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Analysis of the water-spider process in Schneider Electric

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Abstract

In complex and dynamic logistics environments, the efficient management of internal material flows plays a crucial role in supporting overall operational performance. This thesis focuses on the role of the water spider, a key figure responsible for internal replenishment activities, within a distribution center context. The study is conducted within the Schneider Electric logistics hub in Venaria Reale, Italy, and aims to address the lack of standardization in the water spider's daily operations, which historically relied on personal judgment and reactive decision-making.

Grounded in lean methodology principles, the research proposes a standardized framework designed to improve the efficiency, reliability, and repeatability of the water spider process. Through the implementation of visual management tools such as kanban systems and predefined delivery loops, the new method reduces wasteful motion, enhances task clarity, and enables more consistent material availability across workstations.

1 Introduction

In the realm of modern supply chain management, distribution centers are pivotal hubs that facilitate the efficient movement of goods from manufacturers to retailers and, ultimately, to consumers. Distribution centers are tasked with managing complex logistics involving the receipt, storage, and distribution of a wide variety of products, often under tight deadlines and fluctuating demand. To meet these challenges, distribution centers leverage advanced technologies, such as automated picking systems, real-time inventory tracking, and data analytics. These tools help streamline operations, reduce errors, and enhance overall efficiency. This balancing act requires sophisticated forecasting methods that take into account historical sales data, seasonal trends, and market fluctuations. Moreover, distribution centers play a crucial role in the fulfillment process. With the rise of same-day and next-day delivery expectations, centers must be agile and responsive. This often involves optimizing warehouse layouts and implementing efficient picking and packing strategies. Distribution centers must coordinate seamlessly with carriers to ensure timely deliveries to retailers and consumers. This requires effective route planning and communication, as well as flexibility to adapt to changing circumstances, such as traffic delays or unexpected demand surges. Sustainability is also becoming an increasingly important focus for distribution centers. Many are exploring eco-friendly practices, such as optimizing energy use, reducing waste, and incorporating sustainable packaging materials. This not only helps reduce their environmental impact but also aligns with the growing consumer demand for sustainable practices. One innovative approach to enhancing material handling efficiency is the implementation of lean manufacturing principles. Lean principles focus on minimizing waste and maximizing value, making them highly applicable to the dynamic environment of distribution centers. By adopting lean strategies, distribution centers can streamline their operations, reduce lead times, and improve service levels. Among these strategies, the concept of the Water Spider stands out as a critical method for optimizing material flow and ensuring that workstations are continuously supplied with the necessary materials.

The aim of this thesis is to explore the critical role of the water spider within a distribution center, particularly highlighting how it serves as a support function that impacts core processes. The water spider, often responsible for ensuring the timely supply of materials and resources to various workstations, plays a vital role in enhancing operational efficiency and minimizing delays.

To provide a comprehensive understanding, the thesis will analyze a specific case study from an existing distribution center located in northern Italy. This will involve a detailed mapping of the current job structure using lean mapping techniques, which will allow for the identification of inefficiencies, bottlenecks, and areas for improvement within the workflow. Through this mapping process, we will visualize the flow of materials and information, pinpointing how the water spider interacts with other processes in the distribution center.

Following the mapping exercise, the thesis will propose targeted lean solutions aimed at optimizing the current situation. These solutions may include the implementation of standardized work procedures, improved inventory management practices, and enhanced communication strategies among team members. By applying lean principles, the goal is to reduce waste, streamline operations, and ultimately improve the overall performance of the distribution center.

The thesis have a structure that goes from a background introduction, to a detailed description of the topic, to a real case scenario. Chapter 2 focuses on the the foundational theories and frameworks that underpin the research. This includes an in-depth examination of key concepts related to lean methodologies and the specific role of the water spider in distribution centers. Chapter 3 presents the description of the literature review. Here, we will survey existing research and literature relevant to the topic, highlighting previous studies, findings, and gaps in knowledge. This review will provide context for the current research, demonstrating how it builds upon existing works in the field. It will also identify best practices and methodologies that inform the proposed solutions in later chapter. Chapter 4 outlines the proposed method and his applications. In this chapter, we will detail the methodology employed in the previous chapter, including any specific tools, algorithms, or frameworks utilized to analyze the role of the water spider and improve its performances. Chapter 5 propose a real case study, describing the current situation in the distribution center, the proposed solution based on the previous chapters and the obtained results evaluating it with the use of predetermined KPIs. Then chapter 6 will summarize and conclude the work with the relatives observations, explaining if this work can lead to future applications.

2 Theoretical background

2.1 Lean methodology

2.1.1 Toyota Production System and its pillars

In the second part of the last century emerged in production industries a new approach to managing work. This is called lean methodology and takes inspiration from the innovative practices of Toyota Production System (TPS). After World War II Toyota had to face several challenges: the competition of growing car industries in the rest of the world, especially USA, scarcity of resources and a fragmented manufacturing environment, so the company needed to rethink its production methods. Under the leadership of the engineer Taiichi Ohno and Eiji Toyoda, son of Sakichi Toyoda, the founder, Toyota sought to create a more efficient and effective manufacturing process that could deliver high-quality vehicles while minimizing waste. This led to the development of TPS, which introduced key principles that would later evolve into what we now refer to as lean philosophy[2]. One of the pillars of TPS is the concept of "just-in-time" (JIT) production, which takes inspiration from american supermarkets. The scope of just-in-time is producing only what is needed, when it is needed, and in the amount needed. The aim is to reduce waste trougth minimizing excess inventory and aligning production with customer demand; the product is manufactured and then delivered to the customer in the lower possible time[1]. Another pillar is the “jidoka” that emphasizes quality control and human oversight in automated processes. This concept was pioneered by Sakichi Toyoda with his invention of the automatic loom, which could stop itself when a thread broke, preventing defective products from being produced. Jidoka consists of two main components: autonomation and stop-and-fix. Autonomation involves using machines to automate repetitive tasks while incorporating the ability to detect abnormalities. When a machine identifies a defect or an irregularity, it stops automatically, allowing for immediate intervention. Stopping the production process when a defect is detected is useful to analize the issue to prevent further defects from being created. This allows for immediate problem-solving and correction, ensuring that only high-quality products continue through the production line[1]. One of the most interesting aspects of Jidoka is how it integrates human intelligence with mechanical automation. While machines perform repetitive tasks and detect abnormalities, human workers analyze, overcome, and improve the production process. An other important principle of the TPS is Kaizen, a Japanese term meaning "improvement" or "change for the better". It refers to a philosophy and practices that focus on continuous improvement in all aspects of an organization, involving every employee from top management to the shop floor workers. The concept of Kaizen emphasizes that small, incremental changes, when consistently applied, can lead to significant improvements over time. The benefits of Kaizen are numerous and far-reaching. By fostering a culture of continuous improvement, organizations can achieve higher levels of efficiency, quality, and customer satisfaction. Kaizen helps reduce waste, lower costs, and improve productivity by streamlining processes and eliminating non-value-added activities. It also enhances employee engagement and morale by involving workers in the improvement process and recognizing their contributions[3].

2.1.2 Lean methodology and lean principles

In 1980s some researchers at the Massachusetts Institute of Technology (MIT) went to Japan to analize this innovative system and were impressed by the efficiency, quality, and innovative practices used in Japanese factories. Their research highlighted the significant gap between Japanese and American automotive manufacturing in terms of productivity and quality and in 1990 James P. Womack, Daniel T. Jones and Daniel Roos published "The

Machine That Changed the World", a book where they analize what they saw in Toyota's plants. They explain how japaneses were able to evolve the mass production developed in Ford industries maximizing productivity and minimazing wastes. From this book came the concept of lean manufacturing which follows the Toyota Production System pillars. Lean manufacturing emphasizes the importance of understanding customer needs and aligning production processes to meet those demands effectively. This requires a deep commitment to identifying and eliminating waste in all forms, whether it's excess materials, time, or labor[3]. Lean manufacturing is based on five principles that are applicable not only in manufacturing settings but also in service industries, healthcare, and other sectors where efficiency and customer satisfaction are paramount [Figure 1].

