A Matchmaking System to Enhance the Traceability of RTI Returns

A Case Study at Euro Pool System

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EURO POOL SYSTEM

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A Matchmaking System to Enhance the Traceability of RTI Returns

A Case Study at Euro Pool System

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The earth is the Lord's, and the fulness thereof;
the world, and they that dwell therein.

— Psalm 24:1 (KJV)

PREFACE

This thesis marks the final step towards completing my Master of Science degree in Transport, Infrastructure and Logistics, at Delft University of Technology. Undertaking this research has been an exciting "*Alice in Wonderland*" journey for me, one that transcends academic boundaries and delves into the depths of personal growth. I am deeply grateful to God, for providing me with strength, guidance, and wisdom throughout this journey. His presence, grace and blessings have been my source of joy, comfort and peace at all times, filling my heart with gratitude for the opportunity to pursue knowledge and personal growth.

As I reflect upon the completion of this thesis, I am struck by the impact it has had on my understanding of the dynamics between research and practice, the world of reusable trays and myself as a person. This work embodies more than just an accumulation of research efforts; It encapsulates a transformative process. A transformative process in which I learnt to let go of self-doubt, overthinking and my past. I am humbled by the wealth of support and guidance that has shaped its development.

I would like to express my deepest appreciation to my graduation committee, which includes my academic supervisors, John, Wouter and Alessia, and my committee chair, Rudy. Each of them has played a significant role in my growth journey in their own way. Their expertise, patience and guidance were invaluable. Regarding their guidance, they complemented each other like puzzle pieces, without them realizing it. I am extremely grateful for both the academic and personal advice that they provided throughout the project. Their ability to listen attentively and their ability to give precise, constructive and encouraging feedback inspire me. The completion of my thesis would not have been possible without their unwavering support and their profound belief in my abilities.

I am also very grateful to my external supervisor Robbert, for giving me the opportunity to carry out my thesis project at Euro Pool System so I could delve into the world of trays. The balance in guiding me but also letting me figure out things on my own has worked out great for my learning process. I value the discussions we had that offered me practical insights and industry knowledge. I also wish to thank everyone I met at the company during my thesis project, for creating a supportive work environment, sharing their expert knowledge with me and making me feel comfortable in my own skin.

Finally, I would like to thank my brothers and sisters in Christ, my friends, my brothers and my parents, who continuously supported and encouraged me during my studies.

As I step into the next phase of my life, I carry a grateful heart, holding close the invaluable lessons and experiences gathered throughout this journey. My hope is that this thesis captivates your interest and offers an engaging read.

Justine Tang
Amsterdam, December 2024

SUMMARY

The present study was designed to gain a deeper understanding of Returnable Transport Item (RTI) control and Supply Chain Coordination, with a specific focus on the practical challenges experienced in the reverse logistics by asset-owner and asset-users. A case study at Euro Pool System (EPS) - an RTI owner - is performed and a practical problem has been addressed with a design science and TIL systems engineering approach. It was observed that a huge amount of deposit is allocated to a retailer's generic account. The current state analysis found that this problem is mainly due to inefficiency in the current identification process with physical Serial Shipment Container Code (SSCC) labels. The design goal of minimising the Δ -the number of unidentifiable return packages- was defined. Ways to redesign the reverse logistics were determined with the aim that all return packages can be allocated to the retailer at shop level. Based on the future state requirements and the design goal, the concept of matchmaking is developed as a way to achieve the design goal. This thesis shows that a matchmaking system can improve the traceability of return packages and that it has the potential in bringing the Δ of return packages with missing shoplink to zero. The matchmaking system is defined as the framework that ensures matchmaking, which uses a *key* generated by the sender to represent the return package. If the receiver can find the key upon arrival of the return package at the depot, the sender can be identified. Seven matchmaking systems were considered. Five alternatives use unique tray identities as key. One alternative uses the load carrier as key and the last alternative uses the return package identity as key. The validation results show that an "all read" or "reading of all individual trays" is not a requisite for a working matchmaking system. By contrast, as long as a certain ratio of reading at two locations is reached, an all-read scenario can be mimicked. The assessment investigated the instances in which zero mismatch take place. Results show that the higher the data capture capability of both the sender and receiver, the higher the chance a match can take place and the smaller the chance of a mismatch. This thesis creates insights on requirements for enhancing traceability of RTI's in the return chain and developed a matchmaking concept that can address the practical problem of returns without traceability of shop origin. The developed matchmaking concept is the outcome of an analysis of the current state and makes use of data elements that are already being collected in the database, in the case of EPS. The study addresses how collected data can be leveraged for enhanced RTI management in the reverse logistics and may inspire practitioners to face challenges with a similar lean approach.

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ACRONYMS

BSST Business Self Support Tool
CCA Cross-Consistency Assessment
CLSC Closed Loop Supply Chain
CnI Counting and Identification
DC Distribution Centre
EPG Euro Pool Group
EPS Euro Pool System
GMA General Morphological Analysis
GRAI Global Returnable Asset Identifier
RA Returnable Asset
RFID Radio Frequency Identification
RTI Returnable Transport Item
SEU Standard Equivalent Unit
SLA Service Level Agreement
SSCC Serial Shipment Container Code

1 INTRODUCTION

Over time, the logistics industry has transitioned towards sustainable practices. This has resulted in the elimination of single-use packaging and the use of Returnable Transport Items (RTIs) as a sustainable option. In most industries, Returnable Transport Items (RTIs) are key elements for enabling a smooth flow of goods throughout the supply chains. Returnable Transport Items (RTIs) are a packaging medium that allows bundled goods to be transported between vendors and customers multiple times. They are crucial to efficient logistical operations and provide protection of goods during transport, storage, and handling. In the fresh fruit and vegetable industry, RTIs are known as crates, trays, boxes, pallets and roll cages which are returned multiple times in their life cycle. RTIs therefore are considered as a strong instrument for supporting efficient and sustainable supply chain strategies, enabling businesses to free up valuable capital and other resources by lowering the amount of time and money spent transporting goods.

1.1 THE CASE STUDY OF EURO POOL SYSTEM

Euro Pool System (EPS) is part of Euro Pool Group (EPG), a large logistics service provider of reusable standard packaging in Europe [13]. To solve the logistical deadlock caused by inefficient packing of fresh products, Euro Pool System (EPS) is established through the collaboration of three packaging pools that were part of the cooperative auction houses in the Netherlands, Belgium and Germany in 1992. EPS supplies standardized foldable trays in the distribution chain for fresh and packaged foods. Now, thirty years later, EPS manages over 250 million reusable trays, making it one of the largest pool in the world. These trays are used throughout Europe's retail supply chains, from growers (fillers) and food processors (traders) to retailer's distribution centres and finally to retailer's stores. Once the trays have been used, they are returned to the retailer's distribution centre, collected, and transported to an EPS depot, where they are cleaned and restocked for the next use cycle. Figure 1.1 represents this network. The arrows indicate the movement of trays, while the numbers show how the trays are moved.

During the whole use cycle, EPS remains the owner of the trays. In addition, EPS is the controller of the depots, which are used for collecting, washing and storing the trays. EPS is also responsible for the distribution of trays to the fillers, the cleaning and the maintenance of the trays. For every tray that is used, a deposit is paid. The sender debits his recipients for this deposit, who does the same with his recipients, and so forth. Ultimately, the tray reaches back at one of EPS' depots, and EPS refunds the deposit to the retailer from which the tray was collected. The EPS tray pool can be put into the category of a "Depot system with deposit" based on Lützebauer's classification of control strategies for RTI systems, which is mentioned in Kroon and Vrijens [24].

THE RETURN PROCESS AND SHOP TRACEABILITY In order to pay out the correct deposit to the correct customer in the return chain, two processes must take place correctly. First, the returned EPS trays must be counted (hereafter referred as *"Counting"*). Second, the (shop) origin, also called the sender of the trays must be traced back (herafter referred as *"Identification"*). Both processes Counting and Identification (CnI) take place upon arrival at the depot. Currently, the identification process happens through a Serial Shipment Container Code (SSCC) code, which follows the GS1 standard. The SSCC code is encoded in a barcode that is printed on a label. When the retailer places a return order, they apply this label to the return package. The return package consists of a combination of folded trays packed and stacked together on a load carrier (e.g. pallet, dolley).

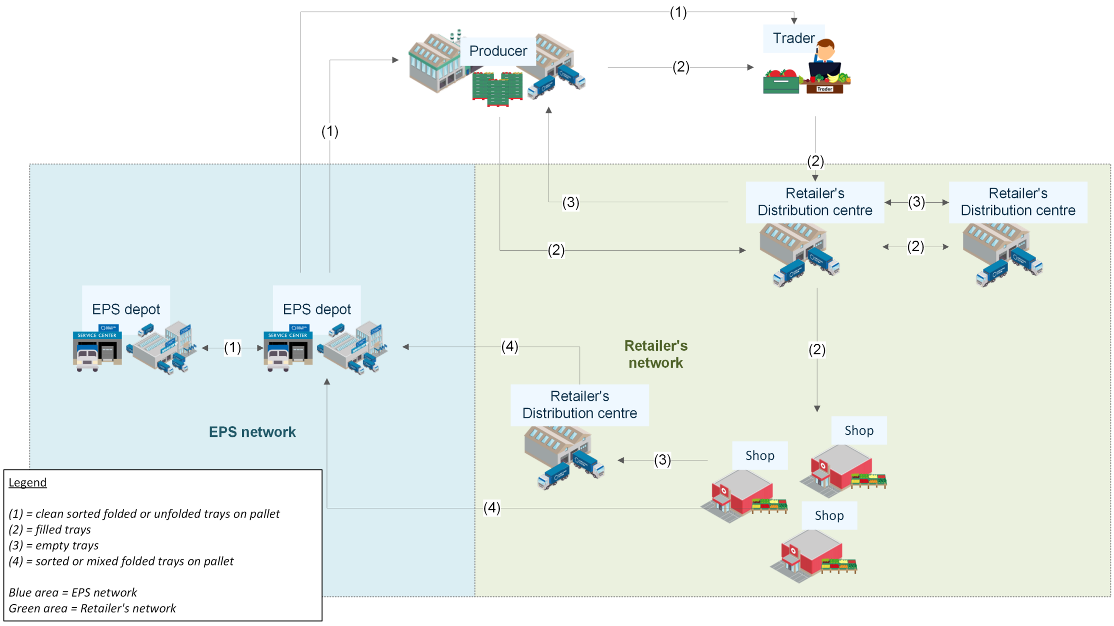


Figure 1.1: EPS' tray flow network

THE INITIAL PRACTICE PROBLEM The SSCC has become a crucial key for traceability, since it uniquely identifies the return order (return package sent from a specific store). The importance of the identification process is obvious, for without correct traceability of the return order, the retailer's affiliate (shop) cannot receive her deposit. With most retailers, it has been agreed upon that the amount is transferred to the retailer's generic account in case when a link on shop level is missing. This is a nuisance for the retailer, especially if the retailer has franchises. An example of the missed deposit is represented in Figure 1.1. Figure 1.1 gives an indication of what the impact of unidentifiable SSCC is for Delhaize and Jumbo. Details can be found in Apendix C. On average Jumbo generates 51,782 SSCCs per month. Of this total, 2.7% is unidentifiable at shop level (1,480)[1]. This corresponds with a rounded amount of €150,000. On average Delhaize generates 112,736 SSCCs per month. Of this total, 15.9% is unidentifiable at shop level (18,422)[2]. This corresponds with a rounded amount of €9 million.

RETAILER	AVG MONTLY SSCC	SSCC GENERAL ACCOUNT	AMOUNT OF DEPOSIT
Delhaize	112,736	18,411 (15.9%)	€8,925,526.57
Jumbo	51,782	1,480 (2.7%)	€149,904.51

Table 1.1: An example estimation of the deposit not allocable to a store in one month

1.2 RESEARCH INITIATIVE

From a practical perspective, an unidentifiable SSCC translates into a deposit-amount of a load-carrier package that cannot be allocated to a retailer's store, meaning that there is no closed accounting on shop level. A quick look, may lead to the conclusion of ignorable percentage. However as can be seen from the sample estimation (fourth collumn), the relatively "small amount" of unidentifiable SSCC conveys a large amount of deposit. From a broader perspective, the effects caused by unidentifiable SSCCs may be bearable for the retailer (whole supermarket-chain).

1 The calculations for Jumbo are based on Jun-22 until Feb-23 (Table C.2)
2 The calculations for Delhaize are based on Feb-22 until Feb-23 (Table C.1)

However considering the fact of differences in store sizes and taking franchises into account, it should be noted that a missing of deposit affects small businesses greatly.

From a scientific perspective, the presenting problem is related to the concept of Supply Chain Visibility, Asset traceability, Service design and Information systems.

The problem statement can be formulated as follows:

> *Retailers consolidate trays from different stores in order to efficiently return them to EPS, however there is ambiguity of which return package originates from which store, which has implications on the refund of deposit and the store's balanced accounting.*

1.3 RESEARCH OBJECTIVES

In follow up of the outcomes of the research initiative and the literature review in Chapter 2, this thesis project aims to minimize the gap between the ideal closed bookkeeping of store allocation and the current state, by redesigning the tray return chain of EPS. The objective is formulated as follows:

> *To design a system that can enhance RTI traceability in the reverse logistics of an existing pool and current network.*

The sub-objectives that are aimed to be achieved in this project are:

- Gain insight into the various strategies and conclusions of Returnable Transport Items in the scientific literature;
- Gain insight into the state-of-the-art technologies that can improve traceability of RTIs in the return chain;
- Gain insight into challenges for asset-managers;
- Measure and analyse the current state of the return chain of trays;
- Understanding of the bottlenecks in the current return chain;
- Design alternatives;
- Assess and evaluate potential alternatives.

1.4 RESEARCH SCOPE

This project will only focus on the reverse logistics of the reusable Closed Loop Supply Chain of RTIs, see figure 1.2. In terms of the time dimension, this signifies the moment that the end-consumer has finished using the asset, until the moment that the asset are collected, identified and counted.

In terms of the physical dimension, the return part of the reusable Closed Loop Chain is part of a complex system. As described briefly in the beginning of this chapter, EPS trays circulate in a complex network (Fig 1.1). In this research, the assumption is made that all assets circulate in a circular loop and that all assets that are distributed into the system

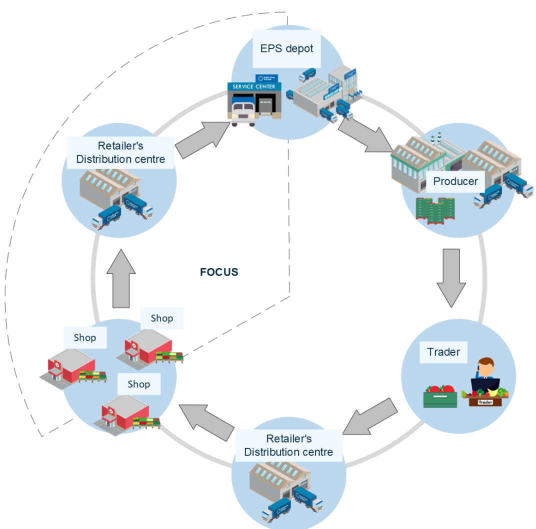


Figure 1.2: Project Scope

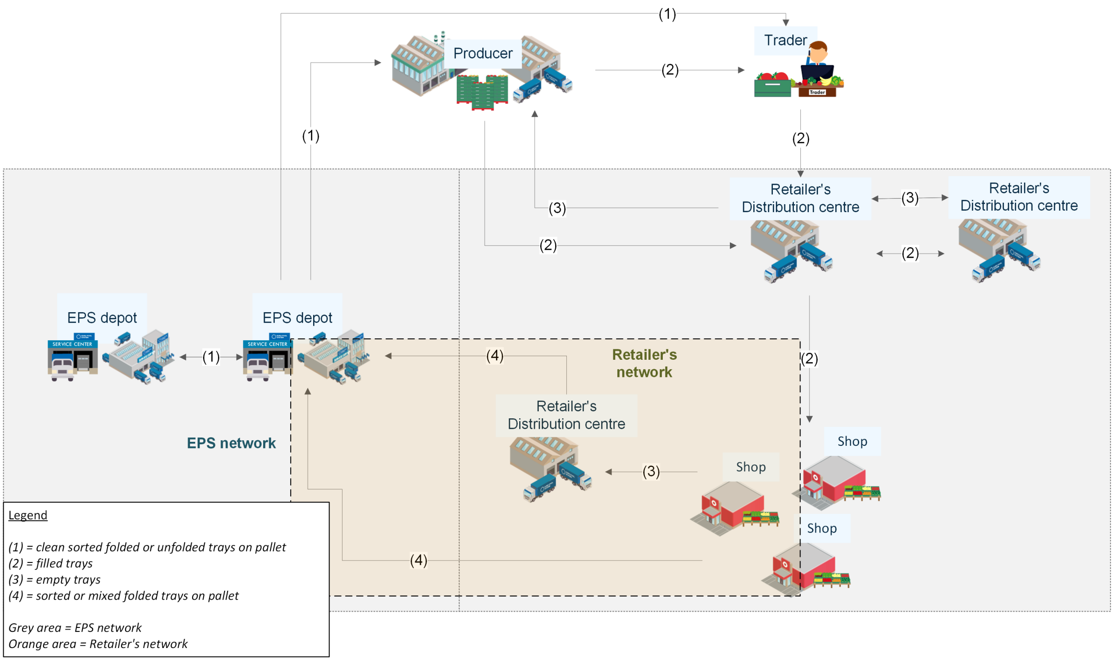


Figure 1.3: Network Scope

(forward logistics) also return (reverse logistics). In other words, no assets can go out of the system. Figure 1.3 depicts the network scope of this project. Considering the different types of RTIs, this project will only focus on the return of EPS green folding trays that have a unique Global Returnable Asset Identifier (GRAI) code. For a return, EPS trays are stacked together on a pallet, which results in a *Return Package*. For details about how trays are stacked, appendix F can be consulted.

1.5 RESEARCH QUESTIONS

Based on the problem statement that this research addresses, the main research question reads:

> *How can the return chain be redesigned so that the deposit of returned trays can be correctly allocated to a retailer's shop?*

In order to answer this research question, the following sub-questions needs to be answered first:

1. How are RTI returns described in academic literature?
2. What is the current state RTI reverse logistics and traceability?
3. What are the requirements for the future state?
4. What are potential ways to achieve the future state?
5. How can zero-defect last-user (shop) traceability of return packages be achieved?

1.6 METHODOLOGY

This thesis sought out the interrelation-dynamics between asset-owners and asset-users and how this affects the outcomes of a process, in this particular case the reverse logistics of reusable trays. A case study at Euro Pool System is performed to gain deeper insights. A combination of TIL systems engineering and the design science approach is taken to investigate ways to improve the traceability in the reverse logistics. The design science approach focuses on the process of determining what is practical and feasible for the creation of possible futures, rather than only focusing on what is presently present. One of the key benefits of employing design research methodology is its capacity to generate both practical solutions and theories concurrently, integrate additional research methods when necessary, and optimise processes through iterative procedures. It also increases efficiency by exploring a vast array of potential solutions with rapid, low-cost methods prior to employing more rigorous empirical methods. Table 1.2 shows an overview of the methods used to answer the research questions.

USED METHOD	THE REASON	EXPECTED OUTCOME
Interviews	To gain expert-knowledge on a specific field	Insights in the Current State Reverse Logistics
Literature study	To gain state-of-the-art knowledge regarding RTI reverse logistics	Scientific relevance
Design Problem Definition	To gain an analysis of different aspects surrounding the practice problem	A quantification of the practice problem, with the goal of creating an explicit statement on the problem and possibly the direction of idea generation
Morphological chart	To generate conceptual designs	Design alternatives
Requirements Analysis	Creating a framework that holds the solution space	A first list of requirements
Brainstorming	To generate out-of-the-box ideas	(Sub)functions and input for the Morphological Chart
Probability model	To simulate the likelihood of matchmaking	Matchmaking performance analysis

Table 1.2: Design Methods Matrix

1.7 STRUCTURE OF THIS WORK

This thesis follows the double diamond framework established by Kochanowska, Gagliardi, and with reference to Jonathan Ball [23]. The choice is based on the earlier decision to take a design science approach to perform the research. It is thought that the double diamond framework is a suitable way to present and structure the research findings.

This thesis consists of seven chapters as visualised in Figure 1.4. After the introduction (1), in which the challenge of deposit allocated to a generic account is proposed, the research part of the thesis is presented (first diamond). The first half of the research part includes a background study section (2) that gives an overview concerning the state of the art in RTI management, traceability and visibility. The second half of the research part comprises of the current state analysis on the traceability of RTIs in the reverse logistics (3). Based on the findings of the first diamond, the problem is specified and the design goal is established. After the problem specification the design part of the thesis is presented (second diamond). To find ways to address the quantified problem, a requirements analysis is performed in the following section after which the concept of matchmaking is proposed(4). In section (5) potential matchmaking systems were developed.

