%	98.0%	98.0%
C1.2	SL Small Installers	%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
C1.3	SL Large Installers	%	97.9%	97.9%	98.0%	97.8%	97.8%	97.9%	97.9%
F1	Recovery value	€	209,510	311,577	369,363	408,573	311,801	369,126	408,609
F2	RL costs internal	€	37,867	48,589	51,495	54,901	53,341	57,037	61,151
F2.1	RL internal cost EMF	€	37,867	48,159	50,709	53,789	53,341	57,037	61,151
F2.2	RL internal cost Whole	€	-	430	787	1,112	-	-	-
F2	RL cost external	€	408	574	610	609	548	583	584
F2	RL costs total	€	38,275	49,163	52,106	55,511	53,890	57,620	61,735
F3	Recovery profitability ratio	%	5.53	6.41	7.17	7.44	5.85	6.47	6.68
F3.1	Recovery profitability EMF	%	5.53	5.94	6.36	6.36	5.85	6.47	6.68
F3.2	Recovery profitability Wholesaler	%	-	59.76	59.78	59.90	-	-	-
F4	RSC Efficiency	%	27.1%	45.6%	57.2%	66.0%	43.7%	55.9%	64.8%
F5	Cost benefit ratio	-	-	1.9	3.2	3.7	1.6	3.0	3.6

Table 6-2 Percentage difference between developed and base scenario

Code	**Parameter**	**Unit**	**Scenario1**	**Scenario2**	**Scenario3**	**Scenario4**	**Scenario5**	**Scenario6**
P1	Return rate	%	33.6%	42.4%	41.9%	34.3%	42.6%	42.8%
P2	Reuse rate (EMF & Wholesaler)	%	52.6%	82.9%	103.9%	44.5%	68.0%	83.6%
P2.1	Reuse rate at EMF	%	38.4%	56.9%	67.2%	44.5%	68.0%	83.6%
P2.2	Reuse rate at Wholesalers	%	-	-	-	-	-	-
P3.1	RL cycle time at EMF via Small Installers	%	- 30.6%	- 31.0%	- 36.3%	- 40.4%	- 40.5%	- 44.7%
P3.2	RL cycle time at EMF via large installers	%	- 14.1%	- 14.2%	- 18.9%	- 23.6%	- 23.6%	- 28.3%
P3.3	RL cycle time at Wholesalers	%	-	-	-	-	-	-
P4	Mean Inventory	%	1.5%	8.0%	13.4%	15.1%	27.6%	30.4%
P4.1	Mean Inventory at EMF	%	14.7%	28.8%	40.6%	40.8%	66.3%	73.8%
P4.2	Mean Inventory at Wholesaler	%	- 11.5%	- 12.6%	- 9.5%	- 0.3%	0.8%	1.5%
P4.3	Mean Inventory at Small Installers	%	- 14.9%	- 15.0%	- 19.9%	- 25.1%	- 25.0%	- 29.9%

P4.4	Mean Inventory at Large Installers	%	- 0.1%	0.3%	- 0.3%	- 0.1%	0.2%	- 0.0%
P4.4	Mean Inventory at Drum Manager	%	32.7%	36.5%	30.9%	40.2%	50.4%	50.5%
P5	Replacement ratio	%	- 48.7%	- 63.9%	- 71.6%	- 46.6%	- 63.0%	- 70.8%
E1	Amount of waste (E1.1+E1.2)	%	21.8%	12.6%	- 5.3%	22.3%	13.0%	- 4.9%
E1.1	Amount of wooden waste	%	- 13.6%	- 53.4%	- 99.1%	- 12.5%	- 53.1%	- 99.1%
E1.2	Amount of plastic waste	%	34.9%	37.1%	29.4%	35.2%	37.4%	30.0%
E2	Inbound transport CO2 emission	%	40.7%	49.5%	49.3%	34.4%	42.8%	43.1%
E3	Disposal CO2 emission	%	30.9%	29.7%	18.8%	31.3%	30.0%	19.3%
E4	New purchase CO2 emission	%	- 17.3%	- 25.7%	- 30.2%	- 14.4%	- 24.0%	- 28.2%
C1.1	SL Wholesalers	%	- 0.7%	0.4%	0.9%	- 0.1%	0.1%	0.0%
C1.2	SL Small Installers	%	-	-	-	-	-	-
C1.3	SL Large Installers	%	0.0%	0.0%	- 0.1%	- 0.1%	- 0.0%	- 0.0%
F1	Recovery value	%	48.7%	76.3%	95.0%	48.8%	76.2%	95.0%
F2	RL costs internal	%	28.3%	36.0%	45.0%	40.9%	50.6%	61.5%
F2.1	RL internal cost EMF	%	27.2%	33.9%	42.0%	40.9%	50.6%	61.5%
F2.2	RL internal cost Whole	%	-	-	-	-	-	-
F2	RL cost external	%	40.7%	49.5%	49.3%	34.4%	42.8%	43.1%
F2	RL costs total	%	28.4%	36.1%	45.0%	40.8%	50.5%	61.3%
F3	Recovery profitability ratio	%	15.9%	29.6%	34.5%	5.7%	17.0%	20.8%
F3.1	Recovery profitability EMF	%	7.3%	14.9%	14.9%	5.7%	17.0%	20.8%
F3.2	Recovery profitability Wholesaler	%	-	-	-	-	-	-
F4	RSC Efficiency	%	68%	111%	144%	62%	107%	139%
F5	Cost benefit ratio	%	-	-	-	-	-	-