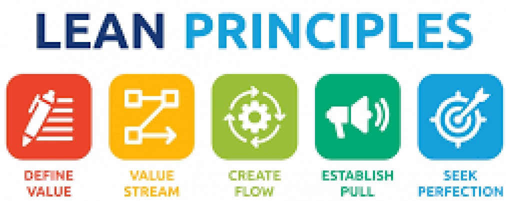


Figure 1- Five lean principles

The first principle lean is based on is value: it is the measure of worth that a product or service holds in the eyes of the customer. It is defined by the features and benefits that fulfill customer needs and solve their problems. In lean thinking, only what constitute value from the customer's perspective is considered something to work on and develop, while what does not create value for the customer can be eliminated. After defining value, the next step is to map the value stream, which includes all the complete set of activities required to design, produce, and deliver a product or service to the customer. This includes both value-adding activities (those that contribute directly to the product or service) and non-value-adding activities (those that do not contribute directly to customer value). This mapping helps visualize the flow of materials and information, identify areas of waste, inefficiencies, and opportunities for improvement. The following principle is flow. Flow refers to the smooth, uninterrupted movement of products or informations through the value stream. This involves organizing workstations and processes so that tasks are completed in a continuous manner without delays, bottlenecks, or interruptions. The goal is to ensure that value-adding steps occur in a continuous sequence, synchronizing all steps in the production or service delivery process which significantly reduces cycle times and enhances overall efficiency maintaining the value of the product. Unlike traditional manufacturing approaches that often rely on a push system (producing goods based on forecasts), lean manufacturing adopts a pull system. A pull system is a production strategy that responds to actual customer demand rather than relying on forecasts or pushing products through the production process. In this system, work is only initiated when there is a specific request from the customer, which helps to minimize excess inventory, cost and overproduction. This principle emphasizes the importance of aligning production with real-time customer needs, ensuring that resources are used efficiently and effectively. The fifth lean principle is perfection. The pursuit of perfection is a key tenet of lean manufacturing. Organizations are encouraged to adopt a mindset of continuous improvement, where processes are regularly evaluated and refined. This principle encourages a culture of innovation, where employees are empowered to identify inefficiencies, propose solutions, and implement changes that enhance productivity and quality[3].

It is the aspiration to eliminate waste and enhance value to the maximum extent possible. The pursuit of perfection is a never-ending journey, as there is always potential for further enhancement and refinement.

2.1.3 3M: Muda Muri & Mura

After having discussed about the foundational principles of lean, it is essential to analize one of its core aspects: the identification and elimination of waste. Lean methodology emphasizes the continuous pursuit of value by recognizing and addressing activities that do not contribute to the final product or service, identifying and eliminating what is more. This leads to the concept of the seven wastes, called Muda (from japanese)[1], which represent key areas where inefficiencies commonly arise within a process. Understanding these wastes is crucial, as they provide a framework for organizations to systematically analyze their operations, reduce non-value-adding activities, and optimize overall performance. These waste are:

- Overproduction, occurs when more products are produced than are immediately needed, leading to excess inventory, increased storage costs, and potential obsolescence. This waste is particularly problematic as it can mask other inefficiencies in the system.
- Waiting refers to idle time when workers, machines, or materials are not actively engaged in production due to delays or bottlenecks, leading to lost productivity.
- Transport involves the unnecessary movement of materials, products, or information, which does not add value to the final product but increases handling time and costs.
- Overprocessing is characterized by performing more work or using higher precision than what is required by the customer, often due to poor design, unclear specifications, or lack of understanding of customer needs. This results in wasted time and resources.
- Inventory, another form of waste, includes excess raw materials, work-in-progress, or finished goods that are not currently needed, tying up capital and increasing storage and management costs.

- Motion waste pertains to unnecessary or excessive movements by workers, such as reaching, bending, or walking, which can lead to fatigue, increased cycle time, and potential safety risks.
- Defects refer to products that do not meet quality standards, necessitating rework, repair, or scrapping, which increases costs and delays delivery. Addressing these seven wastes is fundamental in Lean operations to create a streamlined, efficient process that focuses on delivering maximum value to the customer[2].

Linked to Muda there are two other critical aspects of Lean methodology: Muri and Mura. These concepts are vital for understanding and addressing inefficiencies that can disrupt the smooth flow of operations. Muri refers to the overload of people, equipment, or systems beyond their capacity. This happens when resources are pushed too hard, leading to stress, wear, and an increased possibility of mistakes or breakdowns. For example, machines operating beyond their limits are more inclined to failures, and employees dealing with excessive workloads may experience fatigue, which can result in errors or even injuries. Overload can manifest in various ways, such as too long shifts, inadequate rest periods, or an unsustainable work pace. Similarly, equipment that is overused without proper maintenance is more likely to break down, causing delays and additional costs. The consequences of Muri are significant: decrease in product quality, higher maintenance expenses, and stressed employees, which can lead to burnout and high turnover rates. To prevent Muri, it’s important to balance workloads, ensuring that neither employees nor equipment are pushed beyond their limits. This can be achieved through realistic scheduling, regular maintenance, and fostering a workplace culture that prioritizes well-being and sustainability[3]. Mura refers to inconsistencies or irregularities in processes, which can create inefficiencies and disrupt workflow. Inconsistent production rates, for example, may cause some stages of the process to rush while others slow down, leading to bottlenecks.

Similarly, unpredictable delivery schedules or sudden shifts in customer demand can result in overstocking, shortages, or delays. The impact of Mura can be significant because it can lead to uneven workloads, with some resources being underutilized while others are overloaded. This inconsistency not only causes stress and waste but can also result in customer dissatisfaction due to delays or quality issues. To address Mura, organizations should aim to standardize their processes and reduce variability; Just-in-Time (JIT) production can help align production more closely with actual demand, minimizing irregularities and creating a more consistent workflow. A good combination between the 3M (Muda, Mura, Muri) can lead organizations to optimize their processes while maintaining high-quality standards and employee well-being.

2.1.4 Main tools and techniques

The lean methodology is supported by a wide range of tools and techniques that enable organizations to streamline operations, reduce waste, and continuously improve processes. These tools are designed to address inefficiencies, foster collaboration, and ensure the delivery of value to the customer. Below is an in-depth exploration of the most important lean tools and their applications:

- 5S: Workplace Organization

  The 5S methodology is one of the most fundamental lean tools, focusing on creating an organized and so efficient workplace. As the name suggest, it is divided in five steps which are:

  - Sort (Seiri): Eliminate unnecessary items to reduce clutter and improve focus.
  - Set in Order (Seiton): Arrange tools and materials in logical, easily accessible locations.

   - Shine (Seiso): Regularly clean the workspace to ensure it remains functional and safe.
   - Standardize (Seiketsu): Develop guidelines to maintain the organization achieved in the first three steps.
   - Sustain (Shitsuke): Cultivate discipline and a culture of continuous adherence to the 5S principles.

  By implementing 5S, organizations not only improve operational efficiency but also foster employee engagement and safety.

- Kanban: Visual Workflow Management

  Kanban, a visual tool originating from Toyota, is used to manage inventory and workflow efficiently. It involves the use of visual signals, such as cards or boards, to indicate production or movement needs. It helps prevents overproduction by aligning resources with demand, enhances visibility across the value chain, enabling quick identification of bottlenecks. By helping controlling the quantities of product, it supports Just-in-Time (JIT) production by ensuring the availability of necessary resources without surplus. Kanban's simplicity and adaptability make it an essential tool in both manufacturing and logistics[1].

- Kaizen: Continuous Improvement

  As said before kaizen is a philosophy of incremental improvement that involves all levels of an organization. It encourages employees to identify inefficiencies and propose solutions in their daily work. Cross-functional teams collaborate to analyze specific problems and implement changes. It helps reduce waste and defects and builds a culture of shared responsibility for improvement. Kaizen emphasizes that small, consistent changes can lead to significant long-term benefits.

- Value Stream Mapping (VSM): Process Visualization

  Value Stream Mapping is a powerful tool for identifying and eliminating waste in a process. It involves creating a visual representation of the flow of materials and information. VSM map the current process in order to identify activities that add value and those that do not and highlight inefficiencies, such as delays, excess inventory, or redundancies. Then the following tep is to design a future state map that optimizes the flow and minimizes waste. VSM is widely used in logistics to optimize inventory management and reduce lead times [Figure 2].