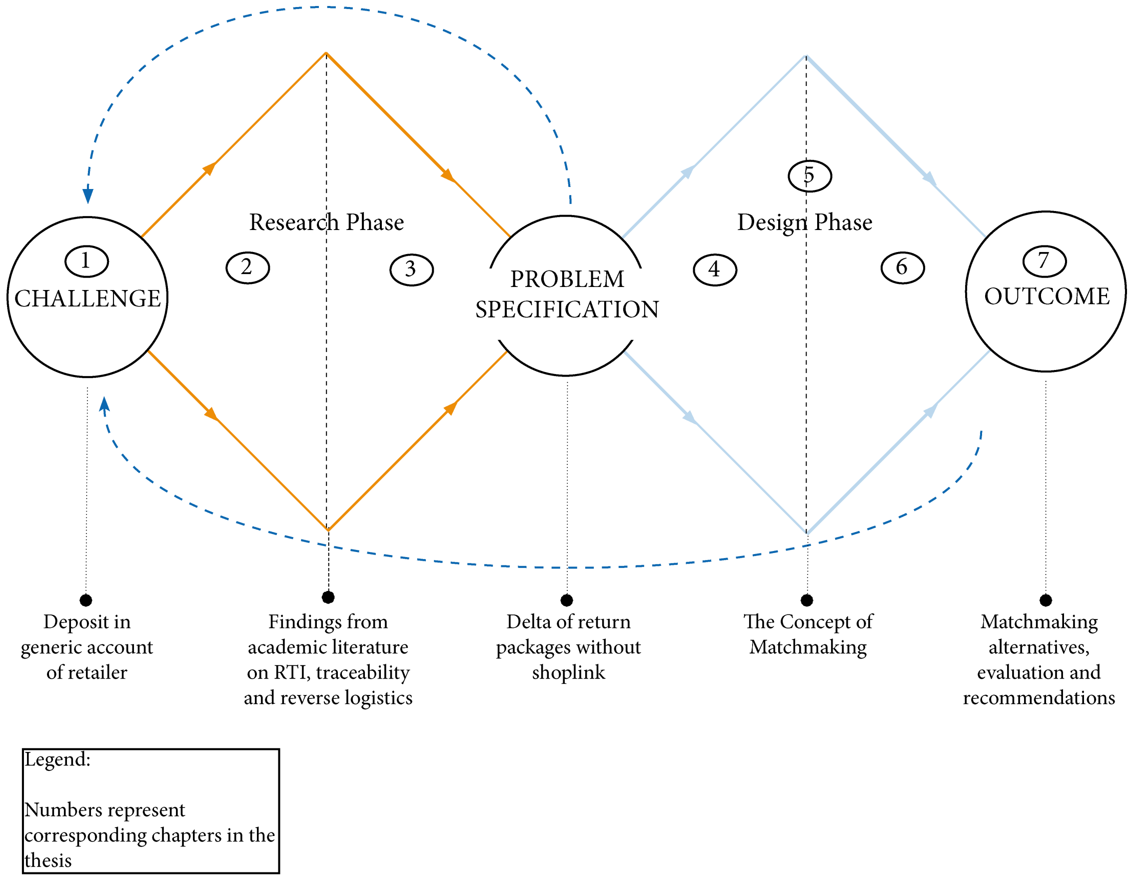


Figure 1.4: Structure of this thesis

In the assessment section (6), the performance of potential matchmaking systems are tested. The thesis ends with a conclusion (7), reflection and recommendations.

2 BACKGROUND STUDY

This chapter comprises of a literature study and seeks to identify the state of the art research on RTI logistics and management. This exploration is part of the research phase to gain better understanding of the practical problem addressed in the previous chapter. In addition, based on the insights of this literature review, research gaps were identified. This chapter includes descriptions of concepts that are most important for this thesis project.

2.1 LITERATURE REVIEW

The most recent literature review which addresses RTI is from [5], and focuses on the sustainability of reusable packaging systems. This review differs by adopting a broader approach. In summary, the aim of this literature review is to answer the question:

How are RTI supply chains described in academic literature from a managerial perspective?

This literature review adds value to the existing research body by addressing the links between previous research on RTIs. The main output is an overview of explored topics within the field of RTI management (Figure 2.1).

METHODOLOGY To gain a comprehensive understanding of the relevant literature on RTI systems a structured search process is followed. The method is mainly based on the principle of snowballing, following Wohlin [38]. First, a few master theses on closed loop supply chains with RTI's were gathered. Second, these papers were read with the purpose of gaining a general understanding and overview of trends in the field. Third, an attempt of convergence towards the state-of-the-art is made by defining keywords. The keywords served as a guideline for finding potential relevant readings. Articles that include the keywords "RTI management/control, Closed Loop Supply Chain, Visibility and Reverse Logistics" were added to the literature selection list. Fourth, after the previous steps, the literature selection contained 35 papers. These papers were all given a skim read. Articles which seemed less relevant were removed from the literature selection list, while backward and forward snowballing were performed on articles which seemed more relevant. This process was performed iteratively, until no new sources came to the surface. This resulted in a final literature list comprising of the following papers: [1, 2, 4–7, 15, 17, 19, 21, 24, 26, 27, 30, 34–36].

2.2 RETURNABLE TRANSPORT ITEMS

DEFINITION To establish a common understanding, it is important to define the terminologies associated with Returnable Transport Items (RTIs). In the academic literature, different terms have been used to describe the same concept, including Returnable Transport Items, Returnable Transport Units, Returnable Transit Items, Returnable Packaging, Reusable Packaging, Reusable Product, and Reusable Articles. In addition, the term packaging systems have also been used to describe the adoption of a type of reusable items [2]. The first adoption of the term RTI is by Johansson and Hellström [21]. Carrasco-Gallego and Ponce-Cueto [6] proposed a typology framework that categorizes RTIs as a subset of Returnable Assets (RAs). RA refers to *"durable products intended to be used multiple times by different users in different locations of a supply-chain network"*. The typology classifies RA into three categories: Returnable Transportation Items (RTI), Returnable Packaging Materials (RPM), and Reusable Products (RP). RPM typically constitutes primary packaging directly in contact with end-customer products (e.g. refillable glass bottles for beverages, toner cartridges, single use cameras, gas cylinders), while RTIs serve as secondary and tertiary packaging with no direct contact (e.g. pallets, crates, trays, roll cages, barrels, trolleys, racks). On the other hand, RP refers to the products themselves that are used multiple times, such as surgical instruments and library books.

ENVIRONMENTAL IMPACTS AND SUSTAINABILITY Several studies emphasize the environmental benefits of reusable packaging and RTIs. Accorsi, Baruffaldi, and Manzini [1] highlight the potential for infinitely reusable and recyclable containers in the food industry, promoting circular economy principles. Albrecht et al. [2] conduct a life cycle analysis and stress the importance of considering multiple sustainability criteria in decision-making. Sarkar, Ullah, and Kim [34] explore the environmental and economic assessment of closed-loop supply chains with remanufacturing, highlighting the potential for waste reduction and resource conservation.

ECONOMIC CONSIDERATIONS The economic aspects of reusable packaging and RTIs are another key focus. Bortolini et al. [4] propose a bi-objective design framework for fresh food supply chain networks, considering both reusable and disposable containers. They emphasize the need to optimize costs while minimizing environmental impacts. Lakhmi, Sahin, and Dallery [26] identify critical success factors for facilitating reusable plastic packaging in sustainable supply chain management, highlighting the economic advantages of integrating reusable packaging systems.

2.3 RTI SUPPLY CHAIN CHARACTERISTICS AND VISIBILITY

RTIs function within Closed Loop Supply Chains (CLSCs) but exhibit unique characteristics compared to conventional CLSCs. The first feature is the low level of disassembly: While a conventional CLSC involves repair, remanufacture and recyling of a product in order to prepare the item to be reintroduced in the forward supply chain. Reuse of RA only requires light reconditioning operations, such as testing, cleaning, minor repairs, or sterilisation. The second unique feature of RA is that new and reused articles are perfect substitutes. This is because the costs for both are the same for the user while both provide the same functionality. The third essential feature is that RA are shared and mobile assets. This means that RA are used by different users in different locations and travel across boundaries of organisations that make up the supply chain network. This implies that at some stages of the product life-cycle, the RA-owner has limited control. Another unique feature of CLSC of RA compared to other CLSCs is the high return rate. It tends to fluctuate between 90 and 97 % according to Carrasco-Gallego, Ponce-Cueto, and Dekker [7]. Despite of the high return rate, firms often do not have full control and visibility over how many will return, when and where. RTI visibility refers to the lack of knowledge or estimation regarding the utilization of RTIs, including when, where, and how they are utilized. It is widely recognized that supply chain visibility is essential for effective management and control of RTI systems. One approach to enhance supply chain visibility is through the implementation of tracking systems. However, as highlighted by Johansson and Hellström [21], tracking systems alone are insufficient. Their study showed that a tracking system with inadequate data analysing and reporting capabilities provides limited visibility. Furthermore, having asset visibility does not automatically translate into the ability to utilize the information effectively. Continuous management of tracking data is required to efficiently use the increased information. Therefore even though there has been a number of articles published that suggest how tracking technology such as Radio Frequency Identification (RFID) can increase visibility which may counter inefficiencies in the RTI management process and improve the overall effectiveness of the RTI supply chain network [19], this suggested improvement can only be achieved in combination of adequate data analysing and reporting capabilities. RFID should be seen as a tool to augment visibility rather than a standalone solution.

2.4 LOGISTICS MANAGEMENT AND REVERSE LOGISTICS

Efficient logistics management and reverse logistics play a vital role in the implementation of reusable packaging and RTIs. Carrasco-Gallego and Ponce-Cueto [6] propose a management model for closed-loop supply chains of reusable articles, focusing on the challenges and issues in reverse logistics. Carrasco-Gallego, Ponce-Cueto, and Dekker [7] present a typology of closed-loop supply chains based on case studies, highlighting different approaches and strategies. Glock [15] provides a systematic literature review of decision support models for managing returnable transport items, emphasizing the importance of effective tracking and management systems. To explore the impact of different control strategies on the management of RTI systems, Hellström and Johansson [17] conducted a simulation study based on the investigation of roll containers at a global dairy company (Arla Foods Group). The different control strategies that were compared were a transfer system with no management action, a transfer system with management action based on tracking data, and a switch pool. The study revealed that the switch-pool design has the potential to reduce the investment cost in RTIs, while a transfer system have the potential to reduce operating costs if tracking data are coupled with correct managerial action. However the study emphasized that collecting tracking data is not equal to having asset visibility, proper actions and continuous management attention are needed for efficient management. Ineffective management of RTIs result in uncertainty en unpredictability of the number and time at which RTIs are returned. Besides it can severely increase labor costs, because the management of RTIs is intensive and requires workers to perform a huge amount of simple and repetitive tasks. Lack of effective monitoring methods for RTIs is regarded as a key problem restricting the sustainable development of multi-modal transport system [40]. IoT technology is proposed by scholars to be a possible solution.

Tracking technologies, such as bar codes and RFID may improve the lack of visibility. Automated identification systems contribute hugely to supply chain visibility, because it functions as a powerful decision support system that can help optimize to perform data entry tasks. It involves the automated extraction of the identity of an object and it enables the interchange of product data seamlessly. A requisite is a unique identity, because without a unique identity it is not possible to associate information with a specific physical product. Ilic et al. [19] discuss the value of RFID technology in RTI management, enabling improved tracking and visibility. The advantages and the possibilities are clear, however because of the very high investment costs, many firms are reluctant of adopting RFID technology. Neal et al. [30] explored the potential of Industry 4.0 Cyber Physical Systems in quality assurance for RTIs. Green [16] address the many effects of using AI in logistics. Biswas et al. [3], Helo and Shamsuzzoha [18], and Wang et al. [37] address potentials in transforming supply chain. Block Chain has the ability to enable transparency, authenticity, trust and security, due to real-time tracking, auditable trace of footprint of a product. It leads to efficiency and cost/waste reduction. Smart contract and the digitalisation of document transfer leads to no need for double verifications and paperless transactions.

The literature suggests the potential of emerging technologies in optimizing the management of reusable packaging and RTIs.

2.5 INSIGHTS FROM THE LITERATURE REVIEW

This literature review discussed what has been studied in the field of RTI supply chain management. From the literature review it can be concluded that research on RTI is fragmented and dispersed. Various researchers have investigated different aspects of RTI logistics and management within CLSCs. For example, Carrasco-Gallego and Ponce-Cueto [6], Hellström and Johansson [17], and Sarkar, Ullah, and Kim [34] have studied control strategies, efficient management practices, and the advantages of reusable packaging. They emphasize the importance of asset visibility in managing RTI effectively and propose methods such as tracking technologies to enhance visibility. Furthermore, Neal et al. [30] demonstrated the implementation of a Cyber-Physical System (CPS) for monitoring and controlling RTIs within the automotive industry. Their study showcased the potential of CPS in providing full visibility and control over RTIs, meeting the requirements of stakeholders within the domain. However, challenges were identified, such as the need for reliable links between RTIs and the CPS, the potential for misidentification of RTIs, and the importance of adaptable data capture and state determination services. Additionally, Carrasco-Gallego and Ponce-Cueto [6] and Kroon and Vrijens [24] classified different network designs for reusable articles, such as transfer systems, depot systems, and switch pool systems. These classifications offer insights into the structural aspects of managing RA within CLSCs.

The reviewed papers provide valuable insights into various aspects of RTIs. This literature review highlights the growing body of research on reusable packaging and RTIs in supply chains. The findings underscore the importance of integrating sustainability considerations, optimizing logistics operations, and leveraging technological advancements. Future research should focus on holistic impact assessments, advanced modeling techniques, circular economy strategies, stakeholder collaboration, and policy frameworks to further advance the field. By addressing these areas, scholars and practitioners can further advance the understanding and adoption of reusable packaging and RTIs, contributing to more sustainable and efficient supply chains.

2.6 IMPLICATION FOR THIS RESEARCH - TRACEABILITY

Johansson and Hellström [21] highlight the importance of asset visibility in the effective management of RTIs. Asset visibility refers to the ability to track and monitor the location, status, and availability of RTIs throughout the supply chain. Tornese et al. [36] argue that efficient reverse logistics systems are crucial for facilitating the return and reuse of pallets, reducing costs, and minimising environmental impacts. The significance of efficient RTI management practices, technological advancements, and sustainable reverse logistics systems in optimizing the performance and sustainability of the pallet supply chain. Mahmoudi and Parviziomran [27] discuss the importance of collaboration and coordination among supply chain partners in implementing reusable packaging systems. Collaboration is required for efficient container management, shared asset pools, optimized transportation, and effective information sharing. The study highlights the need for standardized packaging formats, tracking technologies (e.g., RFID), and data management systems to enable seamless tracking, tracing, and control of reusable packaging in supply chains. These technologies support efficient operations, enable real-time visibility, and facilitate decision-making. Lakhmi, Sahin, and Dallery [26] propose a framework for classifying the issues related to closed-loop and reverse logistics of RTIs. The framework consists of three main dimensions: process issues, system issues, and decision-making issues. These dimensions capture various aspects of RTI management, including operational processes, technological systems, and managerial decision-making. The system dimension of the framework addresses issues related to information systems, tracking technologies, communication networks, and collaboration platforms that support RTI management. It emphasizes the importance of efficient and reliable systems for tracking RTIs, capturing relevant data, and facilitating effective communication among supply chain partners. Current research puts a predominant focus on the smart operations of isolated reverse logistics activities but not on the service innovation.

In the last decade, various articles on RTI are published. Research focus ranges from exploring control strategies and factors that support efficient management of RTI closed-loop supply chain [6, 15, 17, 21, 27], analysing ways to adopt RTIs in the food industry [1], addressing the advantages of reusable packaging [24, 34], to assessing and identifying the effects of costs and (sustainable) effects associated to RTIs on supply chain [4, 14, 35]. Almost every article has mentioned that there is a challenge on managing RTIs and tried to suggest ways to address this problem from their research perspective. One of the main concepts suggested is the positive effect that asset visibility has on managing RTIs. A lack of visibility is seen as one of the key factors that lead to poor RTI management. Research has been focused on qualitative methodology studies, in which deeper understanding has been gained into environmental and economic cost aspects of RTI management, while literature on asset-owner and asset-user could less be found.

Figure 2.1 shows which combination of topics this thesis addresses in relation to other published papers.

This literature review	Year	Title	Recycling / reuse / packaging waste	RTI	Circular economy	Reverse logistics	CLSC	Automatic identification	Digitalisation	SC visibility	Strategic design	Network design	Problems/ Issues	(SC) Management	Support decision tool	Smart logistics/Industrie	Industrial practice	Tactical	Operational	Profitability and sustainability	Design Science approach	Literature Review / Framework	Other
Accorsi	2020	A closed-loop packaging network design model to foster infinetly reusable and recyclable containers		X							X				X					X		X	
Albrecht	2013	An extended life cycle analysis of packaging systems for fruit and vegetable transport in Europe	X	X							X									X			LCA
Bortolini	2018	Bi-objective design of fresh food supply chain networks with reusable and disposable packaging containers		X								X		X	X					X			
Bradley	2023	A literature review and analystical framework of the sustainabilty of reusable packaging	X	X																X		X	
Carrasco-Gallego	2010	A management model for closed-loop supply chains of reusable articles: defining the issues		X			X						X	X			X					X	
Carrasco-Gallego	2012	Closed-loop supply chains of reusable articles: a typology grounded on case studies.		X			X															X	
Glock	2017	Decision support models for managing returnable transport items in supply chains: A systematic literature review.		X			X	X	X					X	X							X	
Hellström	2010	The impact of control strategies on the management of returnable transport items		X			X				X			X					X	X			
Ilic	2009	The value of RFID for RTI management		X				X			X			X								X	
Johansson	2007	The effect of asset visibility on managing returnable tranport items		X					X	X	X	X		X			X			X			
Kroon	1994	Returnable containers: an example of reverse logistics		X		X					X	X					X			X			
Lakhmi	2019	Proposition of a Framework for classifying Returnable Transport Items Closed-loop/Reverse Logistics Issues		X		X	X							X					X				
Mahmoudi	2020	Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations management		X							X	X								X		X	
Neal	2021	The potential of industry 4.0 Cyber Physical System to improve quality assurance: An automotive case study for wash monitoring of returnable transit items		X				X	X							X							
Sarkar	2017	Environmental and economic assessment of closed-loop supply chain with remanufacturing and returnable transport items		X			X					X								X			
Silva	2013	Comparison of disposable and returnable packaging: a case study of reverse logistics in Brazil	X	X		X											X			X			
Tornese	2021	Management and Logistics of Returnable Transport Items: A Review Analysis on the Pallet Supply Chain		X			X						X	X						X		X	
		The Present Study		X		X			X	X	X						X				X		

Figure 2.1: Literature Matrix

2.7 CONCLUDING REMARKS

Research on the control of RTI systems is scarce. Up to date, no research has specifically focused on the traceability of RTIs within the reverse logistics. RTIs are challenging assets to manage, because it requires accurate counting, reporting and shared information among organisations. Based on the conducted literature review, RTI return control seems to be a subpart of the concept of asset visibility. It can be concluded that traceability, visibility and serialization are minimal requirements, to achieve RTI control in the reverse logistics. Additionally to achieve all of these, stakeholders' collaboration, coordination between actors and technology or a system that can ensure return identification is needed. Asset visibility refers to the ability to track and monitor the location, status, and availability of RTIs throughout the supply chain. But to gain visibility, unique identification is a prerequisite of an item. Enhanced asset visibility contributes to the overall performance and efficiency of RTI management in supply chains, including control. Many researchers looked into the role of technology, such as radio frequency identification (RFID) and other tracking systems, in enhancing asset visibility. These technologies enable the automatic identification and monitoring of RTIs, providing real-time data on their location and movement within the supply chain.

3 THE CURRENT STATE VISIBILITY OF THE REVERSE LOGISTICS

This chapter explores all variables in the current return process with the goal of being able to express the variance and to detect which factors causes which (unwanted) symptoms. A bird's view approach is taken to gain an understanding of how and the reasons why things happen as they do and the corresponding implications. The Current State Results have two sections. The first section includes descriptive results based on interviews, observations and a workshop. The second section includes quantified results based on data analysis.

3.1 QUALITATIVE ANALYSIS

STAKEHOLDERS For the description of the parties involved in the return chain, the same terminology "sender" and "receiver" as used by [24] is used in this report. Trays are often used multiple times by multiple actors before it reaches the end of a use cycle. In this case study, Euro Pool System - the tray owner and manager - is denoted as the *receiver*, who collects the trays and prepare them for the next use cycle. The place where this takes place is denoted as a *depot*. The *sender* is the last end-user of the tray, who sends the trays to Euro Pool System and receives the corresponding deposit. The majority of the senders in the return chain are retailers (supermarket chains) with multiple shops.

From the perspective of EPS, two types of clients can be distinguished: 1) traders that want to use EPS trays to carry their produce, and 2) retailers that want to use EPS trays for their logistics processes. In the return chain only the second group (end-users) are relevant, for they are the senders of the trays. If a retailer decides to use EPS trays for their logistic processes, a retailer discusses the possibilities with the customer service department of EPS and agrees on a Service Level Agreement (SLA). If a retailer decides to collaborate with EPS, they usually sign a contract of at least seven years. A Service Level Agreement, states the rules for how trays should be returned (e.g. in a sorted/unsorted way, the height of stacking, etc.), and the consequences of anomalies.

THE USE OF SSCC-LABELS The current way of Identification at the receiver's end is based on SSCCs printed on physical labels. These labels are customer specific. While the operations are region-specific. The first stage label management comprises of three sub-processes including stocking of blank label rolls, the retrieving of unique barcodes and the printing of labels. Customer service assistants are mainly involved in these operational processes. However the specific division of tasks and the method differs per region.

In order to gain better understanding on how the current label management works, a few persons who are involved in the operational process are interviewed and the label management process is mapped out from the knowledge gained. Table 3.1 gives an overview of the interviewees.