Appendix 7

Cost-Benefit Analysis

The calculation for the cost-benefit ratio is explained in this section. Table 7-1 shows the required hardware, software, or brainware to implement the scenarios. On the other hand, Table 7-2 shows the calculation of net present value and cost-benefit ratio.

Table 7-1 List of requirements for each scenario

Description	Units	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
T-1 Installation of RFID tags							
UHF Passive RFID tags	unit	28,928	27,092	25,746	29,220	27,644	26,344
RFID hardware, installation, and configuration at EMF	unit	1	1	1	1	1	1
RFID hardware, installation, and configuration at 5 Wholesalers	unit	5	5	5	5	5	5
RFID hardware, installation, and configuration at Drum Manager	unit	1	1	1	1	1	1
Subtotal							
L-1 Wholesaler return flow							
Inbound transport cost by Wholesaler	unit	-	-	-	-	-	-
Subtotal							
L-2 Scheduled return pickup							
Scheduled pickup transport cost by Transporter	unit	-	-	-	-	-	-
Subtotal							

C-1 Return instruction							
Installing QR code on drum	unit	28,928	0	0	29,220	0	0
Mobile app development	unit	1	0	0	1	0	0
Subtotal							
C-3 Customer Engagement							
Included in current customer engagement meetings and visits	unit	0	1	0	0	1	0
Subtotal							
C-4 Non-return penalty							
Adaptation in current ERP system	unit	0	0	1	0	0	1

Table 7-2 Cost Benefit Ratio calculation

Description	**Unit** price	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**
T-1 Installation of RFID tags							
UHF Passive RFID tags	€ 0.8	[redacted]					
RFID hardware, installation, and configuration at EMF	€ 20,000[1]						
RFID hardware, installation, and configuration at 5 Wholesalers	€ 20,000[1]				Confidential		
RFID hardware, installation, and configuration at Drum Manager	€ 20,000[1]						
Subtotal							
L-1 Wholesaler return flow							
Inbound transport cost by Wholesaler		[redacted]					
Subtotal							
L-2 Scheduled return pickup					Confidential		
Scheduled pickup transport cost by Transporter							
Subtotal							

C-1 Return instruction							
Installing QR code on drum	€ 0.5[3]	Confidential					
Mobile app development	€ 15,000[2]						
Subtotal							
C-3 Customer Engagement							
Included in current customer engagement meetings and visits	€ 0	Confidential					
Subtotal							
C-4 Non-return penalty							
Adaptation in current ERP system	€ 10,000[3]	Confidential					
Subtotal							
Total investment cost							
Expected benefits		Confidential					
Investment period							
Discount rate							
Future Value							
Future Value - Year 1		Confidential					
Future Value - Year 2							
Future Value - Year 3							
Future Value - Year 4							
Net Present Value							
Cost-Benefit Ratio		**1.9**	**3.2**	**3.7**	**1.6**	**3.0**	**3.6**

References 1: Watson T(2013) 2: Gunterman (n.d.) 3: own estimate