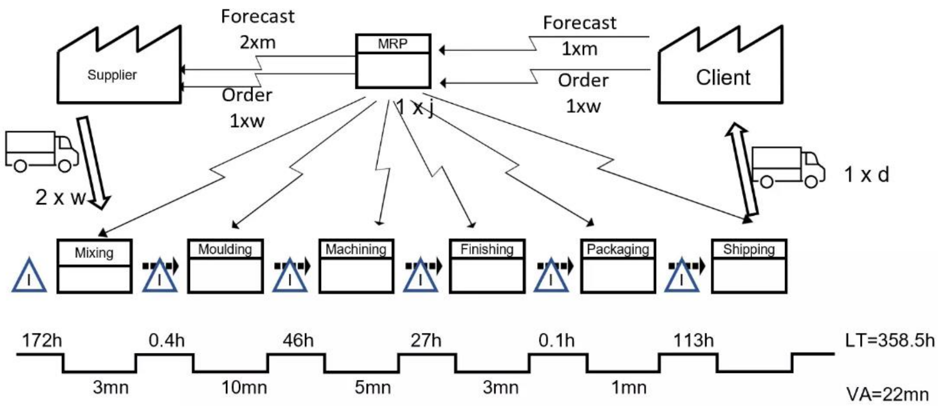


Figure 2- Example of Value Stream Mapping

- Poka-Yoke: Error Proofing

  Poka-Yoke, which translates to "error proofing" in Japanese, focuses on designing processes or devices that prevent human errors or make them immediately noticeable. The idea is to ensure that mistakes do not escalate into defects. For instance, in assembly lines, physical mechanisms such as jigs or fixtures are often employed to prevent incorrect placements. Similarly, warning signals, such as lights or alarms, alert workers when an error occurs. This tool is particularly beneficial in environments where repetitive tasks are performed, as it reduces rework and ensures consistent quality. By addressing errors at their source, organizations can maintain high standards of production while saving time and resources.

- Heijunka: Production Leveling

  Heijunka is a technique used to balance production and align it with demand. It aims to smooth out variations (Mura) and reduce overburden (Muri) in the workflow. This is achieved by distributing workloads evenly across processes and avoiding spikes or pauses in production. For example, instead of producing large batches of a single product, Heijunka schedules smaller, mixed batches based on customer demand. This approach minimizes inventory while ensuring that resources are used efficiently. In the context of lean logistics, Heijunka helps maintain a steady flow of goods, reducing delays and bottlenecks.

- Just-in-Time (JIT): Demand-Driven Production

  As expressed at the beginning of the chapter the concept of just-in-Time (JIT) is a cornerstone of the lean methodology, emphasizing the delivery of materials and products exactly when they are needed, in the right quantity. The JIT approach minimizes waste associated with overproduction, excess inventory, and obsolescence. Implementing JIT requires precise coordination between production schedules, suppliers, and logistics teams. For example, in a warehouse setting, JIT ensures that stock levels are kept minimal, with goods being replenished only when demand arises. While this technique offers significant cost savings, it also requires robust communication and reliable supply chains to avoid disruptions.

Just-in-Time production ensures that materials and products are delivered only when needed, in the exact quantity required. JIT is particularly impactful in logistics, where it optimizes material flows and reduces storage needs.

- Takt Time: Production Rhythm

  Takt time is the rate at which products must be completed to meet customer demand. Derived from the German word for "rhythm," it is calculated as:

  Takt Time = Available Time / Customer Demand

  By setting a clear production pace, takt time ensures that processes are neither too slow nor too fast, preventing both delays and overproduction. For instance, in manufacturing, takt time can be used to synchronize assembly line activities with customer orders, ensuring a smooth and consistent workflow. This tool is essential for maintaining efficiency and aligning operations with market needs.

- SMED (Single-Minute Exchange of Die): Rapid Changeover

  SMED is a lean tool designed to minimize the time required to change equipment or setups between production runs. The goal is to complete these transitions in less than 10 minutes, hence the term "single-minute". This is achieved by separating setup tasks into two categories:
  - Internal tasks: Those that can only be performed when the equipment is stopped.
  - External tasks: Those that can be done while the equipment is running.

By optimizing internal tasks and moving as many tasks as possible to the external category, SMED reduces downtime, increases flexibility, and allows for smaller batch production. This tool is particularly valuable in industries requiring frequent product changes.

- Standardized Work: Consistency in Operations
  Standardized work involves documenting the best-known method for performing a task. This documentation serves as a reference point to ensure consistency, quality, and efficiency. It includes details such as task sequences, time requirements, and resources needed. In addition to ensuring uniformity, standardized work provides a foundation for continuous improvement. For instance, if a team identifies a more efficient way to complete a task, the standard can be updated to reflect the improvement. This tool is especially useful in onboarding new employees and maintaining operational stability in dynamic environments. Standardized work involves documenting the best-known method for performing a task to ensure consistency and quality.

The tools and techniques of lean are fundamental for achieving operational excellence. They provide a structured framework for addressing inefficiencies, fostering continuous improvement, and delivering value to customers. By combining these tools, organizations can build resilient processes and adapt to changing market demands effectively.

2.1.5 Advantages of lean

The lean approach offers significant advantages to organizations seeking to improve efficiency, reduce waste, and create value. Its principles and tools are designed not only to optimize processes but also to foster a culture of continuous improvement. Below, the key benefits of the lean approach are discussed in depth.

- Waste Reduction

  At the core of lean lies the objective of minimizing waste (Muda). By identifying and eliminating non-value-adding activities, organizations can focus their resources on processes that directly contribute to customer satisfaction. This can include reducing overproduction, which often leads to excess inventory, reorganizing transportation and motion to minimize unnecessary movement of materials or people and addressing defects to avoid costly rework and downtime.

- Improved Process Efficiency

  Techniques such as Just-in-Time (JIT) and Heijunka are promoted to enhance process flow and ensure resources are used effectively. By aligning production schedules with customer demand, organizations can: reduce lead times, avoid overburdening workers or equipment (Muri) and ensure a consistent workflow, reducing irregularities (Mura). This results in smoother operations, higher productivity, and the ability to adapt quickly to market changes.

- Enhanced Product and Service Quality

  Lean tools like Poka-Yoke and standardized work ensure that processes are designed to prevent mistakes and maintain quality. By addressing errors at their source and establishing clear procedures, organizations can achieve: higher consistency in product quality, lower defect rates, leading to fewer customer complaints and returns and an increase in customer trust and loyalty. For example, implementing Poka-Yoke mechanisms in manufacturing can prevent assembly errors, ensuring a higher level of precision in the final product.

- Cost Savings

  One of the most tangible benefits of lean is a consequence of eliminating waste and optimizing resource utilization. In this organizations can significantly lower their operational expenses. Key cost-saving areas include:reduced inventory holding costs lower energy and material consumption due to streamlined processes and decreased labor costs by minimizing idle time and improving efficiency. These savings can be reinvested into other areas of the business, such as innovation or employee development.

- Increased Employee Engagement

  Lean fosters a culture of inclusion and empowerment by involving employees at all levels in continuous improvement initiatives like Kaizen. Workers are encouraged to identify inefficiencies and propose solutions, leading to

  higher job satisfaction as employees see the direct impact of their contributions and improved collaboration across teams. This participatory approach not only drives improvements but also reduces resistance to change, a common barrier in organizational transformation.

- Greater Customer Satisfaction

  Lean focuses on delivering value to the customer by understanding their needs and aligning processes to meet those expectations. By improving quality, reducing lead times, and offering competitive pricing, organizations can build long-term relationships with clients based on trust and reliability and gain a competitive advantage in the marketplace.

- Environmental Sustainability

  Lean principles align closely with sustainable practices by emphasizing waste reduction and efficient resource use. Reducing wastes and operational time organizations reduce carbon footprint, energy and water consumption. They also minimize material waste, contributing to a circular economy. This dual capacity of improve efficiency and sustainability at the same time positions lean as a vital strategy for businesses.

The benefits of lean extend beyond mere operational enhancements. By addressing inefficiencies, promoting quality, and fostering a culture of continuous improvement, lean helps organizations build a sustainable and resilient foundation for growth. Moreover, the focus on waste reduction and resource optimization supports not only financial performance but also environmental responsibility. Lean's ability to empower employees through active engagement and collaboration creates a more motivated workforce, further contributing to organizational success. Additionally, the lean approach places customers at the center of every decision, ensuring that the products and services delivered consistently meet or exceed expectations. In an increasingly competitive and dynamic market environment, adopting lean principles furnish businesses the agility and efficiency needed to adapt to changing demands. It is not just a methodology but a strategic philosophy that integrates operational excellence with organizational vision.