NAME	LOCAL OFFICE	REGION	DEPARTMENT
Trandafir, Adina	EPS Romania	CEE	Customer Service
Van Dessel, Kenny	EPS Benelux	West	Customer Service
Rottiers, Inge	EPS Benelux	West	Customer Service
Romero, Paula	EPS España	South	Department Sales & Marketing

Table 3.1: Overview of interviewees involved in label management

GENERAL DESCRIPTION OF LABEL MANAGEMENT Based on interviews with the operators that are responsible for label management and communication with the retailers, a swimlane-diagram is created. Figure 3.1 illustrates the label management process that takes place in the background. Customers usually inform the customer service of EPS a few weeks in advance that the labels are low in stock. The Business Self Support Tool (BSST) keeps track of a specific shop's label stock and gives a notification when the stock of labels falls below a certain set threshold. This threshold is dependent on the shop's tray use. The shop needs to make a label order with EPS if it wished to replenish its label stock. A list of unqiue SSCC codes is then created by the corresponding EPS regional office. Some regional offices have an their own printer that can print the list of SSCC-codes while other regional offices send the list of SSCCs to a print shop. To give an example, countries in CO that have internalised label printing are Bulgaria, Romania Slovakia, Czech Republic and Hungary. And in Poland, the list of SSCC-codes is sent to an external printshop. Printing 6000 labels (8 rolls) takes approximately 6-7 hours. Some retailers attach SSCC-labels at their return DC (e.g. Kaufland Romania and Bulgaria), while other retailers attach SSCC in their shops (e.g. Auchan Poland). Dependent on how the client uses the labels, the rolls of labels with SSCC-code are sent to them. The costs for ordering 54.000 blank labels is 6000 Romanian leu (1000 Euros).

TRAY FLOW TRACEABILITY A workshop is held in order to map out the current state traceability of returns. The current state traceability for EPS can be distinguished into six configurations. Figure 3.2 depicts the six configurations[1]. On the left, a few example retailers that follow a configuration are noted down. The arrows represents the tray flow that can be traced back through EPS' database. The dashed line in configuration 4 means that it is known that the retailer collects this flow information, however they do not share this with EPS.
Return Configuration 1 applies when SSCC labels are attached at shop level and when the return process of trays from shop to EPS depot happens via a retailer's return distribution centre.
Return Configuration 2 applies when the return happens order based on DC-level, and when the customer does not require EPS to trace the shop origin of the load carrier packages.
Return Configuration 3 applies when the return of trays happens directly from shop to EPS depot.
Return Configuration 4 is in principle the same as Return Configuration 2, except that traceability on shop level is actually desired but not on the "EPS way". The retailer manages shop traceability on their own way, and does not make use of the label management system of EPS.
Return Configuration 5 applies when the functions of EPS depot is merged within the retailer's DC: Counting and Identification process happens at the Return DC.
Return Configuration 6 applies when a pool of trays is dedicated to one retailer alone and when the Counting and Identification process happens at a Return DC.

RETURN PROCESS The return process of trays occurs in batched order. Senders are allowed to send trays unsorted, which means that tray types do not need to be sorted and different tray types can be stacked on each other.

Figure 3.3 shows how the current return process works. The return process starts when a shop have gathered enough trays on a loadcarrier. This first step is retailer specific, depending on the Service Level Agreement (SLA) (read collaboration advancement between EPS and the client) some retailers are allowed to send back trays without making a return order via the ERP-system (SAP). In that case the sender just needs to attach a printed SSCC label to the loadcarrier with trays and move it to an EPS depot. Other retailers need to make a planned order. Some shops attach an SSCC-label to each return pallet, while other retailers consolidates used trays in their return (distribution) centre. When enough return packages are ready, a return order with the corresponding depot is made and a SAP order number is generated which also functions as a token for the transporter to enter a depot. At the depot, the return order is verified before a truck

1 the configurations are nominal, meaning they are classified without a rank or order

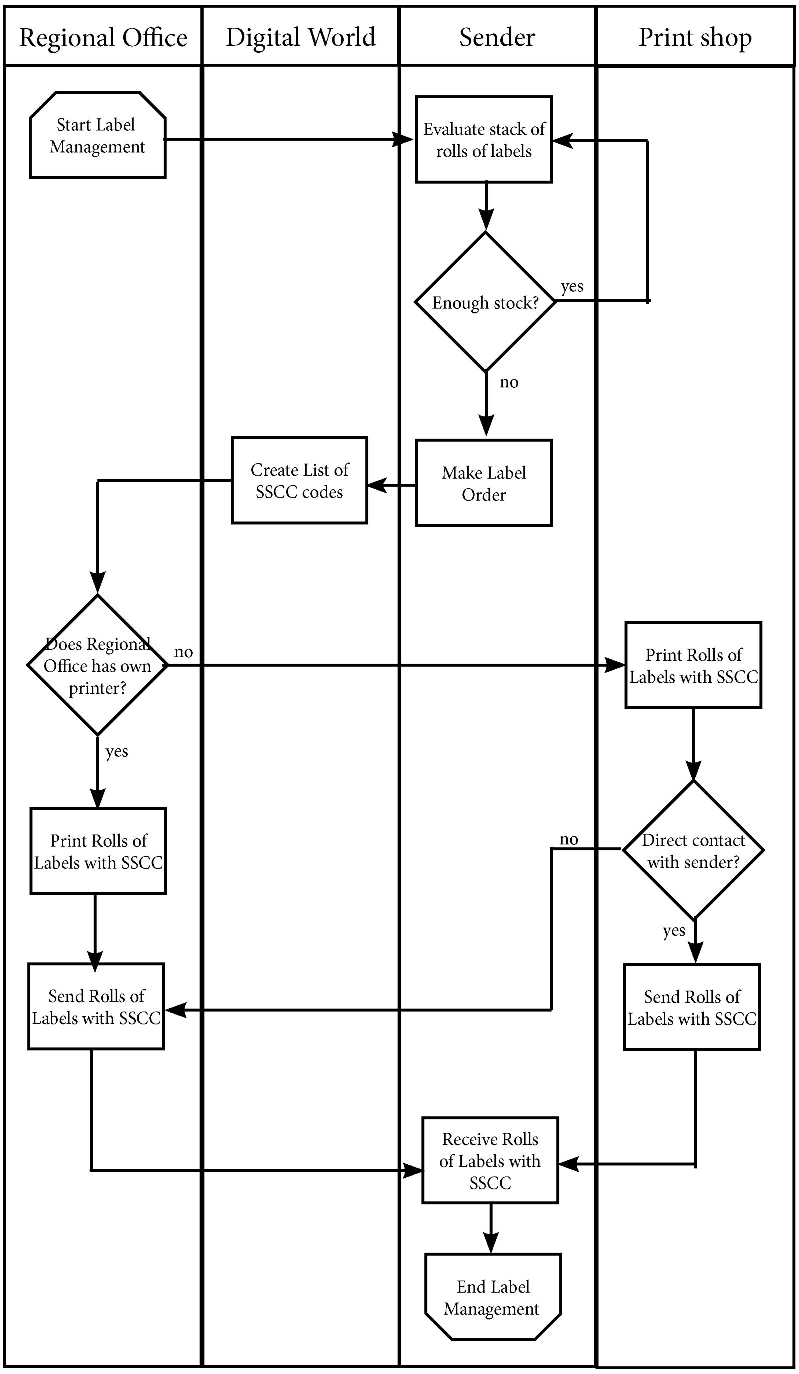


Figure 3.1: Label Management

can dock and unload. Upon unloading the number of return packages arrived is counted which functions as receipt. After unloading of the return packages the Counting and Identification (CnI) process immediately starts, in which each SSCC attached to the return package is scanned and directly linked to the SAP order. Moreover by guiding the return packages through a vision portal, the counting process occurs. A *Depot label* is generated when an SSCC-label is missing on arrival at depot. A depot employee needs to register any observed anomaly. The return process ends when the CnI has taken place. Figure 3.4 shows how the CnI data is processed. NAS stands for Network-Attached Storage. CnI data are first temporarily saved on the NAS and then transferred to the depot server. Subsequently the depot server transfers the data to

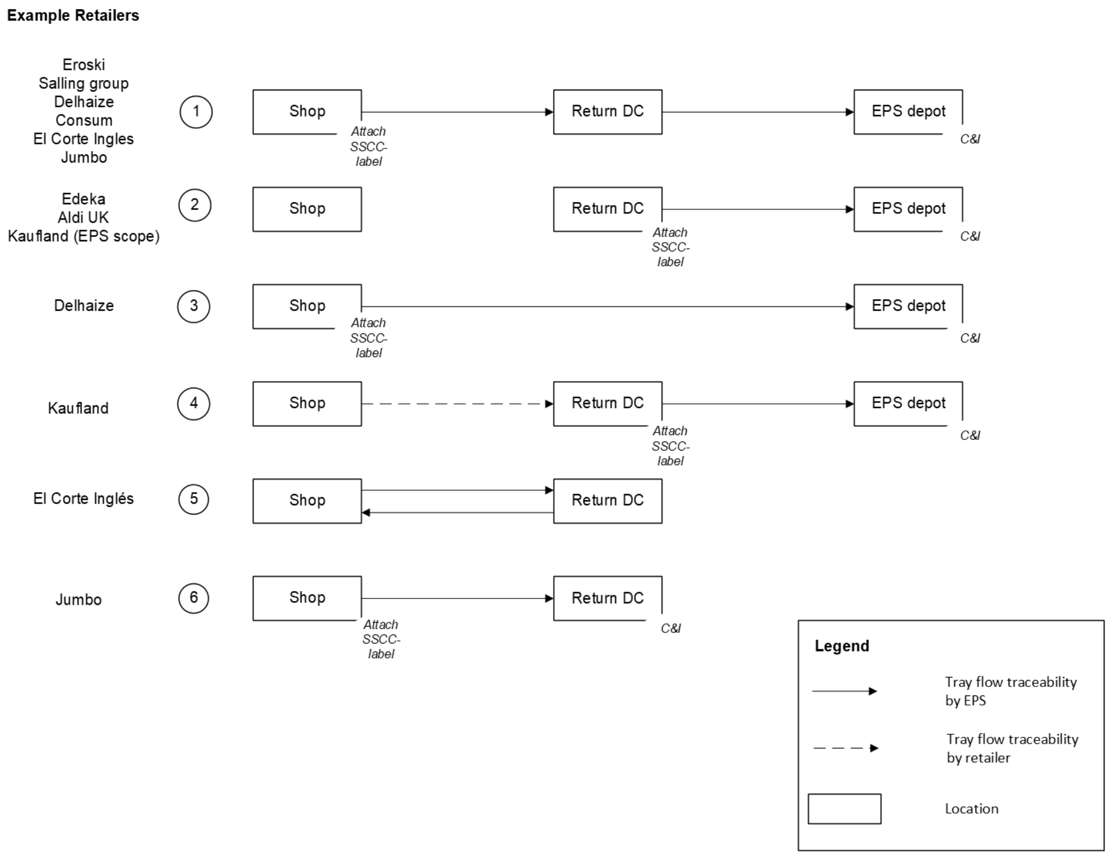


Figure 3.2: Different configurations of tray flow traceability. Each number represents a specific setup.

the operational data hub (ODH) and SRL (Smart Return Logistics). SRL is a platform in which all raw data are gathered and processed to be extractable by the ERP-system (SAP) which the customer has access to.

Summarised, these findings show that EPS traceability performance is dependent on the sender's willingness to take part in EPS' digital services and the way the client uses SSCC-labels. Figure 3.5 gives a simplistic summary of how identification of the sender is currently achieved. Trays arrive at the depot (denoted as receiver in figure) in which Counting and Identification (CnI) take place. SSCC labels are scanned upon arrival and the Counting data are linked to the SSCC and the corresponding return order.

3.2 QUANTITATIVE ANALYSIS

A more in-depth analysis is performed into the amount of return packages that could not be identified at the receiver's site. SRL data from the period of January 2022 until June 2023 were gathered for this analysis. The number of return packages that could not be identified is the sum of SSCC-codes that had the anomalies "SSCC barcode missing" or "not readable" in the data base plus the amount of SSCC's that are allocated to the general deposit account for a specific retailer. Table 3.2 gives a summary of the retailers with the highest yearly volume of return packages. In the first column, the region with whom the retailer communicate is described. In the second column, the corresponding retailer is named. The third column gives one of the retailer's characteristic expressed in the number of "senders" it has. In the fourth column, the amount of return packages sent back by the retailer is given. In the last column, the number of return packages without shoplink is given and the corresponding percentage of the yearly total. The retailer with the highest amount of return packages without shop origin (288,021) is

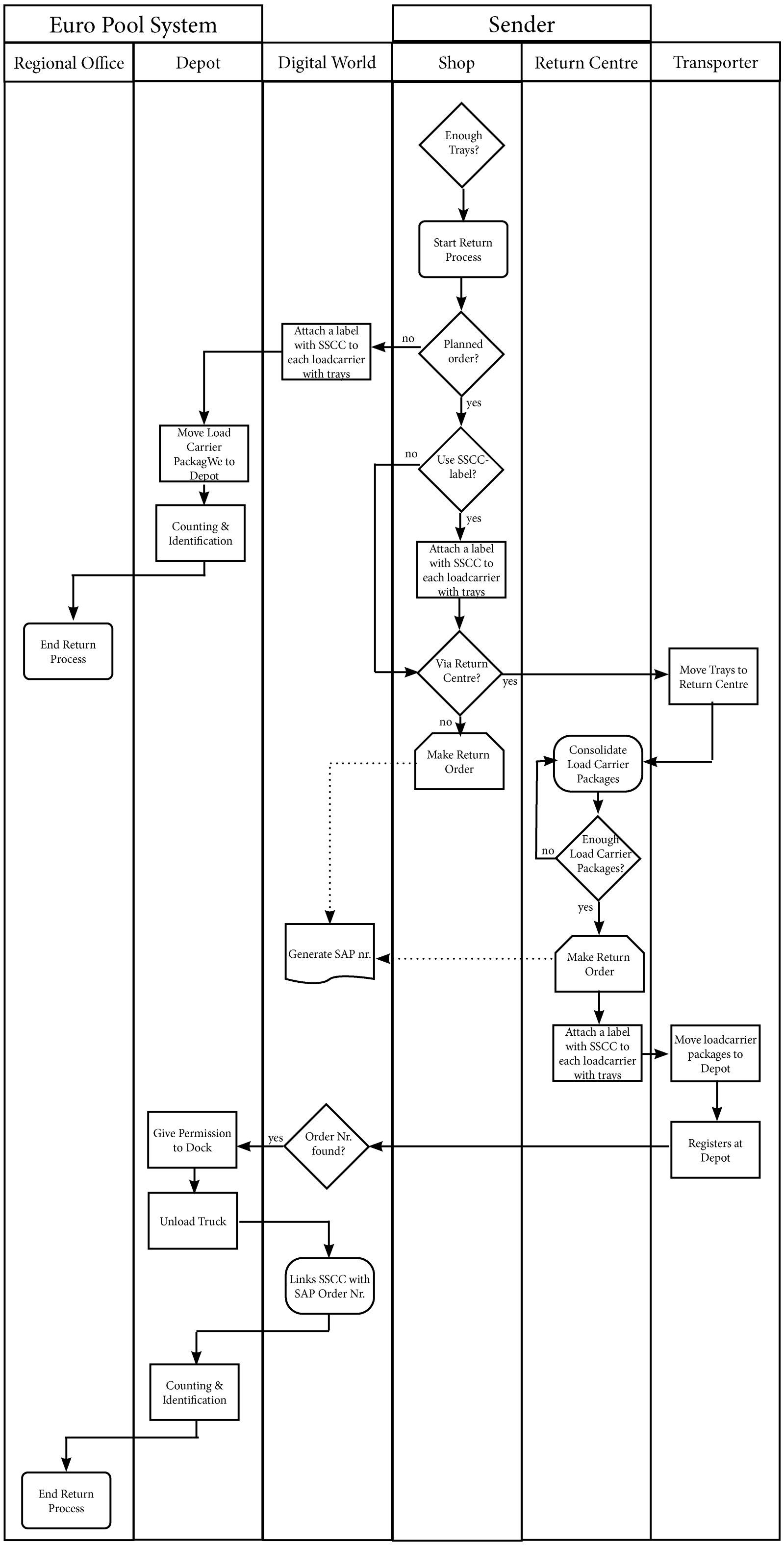


Figure 3.3: Return Process

the retailer with highest SSCC volume, Delhaize. Other retailers with a high amount of return packages without shop origin are Aldi Sud, Consum and Jeronimo Martins, with more than 100,000 unidentifiable return packages.

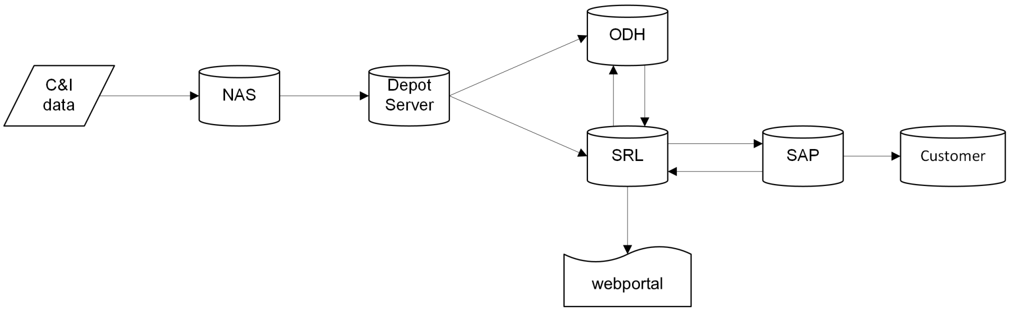


Figure 3.4: Counting and Data processing

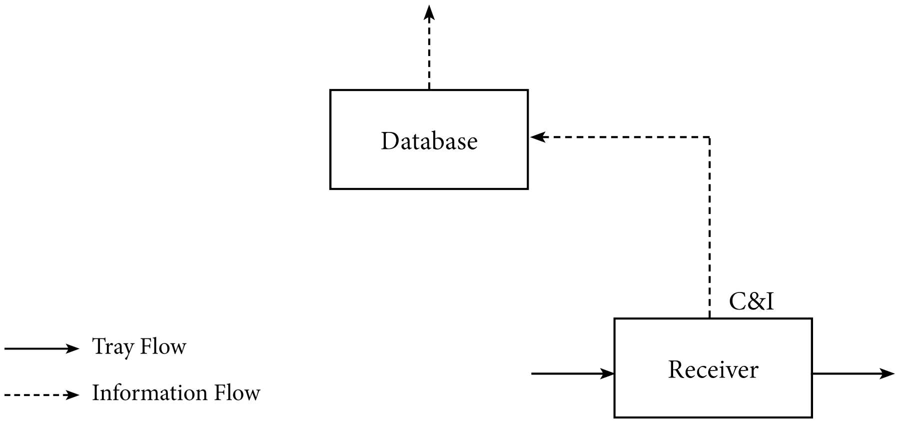


Figure 3.5: Current State Identification

REGION	SC PARTNER	QTY SENDERS	QTY SSCC	QTY SSCC UNIDENTIFIABLE
West	Delhaize (BE)	1.733	1.928.964	288.021 (15%)
Central	Edeka (DE)	79	1.053.263	37.568 (4%)
West	Jumbo (NL)	184	767.744	12.783 (2%)
West	Aldi Sud (GB)	17	670.854	115.698 (17%)
Central	Kaufland (DE)	6	367.030	0 (0%)
South	Consum (ES)	1.147	345.815	162.068 (47%)
South	Jeronimo Martins (PT)	988	217.646	163.959 (75%)
Central	Salling Group (DK)	242	216.134	36.232 (17%)
South	El Corte Ingles (ES)	616	193375	46516 (24%)
South	Eroski (ES)	774	166133	74193 (45%)
South	Ahorramas (ES)	3	112468	19342 (17%)
CEE	Netto (PL)	5	108.446	0 (0%)
West	Carrefour (BE)	4	105170	0 (0%)

Table 3.2: The number of return packages with missing SSCC or allocated to a virtual shop per Supply Chain Partner

3.3 PROBLEM SPECIFICATION

Synthesizing both the qualitative and the quantitative results, the following bottlenecks were found: 1) Traceability is dependent on collaboration between receiver and sender. 2) Clients have freedom to not take part of EPS' digital services, which limits the traceability capacity of EPS. EPS visibility is heavily dependent on what the client shares with them. 3) Many SSCC-labels go missing or do not have a shop link, while this is the main way to identify a shop's origin. Based on these results and in light of the practical problem stated in Chapter 1, the problem is quantified and refined to a Δ that needs to be minimized. The Δ represents a return package without shop link.

3.4 CONCLUDING REMARKS

The current tray return process is standardized. Trays are sent back by retailers in batches, folded and stacked on top of each other on a loadcarrier (e.g. pallet) until a certain height, following standardised rules. The current state visibility for EPS is heavily dependent on what the client shares with EPS and its choice of consolidation. Additionally, each client has a different readiness of technology advancement. The visibility for EPS solely relies on the identification process at the end of the reverse logistics. The identification process of return packages occurs through SSCC labels that are supposed to be attached to each return package. An SSCC-code is unique and is linked to the sender. Six return configurations were distinguished and the implications of traceability for EPS were investigated. Annually, a large amount of return packages are unidentifiable at shop level for many retailers. . After mapping out the current state and in combination with the literature study, the conclusion was drawn that the practical problem is an information flow problem and that the identification structure needs to be redesigned that can ensure zero-defect.

4 BUILDING BLOCKS OF THE MATCHMAKING SYSTEM

In the preceding chapter, an analysis was conducted to identify the bottlenecks within the existing return chain, leading to the establishment of a more specific problem statement. The analysis led to the determination that the deposit/missing-shoplink problem can be attributed to the existing information flow. As a result, the objective of the design is articulated as the minimization of return packages lacking a shop link. This chapter includes a requirements analysis of the future state and posits the concept of employing a matchmaking mechanism to guarantee shoplink.

