

Optimizing Logistics Processes to Minimize Losses at Local Distribution Center

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Master's Thesis
2025



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Univerzita Tomáše Bati ve Zlíně
Fakulta managementu a ekonomiky
Ústav průmyslového inženýrství a informačních systémů

Akademický rok: 2024/2025

ZADÁNÍ DIPLOMOVÉ PRÁCE

(projektu, uměleckého díla, uměleckého výkonu)

Jméno a příjmení: Bc. Ghaith Ashqar
Osobní číslo: M230025
Studijní program: N0488P050002 Průmyslové inženýrství
Forma studia: Kombinovaná
Téma práce: Optimalizace logistických procesů pro minimalizaci ztrát v místním distribučním centru

Zásady pro vypracování

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I. Teoretická část

- Definujte komplexní přehled teoretických základů v oblasti štihlého řízení, logistiky a řízení výroby.

II. Praktická část

- Provedte analýzu současného stavu vybraných logistických procesů ve vybraném distribučním centru.
- Na základě výsledků analýzy vypracujte návrh na zefektivnění vybraných distribučních tras.
- Zhodnotte navrhované řešení.

Závěr

Rozsah diplomové práce: **cca 70 stran**
Forma zpracování diplomové práce: **tištěná/elektronická**
Jazyk zpracování: **Angličtina**

Seznam doporučené literatury:

BUTTKUS, Michael a EBERENZ, Ralf. *Performance Management in Retail and the Consumer Goods Industry: Best Practices and Case Studies*. Cham: Springer Nature Switzerland, 2019. ISBN 978-3-030-12729-9.
CARVALHO, Jose Dinis; GUIMARAES, Levi; SOUSA, Rui a LEAO, Celina. *Waste Identification Diagram and Value Stream Mapping*. Bingley: Emerald Group Publishing Limited, 2019. ISSN 2040-4166.
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Datum zadání diplomové práce: **10. února 2025**
Termín odevzdání diplomové práce: **25. dubna 2025**

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ABSTRAKT

Tato diplomová práce se zaměřuje na optimalizaci procesů doplňování přepravek v oddělení vychystávání vybraného distribučního centra. Hlavním výzkumným cílem je dosáhnout alespoň 10% snížení ztrát času na pracovní směnu prostřednictvím zlepšení procesů. Studie využívá metodiku štíhlé výroby a techniky průmyslového inženýrství. Praktická část provádí podrobnou analýzu vychystávacích operací, se zvláštním důrazem na proces doplňování přepravek. K analýze byly použity nástroje průmyslového inženýrství, včetně diagramů spaghetti, Ishikawovy analýzy a snímkové analýzy pracovního dne. Na základě těchto zjištění práce navrhuje dvě odlišné strategie zlepšení pomocí JIT. Obě řešení vykazují silnou shodu s principy štíhlé výroby a dosahují významného snížení času až o 63,1 %. Výsledky potvrzují účinnost automatizace a optimalizace procesů.

Klíčová slova: Logistika, Štíhlá výroba, Optimalizace procesů, Plýtvání

ABSTRACT

This master's thesis investigates the optimization of tote replenishment processes within the picking department of a selected distribution center. The primary research objective is to achieve a minimum 10% reduction in time losses per working shift through process improvement. The study employs Lean methodology and Industrial engineering techniques. The practical part conducts a comprehensive analysis of picking operations, with particular emphasis on the tote replenishment process. Utilizing industrial engineering tools including spaghetti diagrams, Ishikawa analysis, and workday analysis. Building on these findings, the thesis proposes two distinct improvement strategies using JIT. Both solutions demonstrate strong alignment with Lean manufacturing concepts, achieving significant reductions in time up to 63.1%. The results validate the effectiveness of automation and process optimization.

Keywords: Logistics, Lean Manufacturing, Process Optimization, Waste

First and foremost, I would like to express my deepest gratitude to my wife MUDr. Mona Abughali for her unwavering support, patience, and encouragement throughout this journey. Her understanding and belief in me have been invaluable, especially during the most demanding phases of this work.

I would also like to thank my family, whose continuous love, and motivation have been a foundation of strength for me. Their belief in the importance of education and personal growth has inspired me every step of the way.

My sincere thanks go to my academic supervisor, Ing. Lucie Macurová, PhD, for her insightful guidance, constructive feedback, and support.

I am also grateful to area manager and the team at selected company for granting me the opportunity to conduct my research within the organization. Their openness, collaboration, and professional insights greatly enriched this work.

To all who have supported me in this endeavor—thank you.

„ Begin with the end in mind. “
Stephen Covey

I declare that the submitted version of the thesis and the electronic version uploaded to IS/STAG are identical.

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INTRODUCTION

In today's rapidly evolving global market, logistics and supply chain management play a pivotal role in ensuring business competitiveness. Efficient logistics processes contribute significantly to reducing operational costs, optimizing resource utilization, and eliminating waste in warehouses and distribution centers. The selected distribution center under study faces a challenge of time and cost losses especially at the picking department.

The study focuses on a highly automated distribution center with robotic warehouses and advanced inventory management systems. However, the manual tote replenishment process remains a bottleneck.

The challenge addressed by this thesis is the manual replenishment of totes in a selected distribution center, which involves transporting storage containers or totes to picking stations. This labour-intensive process is prone to errors and inefficiencies, leading to time and cost losses.

This master's thesis is centered on optimizing the current manual tote replenishment process within the picking department of a selected distribution center. The primary objective is to reduce inefficiencies in the replenishment process, aiming for at least a 10% decrease in wasted time during one working shift. Additionally, secondary goals include a 10% reduction in annual costs and a minimum 20% reduction in wasted transportation during one working shift. The research hypotheses are that implementing process optimization techniques will result in a measurable reduction in tote replenishment time and costs, and the introduction of automation in tote replenishment will lead to a significant improvement in warehouse efficiency and worker productivity. This thesis aims to provide both theoretical and practical contributions.

The theoretical part covers a research in logistics, supply chain management, lean manufacturing principles, and industrial engineering. The practical part initially focuses on the use of analytical tools, such as spaghetti diagrams and process mapping, to analyze the current tote replenishment process in the picking department of the distribution center. The subject of the analysis is the collection of hard data, including time studies and cost evaluations, to identify specific inefficiencies, such as unnecessary transportation and wasted time, which negatively impact the replenishment process. Following the identification of these inefficiencies, potential solutions, such as the implementation of an automated conveyance system and buffer capacity adjustments, are proposed to address the

identified issues. The subsequent section provides a detailed definition of the proposed solutions, including a risk analysis using the RIPRAN method to map potential threats that could hinder the project's success.

The effectiveness of the automated conveyance system and buffer capacity adjustments are evaluated at the end of the thesis.

OBJECTIVES AND METHODS OF THESIS DEVELOPMENT

The primary objective of this master's thesis is to reduce tote replenishment time by at least 10%, with implementation targeted for completion by the end of 2026. The secondary goals of this research include achieving a 10% reduction in associated costs and minimizing unnecessary transportation by at least 20%.

The practical section of this thesis begins with a thorough analysis of the current tote replenishment process, including an evaluation of bottlenecks and waste areas. The subsequent proposal and implementation phases rely on a combination of industrial engineering methods and lean logistics principles. The methodology is grounded in a literature review of supply chain management and process optimization techniques, with a strong emphasis on lean manufacturing tools. The key methods applied in the practical part of this thesis include:

- **Data Collection**

Internal data from the distribution center's system was gathered to obtain insights into tote flows, operational cycles, and reported inefficiencies.

- **Interviews and Observations**

Discussions with area managers and warehouse employees, including tote runners and pickers, were conducted to supplement data collection with qualitative insights. This method helped capture unstructured issues that might not be reflected in system-reported data.

- **Spaghetti Diagram**

This tool was used to track the movement of tote runners and visualize unnecessary transportation within the replenishment cycle. This helped highlight areas for potential layout optimization.

- **Group Brainstorming Sessions**

Collaborative workshops with warehouse staff were held to generate improvement ideas through structured brainstorming, ensuring that solutions align with practical workflow constraints.

- **Workday Analysis**

The workday analysis in the thesis examines the distribution of time between value-adding and non-value-adding activities during the tote replenishment process.

- **Ishikawa diagram**

In this thesis, the Ishikawa diagram is utilized to systematically analyze the root cause of inefficiencies within the studied system, by categorizing factors affecting process performance such as workforce, methods, materials, and environment, it provides a structured approach to identifying key problem areas and potential solutions. This visualization aids in targeted improvement strategies, ensuring a data-driven approach to process optimization.

- **TOC**

The Theory of Constraints is applied in the thesis to identify critical bottlenecks that limit overall system performance. By focusing on the weakest link in the process, the study emphasizes how optimizing constraints can lead to significant improvements in efficiency and productivity. The application of TOC allows for a strategic approach to continuous improvement, ensuring that resources are allocated effectively to maximize output.

- **Process Map**

The thesis incorporates process mapping as a fundamental tool to visualize workflow sequences and interactions between different operational stages. This technique is used to identify redundancies, inefficiencies, and potential areas for streamlining. By clearly outlining the process structure, process mapping aids in enhancing coordination and reducing delays in the system.

- **Process Analysis**

The analysis is used in the thesis to break down and understand each step of the current workflow. This helps identify where things might be inefficient or unclear, providing a foundation for improvement.

- **Waste Mapping**

Highlights areas where each waste is evaluated in the process. It shows non-value-adding activities with level of waste impact, helping to pinpoint where changes can make the process more efficient.

- **JIT**

The Just-in-Time methodology is discussed in the thesis as a means to enhance efficiency by reducing wasted time, unnecessary transportation and ensuring materials are available precisely when needed. Its implementation within the studied system contributes to cost savings, minimizes waste, and ensures smoother operations by aligning supply with actual demand. The study highlights JIT as a crucial strategy for achieving lean operations.

I THEORETICAL PART

1 LOGISTICS AND SUPPLY CHAIN MANAGEMENT

According to Christopher (2016), Logistics is the process of strategically managing the procurement, movement, and storage of materials, parts, and finished inventory (and the related information flows) through the organization and its marketing channels so that current and future profitability are maximized through the cost-effective fulfilment of orders.

Christopher (2016) defines supply chain management as managing upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the Supply Chain. Logistics and supply chain management can provide many ways to increase efficiency and productivity, which can, in turn, significantly reduce unit costs.

1.1 Warehouses and Distribution Centers

Hamberg and Verriet (2012) cited Ansems RPWM (2008) and defined a warehouse, or a distribution center, as a facility that stores products from many different suppliers for further distribution to their customers (See Figure 1). Generally, five main processes can be identified in a warehouse: receiving, storage, picking, consolidation, and shipping.

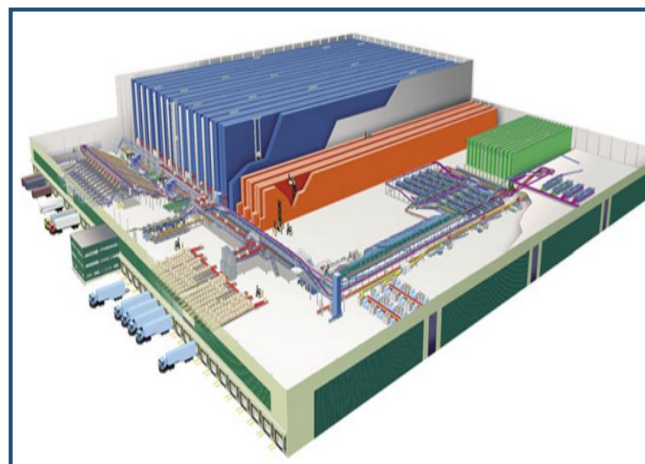


Figure 1 Schematic overview of a retail
(Source: Hamberg and Verriet, 2012)

According to Hamberg and Verriet (2012), they clarified the main five processes as follows:

1. The **receiving** process involves the arrival of products from a supplier and may include a preparation of storage by repacking of the products into special storage containers, e.g. product totes.



Figure 2 Warehouse receiving process area
(Source: Hamberg and Verriet, 2012)

2. The **storage** process is responsible for placing received products into storage areas; there the products remain until they are needed.



Figure 3 Warehouse storage process area
(Source: Hamberg and Verriet, 2012)

3. The **picking** process is triggered by the reception of customer orders. It involves the retrieval of products from storage and placing them in special order containers, e.g. order totes.



Figure 4 Warehouse picking process area
(Source: Hamberg and Verriet, 2012)

4. The **consolidation** process involves collecting order containers and combining them into shipping containers, such as pallets.



Figure 5 Warehouse consolidation process area
(Source: Hamberg and Verriet, 2012)

5. The **shipping** process takes care of the shipment of the combined order containers to the customers. The areas implementing these warehouse processes are connected by a transportation system, e.g. a conveyor system.



Figure 6 Warehouse shipping process area
(Source: Hamberg and Verriet, 2012)

The Figure 7 simplify the sequential flow of goods, beginning with the Manufacturer, where products are initially produced. These goods are then transferred to the Warehouse/Distribution center, which serves as a central hub for inventory management and storage. Subsequently, the process advances to the packed orders stage, where items are prepared and packaged for dispatch. Finally, the workflow concludes with shipment, where the orders are transported to their respective destinations. This visual representation encapsulates the essential components of a supply chain, emphasizing the production, storage, and distribution activities.

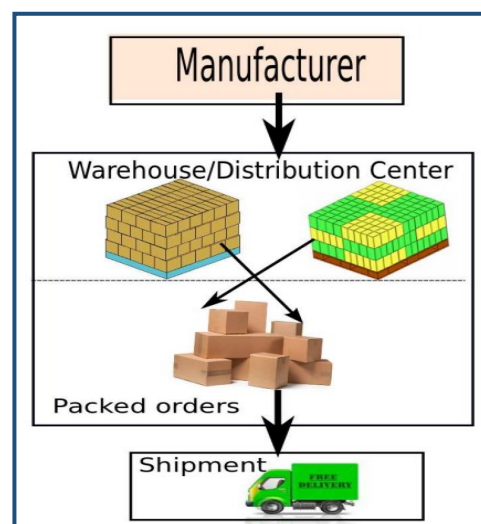


Figure 7 Flow of products from manufacturing to consumers through the distribution center
(Source: Poudel, 2017)

1.1.1 Robotic Warehouse

Li and Liu (2016) according to World Vision (2014) clarified that, In the operation procedure of a distribution center, picking is considered the primary area for improving warehousing efficiency. This is because it consumes significant resources, accounting for fifty percent of the overall operating costs of a distribution center. As one of the largest multinational e-commerce companies, Amazon has developed a new logistics model known as "shelf to the people" by utilizing the Kiva robotic system (See Figure 8). With the help of these robot, the overall efficiency of picking system would improve by 3.5 times to 5 times.



Figure 8 Kiva robots equipped with cameras
(Source: Li and Liu, 2016)

Amazon employees just standing in a fixed point to complete the whole work, that is to say, the timing cost of pickers spent walking could be reduced close to zero in Kiva system. Kiva robotic system could not only reducing unnecessary labour costs, but its thin fuselage and highly efficient route planning also increase the storage space by reducing the passage area to improve throughput of the overall system. Thus, the emergence of Kiva robots better meets the needs of E-company to efficiently handle a large number of diversified orders effectively (Li and Liu, 2016) according to Journal of Robot Technique and Application (2015).

Kiva robot could carry a ton of items in spite of its small size. When order signal is received, the robot is sent to ship the mobile rack with required items to the picking zone (Li and Liu, 2016) according to Zhang (2015). These robots could even find their charging stations to replenish their energy when they are about to run out of energy.

These robots could work in an orderly manner without collision, mainly due to the manipulation of the software (Li and Liu, 2016) according to Journal of Robot Technique and Application (2015).



Figure 9 Navigation System of Amazon
(Source: Li and Liu, 2016)

As shown in Figure 10, Li and Liu (2016) clarified the four steps of Kiva robot to complete the order task:

Step 1: Kiva robots receive orders and navigate to the designated mobile rack.

Step 2: The robots transport the selected mobile rack from its original location to a designated queue, preparing it for order fulfilment.

Step 3: Pickers retrieve items from the rack, package them, and perform a final quality check to fulfill the order.

Step 4: Once the picking process is complete, Kiva robots return the mobile rack to a new storage location.

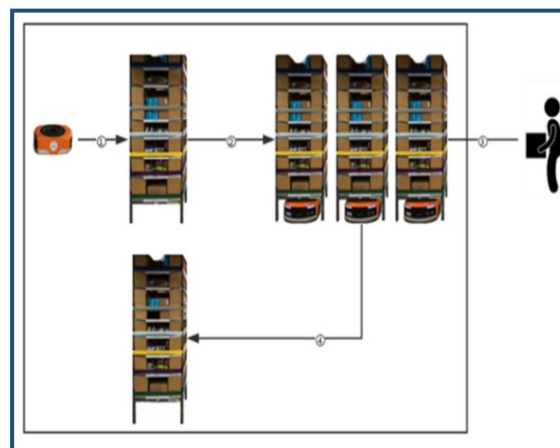


Figure 10 Four steps of Kiva robot complete the order task
(Source: Li and Liu, 2016)

1.2 Production Logistics

It is important to differentiate between Production Management from Production Logistics, where production management is defined according to Tomek and Várová (2007) as the primary goal of production management is to define and specify the main objectives of the entire manufacturing process while ensuring its optimal operation. This is often achieved through activities focused on production planning and day-to-day operational management. Key aspects of production planning include decisions regarding production capacity, workplace layout, and investments in manufacturing units. Operational management is reflected in regular operational meetings, where the coordination of personnel and machinery takes place.

According to Nyhuis and Wiendahl (2009) the primary objective of production logistics is to enhance delivery capability and reliability while minimizing logistic and production costs. Once the desired delivery capability is achievable through the established structures, it becomes the responsibility of process controls to optimize inventory management and operational control of the logistic potential, thereby improving the reliability of logistic processes. Delivery capability, as a logistic factor, indicates how well a company can commit to customers' preferred delivery dates, considering the production situation.

Delivery reliability measures the extent to which promised delivery dates for orders are met. Alongside competitive production costs, delivery capability and reliability are crucial for a company's long-term market success. (Nyhuis and Wiendahl, 2009)

1.2.1 Performance Management Logistics and KPI Set

Buttkus and Eberenzd (2019) explained developing a Key Performance Indicator (KPI) set presents the challenge of narrowing the focus to performance indicators that are truly relevant to a company's specific business model. This requires not only an understanding of the key success factors and the core business processes but also a well-defined and coordinated approach to the purpose, application, and definition of key performance indicators. To achieve this, it is essential to establish clear criteria that differentiate general performance indicators from the truly "key" performance indicators. At Penny International, KPIs represent critical parameters for assessing both strategic and operational success. These indicators may be standalone metrics or measurable at the level of individual employees. For a KPI to be effective, it should meet the following criteria:

- It must drive decision-making processes in response to deviations.
- It should be directly relevant to performance management, meaning it includes at least a target or budget value.
- It must be measurable while maintaining a reasonable cost-benefit ratio.
- It should be influenceable and manageable by the relevant individuals or teams.