2.1.6 Challenges and limitations of the lean approach

While the lean methodology offers significant advantages, its implementation is not so easy. Pass from another work methodology to lean requires organizations to undergo substantial cultural and operational changes, which can be complicated[3]. One of the primary difficulties organizations face when adopting lean is resistance to change. Employees and management may be reluctant to embrace new processes or workflows, especially when they are used to long-standing habits; workers may be skeptical about abandoning traditional practices that have served them well in the past. To overcome this, it is crucial to involve employees at all levels in the transition process, ensuring they understand the benefits of lean both for the organization and for themselves. Initiatives like training programs and Kaizen events can help to alleviate fears and foster a sense of ownership over the improvements. Another notable challenge is the initial investment required to implement lean. Redesigning processes, acquiring new tools, and training employees can demand substantial financial and time resources, particularly for small and medium-sized enterprises. Additionally, during the transition phase, organizations may experience temporary productivity disruptions as teams adapt to new systems. Lean also places heavy reliance on reliable supply chains, particularly with its Just-in-Time (JIT) approach. The success of JIT depends on the timely delivery of materials and components, as any disruption in the supply chain can stop production entirely[1]. This reliance can make organizations vulnerable to external factors, such as supplier delays or global crises. Developing strong relationships with suppliers and investing in supply chain visibility tools can help mitigate this risk.

However, lean’s focus on maximizing efficiency can sometimes lead to unintended consequences. Too much attention on efficiency may result in overly rigid processes that lack flexibility, making it challenging to adapt to sudden changes in demand or market conditions. For instance, an organization that reduces inventory to its bare minimum might struggle to fulfill unexpected large orders. Balancing efficiency with flexibility is critical, and techniques like Heijunka (production leveling) can help maintain a buffer to accommodate such fluctuations. One of the more difficult challenges of lean is the difficulty in sustaining improvements over time. While initial lean implementations may lead to impressive results, maintaining momentum can be difficult without ongoing leadership support and employee engagement. Over time, organizations may gradually revert to old habits if lean principles are not embedded into their culture. To counter this, businesses should integrate lean into their core values and ensure regular follow-ups, audits, and refresher training sessions to sustain progress. Finally, measuring the results of lean implementations can be complex. Some benefits, such as improved employee morale or enhanced customer satisfaction, are intangible and not easily quantified. Additionally, organizations may find it challenging to demonstrate immediate financial returns, especially during the early stages of adoption. Setting clear Key Performance Indicators (KPIs), such as reduced defect rates or shorter lead times, can help track progress and provide tangible evidence of lean’s impact. Combining these with qualitative metrics, such as employee feedback, can offer a more comprehensive understanding of lean’s value. While the challenges associated with lean are significant, they are not impossible. Addressing these limitations requires a thoughtful and proactive approach, with a focus on building a strong foundation for cultural and operational change. By engaging employees, tailoring tools to specific needs, and maintaining a balance between efficiency and flexibility, organizations can overcome these obstacles and fully leverage the benefits of lean.

2.1.7 Applications of lean in different contexts

Lean principles, originally developed for manufacturing, have proven to be highly versatile and applicable across various industries. By adapting its methodologies to address specific inefficiencies, organizations in diverse sectors have achieved significant improvements in quality, efficiency, and customer satisfaction. Below is a more detailed and discursive exploration of lean's applications in key areas:

- Manufacturing

  Lean principles are deeply rooted in this field, largely due to their origins in the Toyota Production System (TPS). The tools and techniques of lean, such as Just-in-Time (JIT) and Heijunka, help streamline production processes by ensuring resources are available exactly when needed, minimizing waste. For instance, tools like Poka-Yoke and standardized work enable manufacturers to reduce defects and improve consistency in product quality, but in general all tools are useful since they are created for a manufacturing industry. Moreover, lean supports greater flexibility in responding to fluctuating demand, ensuring that production schedules are efficient and customer expectations are met.

- Logistics and supply chain

  In logistics lean addresses inefficiencies in the movement of goods and information, creating streamlined operations. Tools like Kanban ensure that materials flow smoothly through the supply chain, reducing delays and bottlenecks. Just-in-Time principles are particularly impactful, as they help organizations reduce excess inventory and lower storage costs. Value Stream Mapping (VSM) is frequently used to visualize the entire supply chain, allowing companies to pinpoint and resolve inefficiencies. For example, lean methodologies enable e-commerce companies to optimize their order fulfillment processes, ensuring timely deliveries and improved customer satisfaction. For lean methodology, supply chain is crucial for granting JIT and maintain low inventory capacity.

- Healthcare

  The application of lean in healthcare has gained significant momentum in recent years, driven by the need to improve patient care while managing costs. Hospitals and clinics use lean tools like VSM to identify delays in patient flow, such as long wait times in emergency departments. Standardized work and Poka-Yoke are applied to reduce errors in medication administration and procedures, enhancing patient safety. Additionally, the 5S methodology is employed to organize equipment and supplies, making them easily accessible for staff. These practices not only enhance the quality of care but also increase the efficiency of healthcare delivery. For instance, a lean-focused hospital might significantly reduce patient wait times while increasing the number of patients treated daily.

- Service industries

  In service industries, lean focuses on improving processes to deliver a better customer experience. Administrative tasks such as billing, customer onboarding, or case processing are streamlined to eliminate redundancies and reduce lead times. Lean tools like Takt Time ensure that services are delivered within expected timeframes, which is crucial for maintaining customer satisfaction. Moreover, continuous improvement practices, such as Kaizen, empower employees to propose and implement changes that enhance efficiency. A practical example is a bank reducing the time required to process loan applications, which not only improves customer trust but also supports business growth.

- Education

  Lean principles are also being applied in education, where they help schools and universities optimize administrative workflows and resource allocation. By simplifying processes such as enrollment or grading, lean ensures that educators and administrators can focus more on delivering value to students. Tools like 5S are used to organize classrooms and teaching materials, while lean thinking helps develop curricula that are directly aligned with student needs. These initiatives create a more efficient learning environment, benefiting both students and educators.

- Public sector

  The public sector has also begun adopting lean principles to improve service delivery and resource utilization. Government agencies often face challenges such as bureaucratic delays and budget constraints. By applying lean tools, agencies can reduce inefficiencies and improve responsiveness. For instance, lean methodologies can streamline the processing of licenses or tax filings, reducing wait times for citizens. Moreover, the emphasis on transparency and accountability builds trust with stakeholders, ensuring that public resources are used effectively. A government office implementing lean might significantly improve the speed of its services while maintaining or even reducing costs.

The adaptability of lean principles has allowed them to transform operations in a wide range of industries. From streamlining manufacturing processes to improving healthcare outcomes and enhancing public services, lean demonstrates its value as a flexible and impactful methodology. However, successful implementation requires more than just adopting tools and techniques. It involves fostering a culture of continuous improvement, engaging employees at all levels, and tailoring lean practices to meet the unique demands of each industry. As organizations continue to face new challenges in an increasingly dynamic environment, lean offers a robust framework for driving innovation, efficiency, and long-term value.

The next chapter will delve into the specific role of lean in logistics, exploring tools like the water spider methodology and their contributions to achieving lean goals in this critical domain.

2.2 Logistics

2.2.1 Definition of logistics

Logistics is a cornerstone of modern business operations, encompassing the planning, execution, and control of the movement and storage of goods, services, and information[5]. It ensures that resources flow efficiently from suppliers to customers, aligning operations with the primary goal of delivering the right product, in the right quantity, at the right time, and in the right condition. This strategic discipline plays a crucial role in reducing costs, improving efficiency, and enhancing customer satisfaction[6]. While logistics is often discussed in conjunction with supply chain management (SCM), it is important to distinguish between the two. Logistics focuses on the tactical and operational aspects of moving and storing goods within a company’s operations. SCM, on the other hand, is a broader, strategic discipline that coordinates all entities involved in the production and delivery of goods, including suppliers, manufacturers, and retailers. In this sense, logistics is a key component of supply chain management, supporting its overarching objectives. The importance of logistics has grown significantly in recent decades, driven by the rise of globalization, technological advancements, and evolving customer expectations[7]. Businesses today operate in increasingly complex environments, requiring robust logistics systems to ensure smooth operations. From managing transportation and inventory to optimizing warehousing and distribution, logistics directly impacts an organization’s ability to remain competitive in dynamic markets. Logistics is also a contributor to strategic goals, including sustainability and resilience. Green logistics initiatives for example aim to reduce environmental impacts by optimizing transportation routes, adopting alternative fuels, and promoting reverse logistics for recycling and reuse.