4.1 THE REQUIREMENTS OF THE DESIGN

This section gives the results of the requirement analysis. Requirements are the fundamentals of a design. A given idea have to meet all requirements in order to become a potential solution. Requirements can be distinguished in two categories, functional and nonfunctional. Functional requirements explain how the system must work, describing system behavior under specific conditions. According to Young [39], a functional requirement describes what the system must do, specifying an action that a system must be able to perform. To come up with the functional requirements, the Delft Design Guide is used [10]. Nonfunctional requirements explain how the system should perform. According to Young [39], a non-functional requirement specifies the system properties. The system design must adequately fulfil nonfunctional requirements to a certain degree. The functional and non-functional requirements of the reverse logistics system design are listed below.

Functional Requirements

- F1 The system must store and retrieve information about the last user of the return package;
- F2 The system must create a unique identification key that can represent the return package and trace back the sender's location;
- F3 The system must be implementable by the customers (e.g. retailer's shop, franchises, distribution centre);
- F4 The system must be private for the customers and EPS.

Nonfunctional Requirements

- NF1 The system should be easier to use than the current physical labeling system (e.g. less adminstrative work);
- NF2 The system should be more sustainable than the physical labeling system (e.g. use of paper);
- NF3 The system should operate in lower costs than the physical labeling system;
- NF4 The system should not leak information to third parties without consent.

The functional requirements are mainly based on adding value to the current visibility of trays in the reverse logistics and the found requirements to achieve asset control from the literature review in Chapter 2. The first functional requirement addresses the aim of the system. The second functional requirement is based on the working principle of traceability and the current way of returning trays (via return packages). The third functional requirement ensures that the system adds value to the current state return. The fourth functional requirement addresses a business principle. The nonfunctional requirements are mainly based on EPS' business incentives that stress out why the system should be implemented. The most important aspect of the non-functional requirements is that the system can improve the found inefficiences in the Current State analysis, e.g. label management. Additionally, they address the company's vision and strategic goals.

4.2 THE CONCEPT OF MATCHMAKING AND A MATCH-MAKING SYSTEM

Based on the requirements analysis and building upon the results of the Current State conclusions, the idea of developing a "matchmaking system" is proposed. *Matchmaking* is considered the action that contributes to traceability and prevent unidentifiable returns. A matchmaking system refers to the set of interconnected components that ensures the matchmaking function. The matchmaking system is defined as a concept of using a *key* generated by a sender (location A) to represent the whole return package, which can be recognised by the receiver (location B). If the key is successfully arrived and identified by the receiver, the door to trace back the sender is opened, and a match is made. In literature, a traceability system is defined as a system that provides and maintains the data records, data associations, and functions to enable tracking and tracing throughout all defined operations. The matchmaking system can therefore be seen as a simplified mini-traceability system that enables the tracing through the return process. An important feature of the matchmaking system is the need of a key that can represent the return package. Since a return package is formed at the start of the return process, the key should also be generated at the start of the return process. Fig. 4.1 shows the basic concept of the matchmaking system.

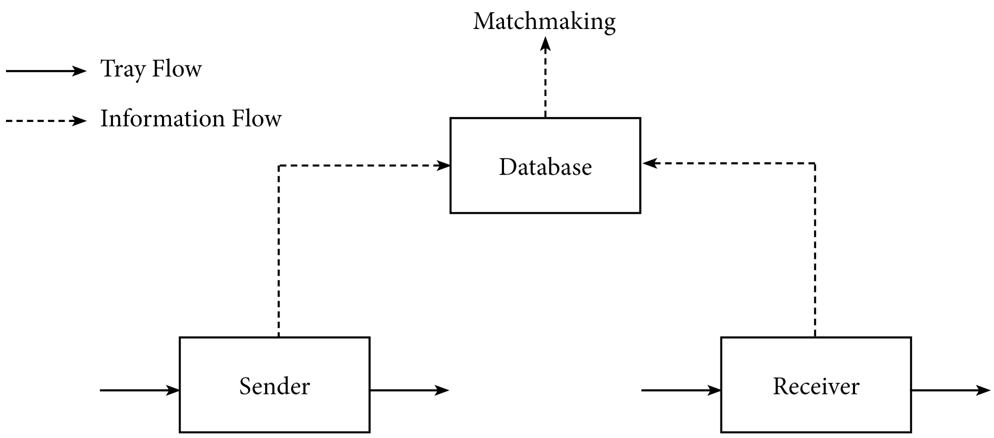


Figure 4.1: The Concept of a Match-Making System

4.3 CONCLUDING REMARKS

The requirements analysis resulted in a set of functional and nonfunctional requirements of a system that can minimise unidentifiable return packages. Moreover, based on the requirements analysis, the concept of matchmaking is developed. Matchmaking ensures that return packages can be identified, while a matchmaking system is the framework that supports matchmaking. In the next chapter the matchmaking concept will be given more shape and alternatives are generated based on this concept.

5 POTENTIAL MATCHMAKING SYSTEMS

In the previous chapter, the concept of devising a Matchmaking System to solve the deposit/shop-link issue was introduced. This chapter builds upon the aforementioned concept and consists of the development of potential Matchmaking System alternatives.

5.1 The generation of potential matchmaking systems

In a systematic way, a range of options for matchmaking was investigated that can address the quantified Δ problem. The General Morphological Analysis (GMA) developed by Zwicky (1966) [31] is chosen as the method for identifying and investigating the total set of possible relationships or "configurations" contained in this matchmaking problem complex.

The first step required an exact as possible formulation of the matchmaking problem. The second step was breaking down the problem into a set of parameters that can define matchmaking. Each parameter must be clearly defined and a comprehensive set of possible states or values for each parameter was determined, ensuring that they are mutually exclusive. The third step involved creating the morphological box - or multidimensional matrix - that included all solutions related to matchmaking. In this context, a "solution" refers to a shape or configuration where a value is assigned to each parameter. The morphological box contains all the possible solutions for the matchmaking. However, normally the problem space often includes many inconsistent or impossible solutions. The fourth step involved analyzing the entire morphological field to reduce this noise and identify a refined subset of solutions that are considered consistent, known as the solution space. In the fifth step the remaining solution space is surveyed and the best solutions are selected to be assessed as practical applications. The outcome of this morphological process is an abstract description of the entire solution space, which includes all possible solutions or forms for matchmaking.

5.2 The parameters and values for the matchmaking system

The matchmaking problem is approached by asking three questions. i) what type unique identity can represent the return package and be a source for matchmaking? ii) how is the data capture quality? iii) what are the characteristics of the tray pool? Thus the parameter set of *unique identity*, *data capture quality* and *serialization of the tray pool* are derived. Each parameter will be explained in the next subsections.

5.2.1 *Unique identity parameter*

The term "unique identity" denotes any unique identity present in the return system that can represent a unique return package.

From the current state analysis, it was found that the reverse flow of trays can be viewed from different levels: tray, the combination of loadcarrier and trays (also called return package), and the freight order level. This insight formed the inspiration for the parameter set and includes the following values: *tray with unique identity*, *loadcarrier with unique identity*, *return package*. The freight order level has been left out in the analysis, because it does not meet the requirement of being able to represent a return package.

5.2.2 *Data capture quality*

The term "data capture quality" denotes the level of process of extracting information. It represents how the match is tried to be found.

The most comprehensive value in the range therefore is the *all-to-all* full match. As a counterpart to all-to-all, we have the one-to-one single match. Between those two extremes, the number of potential intermediate values is unlimited. Here three more distinctive values are defined. The "*many-to-one*" and "*one-to-many*" single match and the "*many-to-many*" partial match.

5.2.3 *Serialization of the tray pool*

The term "serialization of the tray pool" denotes to what context trays on a return package have an identifiable unique identity code.

The most comprehensive value in the range is *full serialization*, in which all trays of the return package are serialized. As a counterpart to full serialization, the value *not serialized* is defined. As the name suggests, this value is the case in which trays in the return chain are not serialized at all. To represent the values in between those two extremes, the value of *partial serialization* is established.

5.3 THE SOLUTION SPACE

A multidimensional matrix contains all solutions related to the problem and is made based on the parameter sets. A "solution" in this respect denotes a configuration where one value is designated for each parameter. To illustrate this, an example is given in Figure 5.1b.

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	One-to-one	Not serialized
Loadcarrier	Many-to-one	**Partially serialized**
Return package	**One-to-many**	Fully serialized
Freight order	Many-to-many	
	All-to-all	

(a) An example solution where one value is designated for each parameter

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	One-to-one	**Not serialized**
Loadcarrier	Many-to-one	Partially serialized
Return package	One-to-many	Fully serialized
Freight order	**Many-to-many**	
	All-to-all	

(b) An example of an inconsistent solution

Figure 5.1: Examples of the General Morphological Analysis

The solution space consists of "noise" in the form of inconsistent solutions. Therefore a cross consistency assessment (CCA) analysis of the entire morphological field is performed in order to reduce the amount of such noise, and to delineate a solution space. The matrix represents the entire morphological field of the problem, which is 3x5x3 = 45 unique configurations. The Cross Consistency Assessment involves a thorough examination of each pair in the matrix. Here, the number of pairs is 39. The results of the CCA is presented in Fig 5.2.

Except for *Tray*, the other "unique identity" values cannot form a consistent value pair with the *many-to-one, one-to-many, many-to-many and the all-to-all* data capture quality values. Additionally, if a return package does not contain serialized trays, a *tray* value in unique identity parameter can not exist.

		Unique Identity				Data capture quality of code					Serialisation of tray pool		
		Tray	Loadcarrier	Return Package	Freight order	One-to-one	Many-to-one	One-to-many	Many-to-many	All-to-all	Not serialized	Partially serialized	Fully serialized
Data capture quality of code	One-to-one												
	Many-to-one		x	x	x								
	One-to-many		x	x	x								
	Many-to-many		x	x	x								
	All-to-all		x	x	x								
Serialisation of tray pool	Not serialized	x											
	Partially serialized												
	Fully serialized												

Figure 5.2: Cross-consistency assessment (CCA) matrix showing the inconsistent value pairs

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	One-to-one	Not serialized
Loadcarrier	Many-to-one	Partially serialized
Return Package	One-to-many	Fully serialized
	Many-to-many	
	All-to-all	

Figure 5.3: Example of a single driver input (Dark blue) and a clustered output

Figure 5.3 shows a single driver input (Dark blue) and a clustered output. In this instance, we are essentially asking the model: "Given the decision that the tray unique identity should be used to represent the return package, what is the option space concerning the other parameters?"

The outcome of the Cross-Consistency Assessment (CCA) is a solution space consisting of 7 "surviving" configurations, based on the double drivers inputs as listed below:

Alternative 1 Tray - one-to-one

Alternative 2 Tray - many-to-one

Alternative 3 Tray - one-to-many

Alternative 4 Tray - many-to-many

Alternative 5 Tray - all-to-all

Alternative 6 Loadcarrier - one-to-one

Alternative 7 Return package - one-to-one

The solution space is presented in Figure 5.4 and is a refined subset of the problem space that only contains solutions that are considered consistent. Note that in almost all surviving configurations, the light blue values are clustered together In the next sections each surviving configuration is explained in more detail.

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	**One-to-one**	Not serialized
Loadcarrier	Many-to-one	Partially serialized
Return Package	One-to-many	Fully serialized
	Many-to-many	
	All-to-all	

(a) Alternative 1

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	One-to-one	Not serialized
Loadcarrier	**Many-to-one**	Partially serialized
Return Package	One-to-many	Fully serialized
	Many-to-many	
	All-to-all	

(b) Alternative 2

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	One-to-one	Not serialized
Loadcarrier	Many-to-one	Partially serialized
Return Package	**One-to-many**	Fully serialized
	Many-to-many	
	All-to-all	

(c) Alternative 3

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	One-to-one	Not serialized
Loadcarrier	Many-to-one	Partially serialized
Return Package	One-to-many	Fully serialized
	Many-to-many	
	All-to-all	

(d) Alternative 4

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	One-to-one	Not serialized
Loadcarrier	Many-to-one	Partially serialized
Return Package	One-to-many	Fully serialized
	Many-to-many	
	All-to-all	

(e) Alternative 5

Unique Identity	Data capture quality of code	Serialization of Pool
Tray	**One-to-one**	Not serialized
Loadcarrier	Many-to-one	Partially serialized
Return Package	One-to-many	Fully serialized
	Many-to-many	
	All-to-all	

(f) Alternative 6

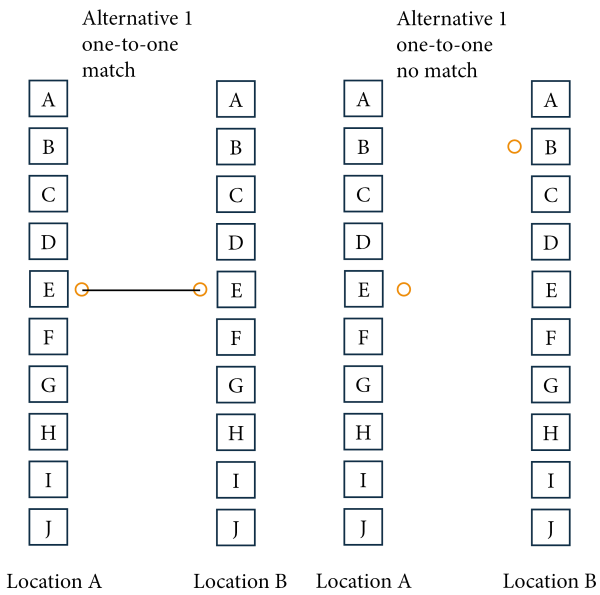
Unique Identity	Data capture quality of code	Serialization of Pool
Tray	**One-to-one**	Not serialized
Loadcarrier	Many-to-one	Partially serialized
Return Package	One-to-many	Fully serialized
	Many-to-many	
	All-to-all	

(g) Alternative 7

Figure 5.4: The outcomes of the GMA, including the process of CCA

5.3.1 *Alternative 1 Tray - One-to-One*

Alternative 1 is the concept of using one unique tray identity to represent the whole return package, in which the sender's information is linked with the tray identity. In a database the code of this unique tray represents and relates all the elements of the pallet. The question remains 'which tray is used to represent the return package?'. Theoretically, any tray can be used as long as it can be identified at the sender's and receiver's location. The *one-to-one* characteristic, means that at location B (receiver) only one tray is picked out each time. The match is fulfilled when the tray that is used to represent the return package is identified at location B (receiver). Figure 5.5 gives an illustration of the matchmaking process of Alternative 1. The squares denoted as A, B, C, ..., J represent unique identifiable trays. The orange circle indicates which tray is identified at a given location. Figure 5.9a shows the scenario in which a match is made because tray E identified at location A (sender) is also identified at location B (receiver). Figure 5.9b shows the scenario in which a match could not be made, because at location B, tray E that represent the whole return package is not identified.

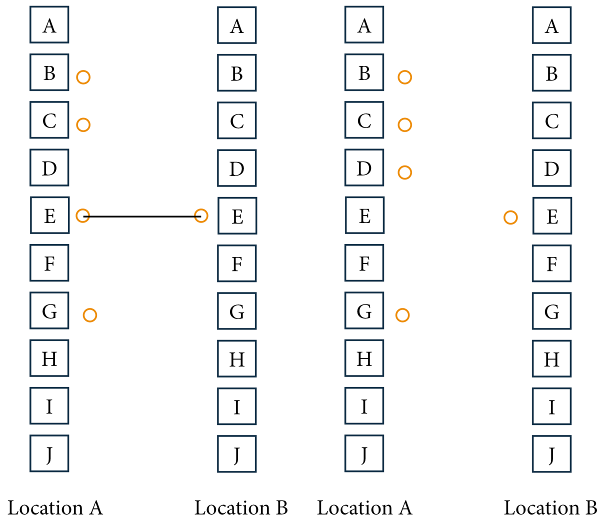


(a) Successful matchmaking (b) No match

Figure 5.5: Matchmaking scenarios for alternative 1 (one-to-one). The squares denoted as A, B, C, ..., J represent unique identifiable trays. The orange circle indicates which tray is identified at a given location. The solid black line indicates a match.

5.3.2 *Alternative 2 Tray - Many-to-One*

Alternative 2 is the concept of having multiple trays to represent the return package. The *Many-to-one* characteristic, means that at location B (receiver) only one tray is picked out each time. The match is fulfilled when one of the multiple trays is identified at location B (receiver).

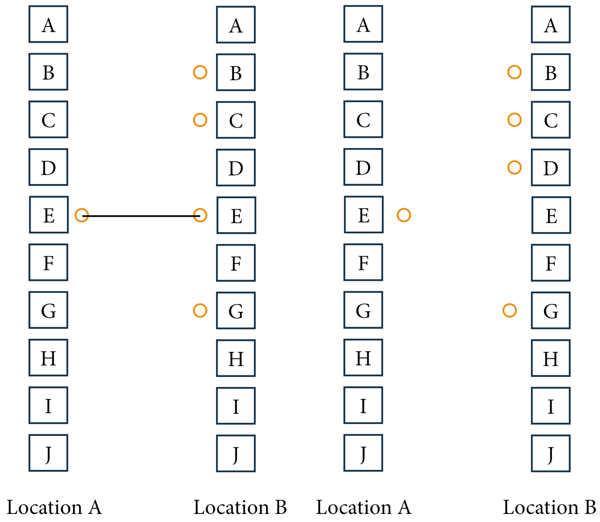


(a) Successful matchmaking (b) No match

Figure 5.6: Matchmaking scenarios for alternative 2 (many-to-one). The squares denoted as A, B, C, ..., J represent unique identifiable trays. The orange circle indicates which tray is identified at a given location. The solid black line indicates a match.

5.3.3 *Alternative 3 Tray - One-to-Many*

Alternative 3 is the concept of using one unique tray identity to represent the return package, and having location B (receiver) picking out multiple trays at every try. The match is fulfilled when the tray that is used to represent the return package is identified at location B (receiver).

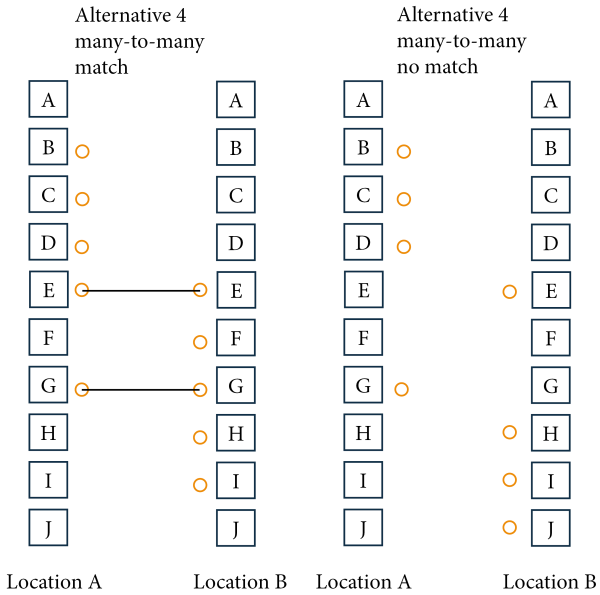


(a) Successful matchmaking (b) No match

Figure 5.7: Matchmaking scenarios for alternative 3 (one-to-many). The squares denoted as A, B, C, ..., J represent unique identifiable trays. The orange circle indicates which tray is identified at a given location. The solid black line indicates a match.

5.3.4 *Alternative 4 Tray - Many-to-Many*

Alternative 4 is the concept of having multiple trays to represent the return package, and having location B (receiver) picking out multiple trays at every try. A match is made when at least one tray that is used to represent the return package is identified at location B (receiver).

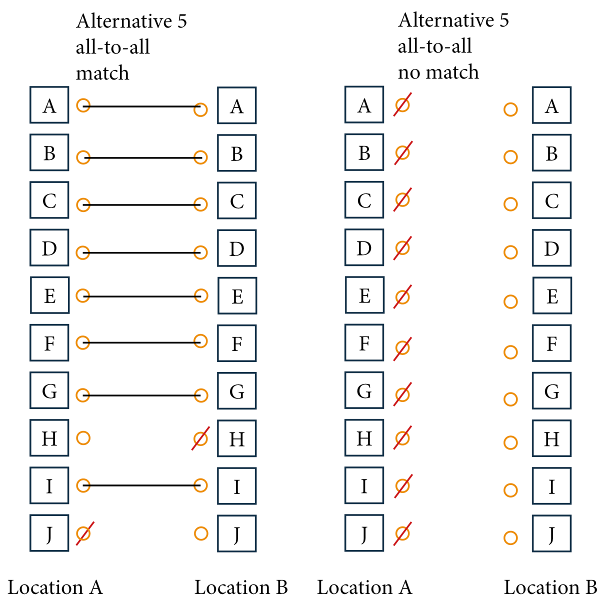


(a) Successful matchmaking (b) No match

Figure 5.8: Matchmaking scenarios for alternative 2 (many-to-one). The squares denoted as A, B, C, ..., J represent unique identifiable trays. The orange circle indicates which tray is identified at a given location. The solid black line indicates a match.

5.3.5 *Alternative 5 Tray - All-to-All*

Alternative 5 is the concept of using all available trays to represent the return package and having location B (receiver) trying all trays. A match is made when at least one tray that is used to represent the return package is identified at location B (receiver).



(a) Successful matchmaking (b) No match

Figure 5.9: Matchmaking scenarios for alternative 5 (all-to-all). The squares denoted as A, B, C, ..., J represent unique identifiable trays. The orange circle indicates which tray is identified at a given location. The solid black line indicates a match.

5.3.6 *Alternative 6 Loadcarrier - One-to-One*

Alternative 6 is the concept of using the unique identity code of the loadcarrier of the return package to make the match. Note that in this system, the serialization of the tray pool does not matter.