Based on this understanding, a three-tiered KPI hierarchy clarified in Figure 11 was developed to provide a structured approach (Buttkus and Eberenzd, 2019):

1. Top KPI Level: This level includes three to five core indicators that guide PENNY International's financial performance management, aligned with the REWE Group's overall requirements.
2. KPI Level: These indicators encompass both financial and non-financial parameters essential for operationalizing the Top KPIs and evaluating the company's overall performance.
3. Functional KPI Level: The third level consists of detailed operational parameters and financial specifics per function, derived from core business processes.

Both the Top KPIs (Level 1) and general KPIs (Level 2) are mandatory for all performance reviews conducted between the holding company and foreign subsidiaries. They serve as the foundation for regular reporting, often presented in management summaries or KPI overviews. While Functional KPIs (Level 3) contribute to overarching Top KPIs and general KPIs, they are primarily used to manage specific operational functions within the organization. These indicators are typically reviewed within functional performance assessments and only referenced in broader performance reviews when they influence major deviations in higher-level performance indicators. In reporting, Level 3 KPIs are included in the functional sections of management reports, ensuring a structured and comprehensive approach to performance evaluation. (Buttkus and Eberenzd, 2019)

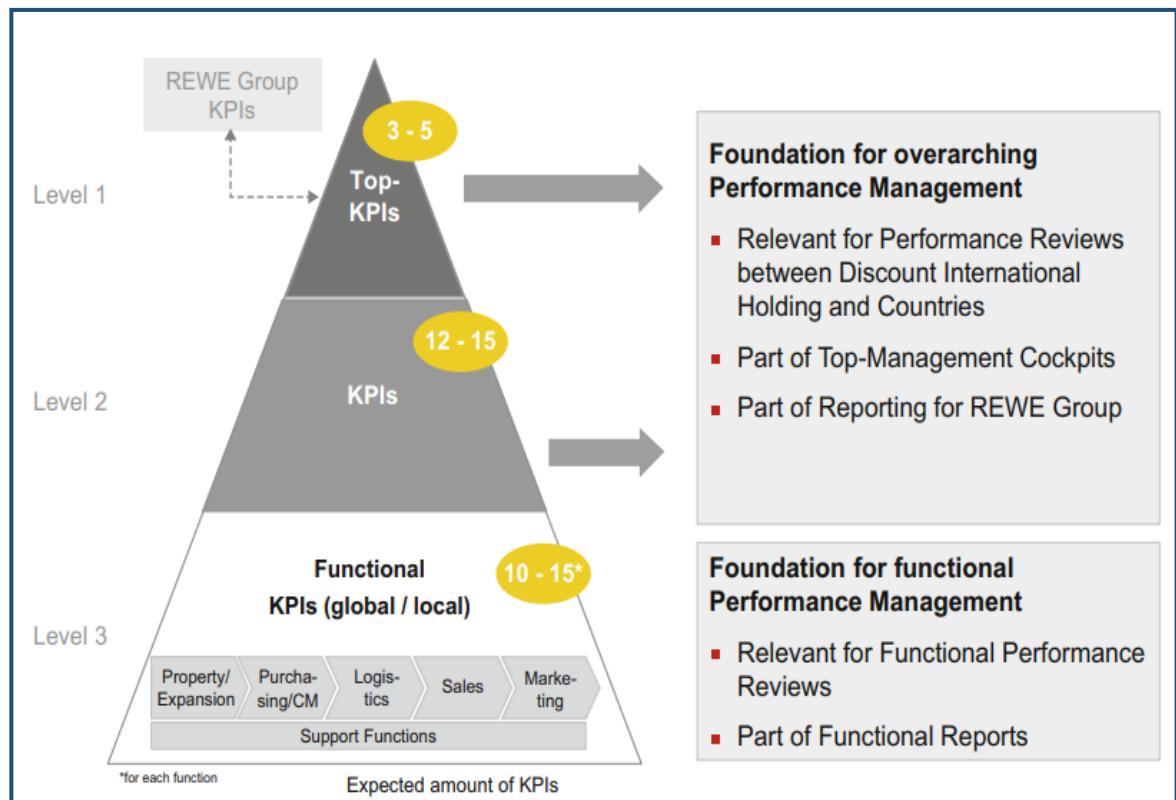


Figure 11 KPI hierarchy with 3 steps
(Source: Buttkus and Eberenzd, 2019)

2 LEAN MANUFACTURING

According to Liker (2021), Lean or TPS (Toyota Production System) aims to create a one-piece flow by constantly eliminating wasted effort and time that does not add value.

Womack and Jones (2003) described Lean thinking against the Japanese word MUDA, which means „Waste,“ Specifically any human activity that absorbs resources but creates no value: mistakes that require rectification, production of items no one wants so that inventories and remaindered goods pile up, processing steps which aren't needed, movement of employees and transport of goods from one place to another without any purpose, groups of people in a downstream activity standing around waiting because an upstream activity has not delivered on time and goods and services which don't meet the needs of the customer. Lean thinking provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more effectively.

2.1 Lean Management System

According to Charron (2015) an effective Lean management system includes all organizational activities and encompasses the following three critical systems: (1) technical system, (2) social system, and (3) educational system. Most prescriptions for implementing Lean are missing one critical ingredient: a Lean management system to tie together company-wide Lean activities that sustain the journey, a system that works to define the link between an organization's culture and its system including performance measures and management and management beliefs, daily habits, and routines. It provides a framework to see the differences between Lean and traditional cultures and details the practices, tools, and thinking for establishing Lean management.

2.2 Lean Logistics

Lean logistics is crucial for the company as it ensures the timely delivery of products to the right place, with the required quality, and at an acceptable cost. In this way, logistics works closely with customers, suppliers, as well as with the management and planning of production processes and inventory. Various aspects of logistics, including production, distribution, waste disposal, reverse, and manufacturing logistics, play a vital role in achieving these objectives. (Jurová, 2016)

Lean logistics is a key component of a lean enterprise, focusing on optimizing transportation, storage, and material handling processes. These areas often represent a significant portion of a company's expenses, resources, and capacity. The primary objective of lean logistics is to minimize inventory while maximizing the efficiency of material and product flow. By implementing lean logistics, companies not only achieve cost savings and higher profitability but also contribute to environmental protection, enhance sustainability, and demonstrate corporate social responsibility. (Wronka, 2017)

2.3 Types of Waste

Waste should be defined as non-value-added activities or outcomes. Typically, activities that contribute to waste are categorized based on Taiichi Ohno's model of the 7 Deadly Wastes, which provides a framework for identifying and eliminating inefficiencies in processes. (Mcloughlin, 2017)

Toyota categorized seven major types of non-value-adding waste in manufacturing processes clarified by Liker (2021) as follows:

1. Overproduction

Overproduction occurs when goods are produced ahead of or in anticipation of demand. Excess Inventory generates waste such as overstaffing, unnecessary storage, and transportation costs.

2. Waiting (time on hand)

Watching or waiting for a machine, waiting for key inputs, or having slack with no immediate deadlines.

3. Unnecessary transport or conveyance

Carrying work in process (WIP) long distances, creating inefficient transport, or moving materials or information into or out of storage or between processes.

4. Overprocessing or incorrect processing

Taking unneeded steps to process the parts. Inefficient processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is also generated when providing higher-quality products or services than is necessary.

5. Excess inventory

Excess raw material, WIP, or finished goods cause longer lead times, obsolescence, damaged goods, transportation and storage costs, and delays. Also, extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.

6. Unnecessary movement

Any wasted motion employees perform during their work, such as looking for, walking to, reaching for, or stacking parts, tools, etc.

7. Defects.

Production of defects and correction. Repair or rework, scrap, replacement production, and inspection waste time, effort, and handling.

3 SELECTED METHODS OF INDUSTRIAL ENGINEERING

The implementation of industrial engineering methods is essential for refining manufacturing processes, enhancing productivity, and eliminating waste. Methods like Value Stream Mapping (VSM), Process Map and Spaghetti Diagrams are particularly effective for visualizing processes.

The primary goal of these methods is to enhance productivity and efficiency, thereby strengthening the company's competitive position. This chapter does not aim to offer an exhaustive overview of all existing methods but rather focuses on those that were applied to achieve the objectives outlined in this thesis.

3.1 Spaghetti Diagram

One of the simplest methods for analysing material flow, used in mapping internal material flow, identifying the most efficient transportation routes, or designing workplace layouts, is the Spaghetti Diagram. (Jurová, 2016)

Spaghetti Diagram is a visual tool that shows the physical movement of a (work object) such as a product, an employee, or through the processes in a value stream. It is a Lean tool that can be used to identify wasted motion and serves the purpose of validating products in a product family. (Pyzdek, 2021)

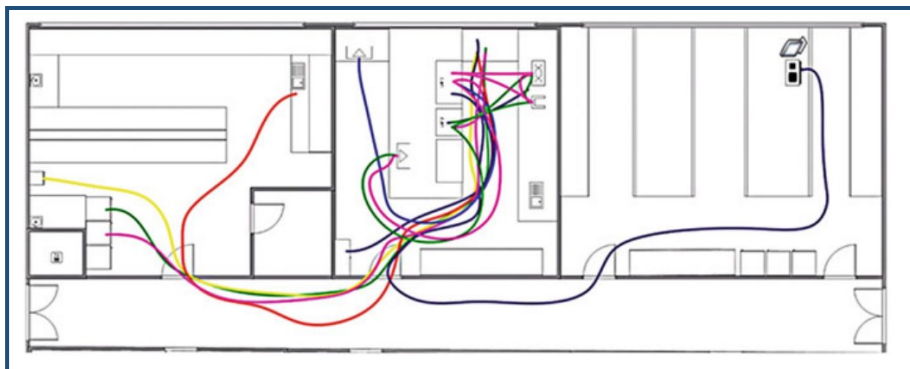


Figure 12 Spaghetti Diagram
(Source: Pyzdek, 2021)

As shown in Figure 12, Pyzdek (2021) illustrates a Spaghetti Diagram before Lean is applied. This spaghetti diagram looks at the movement of people in a small lab. There are six people, each represented by a different colored line. There are a few trips to the room on the left and one trip to the computer workstation on the right. This suggests that the small

room at the center-top would be a good candidate to start looking for reducing wasted movement.

3.2 Value Stream Mapping

An important characteristic of the VSM is its visual nature, allowing for a quick assessment of the state of the production process. (Dinis-Carvalho, Guimaraes, Sousa and Leao, 2019)

Rother and Shook (1999) identify value stream mapping (VSM) as all the actions (both value-added and nonvalue-added) currently required to bring a product through the main flows essential to every product, which goes through the production path from customer to supplier, and carefully draw a visual representation of every process in the material and information flow.

Value stream mapping is a visualization method that allows us to map the flow of value from raw materials to the customer. The primary goal of value stream mapping is to identify waste and propose measures that lead to its reduction or elimination. (Duggan, 2013)

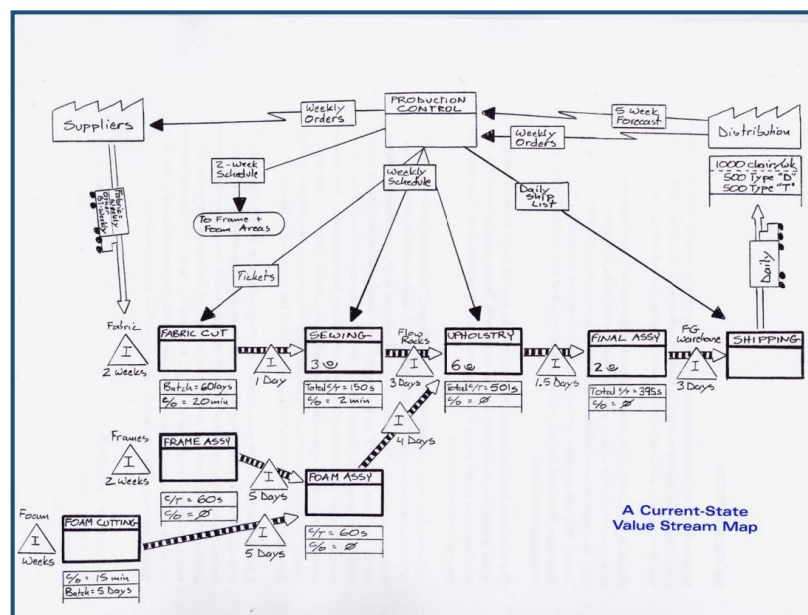


Figure 13 Value Stream Map
(Rother and Shook, 1999)

3.3 Theory of Constraints

The Theory of Constraints is characterized using logical principles upon which it is based, making it easier to understand and apply. Every system has a weak point or constraint that impacts both the productivity and efficiency of the process. The goal of this method is to identify the bottleneck and subsequently eliminate or, at the very least, optimize the other processes to fully utilize its maximum capacity. (Januška, 2018)

The Theory of Constraints is based on continuous improvement, which consists of several steps. The first step is identifying the bottleneck, followed by deciding how to resolve the constraint. Once the constraint is identified, the next step is to resolve it, and then subordinate all other processes to the solution of the bottleneck. Afterward, the goal is to maximize the flow at the constraint. Finally, if successful, the process returns to the first step. The most applied approach of the Theory of Constraints in manufacturing systems is the Drum-Buffer-Rope method (DBR) (See Figure 14). This method focuses on controlling the input material into the production system according to the flow of operations at the bottleneck, referred to as the "drum," which sets the rhythm for the entire production process. The pull system in production is represented by the "rope," which connects the input operation to the bottleneck. Any disruption in activities preceding the bottleneck could negatively affect its performance, so these activities are protected by the "Buffer," which serves to prevent such fluctuations. (Nenadál, 2018)

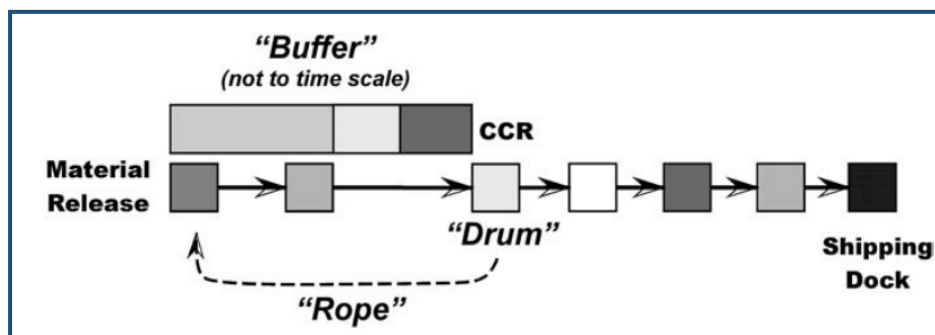


Figure 14 Drum-Buffer-Rope concept
(Source: Schragenheim and Dettmer, 2000)

Instead of accumulating work-in-process in front of the Capacity Constrained Resource (CCR), DBR ensures that each unit arrives at the CCR just in time—neither too early nor too late. (Schragenheim and Dettmer, 2000)

Each component of this method is explained as follows by Schragenheim and Dettmer (2000):

- The drum is the CCR's processing capacity, which dictates the pace of production.
- The rope is the mechanism that controls material release into the system, ensuring it aligns with the CCR's capacity to prevent overload.
- The buffer acts as insurance, protecting the CCR from starvation (idle time) and maintaining the planned schedule despite unexpected disruptions.

3.4 Ishikawa Diagram

The essence of the Ishikawa diagram lies in identifying the causes of a given problem. Visually, the diagram resembles a fishbone, with the fish's head representing the main problem being addressed. The individual bones illustrate the mapped causes of the problem, which can be categorized into several groups. (Košturiak, 2010)

Blecharz (2015) highlights the connection between the interactive brainstorming method and the development of a comprehensive Ishikawa diagram. When creating an Ishikawa diagram, a partial analysis can be conducted using the "5 Whys" technique, which helps clarify individual causes. The Ishikawa diagram then visualizes the analysed causes of the problem under investigation.