Logistics can be defined as the systematic planning, execution, and control of the efficient flow and storage of goods, services, and information from the point of origin to the point of consumption. Its primary goal is to meet customer requirements while minimizing costs and maximizing efficiency. As a critical operational discipline, logistics fill the gap between production and market, ensuring that products and services are delivered to the right place, at the right time, and in the desired condition. Unlike supply chain management, which encompasses a broader strategic focus, logistics concentrates on the tactical and operational aspects of moving and storing goods. This distinction highlights logistics’ essential role in supporting the day-to-day operations of businesses across various industries.

2.2.2 Core functions of logistics

The scope of logistics includes several interconnected functions that collectively ensure the smooth flow of resources and information. These core functions are:

- Transportation

  Transportation is one of the most visible and critical components of logistics. It involves the movement of goods from one location to another using various ways, including road, rail, air, and sea. Efficient transportation management ensures that goods are delivered on time and in good condition, balancing cost, speed, and reliability. The main issues in transportation are choosing the appropriate mode of delivery, the route optimization to minimize travel time and fuel consumption and the last-mile delivery, which has become very important since the rising of e-commerce because the home delivery has increased a lot[6].

- Warehousing and Storage

  Warehousing and storage are critical components of logistics, providing secure facilities for storing goods until they are needed. These spaces serve as buffers between production and distribution, ensuring businesses can respond to fluctuations in demand while maintaining efficiency. Warehouses come in various forms, including traditional storage facilities, automated warehouses with robotics, temperature-controlled spaces for perishables, and distribution centers designed for rapid order fulfillment. Key functions include inbound receivement, inventory storage, order picking and packing, consolidation of shipments, and sorting goods for distribution. Advanced Warehouse Management Systems (WMS) play a vital role in tracking inventory, optimizing space utilization, and minimizing retrieval times.

Additionally, value-added services such as labeling, kitting, and quality checks enhance their role in the supply chain. With technologies like automation and data analytics, modern warehousing ensures faster, more accurate operations, supporting businesses in reducing costs, improving service levels, and meeting customer expectations.

- Inventory Management

  Inventory management focuses on maintaining optimal stock levels to meet customer demand without overstocking or understocking. Proper inventory management ensures that businesses can respond quickly to orders while minimizing holding costs[5]. To optimize inventory management are commonly used trchniques like Just-in-Time, the use of safety stock and demand forecasting.

- Order Processing

  Order processing involves managing the flow of information and materials associated with customer orders. This function includes receiving, verifying, and fulfilling orders while ensuring accurate documentation and timely communication. It follows three main steps: order entry and validation, picking and packing, and shipment. Efficient order processing systems minimize errors, improve customer satisfaction, and enhance overall logistics performance[6].

- Distribution

  Distribution is the final step in the logistics process, where goods are delivered to their final destination, whether it's a retail store, distribution center, or end customer. It encompasses both outbound logistics (from the warehouse to the customer) and reverse logistics (handling returns and recycling). It is important to also mention the cross-docking, which consists in a direct transfer of goods from inbound to outbound transportation without storage. An important piece of distribution are the hub-and-spoke systems, centralized distribution networks that consolidate and redistribute goods efficiently.

- Information Management

  The flow of information is as critical as the flow of goods. Accurate and real-time data enable better decision-making, improved coordination, and enhanced transparency throughout the logistics network. Modern logistics relies heavily on technology to manage information, including:

  - Tracking systems: Real-time tracking of shipments and inventory.
  - Data analytics: Leveraging data to identify inefficiencies and optimize operations.
  - Automation: Integrating software solutions to streamline workflows and improve accuracy[7].

Logistics encompasses a diverse range of functions that collectively ensure the efficient movement and storage of goods and information. By integrating transportation, warehousing, inventory management, order processing, distribution, and information systems, logistics plays a pivotal role in connecting production with the market. Its successful execution not only reduces costs but also enhances customer satisfaction, making it an indispensable element of modern business operations.

2.2.3 Logistics and technology

Technology has revolutionized logistics, transforming how goods, information, and resources are managed throughout the supply chain. By integrating advanced tools and systems, businesses can improve efficiency, enhance visibility, and reduce costs[7]. Below, we explore key technological advancements in logistics and their impact on operations.

- Automation and Robotics

  Automation and robotics have significantly improved productivity in warehousing and transportation. Technologies such as automated storage and retrieval systems (AS/RS), conveyor belts, and robotic pickers reduce manual labor, improve accuracy, and speed up operations. For example, robots are used for picking, packing, and transporting items in warehouses. Autonomous trucks and drones are being developed for long-haul transportation and last-mile delivery.

- Warehouse Management Systems (WMS)

  WMS software plays a vital role in optimizing warehouse operations by tracking inventory, managing storage locations, and streamlining order processing. They are able to track inventory in real-time for better stock control, improve accuracy in order picking and shipping and improve space utilization through optimized storage layouts[6].

- Data Analytics and Artificial Intelligence (AI)

  Data analytics and AI enable businesses to make informed decisions by analyzing large volumes of logistical data. This can permit to forecast the demand, optimize routes and do predictive maintainace

- Blockchain and Supply Chain Transparency

  Blockchain technology enhances transparency and security in logistics by providing an immutable record of transactions. It enables stakeholders to track shipments in real time and verify the authenticity of products, particularly in industries like pharmaceuticals and luxury goods.

- Transportation Management Systems (TMS)

  TMS software helps businesses plan, execute, and optimize transportation operations.

- ERP Systems in Logistics

  Enterprise Resource Planning (ERP) systems are comprehensive software solutions that integrate all key business processes, including logistics, under a single platform. In logistics, ERP systems connects logistics with other business processes such as procurement, sales, and finance, ensuring seamless data flow. By integrating with WMS and TMS, ERP systems provide real-time visibility into inventory levels across multiple locations. They also simplify order management, automating tasks such as order entry, billing, and tracking. Another important added value from ERP system is the possibility to monitor the performances, offering detailed reporting and analytics, and so enabling businesses to monitor key performance indicators (KPIs) such as delivery times, costs, and customer satisfaction. For example, SAP and Oracle ERP solutions are widely used in logistics to improve coordination, reduce errors, and optimize resource utilization. By integrating ERP systems, businesses gain end-to-end visibility and control over their logistics operations.

Technology is a game-changer in logistics, enabling businesses to streamline operations, enhance transparency, and meet evolving customer expectations. From automation and AI to blockchain and ERP systems, the adoption of innovative technologies equips companies with the tools to remain competitive in a fast-paced market. As logistics continues to evolve, the integration of advanced technologies will remain critical for achieving operational excellence and sustainable growth.

2.2.4 Challenges in logistics

Logistics is a critical function in modern businesses, but its effective management comes with a set of significant challenges. These challenges arise from the growing complexity of global supply chains, rapidly changing customer expectations, and the need to balance efficiency with resilience and sustainability. One of the primary challenges in logistics is to face the complexities of globalization. As supply chains become increasingly globalized, managing the movement of goods across multiple countries requires businesses to contend with varying regulations, trade policies, and customs procedures. Companies must invest in advanced technologies and build resilient networks to address these risks, ensuring uninterrupted operations even in volatile environments, in order to not incur in delays and discomforts for the clients[5]. Another significant issue is the volatility of demand. Consumer preferences and market trends can shift rapidly, creating a need for logistics systems that are both flexible and responsive. The rise of e-commerce has amplified this challenge, as customers now expect faster deliveries and greater product availability. Meeting these expectations requires businesses to optimize their inventory management and improve last-mile delivery capabilities. However, achieving this balance without incurring excessive costs remains a persistent struggle for many organizations. Rising operational costs are another pressing concern. Transportation expenses, influenced by fluctuating fuel prices and increased labor costs, account for a substantial portion of logistics budgets. In addition, investments in technology and infrastructure, while essential for staying competitive, add further financial pressures. To counteract these challenges, companies are focusing on innovative solutions such as route optimization, automated warehouses, and shared logistics services to reduce expenses without compromising service quality[6]. Sustainability has also emerged as a critical issue in logistics, driven by growing environmental concerns and regulatory pressures. Transportation and warehousing contribute significantly to carbon emissions and resource consumption, making it imperative for businesses to adopt greener practices. Many companies are transitioning to electric vehicles, optimizing delivery routes to minimize fuel usage, and implementing energy-efficient solutions in warehouses. Reverse logistics, which focuses on recycling and reusing returned goods, is also gaining traction as part of broader sustainability efforts. Furthermore, the rapid pace of technological advancement presents both opportunities and challenges for logistics. While technologies such as automation, artificial intelligence, and blockchain promise to improve efficiency and transparency, integrating these solutions into existing systems is often complex and resource-intensive. Training employees to work with new tools and ensuring the compatibility of legacy systems with modern technologies can delay implementation and increase costs. Despite these challenges, logistics remains a dynamic and evolving field. By embracing innovation and building resilient networks, businesses can turn these obstacles into opportunities for growth and differentiation. The ongoing integration of lean principles and advanced technologies holds the potential to redefine how logistics is managed, enabling organizations to meet the demands of an increasingly complex and environmentally conscious world.