5.3.7 *Alternative 7 Return Package - One-to-One*

Alternative 7 is the concept of the return package having its own unique identity code which can be used to make the match. Since a return package only exists upon return, the identity also needs to be generated when the return package is formed. Note that in this system, the serialization of the tray pool does not matter.

5.4 CONCLUDING REMARKS

Based on the parameters Unique Identity, Data Capture Quality and Serialization of Pools, seven matchmaking systems were generated systematically. The first five matchmaking systems involve the use of trays as key, the sixth matchmaking system involves using the loadcarrier as key, and the seventh matchmaking system involves generating a new unique identity upon forming the return package.

6 ASSESSMENT OF THE MATCH-MAKING ALTERNATIVES

In this chapter, the potential matchmaking alternatives generated in the previous chapter are evaluated. Each alternative is first assessed individually and later compared with each other. By the end of the chapter, each alternative matchmaking system will have answered the question: "How well is the system in matchmaking?". This question is answered with the *probability of making a match*.

6.1 ASSESSMENT METHODOLOGY

In the previous chapter 5 a solution space of potential alternatives were found. The objective of this chapter is to test and evaluate each concept. A set of criteria were predefined during the requirements analysis (Chapter 4, these criteria function as a guideline. The first criteria is the robustness of the redesign and considers the questions "How well are mismatches avoided: What is the chance of mismatch?" and "how well are mismatches taken care of". This criteria reflects on the goal of a feasible alternative that can address the allocation problem. The second criteria pertains to the cost that is involved, including both the fixed costs of establishing the concept as well as the extra costs for solving a mismatch.

Alternatives 1-5 use tray(s) as a key to represent the return package. A return package consists of multiple tray items. Given the variability in data capture quality and the extent of serialisation of the pool, it is hypothesised that there will be variations in matchmaking performance. Therefore a probability model is used to simulate the probability of matchmaking in each potential match-making system. The goal is to find out how well each alternative is in matchmaking and is demonstrated by the likelihood of finding the key in the database at the receiver's end. A testcase is set up for each match-making alternative.

The concepts that surround attempts to measure the likelihood of events are embodied in a field called probability theory. Combinatorics is used to calculate the probability that a match takes place in each alternative using trays as key. The probability of matchmaking using trays as key can be compared to the likelihood of drawing black and green balls from a box without replacement. The sender generates a key that can represent the return package and is linked to the sender. The generation of the key occurs by reading and uploading tray codes in the database that is later used for matchmaking. The concept of matchmaking, *recognizing who the sender of the return package is*, takes place at the receiver's end. At the receiver's end, one or multiple tray codes are read. In the database, the scanned tray codes by the sender are looked for. A match takes place when a tray code read by the receiver is found to be a (part of the) key generated by the sender. Since it is unknown how many and which trays are used to generate the key by the sender. This scenario is analogous of drawing balls from a box, where green balls are the tray codes used as key by the sender, where black balls are the tray codes not used as key by the sender and in which the total number of balls in the box is the amount of tray codes present in a return package.

The variables that influence the results and therefore fixed with the same value in all testcases are:

- Total amount of trays on a loadcarrier (#)
- Number of identifiable items that represent a return package (#)
- Number of unidentifiable trays on a loadcarrier (#)
- Number of items being read (#)

A value for each variable is given based on the outcomes of a set analyses. A performance analysis has been done on the depot and devices performance. Since this is not the focus-point of this chapter, the details will be left out.

The chance of not making a match at first try can be calculated by:

$$P(X = 0) = \frac{\binom{K}{0} \cdot \binom{U}{I}}{\binom{N}{I}} \tag{6.1}$$

Where:

X : is the stochast of picking a key (identifiable tray) by the receiver
I : is the number of trays identified by the receiver
K : is the number of keys (identifiable trays)
U : is the number of unusable trays
N : is the total number of trays in return package

While the chance of making a match is:

$$P(X > 0) = 1 - P(X = 0) \tag{6.2}$$

$$= 1 - \frac{\binom{K}{0} \cdot \binom{U}{I}}{\binom{N}{I}} \tag{6.3}$$

This is based on the assumption that if at least one unique tray identity is recognized at both locations A and B, a match can take place.

The chance of no match on m^{th} try is calculated by

$$P(Y = m) = \frac{\binom{K}{0} \cdot \binom{U - I * (m-1)}{I}}{\binom{N - I * (m+1)}{I}} \tag{6.4}$$

6.2 SIMULATION CONDITIONS FOR ALTERNATIVES 1-5

Tables 6.1-5 show the characteristics of the simulation cases for each alternative.

VARIABLE	NAME	PARAMETER VALUE
K	Number of keys	1
U	Number of unusable trays	N − K
I	Number of trays identified by the receiver per trial	1
N	Total number of trays in return package	200

Table 6.1: Testcase 1 One-to-Many

VARIABLE	NAME	PARAMETER VALUE
K	Number of keys	varies from 2 until N
U	Number of unusable trays	$N - K$
I	Number of trays identified by the receiver per trial	1
N	Total number of trays in return package	200

Table 6.2: Test Case 2 Many-to-One

VARIABLE	NAME	PARAMETER VALUE
K	Number of keys	1
U	Number of unusable trays	$N - K$
I	Number of trays identified by the receiver per trial	varies from 2 until N
N	Total number of trays in return package	200

Table 6.3: Test Case 3 One-to-Many

VARIABLE	NAME	PARAMETER VALUE
K	Number of keys	varies from 2 until K
U	Number of unusable trays	$N - K$
I	Number of trays identified by the receiver per trial	varies from 2 until N
N	Total number of trays in return package	200

Table 6.4: Test Case 4 Many-to-Many

VARIABLE	NAME	PARAMETER VALUE
K	Number of keys	N
U	Number of unusable trays	0
I	Number of trays identified by the receiver per trial	varies from 1 till N
N	Total number of trays in return package	200

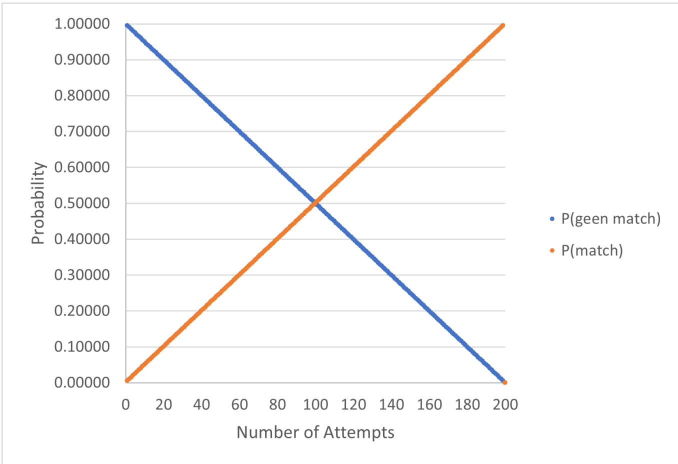
Table 6.5: Test Case 5 All-to-All

6.3 INDIVIDUAL ASSESSMENT OF THE ALTERNATIVES

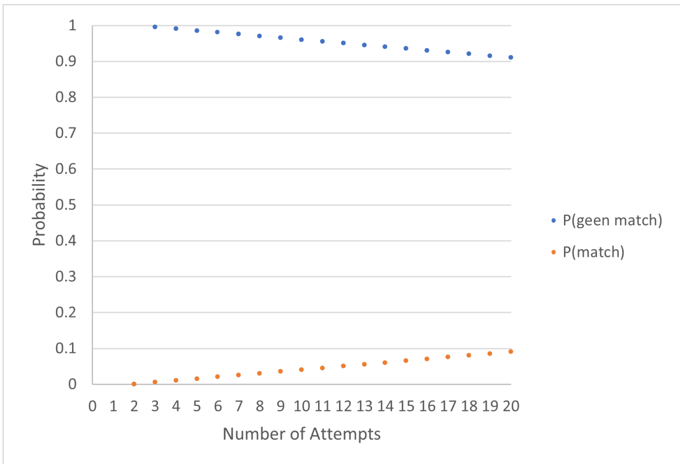
In all testcases, the probability without replacement is considered. Note that the assumption is made that the picking of a tray by the receiver happens randomly.

Alternative 1 One-to-one

In alternative 1, only one tray code is used as key to represent the return package by the sender ($K = 1$) and only one tray is randomly read each time by the receiver ($I = 1$). The probability of making a match is calculated for each reading attempt by the receiver. The results of this test case are shown in Figure 6.1. Figure 6.1a shows a cumulative distribution function of X, where X is the number of attempts. The orange line indicates the probability of making a match, while the blue line indicates the probability of making a mismatch. Figure 6.1b zooms in and shows the probability of making a match (orange) and mismatch (blue) for $0 < 20$. The results show that the probability of making an immediate match (m=1) is 0.005. The probability to make a match increases with each new attempt ($m > 1$), under the condition that the non-matched-tray is excluded in the next attempt. The chance of making a match at second attempt if the first attempt failed is 0.01. The chance of making a match at third attempt is 0.015 etc. The results implicates that the maximum number of attempts (N=200) should be taken, in order to ensure 0 mismatches.



(a) P(match) for 0-200 attempts



(b) P(match) for 0-20 attempts

Figure 6.1: The probability of matchmaking when a tray is randomly picked by the receiver after m number of attempts for alternative 1. The orange line depicts P(match). The blue line depicts P(no match

Alternative 2 Many-to-one

In alternative 2, multiple tray code are used as key to represent the return package by the sender ($K > 1$) and only one tray is randomly read each time by the receiver ($I = 1$). The probability of making a match is calculated for each number of tray codes used as key. The results of this test case are shown in Figure 6.2. Figure 6.2 shows a cumulative distribution function of X, where X is the number of trays used as key. The orange line indicates the probability of making a match, while the blue line indicates the probability of making a mismatch. The results show that the probability of making an immediate match is 0.005. The chance of making a match if 2/200 trays are identified by the sender is 0.015. The chance of making a match if 10/200 trays are identified by the sender is 0.055. The chance of making a match if 50/200 trays are identified by the sender is 0.255 etc. The more trays are identified by the sender, the higher the probability of matchmaking. The match is definitely made if at least 199/200 trays are identified by the sender. See figure 6.2.

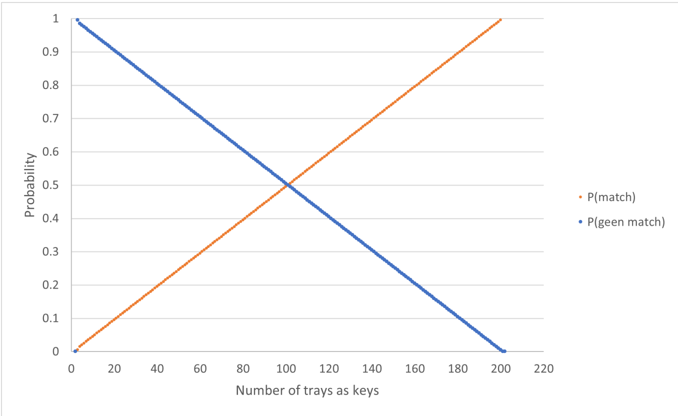
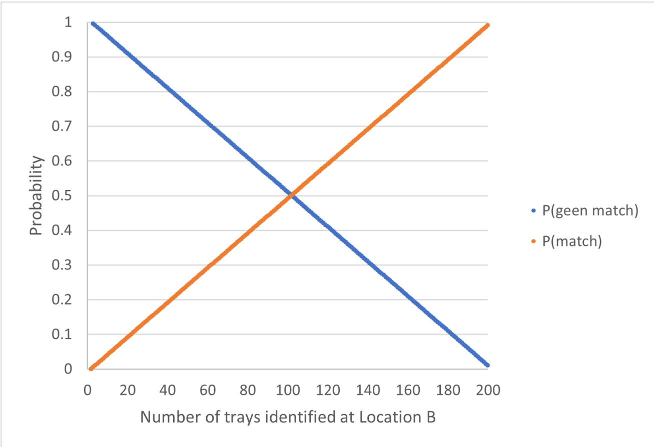


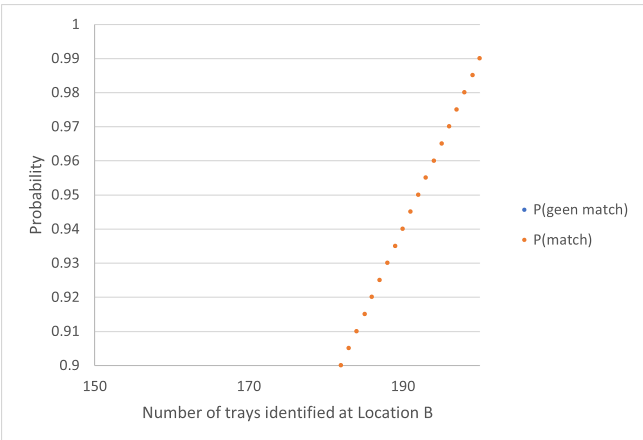
Figure 6.2: The probability of matchmaking plotted against the number of trays used as key by the sender

Alternative 3 One-to-many

In alternative 3, one tray code is used as key to represent the return package by the sender ($K = 1$) and multiple trays are randomly read each time by the receiver ($I > 1$). The probability of making an immediate match is calculated for each number of tray codes read by the receiver. The results of this test case are shown in Figure 6.3. Figure 6.3a shows a cumulative distribution function of X, where X is the number of trays read by the receiver. The orange line indicates the probability of making a match, while the blue line indicates the probability of making a mismatch. Figure 6.3b zooms in and shows the number of tray reads needed to have a probability of immediate match higher than 0.9. The probability of making an immediate match if only one tray is read each time by the receiver is 0.005. The chance of making a match if 2/200 trays are identified by the receiver is 0.01. The chance of making a match if 10/200 trays are identified by the receiver is 0.05. The chance of making a match if 50/200 trays are identified by the receiver is 0.25 etc. The more number of trays are identified by the receiver (at each attempt) the higher the probability of matchmaking. See figure 6.3. The chance of making a match if 199/200 trays are identified by the receiver is 0.995. The match is definitely made if at least 200/200 trays are identified by the receiver.



(a)



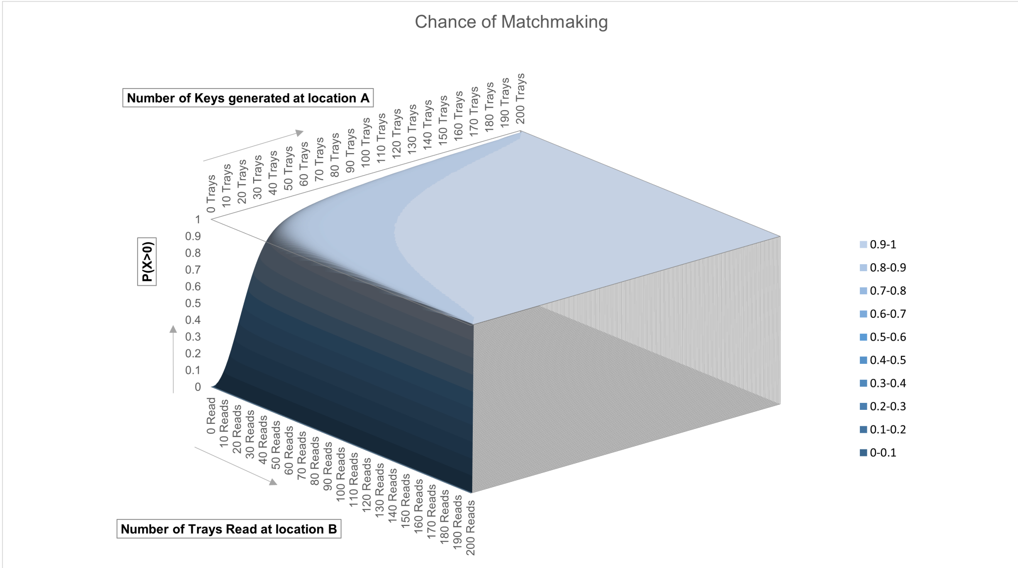
(b) The number of tray identification by the receiver need for a P(match) $\geqslant$ 0.9s

Figure 6.3: The probability of matchmaking plotted against the number of trays identified by the receiver

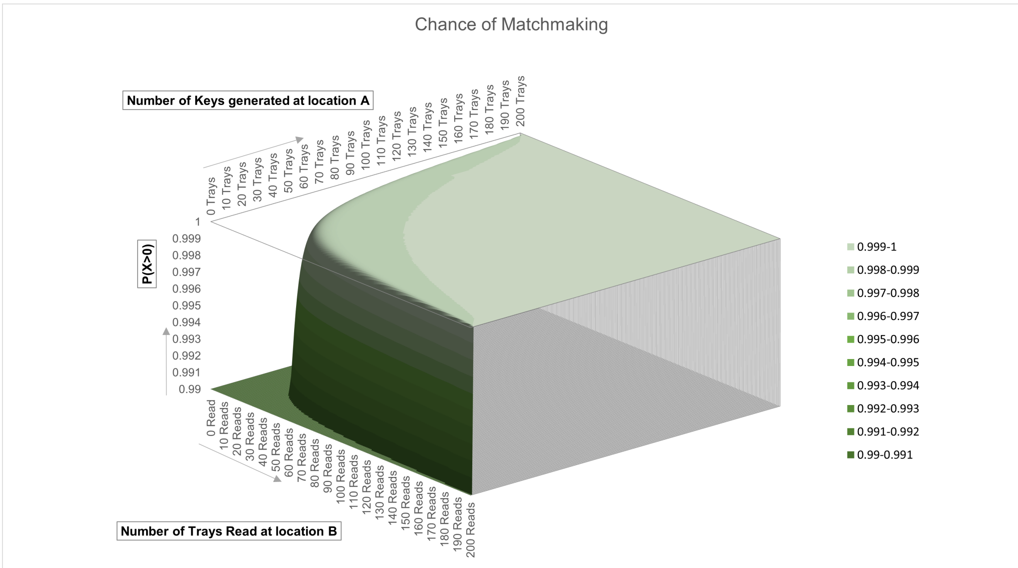
Alternative 4 Many-to-many

In alternative 4, multiple tray codes are used as key to represent the return package by the sender ($K > 1$) and multiple trays are randomly read each time by the receiver ($I > 1$). While testcases 1, 2 and 3 only evaluates one free variable each time, this test case tests 2 free variables. Therefore a 3-D graph is used to set out the probabilities for each combination of I and K. Figure 6.4a shows a 3-D graph of the probability of immediate matchmaking for each possible K and I combination. E.g. 10 tray codes as key by the sender and 50 tray codes identified by the receiver. Figure 6.4b only shows a part of the z-axis with probability of matchmaking between 0.990 and 1.0. This figure is quite revealing in several ways. First, unlike the other figures, it considers two variables at the same time. The following logic can be concluded from this test case:

- The higher the number of trays used as key by the sender (K), the higher the probability of matchmaking;
- The higher the number of trays identified by the receiver (I), the higher the probability of matchmaking;
- If the number of trays used as key generated by the sender is larger than the total number of trays present minus the number of trays identified by the receiver, a match is definitely made. In other words, P(match) = 1.0 if $K > N - I$. This solution space is depicted by the light blue and light green area in figures 6.4a and 6.1b
- The probability of matchmaking increases very steeply after a certain ratio between the number of trays used as key generated by the sender K and $(N - I)$ the total number of trays present minus the number of trays identified by the receiver is reached.



(a) P(match) values from 0.0-1.0



(b) P(match) values from 0.99-1.0

Figure 6.4: A 3-D plot of the probability of matchmaking (z-axis) plotted against the number of trays used as key by the sender (y-axis) and the number of trays identified by the receiver (x-axis)

Alternative 5 All-to-all

In the fifth alternative, all tray codes on the return package are used as key by the sender ($K = N$) and all trays are read by the receiver ($I = N$). This alternative can always make a match, as long as at least one identifiable tray is present at the return package ($N > 0$).

Alternative 6 loadcarrier

The sixth alternative uses the unique ID of the loadcarrier to represent the return package. This implicates that this alternative can can only work if the loadcarriers used by the sender's are serialized. Loadcarriers that are mostly used currently are wooden pallets that do not have a unique identity. Therefore the probability of matchmaking cannot be simulated in the same way as the alternatives that use "tray" as identification key. Further research should be done on the availability and the use of serialised loadcarriers.

Alternative 7 return package

The seventh alternative uses the return package to make a match. This can only work if a return package identity is generated upon the forming of the return package by the sender. The probability of making an immediate match is in this case, theoretically 1.0 within the framework of the made assumption.

6.4 RESULTS & DISCUSSION

In this section, the 7 alternatives are compared with each other based on the criteria "How well are the alternatives in matchmaking?", Each alternative is given a score. See Table 6.6. The likelihood of an immediate match for alternative 1 is 0.005. The likelihood of an immediate match for alternative 2 starts from 0.005 and increases up to 1.0 as the number of trays read by the receiver increases. The likelihood of an immediate match for alternative 3 starts from 0.005 and can also increase to 1.0 as the number of trays used as key by the sender increases. The likelihood of an immediate match for alternative 4 can range from 0.02 to 1.0. For alternative 5 an immediate match is always likely (1.0). The likelihood of an immediate match for alternative 6 is either 1.0 if the loadcarrier has a unique code and 0.0 if the loadcarrier does not have a unique code. Conceptually the likelihood of an immediate match for alternative 7 is 1.0 if a new identity code can be generated by the sender.