3.5 Workday Analysis

The workday analysis technique involves continuous monitoring of time consumption throughout the workday. Its primary objective is to provide a comprehensive overview of time utilization, identify inefficiencies, assess the ratio of value-adding to non-value-adding activities, and propose more efficient work organization where applicable. This method is commonly used to detect recurring activities that may serve as a basis for calculating allowances or whenever an overview of employee workload is needed, such as for implementing multi-machine operation. Workday analysis is not limited to production or support processes but is also widely applied in administrative settings. (Dlabač, 2023)

It can be used for continuous worker observation, providing a comprehensive overview of time consumption throughout the entire shift. This enables the identification of inefficiencies and the detection of non-value-adding (NVA) activities. (Chundela, 2013)

3.6 Kaizen

Kaizen is a principle focused on identifying and eliminating inefficiencies within complex production processes and value streams. Its implementation often involves brainstorming sessions to systematically address and resolve abnormalities. Rooted in a philosophy of continuous improvement, Kaizen leverages various structured methods and approaches to drive future enhancements. (Chromjaková, 2013)

The key principles of Kaizen involve identifying areas for improvement, implementing incremental and manageable changes, and fostering a culture of continuous improvement at both organizational and individual levels. Its primary objective is to enhance processes, improve efficiency, maintain quality control, standardize workflows, utilize resources effectively, eliminate waste, and drive long-term success through sustained refinement. (Bauer, 2012)

3.7 Process Analysis

By employing process analysis, we can assess attributes of each activity, including distance, duration, and the number of personnel involved. Additionally, we can incorporate specific data such as transportation time, batch size, and cycle time (CT) of operations. The goal of subsequent improvements—achieved by comparing process analyses before and after implementing enhancements—is to streamline the process diagram, effectively flattening it and aligning it to the left. This visual adjustment signifies a more efficient and optimized process flow. (Pavelka, 2015)

Process mapping is a technique that enhances understanding of organizational processes by outlining individual steps, identifying task owners, and detailing timelines to highlight areas for improvement. Often beginning at a macro level, process maps communicate workflows clearly among stakeholders and become more detailed as needed. Common symbols used include rectangles for activities, arrows for flow direction, ovals for start or end points, and diamonds for decision points, making it easier to visualize and analyze the process efficiently. (IBM, 2021)

Process mapping is a visual analytical tool within the Kaizen methodology, focusing on the description of processes and activities, as well as their flow within a given organization. By creating process maps and diagrams, they enhance communication and understanding of the current state, ultimately speeding up the implementation of changes and improvements. Regarding waste, by mapping production processes and their material flows, it's possible pinpoint the specific origin of different types of waste, eventually, focus on preventing waste or, if necessary, separating it at the source for future reuse. (Jones, 2014)

Procesní analýza		operace	transport	kontrola	skladování	čekání	vzdálenost (m)	doba trvání (min)	počet pracovníků
č.	činnost								
1	Příjem zboží	○						1	1
2	Kontrola			⊠				0,5	
3	Skladování				△				
4	Transport		⇒				24		
6	Dělení materiálu	○						10	0,5
7	Kontrola			⊠				0,5	
8	Transport		⇒				70		
9	Soustružení	○						7,27	0,5
11	Transport		⇒				32		
12	Broušení	○						7,27	1
14	Transport		⇒				29		
15	Protáhnutí	○						0,94	0,5
16	Jehlení	○						0,35	0,3
17	Kontrola			⊠				1,5	
18	Transport		⇒				9		
19	Soustružení	○						0,75	1
21	Transport		⇒				90		
22	Soustružení	○						3,88	0,5
24	Transport		⇒				59		
25	Skladování				△				
30	Transport		⇒				29		
31	Odmaštění	○						0,27	0,5
32	Transport		⇒				11		
33	Skladování				△				
43	Transport		⇒				300		
45	Broušení	○						5,31	1
48	Transport		⇒				91		
59	Kontrola			⊠				2	
60	Balení	○						2,5	1
Celkem: - četnost		11	11	4	3				7,8
- součet časů (min)								44,04	
- vzdálenost (m)							744		

Figure 15 Example of process analysis

(Source: Pavelka, 2015)

implementation requires a prominent level of coordination and communication across all departments. Additionally, relying on a just-in-time system carries a certain degree of risk, as any disruption in the supply chain can significantly impact production and delivery schedules. By focusing on eliminating waste, reducing costs, improving quality, and increasing responsiveness, JIT can help companies achieve greater efficiency and competitiveness in today's fast-paced business environment. While implementing JIT may require significant changes to existing processes and systems, the benefits of improved performance and customer satisfaction make it a worthwhile investment for companies aiming to stay ahead in an increasingly competitive market. (Hiroyuki, 2009)

3.10 SMART Method

The SMART framework, an acronym representing key goal-setting criteria, consists of the following attributes (Kerzner, 2017):

- S – Specific: Clearly define and focus on performance objectives or business purposes.
- M – Measurable: Quantifiable, allowing progress to be tracked and evaluated.
- A – Attainable: Realistic and achievable within available resources and constraints.
- R – Relevant: Aligned with broader objectives and meaningful to the organization or individual.
- T – Time-bound: Define within a specific timeframe to ensure accountability and progress tracking.

3.11 RIPRAN Method

According to Doležal, Máchal and Lacko (2012) RIPRAN method is a structured approach to risk management within a project. Throughout the project lifecycle, it is crucial for the project team to continuously assess potential threats and challenges that could jeopardize its successful execution. Therefore, ongoing monitoring of potential adverse impacts is essential, along with the development of proactive measures to mitigate these risks. Effective implementation of the RIPRAN method requires an experienced team with in-depth knowledge of the project. Additionally, access to relevant statistical data or insights from previous projects is necessary to accurately identify and quantify potential risks that may arise during execution.

According to Doležal, Máchal, and Lacko (2012), the RIPRAN method for risk management is divided into several key phases, probabilities, and impact categories as follows:

- **Phases of the RIPRAN Method**

1. Risk Identification – Recognizing potential threats to the project.
2. Risk Assessment – Evaluating the likelihood and impact of risks on the project.
3. Risk Response – Implementing actions to mitigate or eliminate identified risks.
4. Overall Risk Evaluation – Using analytical results to assess the project's risk exposure.

- **Probability Categories**

Risk probability is categorized into three levels based on the likelihood of occurrence:

1. Low Probability (LP) – 1% to 20% likelihood.
2. Medium Probability (MP) – 21% to 66% likelihood.
3. High Probability (HP) – 67% to 99% likelihood.

- **Impact Categories**

The impact of risks on a project is classified into three categories:

1. Low Impact (LI) – Minor project impact, causing financial losses up to 0.5% of the project's total value.
2. Medium Impact (MI) – Moderate impact involving resource or cost risks, with financial losses ranging between 0.6% and 20%.
3. High Impact (HI) – Severe impact that endangers the project's objectives, with financial losses exceeding 20%.

- **Risk Value Determination**

The risk value matrix combines probability and impact categories to define the overall risk level (See Table 1).

Table 1 Risk Value Determination of RIPRAN

Impact / Probability	Low Probability	Medium Probability	High Probability
Low Impact	Low Risk	Low Risk	Medium Risk
Medium Impact	Low Risk	Medium Risk	High Risk
High Impact	Medium Risk	High Risk	Very High Risk

(Source: own elaboration)

4 SUMMARY OF THE THEORETICAL PART

The theoretical part of this thesis explores key concepts related to logistics, supply chain management, and lean manufacturing, with a focus on optimizing logistics processes in distribution centers. Logistics and supply chain management play a critical role in ensuring efficiency, reducing costs, and improving operational effectiveness. Warehouses and distribution centers are vital components of supply chains, responsible for receiving, storing, picking, consolidating, and shipping goods. The integration of robotic warehouses has further enhanced efficiency, particularly in order-picking processes.

A major emphasis is placed on lean manufacturing principles, which focus on eliminating waste and improving productivity. Waste in logistics operations can take various forms, such as overproduction, waiting times, unnecessary transportation, and inefficient processing. Lean tools like Just-in-Time, and Value Stream Mapping help organizations streamline processes and optimize resource utilization.

The thesis also introduces several industrial engineering methods to analyse and improve logistics processes. Spaghetti Diagrams help visualize unnecessary movement and transportation waste, while Process Mapping provides a clear workflow structure. The Theory of Constraints identifies and addresses bottlenecks, ensuring a smooth material flow.

By combining logistics principles, lean methodologies, and industrial engineering tools, this section establishes a strong theoretical foundation for the practical part, which aims to optimize the tote replenishment process in a distribution center.

II PRACTICAL PART

5 INTRODUCTION ABOUT THE SELECTED COMPANY (DISTRIBUTION CENTER)

Selected Company, is an American multinational technology company that evolved into a global powerhouse, revolutionizing the way people shop, read, and consume media.

The company's operations span a wide range of industries, including e-commerce, cloud computing, online advertising, digital streaming, and artificial intelligence. The company is known for its vast online marketplace, offering an extensive selection of products across various categories.

Logistics processes at selected distribution centers are a marvel of modern supply chain management, ensuring that millions of packages are delivered to customers around the globe with remarkable speed and efficiency. At the heart of these operations is the intricate dance of advanced automation, data-driven decision-making, and human expertise.

The journey begins with the receipt of inventory at fulfilment centers. Products from various sellers are meticulously scanned, sorted, and stored using advanced inventory management systems. This ensures that each item is precisely tracked and can be swiftly located when needed. These massive warehouses, often spanning hundreds of thousands of square feet, are divided into sortable and non-sortable fulfilment centers to handle different types of products.

The company's distribution center in the Czech Republic is a key facility within the company's global logistics network. It spans over 187,000 square meters. The facility has required an investment of more than billions of Kč without VAT and is equipped with advanced robotic systems to assist employees in processing customer orders efficiently. These robots help reduce the processing time by moving items around the center with precision.

5.1 Associated Processes at the Distribution Center

The distribution center includes four floors. However, scope of thesis is focused only on three floors where total number of stations is 300 and it's equally divided as 100 station per floor, they are divided into three types including stowing, picking, or universal.

5.1.1 Stowing Stations

Definition: Stowing is known as put away, which is the process of placing incoming inventory into designated storage locations within the fulfilment center. This ensures that items are organized and easily retrievable for future orders.

Process Description: In robotic fulfilment centers, robots transport shelves (or pods) to human stowers, who then place the items into the appropriate slots. Each item is scanned and entered the inventory system to ensure accurate tracking. In non-robotic facilities, employees manually stow items using order pickers and racks.

5.1.2 Picking Stations

Definition: Picking is the process of retrieving items from their storage locations to fulfill customer orders. This involves locating the items, collecting them, and preparing them for packing and shipping.

Process Description: In robotic fulfilment centers, robots bring shelves containing the required items to human pickers, who then retrieve and scan the items before placing them into bins or carts. Sophisticated algorithms determine the most efficient routes for picking, reducing errors, and optimizing efficiency.

5.1.3 Universal Stations

Definition: Universal stations are versatile workstations within fulfilment centers designed to handle a variety of tasks, including picking, stowing, and other fulfilment activities. These stations are equipped with the necessary tools and technology to support multiple functions, making them adaptable to different operational needs. These multi-functional workstations are essential for maintaining flexibility and efficiency in the fulfilment process.

Process Description: In universal stations, employees receive task instructions from the system or supervisors and then proceed to execute tasks such as picking items from storage locations, stowing incoming inventory, or performing other fulfilment activities.

5.2 Robotic System at the distribution center

Advanced robotics are integrated to enhance efficiency and safety in warehouse operations. The facility employs various robotic systems, including:

- Autonomous Mobile Robots (AMRs)

These robots, referred to as "Hercules" or Kiva Systems navigate beneath mobile storage pods containing inventory. They transport these pods to pick stations, optimizing storage density and streamlining the order fulfilment process.

- Robotic Palletizers and Depalletizers

These robots handle heavy lifting tasks, such as stacking and unstacking pallets, to streamline the movement of goods. The handling automation of heavy items minimizes the physical strain on human workers.

- Robotic Sorters

Designed to perform repetitive tasks such as lifting, stacking, rotating, and sorting packages, these sorters enhance the speed and accuracy of order processing.

5.2.1 Kiva Systems at the distribution center

According to Poudel (2013) cited Kiva Systems inc. (2012) defined Kiva system as an innovative automation technology to handle the flow of goods from warehouses to the customers. It was developed by Kiva System Inc. Kiva system completely handles the material handling in warehouse to pick the orders, ship the packed orders and replenish the new items in appropriate shelves. Operators stay in the work station and the system delivers the ordered products to the worker. Kiva uses hundreds of autonomous mobile robots and sophisticated control software. These small mobile robots carry the specific pods from the storage area and deliver the products to the human operator. Kiva's innovative approach eliminates the traditional human walking method to pick orders, this feature makes the warehouse 2 or 3 time more productive. Kiva system consist of several components. The mobile robots, inventories, shelves (pods), software are the major components of the Kiva system. Each inventory has unique bar code and the pods are facilitated with pick to light and put to light system. Items to be picked are indicated by laser lights in the pods i.e. pick light system. When item is picked, the operator scans the item's bar code, then the place for the item to place for the fulfilment of the order is again indicated by the laser light i.e. put to

light system. This innovative station-based pick-to-light, put to-light and scanning technique increases the accuracy of the system. The complete material handling solution includes work stations configured to fit customer requirements, a wireless network and a server-based back end system. All of these are deployed within a distribution center and the final pieces are the human operators who pick, pack and ship orders using the automated system.

Poudel (2013) clarifies based on Enright and Wurman (2011) and D'Andrea; Wurman and Mountz (2008) that Kiva system consist of several resources which are useful to accomplish the goal of order picking as follows,

- **Inventory:** Inventories are the products available in the warehouse. Each product is described by its dimensions, packing quantities and its velocity. All the items are assigned unique bar code.
- **Pods:** Pods are the logically storage locations for the inventories in the warehouse. Pods can consist of hundreds of bins hence if there are hundred pods then number of addressable locations for storage of items will be 100,000. They are shared and scheduled resource. One robot can carry a pod at a time, but it can be scheduled to visit many picking stations. Bins are filled by humans at replenishment station and emptied at the pick station. In between these two processes they are stored in the parking areas of the warehouse. A bin does not have to be filled with the same inventory that it previously contained. Pods can be classified as inventory pods and order pods. Inventory pods contain inventories whereas order pods contain the items for fulfilment. In order fetch configuration order pods are carried by the robot from the box induction stations to pick stations, then to the box shipping stations and again to box induction stations.
- **Parking spaces:** These are the spaces where the inventory pods are kept. Every pod is assigned a space to park. Once a pod is removed from a space, that space is available for any other pod to be stored in it.
- **Stations:** The picking and the replenishment stations are placed in the perimeter of the warehouse. Stations are scheduled resources. The robot's buffer in a queue in the station for the picking. Operators interact with the pods in the stations. The time of interaction depends upon the number and type of the items to be picked.
- **Robots:** Robots are shared and scheduled resources of the Kiva system. They are used to carry the inventory pods and order pods. The number of robots can be

increased or decreased depending on the list of orders coming. The robot performs the task in the following steps:

1. Robot receives the message from central server to pick the specific pod from the parking area.
2. The Robot move from its current location to the pod's location.
3. The Robot lift the pod and carry the pod to the specified picking or shipping station.
4. If the pod is of type inventory, it is taken to the picking station, if it is an order pod it is carried to the shipping station for the delivery.
5. If there are other Robots, then robots stay in queue until they have their turn to pick the items from the human operator.
6. After the operator picks the items, the robot move gets back to some parking space and keep the pods back.

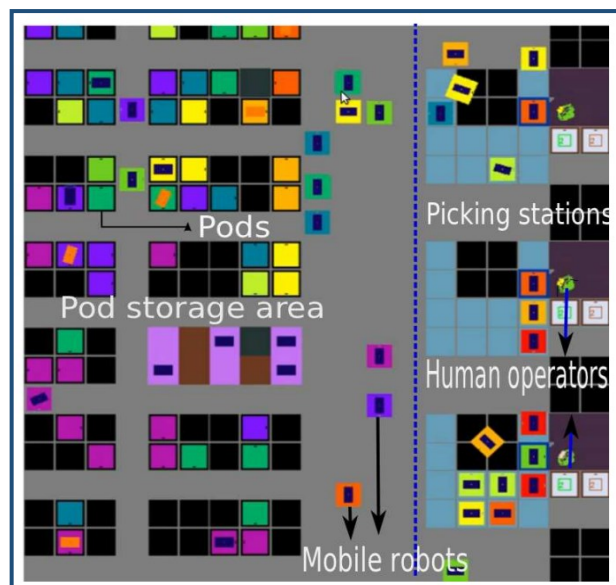


Figure 17 Example of Kiva System Region in a warehouse
(Source: Poudel, 2013)

The Figure 18, is an existing layout for the distribution center especially the second floor with clarification of robotic area or Kiva System.

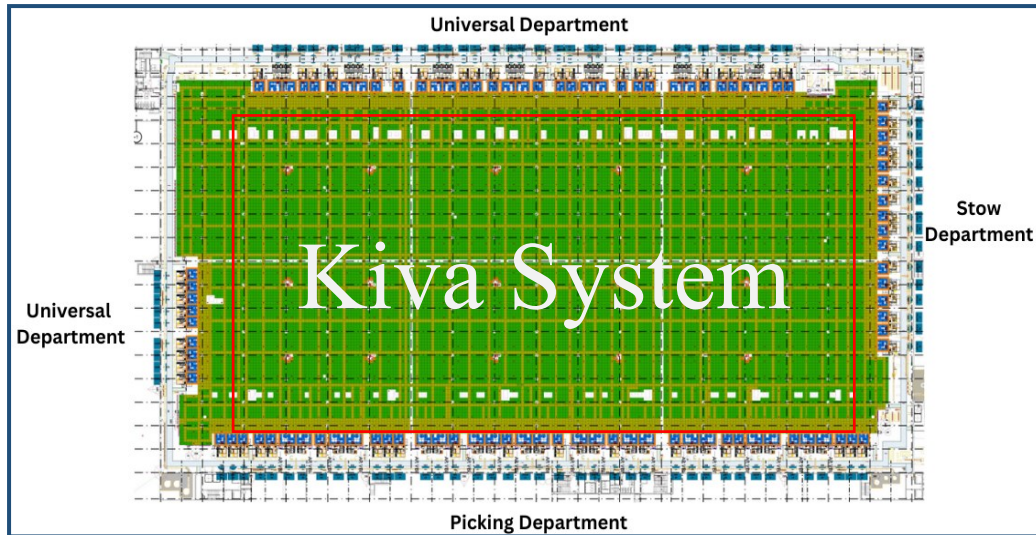


Figure 18 Kiva System Region at selected distribution center
(Source: own elaboration)

5.3 Associated Equipment for Totes Flow

In a tote flow system, several specialized pieces of equipment are used to facilitate the efficient storage, handling, and transportation of totes. Totes themselves are black storage boxes designed to hold a variety of products, typically measuring 60 cm in length, 40 cm in width, and 30 cm in height, with an average of 11 to 12 items per tote. To transport and organize these totes, U-boats play a critical role. These are sturdy trolleys that can hold up to 48 totes, with four stacks of 12 totes each, enabling efficient movement throughout distribution centers.

Additionally, Multi-stackers enhance the workflow by holding and transferring multiple totes at once. Each Multi-stacker can manage 48 totes across four stacks and is connected to conveyors, ensuring a continuous flow to picking stations. EPAL Pallets, standardized wooden platforms, are also used to store and organize totes. These pallets, measuring 1150 mm x 800 mm, can hold 48 totes in 4 stacks of 12, offering both space efficiency and stability for transportation. All of these equipment types work in tandem to optimize the logistics and handling of totes.

5.3.1 Totes

In general terms, they can be described as a black storage box designed for holding various products (See Figure 19). The box, often referred to as a tote, has a capacity defined by its dimensions: approximately 60 cm in length, 40 cm in width, and 30 cm in height. This makes it suitable for storing a wide range of items, providing space while maintaining a manageable size for handling and transportation. Totes storage varies between 11-12 item on average depending on the size of items.



Figure 19 Tote - Isometric view
(Source: own elaboration)

5.3.2 U-boats

A U-boat is a specialized transportation trolley designed for efficiently moving Totes (See Figure 20). This trolley is engineered to accommodate four stacks, each stack holding 12 totes, resulting in a total capacity of 48 totes. The U-boat's robust construction and ergonomic design make it ideal for handling suitable quantities of totes, ensuring secure transportation within distribution center, and other storage facilities. Total number of U-boats used for picking at distribution center is sixty.