2.2.5 Application of lean principles in logistic

The integration of lean principles in logistics has proven to be a transformative approach, enabling organizations to reduce waste, improve efficiency, and enhance customer satisfaction. In logistics, these principles are adapted to address specific challenges, such as reducing delays, minimizing inventory costs, and improving the overall flow of goods and information. One of the most notable applications of lean in logistics is the implementation of Just-in-Time (JIT) practices. This approach not only reduces storage costs but also improves responsiveness to customer demand. However, the success of JIT in logistics depends on highly reliable supply chains and seamless coordination between suppliers and transportation providers[5]. Another essential lean tool in logistics is Value Stream Mapping (VSM), which helps organizations identify inefficiencies and bottlenecks in their processes. By visualizing the flow of materials and information, VSM enables businesses to pinpoint areas of waste, such as unnecessary handling, delays in transit, or redundant processes[4]. Once identified, these inefficiencies can be addressed through targeted improvements, resulting in faster delivery times and reduced operational costs. For example, a logistics provider might use VSM to streamline its warehouse operations, optimizing the picking and packing process to minimize time and effort. Standardization of processes is another key application of lean in logistics. By establishing uniform procedures for tasks such as order picking, packing, and loading, businesses can reduce variability and errors while improving efficiency. Standardized workflows also make it easier to train employees and maintain consistent service quality, even during periods of high demand. For instance, e-commerce companies that handle thousands of orders daily rely on standardized processes to ensure timely and accurate deliveries. The concept of continuous improvement (Kaizen) is deeply embedded in lean logistics. This might involve warehouse staff suggesting new layouts to improve picking efficiency or drivers proposing alternate routes to avoid traffic congestion.

Over time, these incremental improvements can lead to significant gains in productivity and cost savings[3]. Transportation optimization is another area where lean principles are applied. By analyzing routes, consolidating shipments, and reducing empty miles, businesses can lower fuel consumption and transportation costs. Lean logistics also emphasizes the importance of last-mile delivery, ensuring that goods reach customers quickly and efficiently. For example, companies use route optimization software to identify the shortest and most cost-effective paths, reducing delivery times and enhancing customer satisfaction. Finally, inventory management is a critical component of lean logistics. Techniques such as Kanban systems are used to control inventory levels and trigger replenishments only when necessary[1]. This reduces overstocking and minimizes the risk of obsolescence. For instance, a retailer might use a Kanban system to ensure that popular products are always in stock without maintaining excessive inventory, improving cash flow and reducing storage costs. The application of lean principles in logistics not only improves operational efficiency but also aligns closely with sustainability goals. By reducing waste, optimizing resource use, and streamlining processes, lean logistics helps businesses lower their environmental impact[7]. This dual focus on efficiency and sustainability positions lean as a powerful strategy for meeting the challenges of modern logistics.

2.2.6 Future directions and trends

The logistics industry is evolving rapidly in response to technological advancements, shifting consumer expectations, and global challenges. Future trends in logistics promise to reshape the way goods and information are managed, creating opportunities for businesses to enhance efficiency, sustainability, and resilience. One of the most transformative trends is the increasing adoption of digitalization towards technologies such as Internet of Things

(IoT), artificial intelligence (AI), and blockchain. Automation and robotics are also driving the future of logistics, especially in warehousing and transportation. Automated guided vehicles (AGVs) and drones are being deployed for tasks ranging from order picking to last-mile delivery. Robotics are improving efficiency in warehouses, where they can work alongside human operators to speed up packing and sorting processes[7]. Sustainability has become a core focus for logistics providers as businesses face increasing pressure to reduce their environmental footprint. Companies are investing in green technologies, such as electric vehicles, renewable energy-powered warehouses, and energy-efficient transportation routes. Additionally, reverse logistics is gaining prominence as part of a circular economy, where returned goods are recycled, refurbished, or reused. By integrating sustainable practices, businesses can align with regulatory requirements and consumer expectations while reducing operational costs[6]. Finally, the growing importance of collaborative logistics is reshaping how companies manage their supply chains. By sharing resources such as transportation fleets and warehouse space, businesses can reduce costs and improve efficiency. This model, supported by digital platforms, promotes sustainability and enhances service levels by maximizing resource utilization.

Logistics is a dynamic and evolving field, shaped by technological innovation, environmental considerations, and changing market demands. This chapter has highlighted the critical components of logistics, the challenges it faces, and the opportunities presented by integrating lean principles and advanced technologies. The future of logistics lies in its ability to adapt to emerging trends, from digitalization and automation to sustainability and resilience. Businesses that embrace these trends will be better positioned to meet the demands of a globalized and rapidly changing market. By leveraging lean principles, they can optimize their operations, reduce waste, and enhance customer satisfaction while contributing to a more sustainable future. As we move to the next chapter, the focus shifts to the Water Spider methodology, a lean tool specifically applied in logistics to improve workflow and efficiency. This exploration will deepen our understanding of how lean principles are operationalized in real-world logistics settings.

3 Proposed method/framework

3.1 Introduction

The efficiency of internal material handling processes is a key factor in the overall performance of logistics and distribution centers. Among the various operational roles that enable a smooth and continuous flow of consumables, the water spider, originally known as mizusumashi in the Toyota Production System, emerges as a strategic figure in supporting lean-based logistics operations. While the role may vary in detail depending on the layout, material types, and organizational context, the essence of the water spider's work lies in ensuring that operators in value-added areas are consistently supplied with the necessary consumables, without being interrupted or distracted by logistical tasks.

This chapter introduces a standardized method for organizing and executing the Water Spider function within a distribution center. The proposed framework is rooted in lean manufacturing principles, with a focus on eliminating waste, streamlining internal flows, and supporting a pull-based replenishment logic. Rather than presenting a context-specific solution, the framework is designed to be generalizable and applicable across a wide range of logistics environments where variability in material consumption, layout configuration, and staffing is common.

The primary goal of the method is to shift from reactive, ad hoc material delivery to a proactive, standardized, and visual system in which replenishment is driven by operational signals and performed through clearly defined tasks. By doing so, the water spider's activities become predictable, efficient, and replicable, contributing to a stable operating environment and enabling better workload management across the warehouse.

In the following sections, the scope of application and logical structure of the method will be described, followed by an in-depth analysis of the key functional elements and the standardized replenishment procedure. The integration of the framework with physical layout and visual management tools will also be discussed to support a practical and scalable implementation in real-world logistics contexts.

3.2 Scope of application

The proposed framework is designed to address a recurring need in modern logistics and distribution centers: the continuous and timely supply of consumable materials to operational areas without disrupting core activities. While the role of the water spider is most commonly associated with manufacturing settings, it proves equally essential in logistics contexts, particularly where materials such as boxes, labels, pallets, bubble wrap, and similar consumables are required across multiple stations throughout the day.

In distribution centers, the main challenge lies in the variability of demand and consumption frequency across different consumable types. Some materials may require replenishment every hour, while others only once per week. Moreover, the absence of a fixed takt time, typical in production lines, means that traditional lean tools such as work standardization based on cycle time cannot be directly applied. This dynamic consumption pattern complicates the possibility of establishing rigid replenishment paths and necessitates a flexible but structured response system based on lean principles.

The framework is applicable in environments where:

- Consumables are scattered across different functional zones (e.g., packing, quality check, returns);

- Material consumption is repetitive but non-homogeneous;
- Operators are not assigned to fixed cells but move through the warehouse;
- There is a need to decouple value-added activities from internal logistics tasks, allowing operators to focus entirely on core processes.