CRITERIUM	A1	A2	A3	A4	A5	A6	A7
The chance of an immediate match	0.005	0.005 - 0.999	0.005 - 0.999	0.02 - 1.0	1.0	1.0 or 0.0	1.0

Table 6.6: Summary of Individual Assessments

The results of the simulation testcases show that each alternative has a different degree of immediate matchmaking potential. In each test case the specifications/conditions were found in which the likelihood of an immediate match is 1.0. If an immediate match is not made and there are still trays that are not read yet by the receiver, another attempt can be made (example case: alternative 1), The test cases give insights into what set of rules each alternative needs to become a matchmaking system that can ensure zero-defect matchmaking. Following this logic, we are looking for a matchmaking system that has a cumulative probability of 1.0 of making an match. The rules found are listed below for each alternative system.

- Alternative 1 *one-to-one* requires multiple attempts of readings by the receiver. (shown with the first testcase)
- Alternative 2 *one-to-many*, also requires multiple attempts of readings by the receiver.
- Alternative 3 *many-to-one*, requires multiple attempts of readings by the receiver.
- Alternative 4 *many-to-many* requires multiple attempts of readings by the receiver if $I < N - K$, but does not need additional requirements if $I > N - K$.
- Alternative 5 all-to-all does not need additional requirements.
- Alternative 6 loadcarrier does not need additional requirements.
- Alternative 7 return package does not need additional requirements.

6.5 CONCLUDING REMARKS

Zero-defect traceability refers to zero return packages without shop link. This requires the shop to share data in the database and it implies that mismatches are not allowed. Mismatches either needs to be prevented or they must be able to be solved if it takes place. An "all read" or "reading of all individual trays" is not necessary for a working matchmaking system. The outcome of the assessment are a set of rules to which an alternative is bounded in order to become a feasible option. The way of solving a mismatch can be regarded as the same for all potential alternatives, therefore the assessment solely relies on the likelihood of each alternative to make a match. It is found that each potential alternative has the ability to ensure a match, given the assumptions are met.

7 CONCLUSIONS & RECOMMENDATIONS

This is the last chapter of the thesis and includes conclusions and recommendations based on the present case study.

7.1 CONCLUSION

The present study was designed to gain more understanding in the control of RTIs, with a specific focus on the practical challenges experienced in the reverse logistics by asset-owner and asset-users. Based on a quantitative and qualitative analysis of traceability in the reverse logistics of RTI in the EPS case study, it can be concluded that improving the traceability of return packages can minimise the amount of deposit that are allocated to a retailer's generic account. Moreover, the requirements for enhancing traceability of RTIs in the return chain are found to be: a key, key generation and recognition capability and information sharing. For this, collaboration between the sender and receiver is needed. A design science approach is taken to investigate ways to improve the traceability of return packages in the reverse logistics which has led to the birth of the concept of matchmaking. The advantage of the design science approach is that it enables the construction of design models that expand upon existing theoretical products, thereby contributing to the advancement of knowledge. From the matchmaking system it can be concluded that the degree of recognition is an important factor for matchmaking. The choice of unique code to represent the return package is less trivial, as long as the key can be created by the sender and recognized by the receiver. This research illustrates that information sharing and having standardised rules set up by the asset-manager in a complex network with many asset-users are important factors that influence the control and management of RTIs. Besides, it has created insights on requirements for enhancing traceability of RTI's in the return chain.

7.2 REFLECTION

The first question in this study sought to determine the state-of-the-art of RTI control in reverse logistics. The literature study showed how the management of RTIs has a great impact on RTI control and that asset traceability and visibility are required to achieve RTI. It is mentioned that efficient RTI reverse logistics systems are crucial for facilitating the return and reuse of pallets, reducing costs, and minimizing environmental impacts. There are papers that address the problem of overall RTI control throughout the supply chain. Additionally, there are several papers that investigate how advanced technology (such as RFID) can be implemented to improve reverse logistics systems. Researchers have investigated and classified issues related to closed-loop and reverse logistics of RTIs. The importance of efficient and reliable systems for tracking RTIs, capturing relevant data, and facilitating effective communication among supply chain partners have been addressed. However no papers were found that applied this knowledge or tested how the improvement via these channels of the reverse logistics of RTIs can be achieved. The second question in this study sought to determine the current state reverse logistics of RTIs. The most obvious finding to emerge from the current state analysis is that SSCC-labels are supposed to enable the identification of the sender, but the outcomes are not always as desired for the retailer. It was found that the number of return packages that has a missing SSCC and the number of return packages that are allocated to a virtual shop varies between retailers. These findings suggest that a large number of return packages cannot be identified which lead to the problem that deposit is allocated to a retailer's generic account. These findings also suggest that it seems that retailers either undervalue the use of SSCCs or that the use of SSCCs is inefficient and error-prone as an identification method. Even in case of a return package with a missing

SSCC, EPS can still refund the deposit to the corresponding client because the return order is always client based. However the information on shop level misses, therefore the client needs to figure out how to reallocate this deposit to its shops and franchises. A note of caution is due here since the analysis is mainly based on data gathered by EPS. While the findings do reflect on the problem of lack of traceability (and missing shop link) from EPS' perspective, it is possible that these results may either overestimate or underestimate the problem for a certain client. The numbers have been consolidated from all clients, while it is noted that not all clients perceive a missing shop link as a problem. The swimlanes are more general and conceptual and were not derived from observations of operational processes. Therefore the summarized numbers are good for internal communication and reflection, but may not be interpolated to a specific client. One interesting finding is that, while the return procedure is standardised, each client has its "own way of returning and identifying". Despite of the fact that the receiver is the asset-owner, it seems that the receiver has limited control and visibility over the reverse logistics because it is basically a transfer process, both in material flow and information flow. Therefore the traceability of RTI returns is heavily dependent on whether, what and how the sender shares information with EPS. Another important finding is that EPS is relatively technologically advanced and has been collecting data on their individual trays. This finding provide support for the idea to focus on readily available potentials. The third question in this study sought to determine the requirements and criteria for the redesign that can address the deposit problem. The requirements defined were based on findings from the literature study and insights from the current state analysis. The fourth research question was "what are potential redesigns?". A conceptual answer was proposed. Conceptually a matchmaking system is considered to be a solution space for this. A matchmaking system ensures matchmaking between a return package created by the sender and a return package identified (later) by the receiver. It works based on either a newly created key or assigning an existing data element to represents the return package until the return process is finished.

Both the literature study on available technology and the current state analysis support the idea that not the availability of technology is the limitation, but the way people deal with it. A 'simple' request by the receiver of uploading/scanning GRAIs has the potential to eliminate unidentifiable return packages. The findings of this research agree with Johansson and Hellström [21], who warned that having asset visibility does not automatically translate into the ability to utilize the information effectively. Continuous management of tracking data is required to efficiently use the increased information.

7.3 RESEARCH RECOMMENDATIONS

This section gives recommendations based on the findings of this research. This research highlights inefficiencies in the current RTI return identification process using physical SSCC labels and therefore addresses a gap in literature regarding the shortcomings of existing identification methodologies in reverse logistics. The focus on improving traceability in the return chain for RTIs fills a gap in the literature. This thesis developed the concept of a matchmaking system as a way to address the traceability problem of return packages. Several assumptions have been made, including an IT-system that can share and store data, the willingness of the retailer to share the information on the shop origin of a return package, the ability to generate a key by the sender and to identify the key by the receiver, the security of the key that it cannot be switched to another return package and that one unique tray code is enough to represent the whole return package. Further research is needed to understand and determine the reluctance of senders to go on board with a matchmaking system. There is a need for more in-depth research on the impact of collaboration models and mechanisms. Understanding the dynamics, challenges, and benefits of stakeholder collaboration in RTI systems can contribute to more effective and sustainable management practices. Besides, it has been found that there is a lack of standardized metrics and evaluation frameworks for assessing the performance and impact of RTI systems. Future research should focus on developing standardized metrics that can be used to compare and evaluate the effectiveness of different RTI strategies, enabling better benchmarking and knowledge sharing among practitioners and researchers. Lastly, further research can investigate the opportunities of using Artificial Intelligence (AI) to recognize a return package at receiver's site.

7.4 translation into practice

As the emergence of reusable assets such as reusable cups among society is increasing and the desire to recycle and reuse products, the importance of understanding reverse logistics rises. This research proposed a matchmaking system concept as a way to improve the traceability of RTIs in the reverse logistics. A set of rules were found that ensures a zero mismatch. However, what does this combined with the literature study implicates? This section includes recommendations for practitioners. This thesis encourages the implementation of the matchmaking system. The matchmaking system is versatile and can therefore be considered in different cases when increase of visibility in a logistics system is desired to be achieved. Practitioners should consider what devices and methods are readily available and review their code capture capability at both 'sender's' and 'receiver's' site, in order to determine which unique identities can become a key. The code capture ability needs to be checked at both the sender's and receiver's site to find out how many codes need to be read if the chosen unique identity is an element of the whole. The simulation model can help with decision-making, based on the desired probability of matchmaking. A brief analysis is done on the performance of tray-code reading by an EPS depot. The high reading performance by EPS suggests that a less reading capability is allowed for the sender. While it is recommended to keep both the reading capability of the sender and the receiver high, if this is not achievable due to any reasons (e.g. reluctance of the sender, low level of technology readiness etc.). It is advised that EPS look for opportunities to increase the reading rate at their end, to ensure a zero-defect matchmaking. Additionally, an impact analysis is performed that gives insights into the extra cost (in FTE) consequences if a mismatch occurs (See Appendix E). This is dependent on a the data code capture ability and choice of number of trays used as key by the sender and the data code capture ability by the receiver. Lastly, several scenarios should be taken into consideration when considering the implementation of the matchmaking system. For example, what is the probability that trays fall off a return packages or are moved? Can the key go "missing", like an SSCC label? How long are trace-keys stored in the database? Further research in the differences between the effectiveness of punishment and reward in motivating asset-users to follow certain rules might be interesting for asset-managers. As the term *key* as defined in this study is not dependent on one specific technology, this concept can be interpreted in a broader sense and may be even considered in the future or in other industries. To give an example, in the current case study the key is only built by one parameter-value of "unique identity", namely tray codes. However, other characteristics of the return package can be considered as a unique identity too. Moreover, the key can be expanded as a combination of multiple available elements to increase the matchmaking probability. All in all, the concept of matchmaking system can help practitioners reflect on and improve their traceability systems.

APPENDICES

A

SCIENTIFIC ARTICLE

A summary of this research in the format of a scientific paper is provided in this Appendix, starting on the next page.

Enhancing Traceability of RTI Returns: A Matchmaking System

A Case Study at Euro Pool System

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Abstract

This article discusses a case study on RTI returns in which a matchmaking system was developed in order to minimize the number of returns with unidentifiable origin and increase asset visibility of the company. The objective of this study is to present a case study on the reverse logistics of reusable trays by a large tray provider in the fresh fruit and vegetable industry in Europe. This study highlights inefficiencies in the current identification process using physical SSCC labels. Findings show that there is a large amount of return packages that cannot be identified (Δ) due to missing SSCC labels that carry the sender's information upon arrival at the company's depot. This study performed a General Morphological Analysis to develop ways to address this traceability problem. The outcome of this study is the concept of a zero-defect matchmaking system. A matchmaking system ensures matchmaking in the database through a key that is generated by the sender and recognized by the receiver in the reverse logistics. The study explores how collected data can be leveraged for enhanced RTI management in the reverse logistics. Simulation results show that the matchmaking system performance depends on efficient and accurate generation and recognition of the key. The paper provides an improved understanding of the reverse flow of RTIs and complements existing literature on RTI management.

Keywords *- Returnable Transport Items (RTI), Traceability, Reverse Logistics, Asset Visibility, Design Science Approach*

1 Introduction

In recent years, climate change, natural resource depletion and pollution, have became serious matters for many parties in the world. The pressure has increased to minimize environmental damage. As a consequence, the logistics industry has transitioned towards sustainable practices. This has resulted in the elimination of single-use packaging and the use of Returnable Transport Items (RTIs) as a sustainable option. In most industries, RTIs are key elements for enabling a smooth flow of goods throughout the supply chains. RTIs are a packaging medium that allows bundled goods to be transported between vendors and customers multiple times. They are crucial to efficient logistical operations and provide protection of goods during transport, storage, and handling. In the fresh fruit and vegetable industry, RTIs are known as crates, trays, boxes, pallets and roll cages which are returned multiple times in their life cycle. RTIs function within closed-loop supply chains (CLSCs) but exhibit unique characteristics compared to conventional CLSCs [4]. The first feature is the low level of disassembly: While a conventional CLSC involves repair, remanufacture and recyling of a product in order to prepare the item to be reintroduced in the forward supply chain. Reuse of RTIs only requires light reconditioning operations, such as testing, cleaning, minor repairs, or sterilisation. Another essential feature is that RTIs are shared and mobile assets. This means that RTIs are used by different users in different locations and travel across boundaries of organisations that make up the supply chain network. This implies that at some stages of the product life-cycle, the RTI-owner has limited control.

To date, most studies have only focused on the why and how to use Returnable Transport Items in context of Supply Chain Management. No research have addressed the problem of RTI control within reverse logistics. The aim of the present paper is twofold: to provide insights into practical challenges and to propose a systematic approach for improving traceability and efficiency in RTI control within reverse logistics. The main question addressed in this paper is "*How can traceability of RTI Returns for an asset-owner be improved?*" Based on current state traceability findings and a literature review, this paper proposes a matchmaking system. The paper is organised in the following way: the next section presents an overview of RTI and traceability literature. Section 3 presents the research methods and data used. Section 4 examines the current way of identification of returns for the company. Section 5 presents the concept of Matchmaking. A discussion and suggestions for future research are outlined in section 6 and 7 respectively.

2 Literature Background

Research on RTI is fragmented and disparsed. Research focus ranges from exploring control strategies and factors that support

efficient management of RTI closed-loop supply chain [7, 9, 11, 14, 3], analysing ways to adopt RTIs in the food industry [1], addressing the advantages of reusable packaging [12, 19], to assessing and identifying the effects of costs and (sustainable) effects associated to RTIs on supply chain [2, 6, 20]. Studies have developed frameworks and simulation models to explore the impact of control strategies on RTI management [7]. Various researchers have investigated different aspects of RTI logistics and management within CLSCs. For example, [9, 3, 19] have studied control strategies, efficient management practices, and the advantages of reusable packaging. They emphasize the importance of asset visibility in managing RTI effectively and propose methods such as tracking technologies to enhance visibility.
RTI visibility refers to a lack of knowledge about their utilization, prompting efforts to enhance supply chain visibility through tracking systems. However, Hellström and Johansson highlighted the importance of not just collecting tracking data but also ensuring proper actions and continuous management attention for efficient RTI management. RFID technology is suggested as a tool to augment visibility rather than a standalone solution, requiring efficient data analysis [10]. Furthermore, [17] demonstrated the implementation of a Cyber-Physical System (CPS) for monitoring and controlling RTIs within the automotive industry. Their study showcased the potential of CPS in providing full visibility and control over RTIs, meeting the requirements of stakeholders within the domain. However, challenges were identified, such as the need for reliable links between RTIs and the CPS, the potential for misidentification of RTIs, and the importance of adaptable data capture and state determination services.
Additionally, [12, 3] classified different network designs for reusable articles, such as transfer systems, depot systems, and switch pool systems. These classifications offer insights into the structural aspects of managing RTIs within CLSCs.

With the advent of computer systems and information technology, processes involving the movement of goods are increasingly managed, analyzed, and presented using these technologies. However, recording the status of moving objects often involves repetitive, labor-intensive, and error-prone data entry, prompting the development of automated systems to manage physical flows [16]. Previous studies have highlighted the growing role of the Internet of Things (IoT) and Industry 4.0 in efficient supply chain management [13, 17, 8]. Different identification systems, such as barcodes and Auto-ID technologies, have emerged in supply chains. Barcoding, although cost-effective, lacks real-time information and requires manual scanning, making it time-consuming and prone to errors compared to other Auto-ID technologies. Maleki and Reimche named five different technologies that can improve the identification/tracking in supply chains: barcode, passive radio-frequency identification (RFID), active RFID, Wi-Fi, and global positioning system (GPS). Even though the barcode systems is the most economical compared to other auto-ID technologies. The main disadvantage is that it cannot provide real-time information and needs manually scanning, which is a process that is time-consuming and prone to errors.

Research on the control of RTI systems is scarce. Up to date, no research has been specifically focused on the reverse logistics of RTIs. RTIs are challenging assets to manage, because it requires accurate counting, reporting and shared information among organisations. Based on the conducted literature review, RTI return control seems to be a subpart of the concept of asset visibility. It can be concluded that traceability, visibility and serialization are minimal requirements, to achieve RTI control in the reverse logistics. Additionally to achieve all of these, stakeholders' collaboration, coordination between actors and technology or a system that can ensure return identification is needed. Asset visibility refers to the ability to track and monitor the location, status, and availability of RTIs throughout the supply chain. But to gain visibility, unique identification is a prerequisite of an item. Enhanced asset visibility contributes to the overall performance and efficiency of RTI management in supply chains, including control. Many researchers looked into the role of technology, such as radio frequency identification (RFID) and other tracking systems, in enhancing asset visibility. These technologies enable the automatic identification and monitoring of RTIs, providing real-time data on their location and movement within the supply chain.

3 Methodology

The present study contained a research and a design part. It utilised a design science approach combined with TIL systems engineering to analyse a practice problem in the field of RTIs and reverse logistics. The practice problem is derived from a case study at Euro Pool System. The research part includes a literature review and a current state analysis on RTI traceability to gain a comprehensive understanding of the practice problem. The design part had the goal of generating a solution space and adopted a Requirements Analysis and a Morphological Analysis [21, 18]. To validate the generated alternatives, a simulation is performed. In the following subsections the use of each method will be explained. Data were gathered from Euro Pool System.

4 The Traceability of RTI returns - The case of Euro Pool System

A case study is performed at Euro Pool System (EPS), which is part of Euro Pool Group (EPG), a large logistics service provider of reusable standard packaging in Europe [5]. Euro Pool System supplies and manages over 250 million reusable trays in the distribution chain for fresh and packaged foods. Actors involved in this distribution chain are fillers (growers), traders (wholesalers) and retailers (supermarkets). Euro Pool System offers a service called Smart Return Logistics (SRL) to make its distribution partners' reverse logistics easier and more effective. With this service, trays can be placed and returned without any sorting on the same pallet. Each pallet of unsorted folded trays - from now on referred as *return package* - is given a Serial Shipping Container Code (SSCC) label by the sender, allowing for unique identification throughout the return route. This is illustrated by Figure 1.

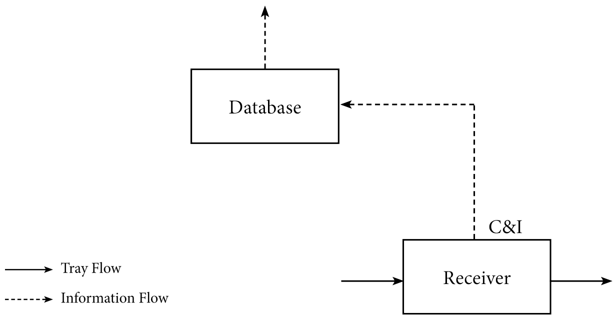

Figure 1: Current State Identification

Return packages are delivered to the Euro Pool System Service Center, where an automated system called Vision Control that offers optical identification of the returning trays, scans the Serial Shipping Container Code (SSCC) label from the pallets. This system has the ability to store data on a cloud platform for online monitoring and the creation of complete reports. The scanning of the SSCC label is the *Identification* part of the Counting & Identification process that occurs at the receiver's site. At the moment, EPS prints the SSCC labels manually in bulk and sends it to their customers (retailers). If a retailer wants to return pallets of used trays, it is up to the retailers to manage the labels for their corresponding stores. The use of printed labels is prone to error. Problems that are faced includes forgetting about making a link between label and retailers store, the disappearances of rolls of labels when needed by retailer store, not knowing when to order new labels and the dropping off of labels somewhere in the return process before the pallet arrives at an EPS depot. In addition, labels of trays need to fall off during washing. Therefore the labels of trays are on a sugar basis, which tend to dry out in one year.

An in-depth analysis is performed into the amount of return packages that cannot be identified by the receiver. Data from the period of January 2022 until June 2023 were gathered from the company's database for this analysis. The number of return packages that could not be identified is the sum of SSCC-codes that had the anomalies "SSCC barcode missing" or "not readable" in the data base plus the amount of SSCC's that are allocated to the general deposit account for a specific retailer. Table 1 gives a summary of the quantity of unidentifiable return packages for a few large retailers. The retailer with the highest amount of return packages without shop origin (288,021) is the retailer with highest SSCC volume, Delhaize. Other retailers with a high amount of return packages without shop origin are Aldi Sud, Consum and Jeronimo Martins, with more than 100,000 unidentifiable return packages.

SC Partner	Qty SSCC	Qty SSCC unidentifiable
Delhaize (BE)	1.928.964	288.021 (15%)
Edeka (DE)	1.053.263	37.568 (4%)
Jumbo (NL)	767.744	12.783 (2%)
Aldi Sud (GB)	670.854	115.698 (17%)
Consum (ES)	345.815	162.068 (47%)
Jeronimo Martins (PT)	217.646	163.959 (75%)
Salling Group (DK)	216.134	36.232 (17%)
El Corte Ingles (ES)	193375	46516 (24%)
Eroski (ES)	166133	74193 (45%)

Table 1: The number of return packages with missing SSCC or allocated to a virtual shop per Supply Chain Partner

Based on these current state findings, the design goal is defined and refined to a quantified Δ that needs to be minimized. The Δ denotes the number of return package without shop link. Ways to address this design goal were investigated systematically. This study proposes the concept of matchmaking as a way to improve traceability and to minimize the number of unidentifiable return packages. This concept will be explained in the following section.