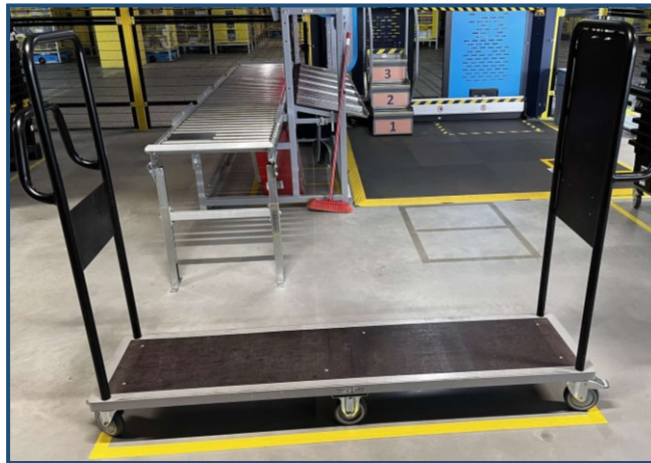


Figure 20 U-boat - Front view
(Source: own elaboration)

5.3.3 Multi-stacker

A Multi-stacker is an advanced storage and transportation system designed to streamline the process of handling totes within the distribution center. Each Multi-stacker has a total capacity of four stacks, with each stack holding 12 totes, resulting in a total capacity of 48 totes per multi-stacker.

Within a single floor, there are ten multi-stackers, each strategically positioned to feed two picking stations simultaneously. These Multi-stackers are connected to two conveyors that facilitate the movement of totes toward picking stations. The system is designed to optimize the workflow: as pickers fill a tote, they send it to the outer conveyor. Sensors detect the empty space and automatically push a new tote into place, ensuring a continuous and efficient supply of totes to the pickers.

Universal stations don't include multi-stackers for feeding, but they get the totes directly from the U-boat buffer.



Figure 21 Totes Multi-Stacker behind full U-boat- Front view
(Source: own elaboration)



Figure 22 Totes Multi-Stacker behind full U-boat- Side view
(Source: own elaboration)

5.3.4 Pallets

EPAL Pallets are highly versatile and robust platforms widely used in logistics and warehousing. These pallets are designed to serve as effective buffers and storage solutions, capable of accommodating 48 totes arranged in 4 stacks stacked in parallel. Each stack can hold 16 totes, ensuring efficient use of space and easy access to stored items.

The standard dimensions of used EPAL pallet are 1150 mm x 800 mm, providing surface area to support the weight and volume of the totes. The pallets are constructed from high-quality wood, ensuring durability and stability.

EPAL pallets are recognized for their adherence to strict quality standards, making them a reliable choice for various storage and transportation needs.



Figure 23 E-pal 1150 mm x 800 mm
(Source: European Pallet Association, 2025)

6 ANALYSIS OF THE CURRENT SITUATION

The current situation is analysed specifically for the picking department and the picking process. The entire optimization effort will be focused on one of the subprocesses called totes replenishment process to ensure seamless support for pickers in fulfilling their tasks.

Totes replenishment process is the focus of optimization in this thesis, where the waste is found, and the company currently is investigating practical solutions to eliminate wasted time and cost of chaotic-manual totes supplement to picking stations. Therefore, this analysis is conducted over a single working shift, with the impact on time, cost, and other parameters evaluated on an annual basis.

Number of workers is directly influenced by working modes, this fact will be clarified in details at each working mode separately.

The working year is divided into two primary modes (Peak and off Peak modes), which will be detailed in this section. Number of working days are calculated as 365 days, excluding public and bank holidays. However, weekends are included as the distribution center operates non-stop. Each day consists of day (7:00 AM – 5:10 PM) and night (6:00 PM – 4:10 AM) working shifts, each lasting 9.67 hours, this time also includes 2x15 minutes breaks without lunch break, so real operational time for each shift is 9.17 hours.

A coefficient was applied to some of the data to preserve the confidentiality of the company while maintaining the integrity of the analysis.

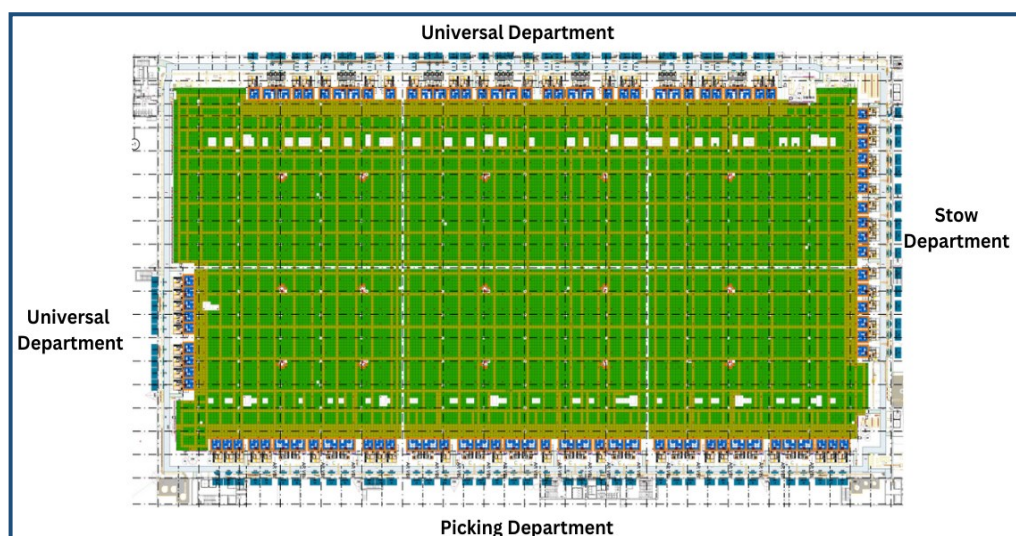


Figure 24 Layout of one floor of total 3 floors
(Source: own elaboration)

6.1 Picking Process

The measurement and analysis of required number of supplied totes to all stations in operation are conducted using two distinct modes including peak mode and off-peak mode. The number of required totes for picking process is relevant to the number of required items for picking.

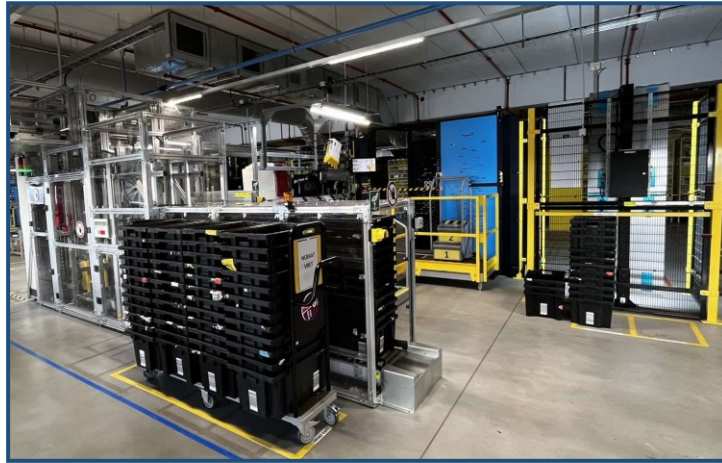


Figure 25 Picking Station
(Source: own elaboration)

6.1.1 Peak Mode

Peak mode refers to a period of high picking demand within the working year, typically lasting for three months. During this time, the entire operational capacity is utilized to meet the increased demand. This includes running all 60 ARSAW (Picking Stations) and 20 universal stations simultaneously. The system is designed to handle the surge volume efficiently, ensuring that shipping needs are met promptly.

To understand required quantity of supplied totes during peak mode for all three floors, it's important to analyse the current usage of the totes in correlation to number of machines in operation, and tote capacity of different items.

During peak mode, based on records provided by the area manager, an average number of 450,000 items per day are expected to be picked within 3 floors. This amount accounts for the busiest period of the distribution center, with all items required to be stored in totes and prepared for shipment and packaging. However, for simplicity and alignment with presented measurement the average required items for picking at one floor during one shift is calculated using equation 1.

$$a = \frac{b}{c * d} \quad (1)$$

a: Total number of items to be picked per floor during one shift

b: Total number of items to be picked at distribution center

c: Number of shifts

d: Number of floors

With respect to equation 1, the required number of totes on average for one floor during day shift is $a = 75,000$ items.

The following data in Table 2 was gathered during one working week including weekends during 2024 which is correlating to previous measured value (a). However, the main goal of this calculation is to measure the required number of totes during one shift where each totes fills approx. 12 items, only maximum value of **8977 totes** is considered as a reference in this study of totes demand during any working shift or at any floor during peak mode.

Table 2 Totes Demand for picking department during peak mode based on picked items

2nd Floor (Day Shift)		
Time [Day]	Total Items	Total required number of totes
Sat	86755	7230
Sun	98549	8212
Mon	107719	8977
Tue	103904	8659
Wed	85511	7126
Thu	61156	5096
Fri	52140	4345

(Source: own elaboration)

The plot below shows the variation of totes consumption during peak mode for 20 ARSAW stations and 10 Universal stations that is equivalent to totes consumption of one floor.

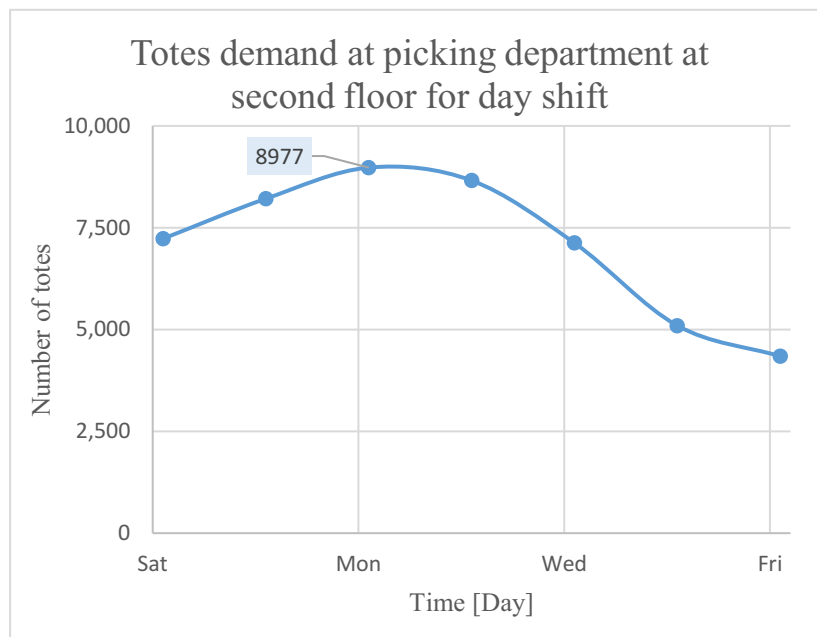


Figure 26 Demand of Totes at picking department at 2nd floor for day shift- Peak Mode
(Source: own elaboration)

6.1.2 Off Peak Mode

Off peak mode refers to a period of lower demand within the working year, typically lasting for nine months. During this time, the operational capacity is adjusted to meet the decreased demand. This includes running 30 ARSAW picking stations, without any universal stations included. The system is designed to handle the reduced order volume efficiently, ensuring that shipping needs are met promptly.

To understand the required quantity of supplied totes during off peak mode for all 3 floors, it's important to analyse the current usage of the totes in correlation to the number of stations in operation.

During off peak mode, based on records provided by the area manager, an average number of 150,000 items per day are expected to be picked within 3 floors. This number considers the less busy period of the distribution center, which requires items to be stored in totes and shipped out for packaging.

With respect to equation 1, the required number of totes on average for one floor during day shift is $a = 25,000$ items.

Table 3 Totes demand for picking department during off peak mode

2nd Floor (Day Shift)		
Time [Day]	Total Items	Total required number of Totes
Sat	22713	1893
Sun	45297	3775
Mon	45141	3762
Tue	42716	3560
Wed	41022	3418
Thu	34396	2866
Fri	30092	2508

(Source: own elaboration)

As explained in Table 3, it provides a detailed breakdown of the totes demand for the picking department on the 2nd floor during the day shift in off peak mode. It shows the total number of items processed from ARSAW and the corresponding number of totes required for each day of the week.

The following data was gathered during one working week during 2024 (See Figure 27), and it captures the demand of totes for one shift, only maximum value of **3775 Totes** is considered as a reference of totes demand during any working shift or at any floor. The plot below shows the variation of totes consumption during off peak mode for 10 ARSAW stations and no Universal stations that is equivalent to operation of one floor.

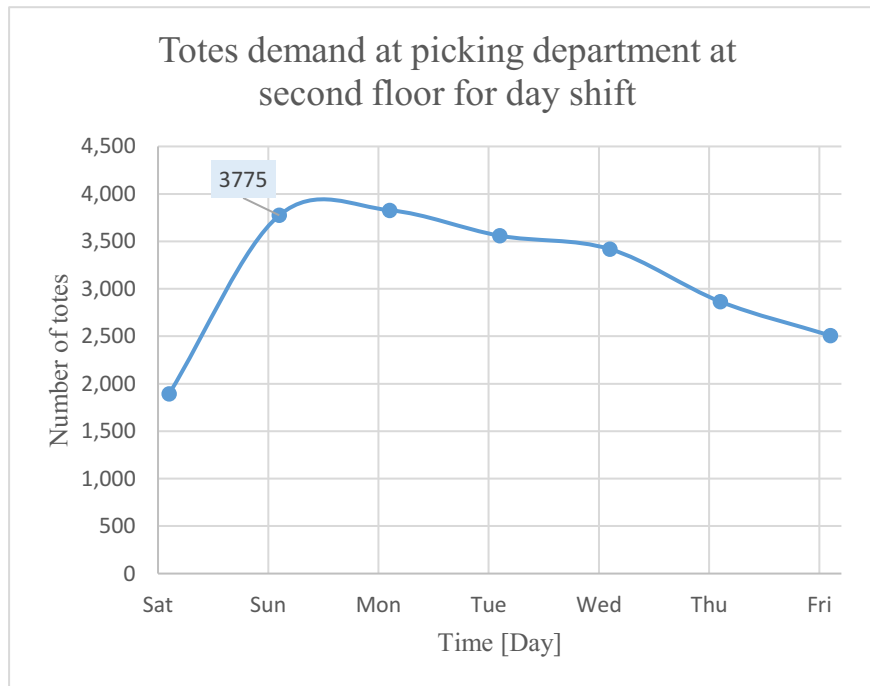


Figure 27 Demand of Totes at picking department at 2nd floor for day shift- Off Peak Mode
(Source: own elaboration)

6.2 Totes Replenishment Process

As illustrated in Figure 28, the tote replenishment process occurs along a 150-meter path within the picking department. The process involves replenishing totes based on stations demand, with a tote runner transporting totes from the source point using a U-boat and delivering them to multi-stackers along the designated route.

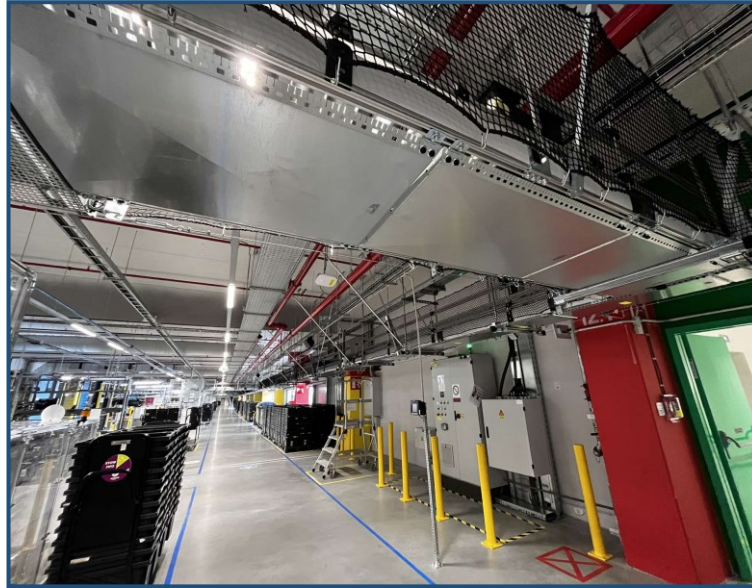


Figure 28 Picking department of 150 Meters from source to last Multi-Stacker
(Source: own elaboration)

This section outlines current process map, theory of constraints and Ishikawa analysis to search for root cause of defined bottleneck and expands on current step-by-step process for filling and transporting stacks of totes using U-boats using process map and Spaghetti Diagram and finally analysing current waste using Workday Analysis tool.

6.2.1 Process Map

The process map supplies a structured overview of the tote replenishment workflow, detailing each step involved in transporting totes from the source to the designated multi-stackers. This mapping technique helps visualize the flow of totes. By outlining each stage from tote collection to final placement, it becomes possible to find potential waste, and enhance overall workflow efficiency. The following steps describe the complete manual replenishment cycle, including tote collection, U-boat loading, transportation, and final distribution to multi-stackers.

Process map step by step:

1. Collect Totes into the source.

It is important to mention that Totes source is filled by different methods. However, it is difficult to calculate the number of generated totes at source due to chaotic and unpredicted number of totes supplied by each department, but it's possible to assume a percentage of number of totes supplied by each department.

For practical reasons, it is considered enough totes generated by the time it's required to support picking stations, so there is no delay calculated for the totes to be generated at source point, therefore it's always considered as available required number of totes.

The three possibilities with their percentages are described as follows:

- A. Totes supplied from stow department (~ 70%)
- B. Totes supplied from CFE department (~ 20%)
- C. Totes supplied from packaging department - only in peak mode (~10%)

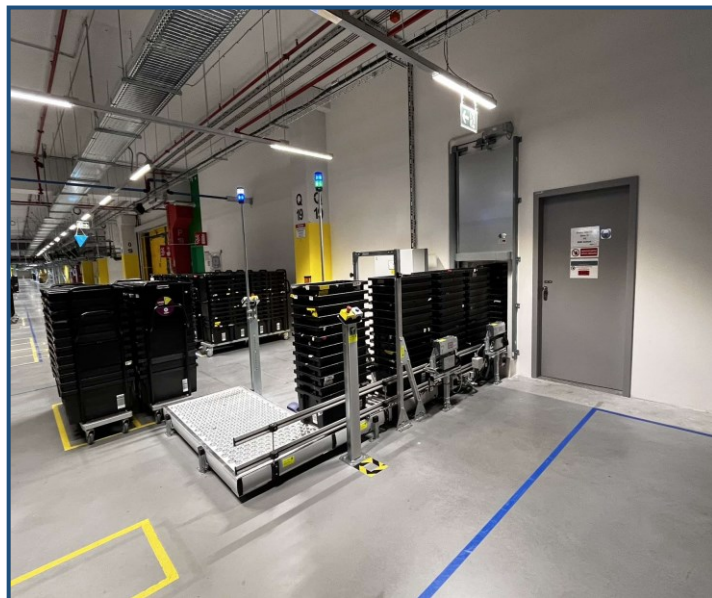


Figure 29 Source point of collected totes from other departments

(Source: own elaboration)

2. Filling the U-boats from source point.

Manual filling of the U-boats with four stacks of total 48 Totes from the source point.