Additionally, the method assumes the presence of clearly identifiable storage points, not necessarily fixed workstations but rather shared supply locations where materials can be deposited and collected by operators as needed. These become the "refill points" to be served cyclically or on demand by the water spider.

Given this context, the framework supports both standardization and flexibility: while the replenishment procedure is codified, the path and sequence can be adapted dynamically based on actual needs. This makes it particularly suitable for logistics centers where visual management tools (e.g., kanban cards, digital dashboards, color-coded bins) are already in place or can be easily introduced, allowing for real-time signaling of material shortages [8].

A diagram illustrating a simplified material flow—from the main consumables stock area to multiple refill stations within a warehouse—could be inserted here to visually reinforce the concept. It should represent:

- main storage area;
- water spider loop path;
- decentralized refill stations;
- visual signal points (kanban or alert triggers).

In summary, this method is suitable for any logistics setting that deals with high variety in consumables, decentralized points of use, and the need for lean-driven material handling optimization. It is not limited to a specific warehouse size or industry sector, making it applicable across a wide range of operational contexts.

3.3 Method overview

While flexibility is crucial to accommodate the variability typical of warehouse operations, a well-defined framework allows companies to optimize internal material flows, minimize waste and ensure operators are never interrupted in their core tasks due to missing consumables.

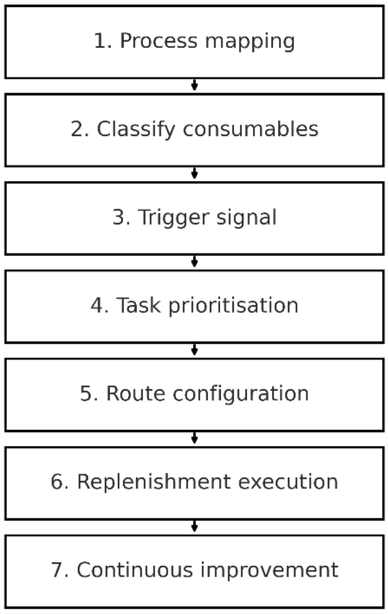
The method consists of four key phases that define the operational logic: demand detection, task prioritization, route configuration and replenishment execution. Each phase is guided by lean principles and supported by practical tools such as visual signals, kanban cards and standardized containers.

In the first phase, demand detection relies on the integration of visual or digital tools that indicate material shortages. These may include physical kanban boards near workstations or digital dashboards linked to real-time inventory levels. Once a shortage is identified, the second phase involves prioritizing tasks based on urgency, distance and potential impact on operations. This ensures that the water spider focuses first on those areas where a delay would have the most disruptive effect.

The third phase, route configuration, adapts the sequence of replenishment tasks to the current layout and workload. Rather than following a static loop, the water spider uses the logic of efficiency-driven path planning, minimizing empty trips and overlapping movements. Simulation models have shown that dynamically adjusting routes based on real-time needs reduces travel time and increases responsiveness [8].

Finally, the fourth phase involves the physical replenishment activity. Standard operating procedures define the type of containers, handling methods and safety checks to be followed. This step, while being the most visible, depends heavily on the previous phases to ensure it is performed smoothly and without waste.

This modular structure not only increases clarity and replicability but also supports continuous improvement through monitoring and feedback. By standardizing the logic of the water spider's work, companies can reduce variability, identify bottlenecks and scale the process in larger or more complex warehouses.



3.4 Process Mapping and Standardization

A core component of the proposed method is the mapping and standardization of the water spider's tasks. In environments like distribution centers, characterized by operational variability, it becomes essential to define the work sequence, roles and interactions clearly. This allows the process to be repeatable, measurable and progressively improvable in accordance with lean principles.

The first step in process mapping is the identification of the relevant consumption points across the warehouse. These may include inbound stations, packing areas, quality control zones or any decentralized location where consumables are stored and used. Each of these points must be documented with details on the type of materials required, average consumption rates and replenishment frequency. The use of value stream mapping tools can help visualize material flows and detect inefficiencies or unnecessary movements.

Once the consumption points are identified, a standard work routine is defined for the water spider. This routine includes a predefined set of actions such as collecting the material, checking the signal system, navigating the shortest path to the station and delivering the items using ergonomic and safe practices. Even though the route may vary daily, the structure of each task remains consistent and traceable. This standardization enables companies to assess performance over time, identify deviations and implement corrective actions.

The introduction of visual management is also crucial. Tools such as color-coded containers, replenishment kanbans, and floor markings help to align expectations and reduce the cognitive load of the operator. These tools, widely adopted in lean logistics environments, increase the predictability of material flows and support a culture of discipline and responsiveness [9].

Furthermore, training programs and checklists ensure that the standardized process is not only implemented but sustained. The goal is to eliminate personal variations in execution while allowing the flexibility required to manage demand variability. This balance between stability and adaptability is the foundation for reliable internal logistics operations and is aligned with the continuous improvement model promoted by lean thinking [2].

3.5 Standardized Replenishment Procedure

The replenishment procedure is the core operational cycle of the water spider. To ensure its effectiveness and replicability across different warehouse contexts, the process must be standardized in terms of timing, materials, containers and delivery modalities. This standardization not only improves efficiency but also enables a more accurate monitoring of performance and the identification of process deviations over time.

Timing is a crucial variable. Although consumption in a distribution center is inherently variable, it is possible to define target replenishment windows based on historical data and predictive analysis. For high-rotation consumables, such as shipping labels and small cardboard boxes, replenishment may occur several times per day, while for less critical materials, such as bubble wrap or secondary pallets, a lower frequency can be established. Setting these time frames allows for the structuring of loops or task clusters that optimize travel time and reduce idle movements [8].

Materials and containers must also follow a clear classification. Consumables are typically grouped by type, size or usage location. Standardizing the type and dimension of containers—e.g. reusable bins, roll containers or trolleys—simplifies handling and guarantees compatibility with storage systems and picking stations. In lean environments, this uniformity reduces variability and supports a smoother replenishment process, as the water spider does not need to adapt tools or search for compatible equipment each time a task is initiated [2].

Delivery modalities should be designed to minimize physical effort and maximize precision. Wherever possible, materials should be delivered directly to point-of-use storage areas, avoiding intermediate stock. Floor markings, visual labels and modular shelving systems can help the water spider position each item in a consistent and accessible location. In addition, the delivery logic may follow a pull-based model triggered by kanban signals, ensuring that materials are replenished exactly when needed without overstocking [9].

Process control is another essential component. Routine checks must be implemented to verify the correctness of delivered materials, the status of the containers and the overall adherence to the procedure. These controls can be manual,such as visual inspections or checklist-based confirmations, or automated through WMS-based confirmations at delivery. In parallel, a maintenance routine should be applied to the tools and vehicles used by the water spider, such as checking the condition of trolleys, cleaning containers and replacing worn-out labels or signal cards.

In sum, the standardized replenishment procedure transforms the work of the water spider from a reactive task into a structured operational process, aligned with the lean principles of stability, efficiency and continuous improvement.

3.6 Integration with Warehouse Layout and Visual Tools

The integration of the replenishment framework into the physical layout of the warehouse is essential to ensure the effective deployment of the water spider methodology. The spatial organization of a distribution center influences every aspect of material flow, visibility, and accessibility. Therefore, the alignment between layout configuration, replenishment logic and visual management tools is not a secondary aspect, but a fundamental enabling condition for the success of a standardized lean process.

A first step in this integration process is the clear identification and mapping of consumption points and replenishment zones. These are typically located near inbound and outbound docks, packing and sorting stations, or areas where consumables are frequently needed by operators. To enable efficient task routing, these points must be grouped into logical clusters based on usage frequency, material category or geographical proximity. This spatial segmentation allows for the design of replenishment loops that are coherent, repeatable and balanced in terms of effort and time required [11].

The paths followed by the water spider must also be optimized considering the structural characteristics of the warehouse. Narrow aisles, intersection points, and one-way traffic rules can become critical constraints if not considered in the initial design. Additionally, replenishment routes must be coordinated with other internal logistics flows, such as forklift routes or AGV lanes, to avoid congestion and ensure safety.