5 The Concept of Matchmaking for RTI returns

Matchmaking is considered the action that contributes to traceability and prevent unidentifiable returns. A matchmaking system refers to the set of interconnected and technical necessary components that ensures the matchmaking function. The matchmaking system is defined as the technical necessities that uphold the matchmaking process. a concept of using a *key* generated by a sender (location A) to represent the whole return package, which can be recognised by the receiver (location B). A *match* denotes the event that a sender's return package is recognized by the receiver. A match occurs when the key that represents a return package generated by the sender is identified by the receiver. Figure 2 gives an illustration of the matchmmaking concept.

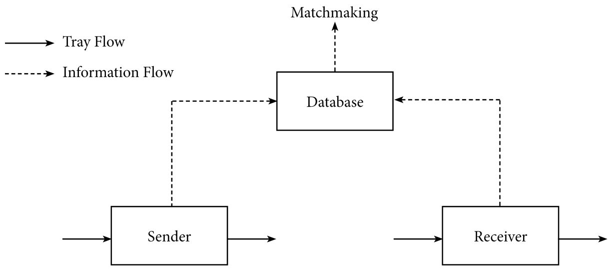

Figure 2: The Concept of a Match-Making System

The General Morphological Analysis resulted in a solution space for matchmaking. Three parameters were defined based on a requirements analysis and the literature study. The parameters are *unique identity*, *data capture quality* and *serialization of the tray pool*. The term "unique identity" denotes any unique identity present in the return system that can represent a unique return package. The term "data capture quality" denotes the level of process of extracting information. It represents how the match is tried to be found. The term "serialization of the tray pool" denotes to what context trays on a return package have an identifiable unique identity code. Each parameter set has its own set of values. The values for unique identity are tray, loadcarrier, return package and freight order. The values for data capture quality of code are one-to-one, many-to-one, one-to-many, many-to-many, and all-to-all. The values for serialisation of tray pool are not serialised, partially serialised, fully serialised. Based on these parameter sets, the solution space for matchmaking is generated. The solution space is illustrated with a multidimensional matrix containing all solutions. A "solution" in this respect denotes a configuration where one value is designated for each parameter. However, the solution space consists of "noise" in the form of inconsistent solutions. Therefore a cross consistency assessment (CCA) analysis of the entire morphological field is performed in order to reduce the amount of such noise, and to delineate a solution space. The matrix represents the entire morphological field of the problem, which is 3x5x3 = 45 unique configurations. The Cross Consistency Assessment involves a thorough examination of each pair in the matrix. Here, the number of pairs is 39. The results of the CCA is presented in Fig 3.

		Unique Identity				Data capture quality of code					Serialisation of tray pool		
		Tray	Loadcarrier	Return Package	Freight order	One-to-one	Many-to-one	One-to-many	Many-to-many	All-to-all	Not serialized	Partially serialized	Fully serialized
Data capture quality of code	One-to-one												
	Many-to-one		x	x	x								
	One-to-many		x	x	x								
	Many-to-many		x	x	x								
	All-to-all		x	x	x								
Serialisation of tray pool	Not serialized	x											
	Partially serialized												
	Fully serialized												

Figure 3: Cross-consistency assessment (CCA) matrix showing the inconsistent value pairs

5.1 The Seven Matchmaking Alternatives

Based on the parameters Unique Identity, Data Capture Quality and Serialization of Pools, seven matchmaking systems were generated systematically. The first five matchmaking systems involve the use of trays as key, the sixth matchmaking system involves using the loadcarrier as key, and the seventh matchmaking system involves generating a new unique identity upon forming the return package. Each matchmaking system will be examined in the following subsections.

5.1.1 Alternative 1 Tray - One-to-One

Alternative 1 is the concept of using one unique tray identity to represent the whole return package, in which the sender's information is linked with the tray identity. In a database the code of this unique tray represents and relates all the elements of the pallet.

5.1.2 Alternative 2 Tray - Many-to-One

Alternative 2 is the concept of having multiple trays to represent the return package. The *Many-to-one* characteristic, means that at location B (receiver) only one tray is picked out each time. The match is fulfilled when one of the multiple trays is identified at location B (receiver).

5.1.3 Alternative 3 Tray - One-to-Many

Alternative 3 is the concept of using one unique tray identity to represent the return package, and having location B (receiver) picking out multiple trays at every try. The match is fulfilled when the tray that is used to represent the return package is identified at location B (receiver).

5.1.4 Alternative 4 Tray - Many-to-Many

Alternative 4 is the concept of having multiple trays to represent the return package, and having location B (receiver) picking out multiple trays at every try. A match is made when at least one tray that is used to represent the return package is identified at location B (receiver).

5.1.5 Alternative 5 Tray - All-to-All

Alternative 5 is the concept of using all available trays to represent the return package and having location B (receiver) trying all trays. A match is made when at least one tray that is used to represent the return package is identified at location B (receiver).

5.1.6 Alternative 6 Loadcarrier - One-to-One

Alternative 6 is the concept of using the unique identity code of the loadcarrier of the return package to make the match. Note that in this system, the serialization of the tray pool does not matter.

5.1.7 Alternative 7 Return Package - One-to-One

Alternative 7 is the concept of the return package having its own unique identity code which can be used to make the match. Since a return package only exists upon return, the identity also needs to be generated when the return package is formed. Note that in this system, the serialization of the tray pool does not matter.

5.2 Testing of the Matchmaking Systems through simulation

The effectiveness of the matchmaking system is assessed by the probability of matchmaking, which can be translated into the KPI (key performance indicator) percentage identifiable return packages. A simulation based on combinatorics is used to calculate the likelihood that a match takes place in each alternative using trays as key (alternatives 1 - 5). The concept of matchmaking, *recognizing who the sender of the return package is*, takes place at the receiver's end. At the receiver's end, one or multiple tray codes are read. In the database, the scanned tray codes by the sender are looked for. A match takes place when a tray code read by the receiver is found to be a (part of the) key generated by the sender. Since it is unknown how many and which trays are used to generate the key by the sender. This scenario is analogous of drawing balls from a box, where green balls are the tray codes used as key by the sender, where black balls are the tray codes not used as key by the sender and in which the total number of balls in the box is the amount of tray codes present in a return package.

The variables in this simulation analysis are:

- Total amount of trays on a loadcarrier (#)
- Number of identifiable items that represent a return package (#)

- Number of unidentifiable trays on a loadcarrier (#)
- Number of items being read (#)

The chance of not making a match at first try can be calculated by:

$$P(X=0) = \frac{\binom{K}{0} \cdot \binom{U}{I}}{\binom{N}{I}} \tag{1}$$

Where:

X : is the stochast of picking an identifiable tray by the receiver
I : is the number of trays identified by the receiver
K : is the number of keys (identifiable trays)
U : is the number of unidentifiable trays
N : is the total number of trays in return package

While the chance of making a match is:

$$P(X>0) = 1 - P(X=0) \tag{2}$$

$$= 1 - \frac{\binom{K}{0} \cdot \binom{U}{I}}{\binom{N}{I}} \tag{3}$$

This is based on the assumption that if at least one unique tray identity is recognized at both locations A and B, a match can take place. Five testcases are considered. In all testcases, the probability without replacement is considered. Note that the assumption is made that the picking of a tray by the receiver occurs randomly. Tables 2-5 show the characteristics of the simulation cases for each alternative.

Variable	Name	Parameter Value
K	Number of keys	1
U	Number of unidentifiable trays	$N-K$
I	Number of trays identified by the receiver	1
N	Total number of trays in return package	200

Table 2: Alternative 1 One-to-Many

Variable	Name	Parameter Value
K	Number of keys	between 2 and N
U	Number of unidentifiable trays	$N-K$
I	Number of trays identified by the receiver	1
N	Total number of trays in return package	200

Table 3: Alternative 2 Many-to-One

Variable	Name	Parameter Value
K	Number of keys	1
U	Number of unidentifiable trays	$N-K$
I	Number of trays identified by the receiver	between 2 and N
N	Total number of trays in return package	200

Table 4: Alternative 3 One-to-Many

Variable	Name	Parameter Value
K	Number of keys	between 2 and K
U	Number of unidentifiable trays	$N-K$
I	Number of trays identified by the receiver	between 2 and N
N	Total number of trays in return package	200

Table 5: Alternative 4 Many-to-Many

Variable	Name	Parameter Value
K	Number of keys	between 1 and N
U	Number of unidentifiable trays	0
I	Number of trays identified by the receiver	between 1 and N
N	Total number of trays in return package	200

Table 6: Alternative 5 All-to-All

A 3-D graph is used to summarise all simulation results. Probabilities for each combination of I and K. Figure 4 shows a 3-D graph of the probability of immediate matchmaking for each possible number of codes as key (K) and number of tray identified by the receiver (I) combination, with a fixed total number of trays of 200 (N). E.g. 10 tray codes as key by the sender and 50 tray codes identified by the receiver. Figure 5 only shows a part of the z-axis with probability of matchmaking between 0.990 and 1.0. This figure is quite revealing in several ways, since it considers two variables at the same time. The following logic can be concluded from this test case:

- The higher the number of trays used as key by the sender (K), the higher the probability of matchmaking;
- The higher the number of trays identified by the receiver (I), the higher the probability of matchmaking;
- If the number of trays used as key generated by the sender is larger than the total number of trays present minus the number of trays identified by the receiver, a match is definitely made. In other words, P(match) = 1.0 if $K > N - I$. This solution space is depicted by the light blue and light green area in figures 4 and 5
- The probability of matchmaking increases very steeply after a certain ratio between the number of trays used as key generated by the sender K and $(N - I)$ the total number of trays present minus the number of trays identified by the receiver is reached.

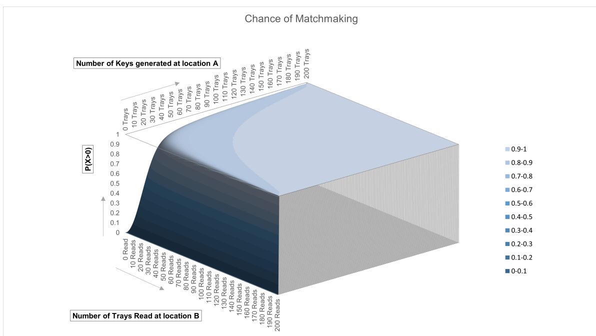

Figure 4: A 3-D plot of the probability of matchmaking from 0.0 to 1.0 (z-axis) plotted against the number of trays used as key by the sender (y-axis) and the number of trays identified by the receiver (x-axis)

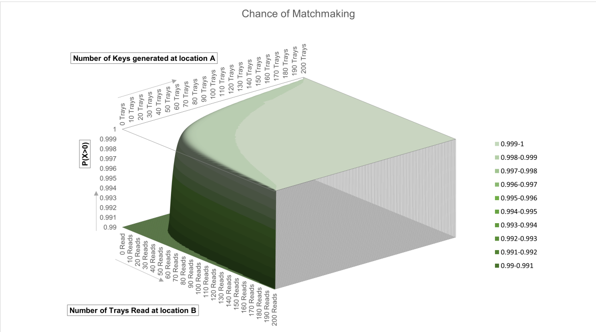

Figure 5: A 3-D plot of the probability of matchmaking between 0.990 and 1.0 (z-axis) plotted against the number of trays used as key by the sender (y-axis) and the number of trays identified by the receiver (x-axis)

Table 7. The likelihood of an immediate match for alternative 1 is 0.005. The likelihood of an immediate match for alternative 2 starts from 0.005 and increases up to 1.0 as the number of trays read by the receiver increases. The likelihood of an immediate match for alternative 3 starts from 0.005 and can also increase to 1.0 as the number of trays used as key by the sender increases. The likelihood of an immediate match for alternative 4 can range from 0.02 to 1.0. For alternative 5 an immediate match is always likely (1.0). The likelihood of an immediate match for alternative 6 is either 1.0 if the loadcarrier has a unique code and 0.0 if the loadcarrier does not have a unique code. Conceptually the likelihood of an immediate match for alternative 7 is 1.0 if a new identity code can be generated by the sender.

Criterium	A1	A2	A3	A4	A5	A6	A7
The chance of an immediate match	0.005	0.005 - 0.999	0.005 - 0.999	0.02 - 1.0	1.0	1.0 or 0.0	1.0

Table 7: Summary of Individual Assessments

The results of the simulation testcases show that each alternative has a different degree of immediate matchmaking potential. In each test case the specifications/conditions were found in which the likelihood of an immediate match is 1.0. If an immediate match is not made and there are still trays that are not read yet by the receiver, another attempt can be made (example case: alternative 1), The test cases give insights into what set of rules each alternative needs to become a matchmaking system that can ensure zero-defect matchmaking. Following this logic, we are looking for a matchmaking system that has a cumulative probability of 1.0 of making an match. The rules found are listed below for each alternative system.

- Alternative 1 *one-to-one* requires multiple attempts of readings by the receiver. (shown with the first testcase)
- Alternative 2 *one-to-many*, also requires multiple attempts of readings by the receiver.
- Alternative 3 *many-to-one*, requires multiple attempts of readings by the receiver.
- Alternative 4 *many-to-many* requires multiple attempts of readings by the receiver if $I < N - K$, but does not need additional requirements if $I > N - K$.
- Alternative 5 all-to-all does not need additional requirements.
- Alternative 6 loadcarrier does not need additional requirements.
- Alternative 7 return package does not need additional requirements.

6 Discussion

It is true that in this research I have not looked into the operational process nor observed the use of SSCC label from the perspective of the sender. This would be the subject of an entirely worthwhile research project. Additional research is needed to specify more precisely the conditions of matchmaking system and the feasibility to implement it on a larger scale within the industry. Another promising line of research would be to carry out research on the possibilities to use advanced technologies (such as RFID, IoT, or machine learning) to further enhance the matchmaking system's capability.

As the term *key* as defined in this study is not dependent on one specific technology, this concept can be interpreted in a broader sense and may be even considered in the future or in other industries. To give an example, in the current case study the key is only built by one parameter-value of "unique identity". The key-concept can be expanded as a combination of multiple available elements to increase the matchmaking probability.

7 Concluding Remarks

This research proposed a matchmaking system concept as a way to improve the traceability of RTIs in the reverse logistics. This study highlights inefficiencies in the current RTI return identification process using physical SSCC labels and therefore addresses a gap in literature regarding the shortcomings of existing identification methodologies in reverse logistics. The focus on improving traceability in the return chain for RTIs fills a gap in the literature. Addressing the problem of unidentifiable return packages reduces operational inefficiencies and costs associated with misallocated deposits and unidentified returns. It streamlines the reverse logistics process, optimizing resource utilization and potentially reducing financial losses. Traceability issues concerning shop-origin identification and the methods to overcome these gaps have not yet been extensively covered in existing research. The development of matchmaking systems and the exploration of using unique tray codes as a solution for improving traceability of return packages is therefore a new contribution.

Further research is needed to determine the cost involved for sustaining a matchmaking systems. It is assumed that this is dependent on the level of systemic cooperation and collaboration between sender and receiver. Therefore further research is needed to understand and determine the reluctance of senders to go on board with a matchmaking system. More in-depth research on the impact of collaboration models and mechanisms may help to make better decisions. Understanding the dynamics, challenges, and benefits of stakeholder collaboration in RTI systems can contribute to more effective and sustainable management practices. Besides, it has been found that there is a lack of standardized metrics and evaluation frameworks for assessing the performance and impact of RTI systems. All in all, the concept of matchmaking system can help practitioners reflect on and improve their traceability systems.

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B LITERATURE OVERVIEW

This appendix provides an in-depth overview of the literature reviewed for this study. The included table presents a comprehensive summary of key literature sources, highlighting their main findings, purpose and uniqueness. The table is organized to facilitate a comparative analysis of the various works consulted during the research process. This literature table offers valuable insights into the existing body of knowledge, providing a foundation for the discussion and analysis presented in this study.

Table B.1: Literature Overview

Author	Purpose	Uniqueness	Findings
Accorsi, Baruffaldi, and Manzini [1]	fosters the adoption of reusable containers in the food industry by proposing an optimization mixed-integer linear programming model (MILP) intended to design a closed-loop packaging network	first attempt to integrate the design of closed-loop reusable containers networks under package lifespan constraints	1) it enables the pooler to estimate how the service costs might vary with the demand and when new investment on the network infrastructure is needed. 2) it reveals to other stakeholders the threshold of profitability of the pooler and encourages targeted regulation and incentives to foster the reusable packaging market share
Bortolini et al. [4]	addresses the effects of costs and emissions associated to disposable and reusable packaging containers on the supply chain network structure and management	presents a bi-objective model for the strategic design of a multi-packaging fruit and vegetable fresh food supply chain to optimise the forward and reverse logistics of fresh products including the packaging container choice within the decision boundaries; the model minimises the cost and environmental emissions through the whole supply chain network finding the Pareto frontier of the efficient network configurations	the chosen FSC network configuration almost equals reusable and disposable packaging containers (47.1% vs. 52.9%) with 45.1% CO_{2eq} emission saving and 35.8% logistic cost increase.
Casella, Bigliardi, and Bottani [8]	the goal of this paper is to increase researchers' and practitioners' knowledge on the usage of RFID technology in logistics field	an attempt to delineate the status of the research activities about RFID technology in the logistics field	In quantitative terms, the results of classification showed that RFID has mainly been used for tracking purpose (41.67% of the results) or for monitoring applications (31.23%)

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Table B.1 – continued from previous page

Author	Purpose	Uniqueness	Findings
Chung, Ma, and Chan [9]	to propose a new optimization methodology "modified Genetic Algorithm with Crossing Date heuristic" to maximize the collection of used tertiary packaging for reuse, meanwhile minimize the total operating cost by taking the advantages of simultaneous optimization of a multi-day planning	the new approach takes in the consideration of the variety in the handling ability and recyclability of DCs, and the interrelationship of demands between different planning days	the proposed new crossing date crossover operation and mutation operation contribute in improving the genetic searching ability of the GA; by the consideration of the interrelationship of demands between different planning days, the total operating cost in general is lower than planning for every individual day with a maximum reduction of about 10%
Ellsworth-Krebs et al. [11]	contribute to understanding how digital technologies, as boundary objects, could support businesse's adopting reusable packaging into their supply chains	this paper adopts a socio-material lens to understand the role Data Standards and Digital Passports can play in creating CLSCs as boundary objects that crucially creates a safe-haven for collaboration and trust in an increasingly complex, competitive and globalised world	four main business' concerns about reusable packaging and how digital traceability have the potential to partly address these concerns: 1) determining affordability through measuring return and failure rates of products; 2) meeting health and safety standards through batch coding and evidencing cleaning checks; 3) addressing reputational concerns through clear documentation on the environmental breakeven point; 4)and supporting waste taxation that could make reuse competitive by incentivising reuse rather than charging for weight of packaging put onto the market
Ertz et al. [12]	to identify the mechanism that underlies the consumption of reusable containers	insight into how different intra-psychic variables simultaneously affect the consumption of reusable containers and whether their effects differ across cultures	the present study confirms TPB as an appropriate framework for representing consumers'reusable containers consumption
Gardas, Raut, and Narkhede [14]	to identify critical success factors (CSFs) of the reusable plastic packaging system and to establish their interrelationship in the context of manufacturing industries	a structural model of all the fourteen CSFs was formulated by using the ISM and TISM methodology	fourteen CSFs to help promote reusale plastic packaging system and achieve sustainability were determined through expert inputs and from literature survey. 'top management commitment', 'lean support', and 'optimized inventory management' were the CSFs with high influential power

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Author	Purpose	Uniqueness	Findings
Glock [15]	to review works that propose decision support models for an efficient management of RTI closed-loop supply chains and to provide suggestions for future research opportunities	a summary of the scientific state-of-the-art and identification of several promising research opportunities	further research on managing RTI closed-loop supply chains that use rented or leased RTI is necessary; the role service providers play in shipping loaded and collecting empty RTIs needs to be studied in greater detail; developing further decision support models that consider alternative design options for an RTI deposit system seems to be promising; the design of RITs (selection of materials and sizing) has not attracted much attention so far
Hellström and Johansson [17]	explore the impact of different control strategies on the management of RTI systems in a combined case and simulation study	the focus is on investments and operational costs from an RTI owner	the choice of control strategy has a significant impact on investments and operating costs and on the management of a RTI system; transfer systems where the tracking system has inadequate data capture, data-analysing and reporting capabilities, provide limited control thereby resulting in potentially high shrinkage. However, having a tracking system with decision-support features does not necessarily guarantee that firms are able to use increased information, or to use it efficiently
Ilie-Zudor et al. [20]	contains an overview of unique identification issues and of the various radio frequency identification techniques that are available now or will become available in the short term	presents a framework for choosing an auto-ID technique in a supply chain	shows application possibilities and gives examples of current implementations; each application has its own requirements that translate into specific RFID-techniques, -options and -parameters
Kim and Glock [22]	to propose a method for managing and evaluating the use of RFID in the tracking of reusable containers; to study the effect of RFID-tagged containers on the supply chain, and to study how RFID-tagged containers diffuse in the system if RFID-tagged containers are introduced as substitue purchases in an existing system that used non-tagged containers at the outset	two models are developed, one for the case where RFID is used to track containers, and one where RFID is not used, and the performance of both systems are compared; only a single supplier and a single vendor is considered	the results of the paper illustrate that the use of RFID-tagged containers can be justified despite their higher purchase cost if they improve the predictability of container flows and induce buyers to return a higher fraction of containers