Figure 30 Totes Multi-Stacker behind U-boat
(Source: own elaboration)

3. Transport full U-boat.

Manual drive of the U-boat to targeted multi-stacker or defined spot in case of universal station, check if multi-stacker/defined spot is not full.

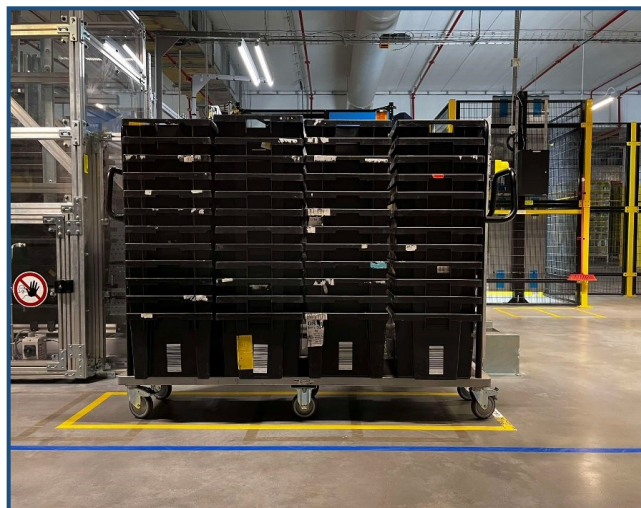


Figure 31 Fully Loaded U-boat parking beside
multi-stacker
(Source: own elaboration)

4. Transfer stacks to multi-stacker.

If a multi-stacker is not full, the required number of stacks is pushed from the U-boat into the multi-stacker to ensure it is fully stocked, then multi-stackers push the Totes to the stations depending on demand totes that is coming from continuous usage of totes by pickers.

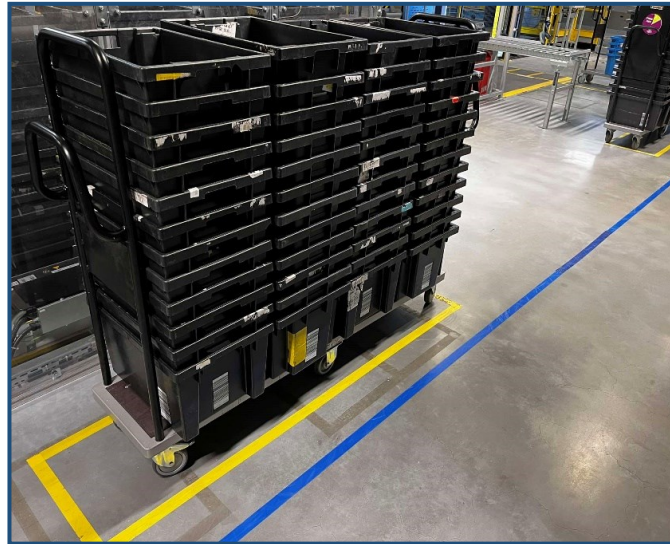


Figure 32 Fully Loaded U-boat
(Source: own elaboration)

5. Continue movement of U-boat until all four stacks are empty, then U-boat should be recharged from origin point at source and steps from number 2 to 5 are repeated until whole floor multi-stackers are full.

6. Move to next floor.

Once all multi-stackers on the current floor are full, move to the next floor.

7. Repeat for next floors.

Continue this process in a circular manner for all three floors until end of shift.

As outlined in this section, during lower-volume shifts, totes replenishment was typically managed by a single tote runner. This individual would fill all multi stackers across the floors before proceeding to the next level. In contrast, under higher-volume conditions, the approach shifted either with multiple tote runners sharing responsibilities on a single floor or each assigned to a specific floor to maintain operational efficiency.

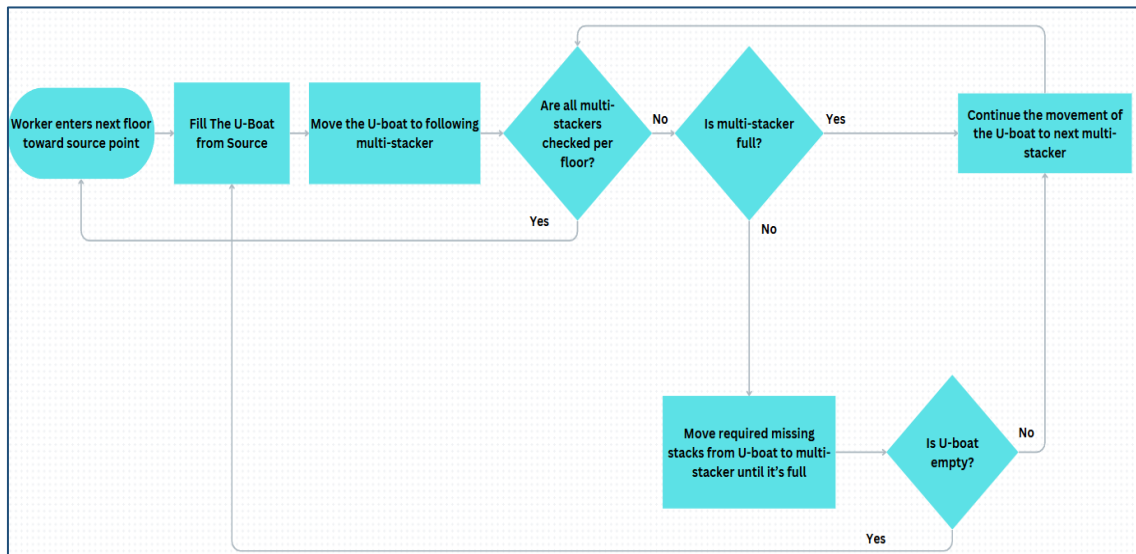


Figure 33 Process Map of Manual Totes Flow

(Source: own elaboration)

6.2.2 Buffer Capacity

An existing buffer area in front of the stations (See Figure 44) currently contains fully loaded U-boats and pallets with totes. These items are not actively used and occupy valuable floor space. In a later section of this thesis, a proposed solution will address how to optimize and repurpose this space to improve efficiency under both demand modes.

6.2.3 Theory of Constraints

As shown in process map, the tote replenishment process in the distribution center faces a major constraint in the form of manual transportation. The current system relies heavily on labour-intensive movement of totes along a 150-meter back and forth at each floor in cycles, which introduces unnecessary transportation. This inefficiency creates a waste, particularly at transporting totes toward unwanted multi-stackers, where uncoordinated tote supply results in delays. Additionally, the lack of real-time monitoring further disrupts replenishment cycles, leading to wasted time and costs. Addressing this constraint is essential to improving overall workflow efficiency.

6.2.4 Ishikawa Diagram

This method highlights critical issues such as manual labour dependency combined with poor real-time monitoring, which collectively contribute to bottlenecks in tote transportation. Understanding these root causes is essential for developing targeted solutions.

- **People (Labour-Related Issues)**

1. Manual Labour Dependency – High reliance on workers for tote movement increases operational time.
2. Workforce Coordination Issues – Lack of proper communication between tote runners and pickers results in inefficient workflows.
3. Fatigue and Human Errors – Physically demanding tasks lead to exhaustion and mistakes, increasing inefficiency.

- **Methods (Process Inefficiencies)**

1. Chaotic Tote Flow – Unstructured movement of totes causes unnecessary transport and time waste.
2. Lack of Standardized Process – No clearly defined procedure for tote replenishment leads to inconsistencies.
3. No Real-Time Monitoring – Lack of tracking systems makes it difficult to predict tote shortages and optimize supply.
4. Limited Use of Industrial Engineering Methods – Not all available lean tools (e.g., JIT) are fully implemented.

- **Machines (Equipment and Technology)**

1. Absence of Automated Systems – No conveyor belts or robotic solutions for tote transportation, increasing manual effort.
2. Limited Use of Signal Systems – Lack of an automated notification system to indicate empty multi-stackers.
3. Frequent Equipment Downtime – Existing tote-moving equipment may suffer from cracks, leading to damaged totes and delays.

- **Materials (Tote and Inventory Management)**

1. Unbalanced Tote Supply – Unpredictable arrival of totes from different departments causes shortages or mostly overflows.
2. Inconsistent Tote Quality – Variation in tote conditions (damaged totes, incorrect sizes) affects process efficiency.

- **Environment (Layout and Space Utilization)**

1. Poor Layout Design – Distance between the tote source and pickers is long, leading to unnecessary movement.
2. Multi-Floor Complexity – Tote replenishment must occur across multiple floors, complicating material flow.

- **Measurement (Lack of Performance Tracking)**

1. No Clear Performance Metrics – KPIs such as tote replenishment speed and worker productivity are not effectively tracked.
2. Limited Data Utilization – Existing system data on tote flow is not leveraged to optimize replenishment schedules.
3. Inefficient Bottleneck Analysis – No systematic method to continuously assess and improve the tote replenishment process.

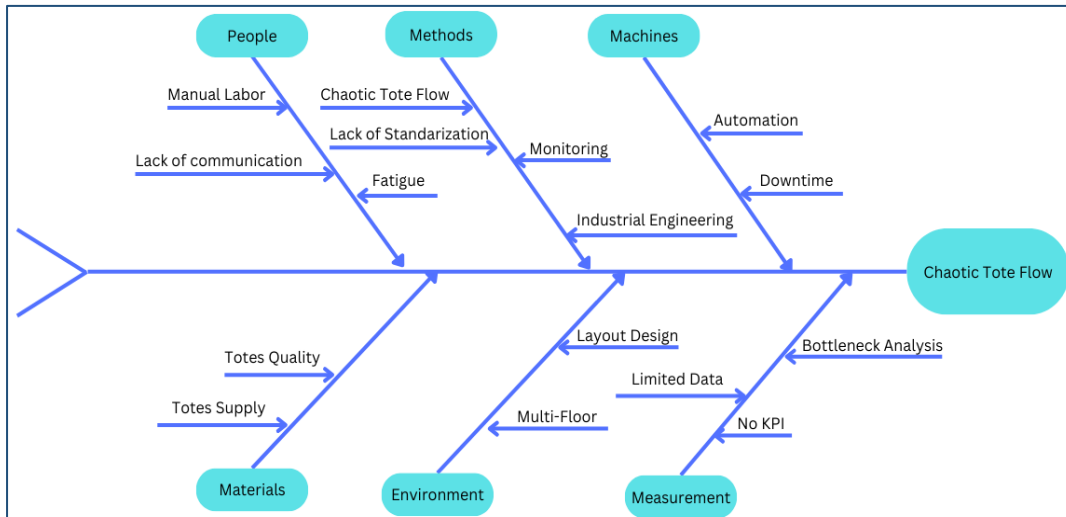


Figure 34 Ishikawa Diagram for Totes Replenishment Process
(Source: own elaboration)

The root cause of the inefficiencies in the tote replenishment process is the chaotic movement of tote flow, caused by the lack of an automated or standardized system to manage and monitor tote replenishment needs in real time as clarified in the 5Why table below.

Table 4 5Why for tote replenishment process

Why question	Reason
Why is the tote replenishment process inefficient?	Because there is a lot of unnecessary movement and transportation of totes, which wastes time and resources
Why is there unnecessary movement and transportation of totes?	Because the tote flow is chaotic and unstructured, with totes being moved to full multi-stackers or areas where they are not immediately needed
Why is the tote flow chaotic and unstructured?	Because there is no real-time monitoring or system to track which multi-stackers need replenishment, leading to uncoordinated tote movement
Why is there no real-time monitoring or system to track tote replenishment needs?	Because the current process relies on manual communication and observation, which is prone to errors and delays
Why does the process rely on manual communication and observation?	Because the company has not implemented an automated or standardized system to manage tote replenishment, resulting in a chaotic movement of tote flow

(Source: own elaboration)

6.2.5 Spaghetti Diagram

In this section, the movement of workers will be analysed in detail using spaghetti diagram at each floor for one shift during off-Peak mode, this analysis will be helpful to identify the waste in movement, transportation, and time which will be presented in later sections with measured values on site.

As shown in Figure 35, the spaghetti diagram highlights several inefficiencies in the current layout and workflow. As workers enter the floor and proceed to the counter to begin operations, they are tasked with moving totes from the source and distributing them across 10 multi-stackers (yellow blocks) using a U-boat. However, the diagram reveals wasted movement during the loading and unloading of the U-boat, as well as during the recharging process from the source. Additionally, there is noticeable uncertainty in the workers movements towards either full or empty multi-stackers. This uncertainty is compounded by the inability of pickers to record the need for tote support, leading to unrecorded demands for empty multi-stackers and a lack of timely notifications for workers to refill the required multi-stackers. Consequently, this results in wasted transportation and inefficient movement between full multi-stackers and unrecorded demands, highlighting the need for a more streamlined and efficient workflow.

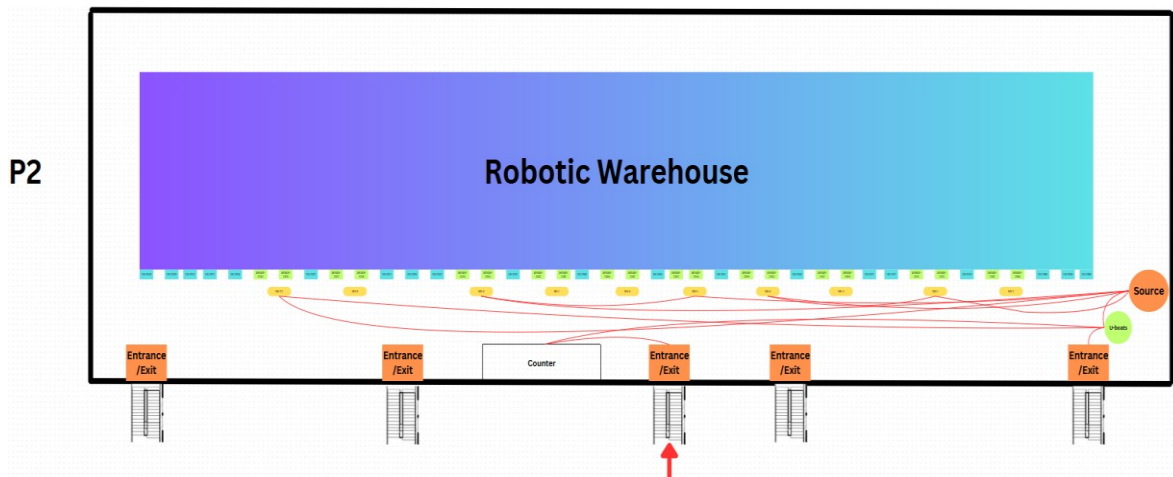


Figure 35 Spaghetti Diagram for One floor-off Peak mode
(Source: own elaboration)

During peak periods, the movement patterns of workers are similar to those observed during off-peak times except universal stations. However, the transport toward full Multi-Stackers will be less in percentage due to increased number of operational stations. While the Spaghetti diagram from the off-peak period can serve as a reference for an individual worker's movement during peak times, it does not fully capture the complexities introduced by the collective movements of multiple workers across the three floors. However, to calculate the expected waste captured during peak mode, it's possible to rely on the number of stations in operation between peak and off-peak modes, where workers behave in similar pattern, except the fact of higher number of stations in operation and number of workers.

As illustrated in Figure 36, the diagram provides an explanation of the Spaghetti diagram, depicting movement across all three floors. This movement pattern closely resembles the case study conducted on the second floor. However, usually workers are distributed to carry the duty of one floor and half only, but that might be a subject of change depending on various demands.

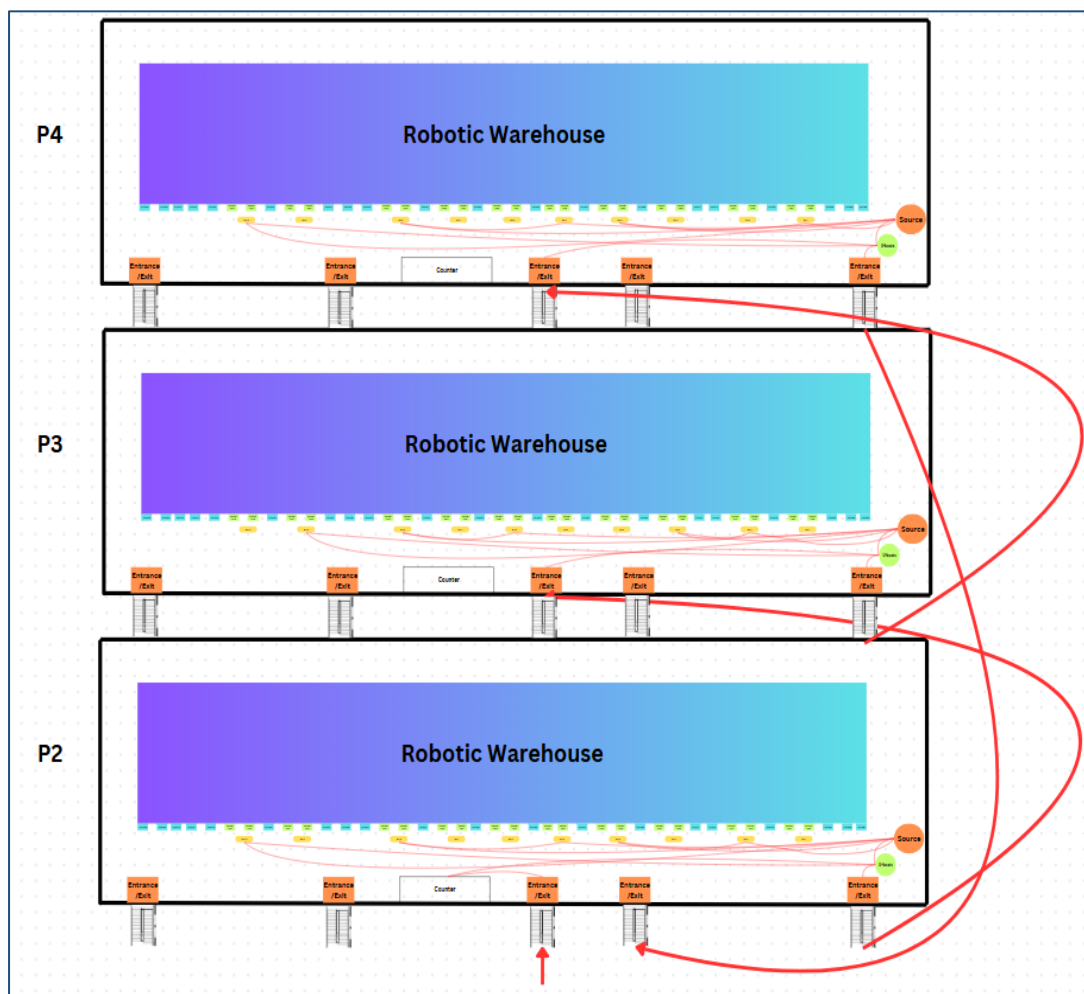


Figure 36 Spaghetti Diagram for 3 Floors-off Peak mode
(Source: own elaboration)

6.2.6 Process Analysis

To gain a comprehensive understanding of the current process, a process analysis tool was employed to track and monitor the manual replenishment of totes over a complete cycle, out of a total of nine cycles conducted during the day shift. The data was collected by tracking the movement of the tote runner across all three floors. The recorded information, including time and distance metrics for the entire process, is detailed in Appendix 1. The analysis indicates that a single replenishment cycle takes approximately one hour, with a total walking distance of 1.5 km, excluding movement between floors. However, certain inefficiencies, such as wasted movement and transport during storage (specifically in the loading and unloading phase of U-boats' contents to multi-stackers), were identified but not factored into the calculation.

Based on this data, the total walked distance for one worker across all nine cycles is 13.5 km. Additionally, the analysis accounts for the total distance walked by all workers during a full shift, which will be further examined later in this thesis.

The total transportation of two workers considering off peak mode results in 27 km during one working shift, big portion of this distance is considered an unnecessary transport which will be evaluated later against proposed solutions in this thesis.

6.2.7 Waste Map

The table 5 below presents an evaluation of different types of waste identified in the manual replenishment process of totes within the distribution center. This assessment was conducted as part of a collaborative effort between the author of this thesis and the area manager, with the primary objective of identifying inefficiencies and areas for potential process improvement. Each type of waste was assessed on a scale from 1 (Low Waste) to 10 (Maximum Waste) based on its impact on operational efficiency, with evaluations weighted 80% for the area manager and 20% for the student to prioritize practical experience while incorporating an analytical perspective. The final points column reflects the weighted score assigned to each waste type. The analysis revealed that Transport (Score: 9/10) and Unnecessary Movement (Score: 9/10) were the most critical inefficiencies, while Overproduction (Score: 2/10) had the lowest impact. This structured analysis provides a data-driven understanding of waste in the replenishment process, laying the foundation for targeted optimization strategies. The focus will be on minimizing high-impact inefficiencies such as transport and unnecessary movement while also addressing other forms of waste to

improve overall workflow efficiency. Further details on proposed improvements will be discussed in subsequent sections of this thesis.

The points for each waste in Table 5 is calculated using the following formula:

$$y_{points} = \frac{w_1 * y_1 + w_2 * y_2}{w_1 + w_2} \quad (2)$$

Table 5 Waste map with evaluation matrix

Waste number	Category	Description	Evaluation of Area Manager (80%)	Evaluation of Student (20%)	Points
1	Transport	Long walked distances to move the totes	9	9	9
2	Unnecessary movement	Excessive bending, reaching, or carrying totes manually	9	7	9
3	Waiting	Pickers waiting for totes to be replenished	4	4	4
4	Defects	Misplaced or damaged totes	4	4	4
5	Overprocessing	Unnecessary handling of totes	3	2	3
6	Excess inventory	Overstocking totes at the picking station	3	2	3
7	Overproduction	Replenishing totes before needed	2	2	2

(Source: own elaboration)

6.2.8 Workday Analysis

Table 6 provides a detailed analysis of waste during off Peak mode for one shift at the Picking department depending on data collected on February 8, 2025. The analysis was collected by recording the movement of one worker or tote runner, furthermore it categorizes activities as Value-Adding (VA) or Non-Value-Adding (NVA) based on their contribution to the overall process.

The total shift time analysed was 9 hours, 33 minutes. Out of this, only 4 hours (42%) were spent on value-adding activities, specifically loading, and unloading on a U-boat, regardless of the unnecessary movement that isn't captured in this thesis. The remaining 5 hours, 41 minutes (58%) were considered wasted time, primarily due to non-value-adding activities such as getting ready, transporting towards full multi-stackers, moving to the next floor, and breaks.

Table 6 Workday analysis of waste during one shift-off Peak mode

Date: 08. Feb.2025	Monitoring List	List no: one
Shift: Day shift		
(From - To): 7:00 - 17:10		
Workplace: Picking dep.		Monitored by: Ghaith Ashqar
Consumed product: Totes		Monitored: Tote Runner
Progressive time	Description	Activity added value
0:15:13	Getting ready	NVA
4:00:00	Loading/Unloading on U-boat	VA
4:15:00	Transport towards full MS	NVA
0:11:00	Move to next floor	NVA
1:00:00	Break	NVA

(Source: own elaboration)

Each multi-stacker mentioned in this case study was replenished for 9 times or cycles during one shift. However, the time spent for one cycle of replenishment for all within all 3 floors is around 1 hour.

This analysis highlights significant inefficiencies in the process, with more than half of the shift time being non-productive. Addressing these inefficiencies could lead to substantial improvements in productivity and resource utilization.

The piechart in Figure 37 visually represents the time spent on different activities using color-coded segments, the chart effectively shows how time is distributed across different work activities. It's clear that (Transport towards full MS) is the most significant non-added value activity, taking up 4 hours and 15 minutes, the largest portion of the process. This represents a major inefficiency and a prime target for waste elimination in this thesis.

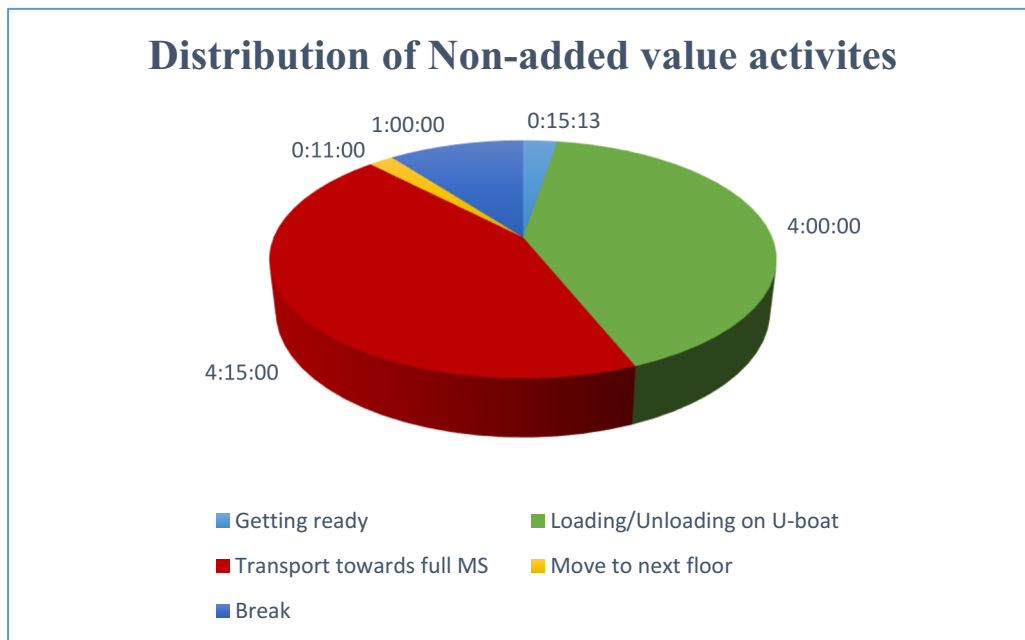


Figure 37 Pie chart of Non-added value activities considering consumed time
(Source: own elaboration)

6.3 Cost of Totes Supplement

The cost calculation is based on the number of workers, hours per shift, the number of shifts, hourly labour costs, and the number of days worked per year.

The number of workers or tote runners is calculated based on the number of stations in operation. However, the standard ratio for calculating the number of workers is one worker for each 15 ARSAW stations and 1 worker for 4 Universal Stations.

The total cost of manual labour is approximated to be 7.83 million Kč without VAT annually. Therefore, this assessment can be analysed and divided over two operational modes: Peak Mode and Off-Peak Mode, each with different workforce requirements and annual working days.

6.3.1 Peak Mode

During peak periods, the total number of operational stations is 60 ARSAW stations, requiring four tote runners per station, and 20 Universal stations, requiring five workers each. This results in a minimum requirement of 9 tote runners during peak mode. Each worker operates for 9.67 hours per shift across two shifts per day.

The hourly labour cost, as provided by the company's payroll specialist, is 300 Kč without VAT. Peak mode remains active for 90 days per year. Based on these parameters, the total labour cost incurred during peak periods amounts to 4,699,620 Kč without VAT per year, further clarification of this calculation is shown in equation below.

$$TC = N1 * N2 * N3 * N4 * HC \quad (3)$$

TC: Total Labour Cost

N1: Number of Workers

N2: Number of Hours per One Shift

N3: Number of Shifts

N4: Number of days per year

HC: Hour Cost

$$TC_p = 9 * 9.67 * 2 * 90 * 300 = 4,699,620 \text{ CZK/Year}$$

6.3.2 Off Peak Mode

In off-peak periods, fewer workers are required to manage the tote supplementation process for the 30 ARSAW stations. Only 2 workers are assigned per shift, but they maintain the same 9.67-hour shift structure across two shifts per day. The hourly labour cost remains 300 Kč without VAT, but off-peak mode operates for a significantly longer duration of 270 days per year. As a result, the total labour cost in this mode is 3,133,080 Kč without VAT.

$$TC_{OP} = 2 * 9.67 * 2 * 270 * 300 = 3,133,080 \text{ CZK/Year}$$

7 DETERMINE KEY IMPROVEMENT INDICATORS

The optimization of the tote replenishment process within the distribution center is aimed at enhancing time efficiency at picking department by using JIT, reducing costs, and minimizing unnecessary transportation waste. The primary indicator for monitoring improvements is the tote replenishment time and improving it by 10% reduction compared to current situation. By focusing on this primary goal, improvements in other areas will naturally follow.

In case of implementing an optimized manual totes flow, then the main monitored metric is the non-added value recorded time captured in section 6.2.7 in Table 6, where mentioned the transportation towards full multi-stackers and reducing it further for at least 10% of total time per shift. However, if automated solution will be considered, then main factor to be monitored include tote throughput rate per hour, and labour cost reduction.

Cost reduction is a natural outcome of these improvements, with a targeted 10% decrease in annual labour costs. Additionally, reducing unnecessary transport within the 150-meter replenishment path will minimize transportation waste. The subsidiary goal is to cut excess transport by 20% by strategic JIT replenishment planning.

By implementing these improvement measures, with a strong focus on reducing tote replenishment time as the primary KPI, the tote replenishment process will become more streamlined, cost-effective, and less labour-intensive, ultimately enhancing overall operational efficiency within the distribution center.

8 SUMMARY OF THE RESULTS OF PERFORMED ANALYSIS

The study primarily examines the picking department, where tote replenishment is a critical yet problematic operation. The analysis aims to reduce time loss, costs, and unnecessary transport.

The chapter examines two modes of operation: peak mode, during which all stations operate at full capacity, increasing the need for tote replenishment, and off-peak mode, where fewer stations operate, requiring a lower volume of totes but still facing inefficiencies. The Ishikawa diagram analysis identifies key inefficiencies in the tote replenishment process, with the main cause of chaotic transportation of the replenishment process. The tote replenishment system is mapped using process maps and spaghetti diagrams to track unnecessary transportation. A workday analysis highlights the excessive time spent on non-value-added activities with a remarked 58% of wasted time including break time and identified unnecessary transport. The cost of tote supplementation is also examined, showing that in peak mode, high labour costs result from more workers being required per shift, whereas in off-peak mode, fewer workers are needed, but inefficiencies over a longer operational period led to higher overall costs, which result in a total of 7.83 million Kč without VAT.

The analysis concludes that the manual replenishment process is a major bottleneck, leading to wasted time and increased costs. The inefficiencies identified serve as a basis for proposed improvements, such as implementing automated conveyor systems for tote movement, adjusting buffer capacity to reduce unnecessary tote handling, and applying Just-In-Time (JIT) replenishment strategies to optimize supply flow. This chapter sets the foundation for the suggested improvements in the following sections of the study.

9 SUGGESTIONS FOR IMPROVEMENTS

To enhance the efficiency of the tote replenishment process in the distribution center, two improvements are proposed. These improvements focus on automation, process optimization, and real-time monitoring to eliminate inefficiencies and streamline operations.

The first improvement involves the implementation of an automated conveyance system, such as conveyor belts. By replacing manual tote transportation with automation, unnecessary movement and delays can be eliminated. This system ensures a steady and reliable supply of totes to picking stations, reducing reliance on human labour, and minimizing errors. Automation will lead to significant cost savings and increased operational efficiency.

Another alternative improvement is optimizing buffer capacity near picking stations. By adjusting the buffer storage system, totes can be supplied precisely when needed, preventing delays caused by shortages. This strategy aligns with Just-In-Time (JIT) principles, ensuring that totes are available without excessive handling or storage. A well-structured buffer improves workflow consistency, leading to decreased transport and saved process time.

Additionally, implementing lean logistics principles such as Kaizen will help in continuously optimizing the replenishment process. These methodologies ensure that resources are allocated efficiently, and workflows remain streamlined. These improvements are expected to deliver substantial benefits, reduced labour costs, and increased accuracy in tote replenishment. By adopting these strategies, the distribution center will achieve a smoother, more reliable, and cost-effective replenishment process, contributing to overall productivity gains.

10 PROJECT DEFINITION

This section introduces project workshop of required members, timeline plan, and risk analysis of suggested improvements. Each solution is planned separately in the following modules.

10.1 Project List

The following capitols include a list of participants for realization of suggested improvements of automated and manual optimization solutions.

10.1.1 Conveyance System

Table 7 illustrates primary list of project components for clarity of scope of work to implement Conveyance System.

Table 7 Project List of Conveyance System

Project List	Description
Main Objective	Proposal for optimized manual replenishment process with time saving of at least 10%
Secondary Objectives	Decrease cost by at least 10%, reduce tote transportation time by at least 20% per shift
Project Team	Area Manager, Process Engineer: Ghaith Ashqar, IT Specialist, Financial Analyst
Project Budget	Investment for payback period of maximum 3 years

(Source: own elaboration)

Table 8 Implementation of SMART for Conveyance System solution

SMART	Description
Specific	Implement an automated conveyance system (Roller Conveyor) to replace manual tote replenishment
Measurable	Time saving factor by at least 10%, reduce tote transportation time by at least 20% per shift and decrease manual labour costs with ROI of 2-3 years at maximum, which is a standard limit for investment at the company
Attainable	The project aligns with available budget constraints and facility layout. Feasibility studies indicate that the conveyor system can be installed without major disruptions. Maintenance requirements are manageable, with industry-standard solutions available
Relevant	Current solution directly addresses inefficiencies in manual tote replenishment, reducing labour dependency and improving the automation of workflow. It supports lean logistics principles and aligns with the company's and thesis goal of time optimization and cost reduction
Time Bound	Full project implementation during 2026

(Source: own elaboration)

10.1.2 Buffer Capacity Adjustment

Table 9 illustrates primary list of project components for clarity of scope of work to implement Buffer Capacity Adjustment.

Table 9 Project List of Buffer Capacity Adjustment

Project List	Description
Main Objective	Proposal for optimized manual replenishment process with time saving of at least 10%
Secondary Objectives	Decrease cost by at least 10%, reduce tote transportation time by at least 20% per shift
Project Team	Area Manager, Process Engineer: Ghaith Ashqar, IT Specialist, Financial Analyst
Project Budget	Investment for payback period of maximum 3 years

(Source: own elaboration)

Table 10 Implementation of SMART for Buffer Capacity Adjustment

SMART	Description
Specific	Optimize the tote buffer system by dynamically adjusting storage capacity based on peak and off-peak operational demands
Measurable	Time saving factor by at least 10%, reduce tote transportation time by at least 20% per shift and decrease manual labour costs with ROI of 2-3 years at maximum, which is a standard limit for investment at the company
Attainable	Utilize existing U-boats and multi-stackers storage to implement buffer adjustments with minimal investment, introduce real-time monitoring (smart watch alerts + indicator lights) to track buffer levels efficiently
Relevant	Aligns with the lean logistics approach to reduce waste and enhance operational efficiency, supports the Just-In-Time (JIT) methodology, ensuring totes are supplied only when needed. Directly reduces manual labour dependency and optimizes workforce allocation
Time Bound	Full project implementation during 2025

(Source: own elaboration)

10.2 Project Schedule

The provided timeline for both the buffer capacity adjustment and the conveyance system implementation have been developed to outline the structured approach for their execution. These schedules detail the key phases, expected durations, and necessary steps to ensure efficient implementation (See Appendix PII and PIII)

10.3 Risk Analysis

The RIPRAN method is a structured approach to risk management. Below is a risk analysis for the two proposed solutions: Conveyance System and Buffer Capacity Adjustment.

10.3.1 Conveyance System

The implementation of a conveyance system in the distribution center introduces several potential risks that need to be carefully managed. Technical failures are a concern, as the conveyor system may experience mechanical or electrical issues, leading to operational downtime. Integration issues could arise due to difficulties in aligning the new system with the existing warehouse infrastructure, potentially causing delays and inefficiencies. Safety hazards are another risk, as the automated system's moving parts could pose dangers to workers if not responsibly managed. Additionally, the high initial investment required for the conveyor system could strain financial resources, while maintenance costs might exceed expectations, adding to long-term operational expenses. Operational disruptions during the installation and testing phases could temporarily hinder normal operations, and there is a risk that the system may not adequately handle peak demand, leading to inefficiencies during high-volume periods (See Table 11).

Table 11 Risk Identification and description

Risk Identification	Description
Technical Failures	The conveyor system may experience mechanical or electrical failures, leading to downtime
Integration Issues	Difficulty in integrating the conveyor system with existing warehouse infrastructure
Safety Hazards	Potential safety risks for workers due to moving parts and automated systems
High Initial Investment	The capital cost of installing the conveyor system is significant
Maintenance Costs	Ongoing maintenance and repair costs could be higher than anticipated
Operational Disruptions	Installation and testing phases may disrupt normal operations
Inadequate Capacity	The conveyor system may not handle peak demand efficiently

(Source: own elaboration)

The risks associated with the conveyance system implementation are categorized based on their probability and impact according to Ripran. High Probability (HP) risks include high initial investment and operational disruptions, as these are almost certain during the initial phases of the project. Medium Probability (MP) risks encompass technical failures, maintenance costs, and integration issues, which are likely but not guaranteed. Low Probability (LP) risks involve safety hazards and inadequate capacity, which are less likely but still possible. This assessment helps prioritize which risks require immediate attention and which can be monitored over time (See Table 12).