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Author	Purpose	Uniqueness	Findings
Kroon and Vrijens [24]	this article considers a practical application of reverse logistics: the reuse of secondary packaging material	a case study involving the design of such a return logistic system in The Netherlands and outlines a quantitative model that can be used to support the related planning process	the advantage of the system of returnable containers for the logistics service organization are obvious; if the distribution and the collection fees are sufficiently high, then this organization makes a profit on each container distributed or collected
Kuo et al. [25]	to answer the questions "how will be the reuse and recycling of packaging implemented in manufacturing under the context of a global supply chain?" and "how will such a packaging logistics system perform economically?"	the paper presents a case of LCD (liquid-crystal display) panel manufacturing to illustrate the economic practicability of a packaging recycling logistics system in combination with a reusable package design under the context of global manufacturing	the total cost of the green logistics mode is beneficial, always lower than that of the traditional logistics mode, even at a low recycling rate (30%)
Mahmoudi and Parviziomran [27]	To review the extant literature in light of 1) the environmental and economic costs of reusable packaging, 2) the design of reusable packaging logistics systems, and 3) the implications of operations management for reusable packaging.	The paper is among the first studies reviewing the operations of reusable packaging systems; The paper addresses the questions 1) "Is reusable packaging environmentally and economically feasible?", 2) "If so, what is the proper design for their logistics system?", 3) "What are the implications of operations management for reusable packages?"	Works that provide information for decision making to shift from single-use to reusable packaging systems are differentiated into three categories: those studying 1) the feasibility/viability of reusable packaging systems in terms of environmental and economic factors, 2) various designs of a logistics system using reusable packages, and 3) operations management of reusables.
Mason, Shaw, and Al-Shamma'A [28]	To reduce RTI shrinkage within the context of the packaged gas industry with an effective method for managing inventory	This paper takes a design science approach to the inventory management problem faced in the packaged gas industry and develops an artifact in the form of an advanced peer-to-peer RFID technology	The paper communicates empirical evidence to suggest that the developed artifact would be suitable in the target environment;

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Table B.1 – continued from previous page

Author	Purpose	Uniqueness	Findings
Neal et al. [29]	to look at the intelligent RTI concept for component traceability within the automotive domain and to present a hardware and software platform, known as smaRTI (smart Returnable Transit Item) that provides a foundation for intelligent container research, development and implementation	this research has implemented a proof of concept device for creating intelligent RTIs that have the ability to interact with intelligent components, its environment and an intelligent manufacturing system within the harsh automotive manufacturing domain	
Rogers and Tibben-Lembke [33]	to know more about the size and scope of reverse logistics activities	The paper discussed the definition of reverse logistics and presented an overview of the current state and estimated the size of reverse logistics activities	This research found many examples of large bottom-line impact; Good reverse logistics management not only results in reduced costs, but it can also increase revenues; In some cases, reverse logistics can even be strategic
Rogers and Tibben-Lembke [32] [book]	to present an overview and introduction to reverse logistics, and to provide insights on how to manage reverse logistics well	defines the state of the art in reverse logistics and to determine trends and best reverse logistics practices	
Silva et al. [35]	to present a case study on reverse flow of returnable packaging to replace a disposable packaging system used by a company located in Joinville, Brazil to export machined engine heads to Petersborough, UK	Attempt to standardize a returnable packaging model to replace the disposable packaging	The practice of reverse logistics concerning the use of returnable packaging can bring important results for the logistic process in terms of technical, economic, and environmental benefits

C

RAW DATA TABLES ILLUSTRATING THE DEPOSIT PROBLEM

This appendix presents detailed raw data tables that serve to illustrate and substantiate the practice problem outlined in Chapter 1 of this study. In Chapter 1 the practice problem found in the case study of Euro Pool System is described. The practice problem is expressed as the number of missing Serial Shipment Container Codes (SSCCs) upon return and explained by two examples, Delhaize and Jumbo. A summary of the quantities was given in the main text. Table C.1 and C.2 present the raw data on which Table 1.1 is based. Table C.1 shows per month (column 1) the total number of SSCC sent to EPS (second column), the number of return packages without SSCC-label (third column), the percentage coverage (fourth column) and the estimated correesponding deposit amount (fifth column) for the retailer *Delhaize*.

Month	**Qty of identified SSCC**	**Qty of unidentifiable SSCC**	**Percentage of unidentifiable SSCC**	**Amount of deposit (€)**
February 2022	65,565	6,459	9.9%	€5,516,723.86
March 2022	122,790	11,604	9.5%	€5,292,157.34
April 2022	117,888	15,773	13.4%	€7,492,603.15
May 2022	125,171	30,268	24.2%	€13,541,539.17
June 2022	129,480	22,558	17.4%	€9,756,317.58
July 2022	117,423	18,139	15.4%	€8,650,639.14
August 2022	123,618	25,799	20.9%	€11,687,165.30
September 2022	119,515	25,388	21.2%	€11,895,812.24
October 2022	122,568	21,883	17.9%	€9,998,107.17
November 2022	123,109	18,738	15.2%	€8,523,568.54
December 2022	134,170	19,788	14.7%	€8,259,133.93
January 2023	125,916	17,805	14.1%	€7,918,612.41
February 2023	38,359	5,137	13.4%	€7,499,465.58
Total	1,465,572	239,339	16.3%	€116,031,845.42

Table C.1: Deposit problem Delhaize

Table C.2 shows per month (column 1) the total number of SSCC sent to EPS (second column), the number of return packages without SSCC-label (third column), the percentage coverage (fourth column) and the estimated correesponding deposit amount (fifth column) for the retailer *Jumbo*.

Month	**Qty of identified SSCC**	**Qty of unidentifiable SSCC**	**Percentage of unidentifiable SSCC**	**Amount of deposit (€)**
May 2022	695	unavailable	unavailable	unavailable
June 2022	54,768	210	0.4%	€20,917.00
July 2022	57,956	4,168	7.2%	€392,322.56
August 2022	56,790	1,923	3.4%	€184,723.18
September 2022	53,768	1,823	3.4%	184,959.55
October 2022	57,261	1,598	2.8%	€152,241.07
November 2022	53,834	1,237	2.3%	€125,350.77
December 2022	59,152	1,117	1.9%	€103,014.35
January 2023	56,660	977	1.7%	€94,065.85
February 2023	15,851	266	1.7%	€91,545.91
Total	466,735	13,319	2.9%	€155,673.59

Table C.2: Deposit problem Jumbo

D

SOLUTION SPACE WITH ALMOST ZERO MISMATCH

This appendix provides more in depth insight into the solution space of matchmaking systems using tray unique codes (Global Returnable Asset Identifier (GRAI)). In chapter 6 a simulation was performed to test different scenarios and validate the matchmaking system. Each combination of parameter-values has a different probability of immediate matchmaking. The parameter-value combinations that have a immediate matchmaking probability of 0.999 or higher were highlighted in green (Figure E.1). Figure E.1 illustrates the solution space that is interesting for further research, even though it cannot ensure a mismatch of zero.

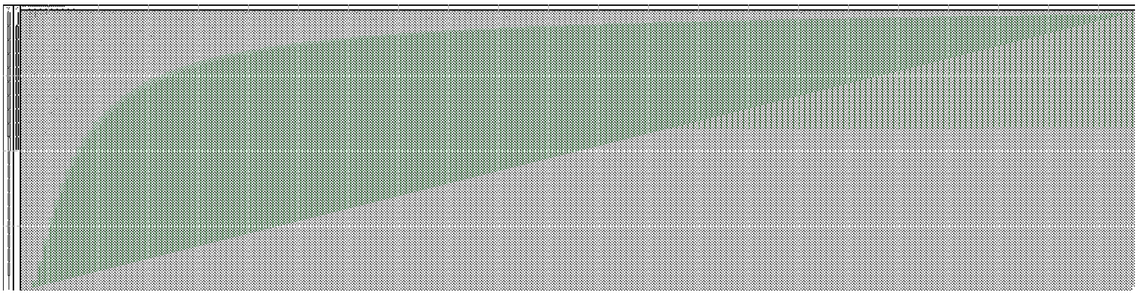


Figure D.1: The green area shows the data capture combinations that has the interesting probability of matchmaking higher than 0.999 and below 1.0. Each row denotes a percentage of GRAI capture per return package by the sender. Each column denotes a percentage of GRAI capture per return package by the receiver.

E

IMPACT ANALYSIS OF NON-ZERO DEFECT MATCHMAKING

This appendix presents an impact analysis to provide insight into the effect and implications resulting from not having a Δ of zero. The analysis incorporates a quantitative assessment to gauge the potential impact on the key performance indicator (KPI) resource utilization. Figure E.1 gives an indication of the consequences of allowing mismatches to occur in a given scenario for one year. The computation is based on the need for back-end office to help allocate a return package to a sender if the proposed matchmaking does not work. The assumption is made that it takes 2 minutes to handle this situation for an EPS employee. An editable excel-model is made available to provide deeper insights.

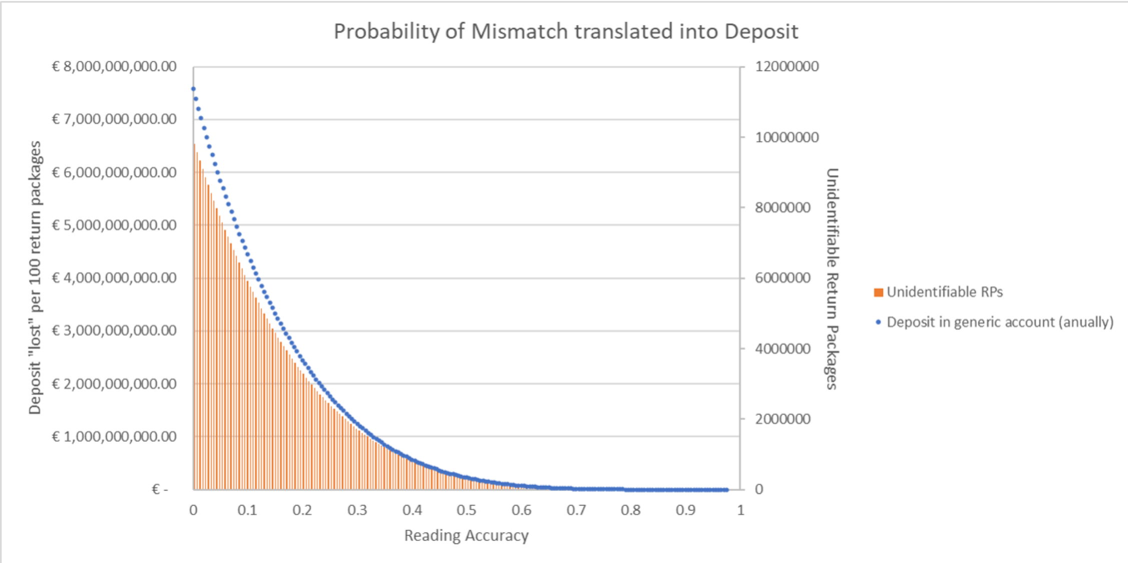


Figure E.1: A brief impact analysis. The graph is based on 9818830 return packages, 200 trays per return package, 5 tray codes as key by sender, and a time of 2 minutes needed for back-end office to solve a mismatch

F

EPS GENERAL INFORMATION

This appendix supplements the main body of the research by offering comprehensive details regarding the case study company, Euro Pool System (EPS). The inclusion of this information serves to provide readers with a foundational understanding of the organization that was pivotal in conducting the study detailed in this research. The data presented in this appendix encompasses a range of general information about EPS, including but not limited to its history, industry sector, geographical scope, organizational structure, key stakeholders, and any relevant contextual details that contributed to the setting of the study. This information has been instrumental in shaping the research methodology, guiding the analysis, and contextualizing the findings within the operational framework of the case study company.

INDUSTRY SECTOR To solve the logistical deadlock caused by inefficient packing of fresh products, Euro Pool System (EPS) is established through the collaboration of three packaging pools that were part of the cooperative auction houses in the Netherlands, Belgium and Germany in 1992. Now, thirty years later, Euro Pool System (EPS) has become the leading logistical partner for European retailers in the area of reusable packaging. EPS manages over 250 million reusable trays, making it one of the largest pool in the world. These trays are used throughout Europe's retail supply chains, from growers (fillers) and food processors (traders) to retailer's distribution centres and finally to retailer's stores. Once the trays have been used, they are returned to the retailer's distribution centre, collected, and transported to an EPS depot, where they are cleaned and restocked for the next use cycle.

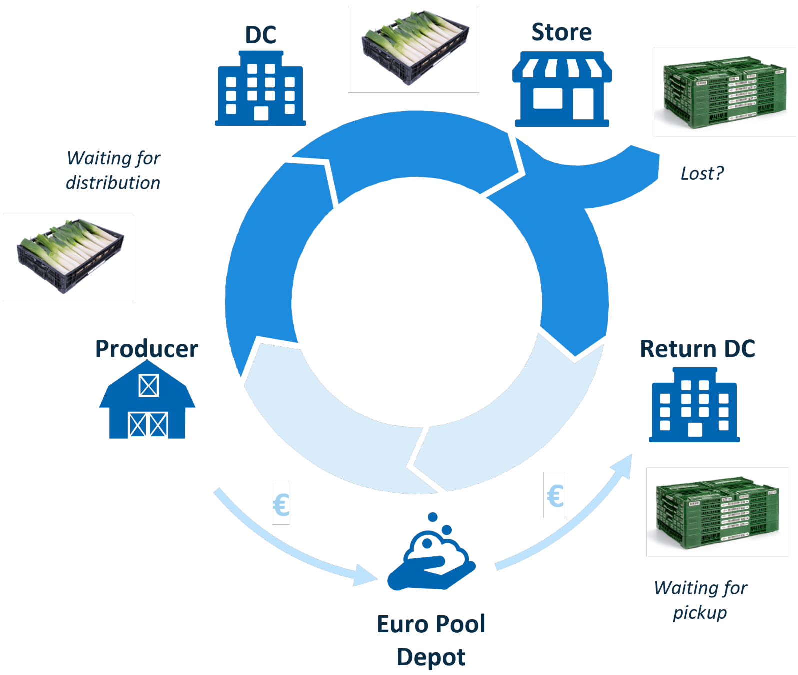


Figure F.1: EPS' Business Model

BUSINESS MODEL The business model of EPS is based on the rotation speed of their trays (Fig. F.1). The incentive for continually improving the rotation speed is deposit. A large part of EPS' working capital is namely covered by the producers and retailers who are having the trays. With a pool size of 250 million trays, EPS has a working capital of €965 million. Maintaining a high rotation speed is important to EPS. For the customer this is also of importance, as the trays consume the customer's working capital. In addition to the retailer's obligation to pay a deposit, an uncontrolled system is subject to losses and theft.

During the whole use cycle, EPS remains the owner of the trays. In addition, EPS is the controller of the depots, which are used for collecting, washing and storing the trays. EPS is also responsible for the distribution of trays to the fillers, the cleaning and the maintenance of the trays. For every tray that is used, a deposit is paid. The sender debits his recipients for this deposit, who does the same with his recipients, and so forth. Ultimately, the tray reaches back at one of EPS' depot, and EPS refunds the deposit to the retailer from which the tray was collected.

Figure F.2: Map of EPS' local offices and depots

GEOGRAPHICAL SCOPE The geographical map (Figure F.2) illustrates the expansive reach of EPS's operations. The map provides a visual overview of the regions covered by the company's services or activities. It encompasses various locations, including depots and local offices that manage key operational areas across different countries. The highlighted areas denote the primary geographical reach of our company's operations, showcasing the breadth and diversity of our presence in serving our customers or stakeholders across these regions. This map serves as a valuable reference to understand the extensive footprint and geographic coverage of the company's endeavors.

ORGANIZATIONAL STRUCTURE The organizational chart (Figure F.3) represents the hierarchical structure and reporting relationships within the company. The organizational chart outlines the reporting relationships, divisions, and key roles within the company. This visual representation provides insights into the chain of command, departmental hierarchies, and the distribution of responsibilities across different levels of the organization.

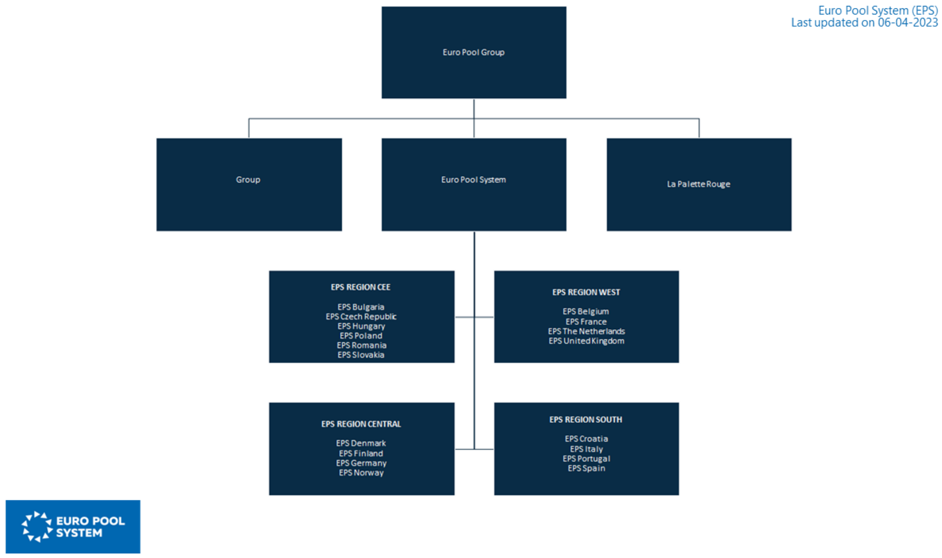


Figure F.3: EPS Organizational Chart

Figure F.4: Return Pallet

EPS TRAY TYPES In 1998 the first standard tray is launched and in 2005 the first green folding tray was introduced. Currently, EPS' green folding trays are the standard in the European fresh supply chain. They are strong and have a simple fold and unfold mechanism and can be handled by automated systems with ease. The reusable green folding trays are available in nine types, based on the size when unfolded. When folded, each tray type has either a half standard crate format (40x30x3cm), a standard crate format (40x60x3cm) or a double standard crate format

(40x60x6cm) enabling the trays to be stackable on top of each other (Figure F.5). A standard crate format of 40x60x3cm is called 1 Standard Equivalent Unit (SEU) Because of this modularity, the collection process can be simplified by maintaining a return standard (per customer). The return standard is based on a fixed amount layers of folded (green) EPS standard crates. For example, a EUR-pallet (800x1200cm (lxb)) with 60 layers of green EPS standard crates always have a control value of 240 Standard Equivalent Unit (SEU) independent from the sorting type.

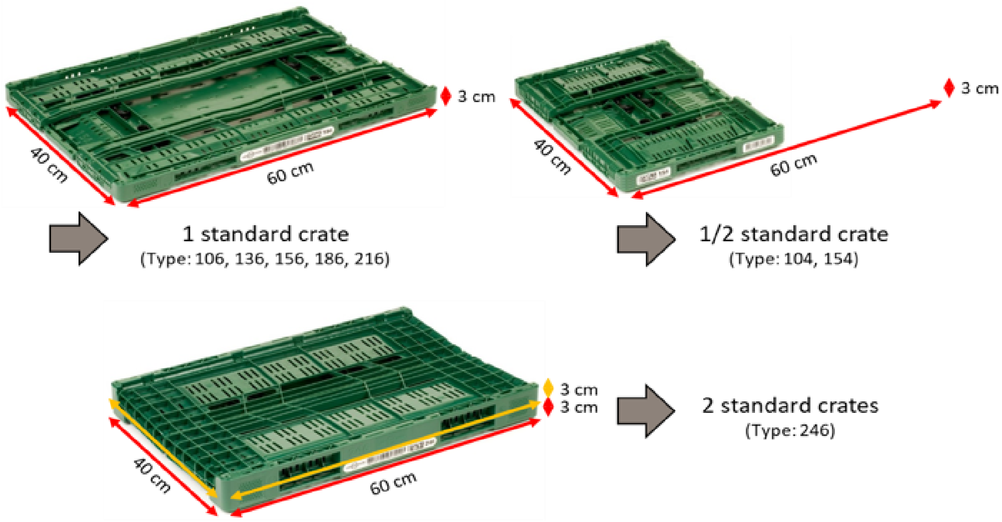
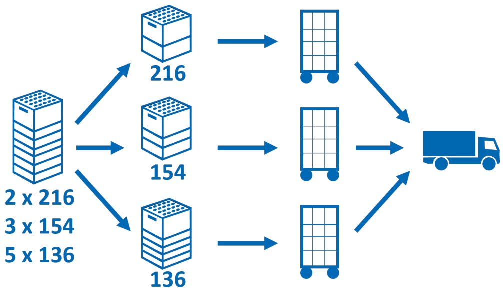
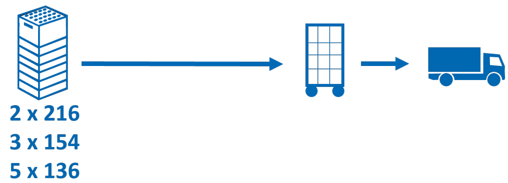


Figure F.5: standardized crate calculation

CONSTRUCTION RETURN PACKAGE Historically retailers sorted out trays in their Distribution Centre (DC) before returning them to EPS. It was needed that the trays were stacked based on their crate type (Figure F.6a) . However since 2016, EPS enabled the possibility for the retailers to stack and return trays mixed without sorting (see Fig. F.6b). The main advantage of this is that it has accelerated the return rate of trays. However the enabling of the option to return trays mixed also lead to a new challenge for EPS: In order to pay out the correct deposit, there is a need to recognize mixed EPS trays in the return chain. The recognizing of a load-carrier with unsorted trays can be divided into two processes, the counting of trays based on type and the identification of shop origin, which can also be named as "shop allocation".



(a) Sorted Return



(b) Full Mixed Return

Figure F.6: An illustration of the previous (sorted) and current (mixed) way of return

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