Table 12 Risk Assessment

Probability Category	Risk
High Probability (HP)	High Initial Investment, Operational disruptions, Integration issue
Medium Probability (MP)	Technical failure, Maintenance cost
Low Probability (LP)	Safety hazard, Inadequate capacity

(Source: own elaboration)

The impact of each risk is also categorized to understand its potential severity. High Impact (HI) risks, such as safety hazards, could have severe consequences for worker safety and operational continuity. Medium Impact (MI) risks include integration issues and maintenance capacity, which could disrupt operations but are manageable with proper planning. Low Impact (LI) risks, such as technical failures, high initial investment, maintenance costs, and operational disruptions, are less severe but still require mitigation plan to ensure smooth implementation and operation of the conveyance system. This categorization helps in developing targeted strategies to address the most critical risks first (See Table 13).

Table 13 Impact Categories

Impact Category	Risk
High Impact (HI)	Safety hazards
Medium Impact (MI)	Integration Issue, Inadequate capacity
Low Impact (LI)	Technical failure, High Initial Investment, Maintenance Costs, Operational disruptions

(Source: own elaboration)

The risk value determination table below evaluates the identified risks based on their probability and impact, assigning a risk value to each. Technical failures are categorized as Low Risk (LR) due to their medium probability and low impact, while integration issues are also Low Risk because of their low probability and medium impact. Safety hazards are classified as Medium Risk (MR) due to their low probability but high impact, which could significantly affect worker safety. High initial investment and operational disruptions are both Medium Risk because of their high probability, even though their impact is low. Maintenance costs are Low Risk (LR) due to their medium probability and low impact, and inadequate capacity is Medium Risk (MR) because of its medium probability and medium impact. This categorization helps prioritize risks and focus mitigation efforts on the most critical areas.

Table 14 Risk Value Determination

Risk Identification	Probability	Impact	Risk Value
Technical Failures	MP	LI	LR
Integration Issues	LP	MI	LR
Safety Hazards	LP	HI	MR
High Initial Investment	HP	LI	MR
Maintenance Costs	MP	LI	LR
Operational Disruptions	HP	LI	MR
Inadequate Capacity	MP	MI	MR

(Source: own elaboration)

The Risk Response table outlines mitigation plans for each identified risk (See Table 15). For technical failures, regular maintenance schedules and backup systems are recommended to minimize downtime. Integration issues can be mitigated by conducting thorough testing, simulations, and pilot runs before full implementation. Safety hazards require worker training and the installation of safety guards to reduce risks. To address high initial investment, securing funding and ensuring a return on investment (ROI) that covers expenses is essential. Maintenance costs can be managed by allocating a budget for ongoing maintenance and training staff for minor repairs. Operational disruptions should be minimized by scheduling installation during off-peak periods. Finally, to handle inadequate capacity, the system should be designed with scalability in mind to accommodate future demand. These mitigation plans aim to reduce the likelihood and impact of each risk, ensuring a smoother implementation process.

Table 15 Possible Mitigation plans for identified risks

Risk Identification	Mitigation Plan
Technical Failures	Implement regular maintenance schedules and have backup systems in place for expected downtime of 2hrs/month
Integration Issues	Conduct thorough testing, simulations and pilot runs before full implementation
Safety Hazards	Provide training for workers and install safety guards
High Initial Investment	Secure funding and ensure ROI to cover expenses
Maintenance Costs	Allocate a budget for ongoing maintenance and train staff for minor repairs
Operational Disruptions	Schedule installation during off-peak mode for off stations to minimize disruptions
Inadequate Capacity	Design the system with scalability in mind to handle future demand

(Source: own elaboration)

10.3.2 Buffer Capacity Adjustment

The implementation of an adjusted buffer capacity solution in the distribution center introduces several potential risks that need to be carefully managed. Human error is a significant concern, as manual processes are prone to mistakes, leading to incorrect tote replenishment. Workforce coordination issues could arise due to miscommunication between tote runners, causing inefficiencies. Real-time monitoring failures are another critical risk, as the system for tracking tote levels may experience technical issues.

Buffer overload could occur if the system is not effectively managed, leading to congestion and inefficiency. Training requirements for workers to adapt to the new system may be extensive, and system downtime could disrupt operations. Additionally, inconsistent tote quality, such as damaged or incorrect totes, could further complicate the replenishment process.

Table 16 Risk Determination Value

Risk Identification	Probability	Impact	Risk Value
Human Error	HP	LI	MR
Workforce Coordination	LP	LI	LR
Real-Time Monitoring	MP	MI	MR
Buffer Overload	MP	LI	LR
Training Requirements	MP	LI	LR
System Downtime	LP	LI	LR
Inconsistent Tote Quality	LP	LI	LR

(Source: own elaboration)

A mitigation plan is also provided, detailing strategies to address each risk. For example, human error is mitigated through double-check systems, while workforce coordination issues are addressed by improving communication channels. The plan ensures that risks are managed effectively, minimizing disruptions, and enhancing the efficiency of the buffer capacity solution (See Table 17).

Table 17 Possible mitigation plans for identified risks

Risk Identification	Mitigation Plan
Human Error	Implement double-check systems and provide clear guidelines for tote replenishment
Workforce Coordination	Improve communication channels and conduct regular team briefings
Real-Time Monitoring	Have backup manual systems in place and regularly test the monitoring tools
Buffer Overload	Set clear buffer capacity limits and monitor stock levels continuously
Training Requirements	Provide training sessions and refresher courses
System Downtime	Ensure the monitoring system has redundancy and can switch to manual mode if needed
Inconsistent Tote Quality	Regularly inspect totes and replace damaged ones immediately

(Source: own elaboration)

10.3.3 Risk Analysis Conclusion

The risk analysis conducted for the two proposed solutions—Conveyance System and Buffer Capacity Adjustment—reveals several risks that need to be managed to ensure successful implementation and long-term operational efficiency. Both solutions aim to optimize the tote replenishment process in the distribution center, but each comes with its own set of challenges and potential pitfalls.

Conveyance System Risks

The implementation of an automated conveyor system introduces risks such as technical failures, integration issues, and safety hazards. These risks are primarily related to the mechanical and operational aspects of the system. The high initial investment and potential for operational disruptions during installation are also significant concerns. However, with proper mitigation strategies—such as regular maintenance, thorough testing, and worker training—these risks can be effectively managed.

Buffer Capacity Adjustment Risks

The adjustment of buffer capacity, while less capital-intensive, introduces risks related to human error, workforce coordination, and real-time monitoring failures. These risks are more focused on the human and procedural aspects of the solution. The reliance on manual processes including human errors and the down time for monitoring system for totes level could impact the success of this solution. Mitigation strategies, such as implementing double-check systems, improving communication channels, and ensuring backup monitoring systems, are essential to minimize these risks.

Comparative Analysis

Conveyance System: Offers a more automated and long-term solution but requires significant upfront investment and careful management of technical and safety risks.

Buffer Capacity Adjustment: Provides a quicker, cost-effective solution but relies more on human processes and coordination, which could lead to inefficiencies if not properly managed.

Final Recommendation

Both solutions have their merits and challenges. The Conveyance System is ideal for long-term efficiency and scalability, especially in high-demand environments, while the Buffer Capacity Adjustment is better suited for immediate cost savings and operational improvements with minimal investment. A hybrid approach, combining elements of both solutions, could provide a balanced strategy, leveraging the strengths of each while mitigating their respective risks.

In conclusion, the risk analysis highlights the importance of careful planning, continuous monitoring, and proactive risk management to ensure the successful implementation of either solution. By addressing the identified risks and implementing the recommended mitigation strategies, the distribution center can achieve significant improvements in operational efficiency, cost savings, and overall productivity.

11 IMPLEMENTATION OF PROPOSALS

As the situation was analysed, it is possible to address the problem with the following solutions considering calculated percentage of reduced identified waste.

SMART method is used in both solutions separately as a project management method to help for identifying the most efficient solution to be implemented for defined problem.

11.1 Conveyance System

First solution is an automated method of totes supplement; therefore, it is essential to understand the possibility of implementing the solution within a specified geometry, safety, and cost constraints.

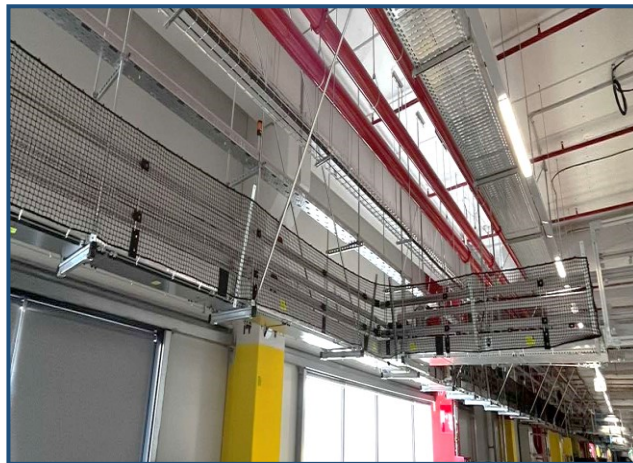


Figure 38 Existing Conveyor at Selected Distribution Center for leaving totes from picking department
(Source: own elaboration)

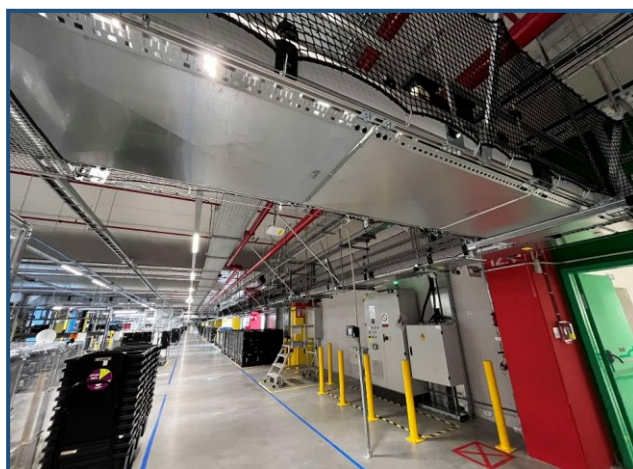


Figure 39 Merger Conveyor feeding main Conveyor leaving picking station
(Source: own elaboration)

11.1.1 Considerations for the Implementation of a Conveyance System

The Conveyor Belt will cover a total distance of 150 meters, exclusively serving the picking department as highlighted in the designated “Focus Area”. The system will begin at the first picking station and extend to the last station, ensuring a seamless flow of totes while avoiding any intersections with the red pipelines in the ceiling.

To facilitate the effective implementation of the conveyance system, a detailed floor layout must be reviewed, outlining the designated construction areas. The Focus Area represents a section of the picking department, as illustrated in Figure 40. This layout serves as a reference, and the same design principles should be consistently applied across the entire distribution center to maintain uniformity and efficiency.

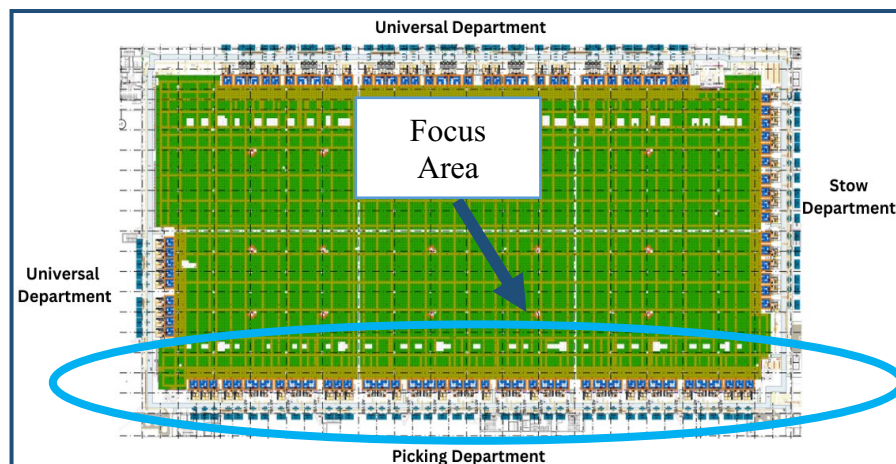


Figure 40 Focus Area With Defined Layout Modules
(Source: own elaboration)



Figure 41 Top View of Floor Plan (1st Floor)
(Source: own elaboration)

The feasibility of implementing a conveyance system must be assessed based on the following key factors:

1. Location & Distance

The proposed conveyance system will be installed on the first floor, beginning at the totes source, and extending to the latest multi-stacker. The system must span a total distance of 150 meters to ensure efficient material flow.

2. Shape & Optimization

Feeding the multi-stackers through the conveyance system presents certain challenges. However, optimization of the conveyor's design is possible by considering multiple factors, including:

- The feeding point from the source.
- The distance to the first multi-stacker.
- The position and accessibility of each multi-stacker.
- Ensuring a continuous flow of totes to all multi-stackers.

To maximize efficiency and minimize space constraints, the conveyance system should be installed near the ceiling at a specified height from the floor. This placement will enhance operational flow while maintaining accessibility.

3. Emergency Pipelines in the Ceiling

It is crucial to maintain a safe distance from the red emergency pipelines installed at the ceiling. The design must ensure that the conveyance system does not interfere with these pipelines while also providing easy access for maintenance or in case of downtime. A suitable construction approach must be adopted to prevent disruptions in the tote flow.

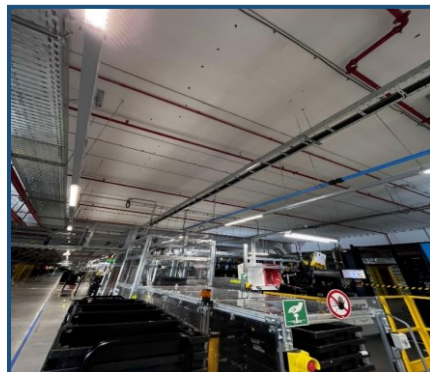


Figure 42 Red Pipelines at the Ceiling
(Source: own elaboration)

11.1.2 Financial analysis

The implementation of a 150-meter conveyor belt system in a distribution center requires investment in equipment, installation, maintenance, and operational costs. Below is an estimated cost breakdown and potential savings for total cost of 6.9 million Kč without VAT for three floors within the distribution center.

1. Capital Investment

The cost of conveyor components per meter depends on system length and complexity. However, the product cost is measured based on provider JVM Metal Technology, who offers this service of 150-meter roller conveyor for cost of two million Kč including VAT and installation costs for one floor. However, to implement this technology for all three floors, the total one-time cost will go up to six million Kč.

2. Operational and Maintenance Expenses

Annual maintenance costs according to JVM for downtime, including inspections, belt adjustments, and part replacements, are expected to be 500,000 Kč without VAT approximately, electricity consumption for motorized conveyors is estimated at Kč without VAT 400,000 per year.



Figure 43 Example of Roller Conveyor offered by JVM Metal Technology s.r.o

(Source: JVM Metal Technology, 2025)

11.1.3 Time analysis

The time it takes to deliver the same demand of totes to required destination using the conveyor system is analysed for both time modes.

Off peak mode

The system will use automatic sorting and redirection to distribute totes without delays, the total time taken using conveyor rollers to fill thirty stations in off peak mode is around 3.5 hours for all three floors simultaneously.

This analysis is calculated based on the following factors:

- Number of operating multi-stackers in off peak mode (OM15): 15 (OM5: 5 MS/Floor)
- Maximum totes demand during off peak mode per shift of one floor (TD): 3775 totes (See 6.1.2).
- Maximum totes demand during off peak mode per one multi-stacker (TD_{ms}):

$$TD_{ms} = \frac{TD}{OM_5} = 755 \text{ totes} \quad (4)$$

- Expected travel distance by conveyor for running closest ten stations to source within one floor (D₅₀): fifty meters.
- Minimum required Conveyor speed (CS): 3 m/s (10.8 Km/hr).
- Calculated time based on mentioned distance and speed until last station of fifty meters (T₅₀): 16.6 Seconds.

$$T_{50} = \frac{D_{50}}{CS} = \frac{50}{3} = 16.66 \text{ Seconds} \quad (5)$$

- One tote will take maximum of 16.66 Seconds to reach latest assigned station, relatively considering a full replenishment of furthest station:

$$\text{Total Replenishment Time (In hours)} = TD_{ms} * T_{50} = 3.5 \text{ Hours}$$

- Calculated total time depending on required number of totes supplied to last reached station for fifty meters: **3.5 hours.**

In other words, the total time required to fill the same demand of totes in comparison to manual labour which lasts for 9.67 hours is only 3.5 hours by automated system.

By implementing an automated conveyor system with the Just-In-Time (JIT) method, tote distribution becomes faster compared to manual labour.

11.1.4 Process Map

Off peak mode

The process is clarified as follows for off peak mode only without visual representation:

1. Totes loaded onto the conveyor at the source point.
2. Conveyor transports totes along only operation within first 50 meters.
3. Tote distribution begins as the conveyor approaches the first multi-stacker.
4. Automated sensors detect tote levels at each multi-stacker.
5. If the multi-stacker needs totes, the conveyor system directs the required totes to the stacker.
6. If the multi-stacker is full, totes continue to the next stacker.
7. Process repeats for all 5 multi-stackers along the conveyor path.
8. The conveyor continuously operates, ensuring a steady flow of totes without manual intervention.

11.2 Buffer Capacity Adjustment

To maintain an efficient and streamlined tote management system, it is essential to adjust buffer capacity based on operational demand. The system should be flexible enough to accommodate fluctuations in workload, ensuring optimal tote availability while preventing excess storage that could decrease productivity.

By strategically managing buffer levels during peak and off-peak periods, the warehouse can maximize space utilization, reduce congestion, and enhance the overall flow of operations.

11.2.1 Peak & Off Peak Modes Buffer Requirements

To optimize the buffer system during peak operations, a decision must be made regarding the use of U-boats or pallets for tote transportation and storage. The correct number of totes to be held on each floor should be determined based on the required number of pickers and their productivity rates. The following calculations are based on a three-floor system.



Figure 44 U-boats as buffers of increased capacity Infront of stations

(Source: own elaboration)

Since U-boats are easier to move and manipulate, they are chosen as a solution to increase buffers capacity over traditional pallets and they will be placed in front of each station directly as shown in the Figure 44.

Total required number of totes during peak mode to be covered at each floor is at maximum value of 8977 totes per shift as recorded previously (See 6.1.1). However, since U-boats can carry a maximum of 48 totes, then required U-boats will be approximately **187 U-boat** for each floor per shift (561 U-boats for 3 floors). This results in using 19 U-boats as a safety stock in designated area shown in Figure 44 each shift for one floor. However, for off peak mode the tote demand for each floor per shift is 3775 totes (See 6.1.2). Therefore, only 79 U-boats (237 U-boats for 3 floors) will be required for each floor during off peak mode, which is approximately 6 U-boats at each designated area in front of operating stations respectively. However, currently there is 60 U-boats designated for picking department distributed over the floors, therefore, it will be required to order **501 U-boats** in order to implement buffer capacity adjustment solution.

Always after consumption of 50% of totes, tote runners are alerted to replenish consumed totes by additional 50% from source, this should be done twice at the beginning and half of the shift.

By scaling buffer capacity based on demand, the warehouse can optimize resource allocation while maintaining a just-in-time (JIT) approach for tote replenishment. This ensures that totes are supplied efficiently without excessive build-up, improving space utilization and operational flow.

11.2.2 Financial analysis

The implementation of the proposed solution involves several cost components. The U-boats each at price of 5400 Kč without VAT based on internal information at the company. Depending on required number of 501 U-boats, the total investment will be 2,705,400 Kč without VAT, additionally smartwatch alert system for tote runners, requiring 9 devices (for ex. Apple watch SE), is estimated to cost 36,000 Kč without VAT in total for all the 9 watches. System integration and training are expected to incur costs of 100,000 Kč Without VAT based on internal information at the company.

The total estimated one time cost of investment clarified above is expected to be 2,841,400 Kč without VAT.

In case of off peak mode, the number of workers required to perform the stacking will be less than what currently required, using increased buffer capacity and JIT totes replenishment will deduct the travel toward full multi-stacker which occupies 44% of total wasted time (See 6.2.5), therefore having only half of the number of workers for off peak mode that is only one worker should be able to carry out the work.

Subtraction of one worker should be 522,180 Kč without VAT, this calculation includes the current cost for one worker annually which is 522,180 Kč without VAT (See 6.3.2), and previous mentioned cost of one time investment.

The same calculation can be made for peak mode which will result in subtraction of half of the workers 2,349,810 Kč without VAT plus previous measured total of off peak mode and one time cost for required equipments, the final total cost of this solution includes (One time cost+Cost of workers during peak/offpeak modes), which is 5,713,390 Kč without VAT.

11.2.3 Time analysis

As analyzed in Table 6 (See Section 6.2.7), the expected total shift time for the adjusted buffer capacity will be reduced by 4 hours and 15 minutes. This reduction is attributed to the corrective nature of the movement, which aligns with Just-in-Time (JIT) principles, thereby minimizing non-value-added activities in the transportation toward full multi-stackers.

Transportation towards full multistackers will be totally eliminated and the resultant time to complete the demand of totes will be **5 hours and 26 minutes** as shown in Table 18.

Table 18 Time analysis of buffer capacity adjustment

Date: 08. Feb.2025	Monitoring List	List no: one
Shift: Day shift		
(From - To): 7:00 - 17:10		
Workplace: Picking dep.		Monitored by: Ghaith Ashqar
Consumed product: Totes		Monitored: Tote Runner
Progressive time	Description	Activity added value
0:15:13	Getting ready	NVA
4:00:00	Loading/Unloading on U-boat	VA
4:15:00	Transport towards full MS	NVA
0:11:00	Move to next floor	NVA
1:00:00	Break	NVA

(Source: own elaboration)

If we consider a speed of 3.5 km/hr for totes runner, the expected walked distance can be measured using similar approach as equation 4, therefore the walked distance will be approx. 19.25 km.

11.2.4 Process Map

To optimize operations at the distribution center, a Just-In-Time (JIT) approach should be integrated into the process, ensuring that totes are delivered only when needed, minimizing waste, and enhancing efficiency across all floors. Below is a structured process map with implementation steps at each floor.

- **Start of Shift & System Check**

1. Workers arrive and participate in a shift briefing that includes an overview of demand forecasts.
2. Area Manager assess tote availability based on expected pick rates to ensure sufficient supply.
3. Buffers are replenished at beginning and middle of the shift when reach 50% of totes consumption rate.
4. If the buffer capacity is full, area manager confirms the required number of U-boats based on the designated time mode (peak or off-peak).
5. Automated systems conduct a status check on Multi-stackers to prevent unnecessary tote accumulation.
6. Each Multi-stacker is pre-stocked with U-boats filled with totes at each floor:
 - Peak Mode: 19 U-boats stocked for the entire shift.
 - Off-Peak Mode: 6 U-boats stocked for the entire shift.
7. Tote Runner Allocation:
 - Peak Mode: 1-2 tote runners are assigned to each floor per shift to continuously monitor and track the process.
 - Off-Peak Mode: Only one tote runner manage all three floors, optimizing workforce allocation.
8. These U-boats remain available for tote runners to access as needed at the picking stations.

• Tote Allocation & Buffer Replenishment (JIT Integration)

Just-In-Time (JIT) system ensures that only the necessary number of totes (stacks) is deployed. At least two sets of stacks (24 totes) must be available at all times or 50% of capacity.

1. Multi-stackers are replenished dynamically based on real-time order demand instead of using fixed stocking numbers.
2. When at least 50% of a Multi-stacker's capacity is consumed, tote runners receive automated alerts for replenishment.
3. The system sends replenishment orders directly to the tote runner's smartwatch, specifying:
 - The exact location of the required Multi-stacker.
 - Instructions to proceed with replenishment.
4. The designated Multi-stacker turns red at the location where replenishment is required, making it easily identifiable.
5. The automated system optimizes replenishment orders by considering:
 - FIFO (First In, First Out) principles to maintain stock rotation.
 - The current location of the tote runner to minimize travel time and improve efficiency.

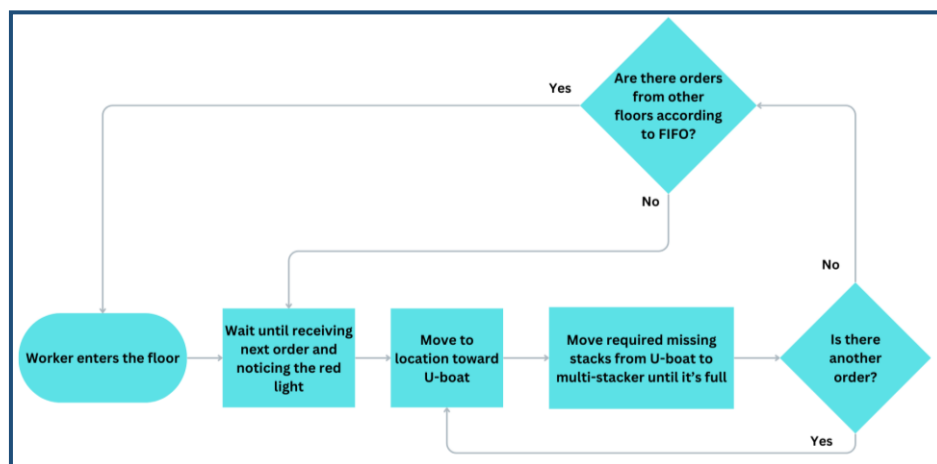


Figure 45 Process map for optimized manual tote replenishment in off peak mode

(Source: own elaboration)

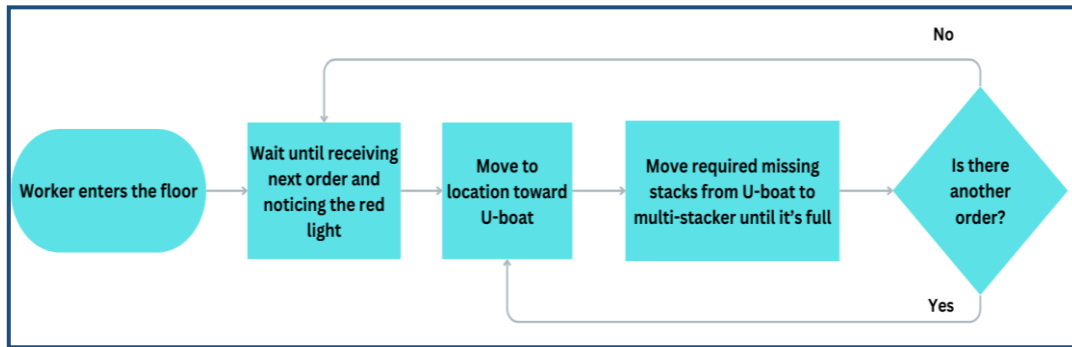


Figure 46 Process map for optimized manual tote replenishment in peak mode
(Source: own elaboration)

12 EVALUATION OF IMPLEMENTED SOLUTIONS

This section provides a detailed analysis of the outcomes of the implemented solutions, evaluating their impact on time efficiency, potential cost savings, and the elimination of unnecessary transportation. The assessment is conducted in comparison to the current situation, which serves as the baseline for evaluation.

Performance targets by minimum requirement:

- Total Time Reduction per shift: 10%
- Cost Reduction annually: 10%
- Transportation Reduction per shift: 20%

12.1 Time Evaluation

In this section, the saved time is analyzed against current situation as baseline and potential eliminated waste by each suggested solution.

Table 19 Potential time saving in comparison with current situation

Totes Replenishment Process	Baseline: Manual Process	1 st Solution: Conveyance System (Automated)	2 nd Solution: Buffer Capacity Adjustment
Shift time (Hour)	09:33:00	03:30:00	05:26:00
Reduced time (Hour)	0:00:00	06:03:00 ↑	04:07:00 ↑
Percentage of wasted time elimination	0%	63.1%	56.8%
Goal of time reduction by min. 10%	-	✓	✓

(Source: own elaboration)

12.2 Financial Evaluation

The evaluation of the proposed solutions for tote replenishment, Conveyance System and Buffer Capacity Adjustment requires a Return on Investment (ROI) analysis and pay back period. This analysis compares the total costs associated with each solution to the projected financial benefits.

Table 20 Financial Analysis and Comparison of Proposed Solutions vs. Baseline

Totes Replenishment Process	Baseline: Manual Process	1 st Solution: Conveyance System (Automated)	2 nd Solution: Buffer Capacity Adjustment
One time Cost (CZK without VAT)	-	6,000,000	2,841,400
Annual Cost (CZK without VAT)	7,832,700	900,000	2,871,990
Total Investment (CZK without VAT)		6,900,000	5,713,390
Annual Savings- Profit (CZK without VAT)	-	6,932,700 ↑	4,960,710 ↑
Payback period (Max. 2-3 years)	-	0.87 year	0.57 year
Percentage of reduced cost (After Payback period)	0%	88.5%	63.3%
Goal of cost reduction by min. 10%	-	✓	✓

(Source: own elaboration)

The profit is measured in comparison with existing budget for current manual totes replenishment that stands for 7,832,700 CZK without VAT subtracted by one time investment and/or operational annual cost as shown in the table 21 and 22, tables also illustrate ROI factor over the years with significant amount of savings in comparison to current cost.

Table 21 Financial Summary of ROI for Conveyance System

Year	Profit (CZK)	One time Investment (CZK)	Operational annual Cost (CZK)	ROI
1	932,700	6,000,000	900,000	13.51%
2	6,932,700	0	900,000	770.3%
3	6,932,700	0	900,000	770.3%

(Source: own elaboration)

Table 22 Financial Summary of ROI for Buffer Capacity Adjustment

Year	Profit (CZK)	One time Investment (CZK)	Operational annual Cost (CZK)	ROI
1	2,119,310	2,841,400	2,871,990	37.09%
2	4,960,710	0	2,871,990	172.72%
3	4,960,710	0	2,871,990	172.72%

(Source: own elaboration)

The Conveyance System has a higher upfront cost but provides significantly higher long-term savings (88.5%). The Buffer Capacity Adjustment is cheaper initially but offers lower cost savings (63.3%), with ongoing labour expenses. Long-term recommendation: If budget allows, the Conveyance System is the best option for maximizing savings. However, if an immediate investment is a concern, Buffer Capacity Adjustment provides moderate savings with a lower initial cost.

12.3 Transportation Evaluation

The transportation can be studied based on number of Kilometers consumed by workers or to cover total demand during replenishment process. The evaluation was done based on walked distance during off peak mode of current process of two workers during one shift that is correspondent to shown data for time saving during one shift in section 12.1.

Automated system eliminates the total transportation of workers; therefore, it's considering of achieving **100%** of total transport waste elimination.

Table 23 Transport Results in comparison with current situation

Totes Replenishment Process	Baseline: Manual Process	1 st Solution: Conveyance System (Automated)	2 nd Solution: Buffer Capacity Adjustment
Traveled distance per shift (km)	27	0	19.25
Reduced Distance (km)	0	27 ↑	7.75 ↑
Percentage of eliminated wasted transport	0%	100%	28.7%
Goal of transport reduction by min. 20%	-	✓	✓

(Source: own elaboration)

12.4 Evaluation Summary

All key performance indicators, including time savings, cost reduction, and transportation efficiency, are summarized in table 24. The results clearly demonstrate that both proposed solutions effectively met or exceeded the defined improvement targets. This confirms the validity of the optimization approach and supports the feasibility of implementing the suggested changes within the distribution center operations.

Table 24 Evaluation Summary

Goal	Target	1 st Solution: Conveyance System (Automated)	2 nd Solution: Buffer Capacity Adjustment	Achieved
Time Reduction	10%	63.1%	56.8%	✓
Cost Reduction	10%	88.5%	63.3%	✓
Transportation Reduction	20%	100%	28.7%	✓

(Source: own elaboration)

13 SUMMARY OF PRACTICAL PART

The practical section of this thesis analyzes the tote replenishment process in a distribution center, focusing on inefficiencies during peak and off-peak operational modes. Key findings include:

- **Current State:** Manual replenishment leads to 58% wasted time per shift, with 48% attributed to unnecessary transportation. Annual labour costs reach 7.83 million Kč without VAT.
- **Root Causes:** Chaotic tote flow, lack of real-time monitoring, and dependency on manual labour are identified through Ishikawa diagrams and spaghetti diagrams.
- **Proposed Solutions:**
 1. **Automated Conveyance System:** A 150-meter roller conveyor reduces replenishment time by 63.1%, eliminates transportation waste, and cuts costs by 88.5%. one time investment is 6 million Kč with a 3-year ROI.
 2. **Buffer Capacity Adjustment:** Implementing JIT with U-boats and smartwatch alerts reduces time waste by 56.8% and costs by 63.3%, with a one-time investment of 2.84 million Kč.
- **Evaluation:** Both solutions exceed the thesis goals (10% time reduction, 10% cost savings, 20% transport reduction). The conveyor system offers long-term efficiency, while the buffer adjustment provides immediate, cost-effective improvements.

CONCLUSION

This thesis has successfully evaluated the achievement of the main objective, which was to optimize the tote replenishment process at a distribution center through the application of lean manufacturing and industrial engineering methodologies. The analysis has revealed significant inefficiencies, including waste in time, cost, and transportation, primarily caused by manual processes and unstructured workflows. The proposed solutions, namely automated conveyance and buffer capacity adjustment have demonstrated clear and measurable improvements.

The implementation of the conveyor system stands out as a long-term solution, contributing to the near-total elimination of transportation waste and substantial cost savings. The buffer adjustment, while requiring a lower capital investment, effectively integrates Just-in-Time (JIT) principles, thus streamlining operations. These improvements would result in enhanced productivity, reduced operational costs, and more reliable workflows for the distribution center.

In addition to meeting the research objectives, this thesis provides important theoretical contributions by integrating lean tools with logistics theory. On a practical level, the proposed solutions have been validated by key performance indicators (KPIs), confirming their effectiveness. This aligns with the industry's growing trend towards automation and waste minimization, offering a replicable model for similar facilities.

The author's personal reflection on the findings highlights the critical role of automation and lean principles in driving logistics optimization. Based on the results obtained, future research could investigate hybrid models that combine both automation and buffer adjustments to ensure a balanced approach to efficiency and scalability.

In conclusion, this thesis contributes to both practical and theoretical advancements, and it suggests further exploration into hybrid models that could optimize processes while addressing emerging challenges in the logistics sector.

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LIST OF ABBREVIATIONS

AMR	Autonomous Mobile Robot
ARSAW	Picking Stations
CCR	Capacity Constrained Resource
CFE	Company Fulfilment Execution
CT	Cycle Time
DBR	Drum-Buffer-Rope
VAT	Value Added Tax
EPAL	European Pallet Association
HI	High Impact
HP	High Probability
JIT	Just-In-Time
KPIs	Key Performance Indicators
LI	Low Impact
LP	Low Probability
MI	Medium Impact
MP	Medium Probability
NVA	Non-Value-Added
REWE	Handelsgruppe REWE (German Retail Group)
RIPRAN	Risk Project Analysis
ROI	Return on Investment
SMART	Specific, Measurable, Attainable, Relevant, Time-bound
TOC	Theory of Constraints
TPS	Toyota Production System
VSM	Value Stream Mapping
WIP	Work in Progress

APPENDICES

Appendix PI: Current Process Analysis

Appendix PII: Conveyance system project realization schedule

Appendix PIII: Buffer capacity adjustment realization schedule

APPENDIX PI: CURRENT PROCESS ANALYSIS

Number of Activity	Activity	Operation	Transport	Storage	Distance (m)	Duration of activity (min)
1	Totes collected at source					
2	Prepare U-boat					3.0
3	Transport to MS				90	1.1
4	Storage					2.0
5	Transport to another MS				20	0.2
6	Storage					2.0
7	Transport to source				110	1.3
8	Storage					2.0
9	Transport to MS				135	1.6
10	Storage					2.0
11	Transport				135	1.6
12	Park U-boat at source					1.0
13	Move to next floor					4.0
14	Prepare U-boat					2.0
15	Transport to MS				150	1.8
16	Storage					2.0
17	Transport				150	1.8
18	Park U-boat at source					1.0
19	Move to next floor					4.0
20	Storage					2.0
21	Transport to MS				60	0.7
22	Storage					2.0
23	Transport to source				60	0.7
24	Storage					2.0
25	Transport to MS				90	1.1
26	Storage					2.0
27	Transport to MS				45	0.5
28	Storage					2.0
29	Transport to source				135	1.6
30	Storage					2.0
31	Transport to MS				150	1.8
32	Storage					2.0
33	Transport to source				150	1.8
34	Park U-boat at source					1.0
35	Move to next floor					4.0
Total Readings		9	14	12		
Total Time (min)						61.6
Total Distance (m)					1480	

APPENDIX PII: CONVEYANCE SYSTEM PROJECT REALIZATION SCHEDULE

[illegible]

APPENDIX PIII: BUFFER CAPACITY ADJUSTMENT REALIZATION SCHEDULE

[illegible]