Visual management plays a key role in supporting the standardization of both movement and material placement. The use of floor markings, color-coded areas, shadow boards and signage helps ensure that materials are always delivered to the correct location, in the right quantity and condition. This not only improves efficiency but also reduces dependency on individual operator experience, making the system more robust [3]. For example, shadow boards for tape dispensers or boxed labels can include printed usage guidelines, reorder thresholds and QR codes to trigger replenishment.

In more advanced settings, visual tools can be complemented by digital interfaces. Warehouse management systems (WMS) and real-time locating systems (RTLS) allow operators and the water spider to monitor inventory levels and task status from mobile terminals or wall-mounted dashboards. These systems can also highlight replenishment urgencies through color-coded alerts and automatically assign priorities based on pre-defined business rules [12]. For instance, a low-stock notification on a high-priority station can be highlighted in red, triggering an immediate task assignment.

The design of storage stations also impacts the success of visual integration. Materials should be stored in standardized containers, such as bins, trays or trolleys, appropriately labeled and placed at ergonomic height. Clear signage should indicate the item, its unit of measure, reorder level and replenishment frequency. The presence of visual indicators, such as empty-bin flags or kanban cards, simplifies the signaling process and ensures replenishment actions are initiated without delay [1].

Finally, integration is not a one-time activity but a continuous improvement process. Feedback loops must be created to assess the effectiveness of layout and visual tools in supporting water spider tasks. Metrics such as replenishment lead time, travel distance, error rate and idle time should be collected and analyzed periodically. Layout modifications, signage updates or the redesign of replenishment routes can be implemented through PDCA (Plan-Do-Check-Act) cycles, involving both operators and supervisors in the refinement of the system.

3.7 Conclusions

This chapter has presented a standardized lean framework for the water spider role in logistic distribution centers. Starting from the identification of a general context of application, the proposed method was built on the recognition of key operational variables, including the types of consumables handled, the characteristics of consumption points, and the inherent variability of warehouse operations. Despite the dynamic nature of logistics, the method emphasizes the possibility of standardizing certain aspects of the water spider's role, such as replenishment logic, communication protocols, and travel patterns.

A detailed method overview introduced the structure of the proposed framework, distinguishing between fixed and flexible components. In particular, the role of the water spider was explored through the lenses of standardization, responsiveness and visual control, while the integration of visual tools and layout configuration was shown to be a critical success factor for implementation. The replenishment procedure was codified into time-based and signal-based routines, supported by visual management and continuous monitoring.

Rather than proposing a one-size-fits-all solution, the method provides a scalable structure that can be tailored to the specific layout, operational constraints and replenishment needs of different warehouses. Furthermore, the method's principles are aligned with lean thinking, promoting flow stability, error prevention and waste reduction.

In conclusion, the framework defines a structured, yet adaptable approach to enhance the efficiency and clarity of internal logistics, positioning the water spider as a key enabler of operational excellence in the warehouse environment. In the next chapter, this method will be applied to a real case study, illustrating its practical relevance and effectiveness through data-driven results and observed improvements.

4 Results/Case study

4.1 Company Overview and Problem Definition

This project has been developed in the distribution center of Schneider Electric in Venaria Reale (TO). Schneider Electric is a multinational company specialized in industrial automation and energy management. The company offers a wide range of products and services, including automation systems, energy management software, and infrastructure solutions, serving a broad spectrum of sectors including residential, industrial, infrastructure, and data centers.

The company stands out for its commitment to sustainability and innovation, promoting practices that reduce environmental impact and enhance the resilience of businesses. Schneider has got a strong presence in Italy, with numerous factories and lot of clients distributed along the nation; Venaria site is responsible for the last piece of the supply chain: it receives the goods produced by all factories around the world, group them and ship to the client in every part of Italy. It is a warehouse where all goods are received, stocked and then shipped to the clients.

The center operates with a combination of manual and semi-automated systems for material handling, including order pickers, forklifts, and barcode-based inventory management tools. Material flow is driven primarily by customer demand, resulting in high variability in terms of order profiles, volumes, and frequency.

Despite the company's commitment to lean principles, one area that has proven difficult to standardize is the internal replenishment process for consumable materials, such as packaging supplies (boxes, labels, pallets), which are essential to support logistics activities.

These items are not part of the bill of materials for customer orders but are indispensable for packaging, labeling, and preparing shipments.

Currently, the replenishment of these consumables is handled by a water spider, a dedicated operator responsible for supplying workstations throughout the warehouse. However, the process lacks a codified procedure, resulting in inefficiencies such as redundant travel, inconsistent delivery frequencies, and operator uncertainty regarding priorities. The absence of predefined routes or visual management systems further contributes to process variability and dependency on individual experience of the operator.

This situation generates several forms of muda (waste), including over-processing, motion, waiting, both by water spider and the other operators. Moreover, these inefficiencies compromise the visibility and traceability of material flows, increase the cognitive load on the water spider, and occasionally cause delays or disruptions in packing and inbound operations.

From a strategic perspective, solving this problem aligns closely with Schneider Electric's broader objectives of improving process reliability, minimizing non-value-added activities, and fostering lean culture in support functions. By introducing a standardized method for internal replenishment, the company aims to stabilize flows, reduce variability, and enhance the responsiveness of its outbound logistics. The approach is also expected to improve worker coordination and reduce waste, contributing to the center's overall operational performance and service level targets.

4.2 Application of the Proposed Lean Method

The standardized lean framework developed in Chapter 4 was applied to the Schneider Electric logistics distribution center in Venaria Reale with the objective of improving the internal replenishment process of consumable materials. The application was structured in a sequence of practical phases, starting with the mapping of the current state and progressing to the implementation of a structured, responsive, and visually supported replenishment system.

The first step involved a thorough mapping of the existing flows of consumables, which included observing the movements of the water spider over several working days and conducting interviews with warehouse operators and team leaders. The images below show some spaghetti charts of the water spider movements done during the observations.

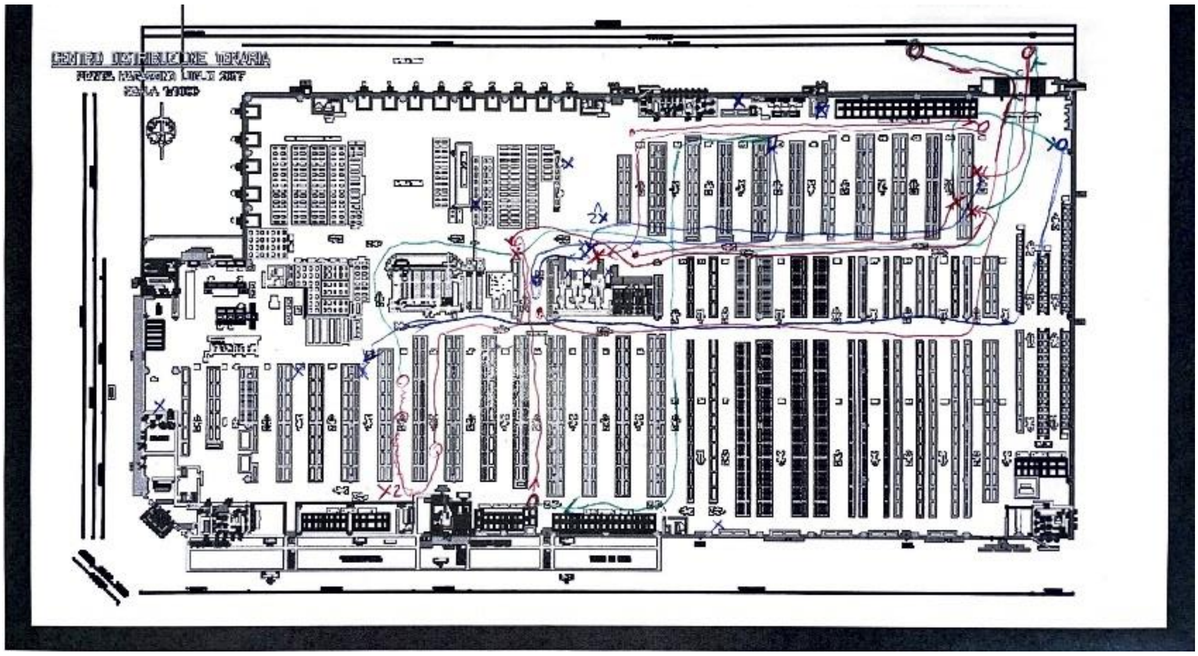


Figure 1 - Spaghetti chart

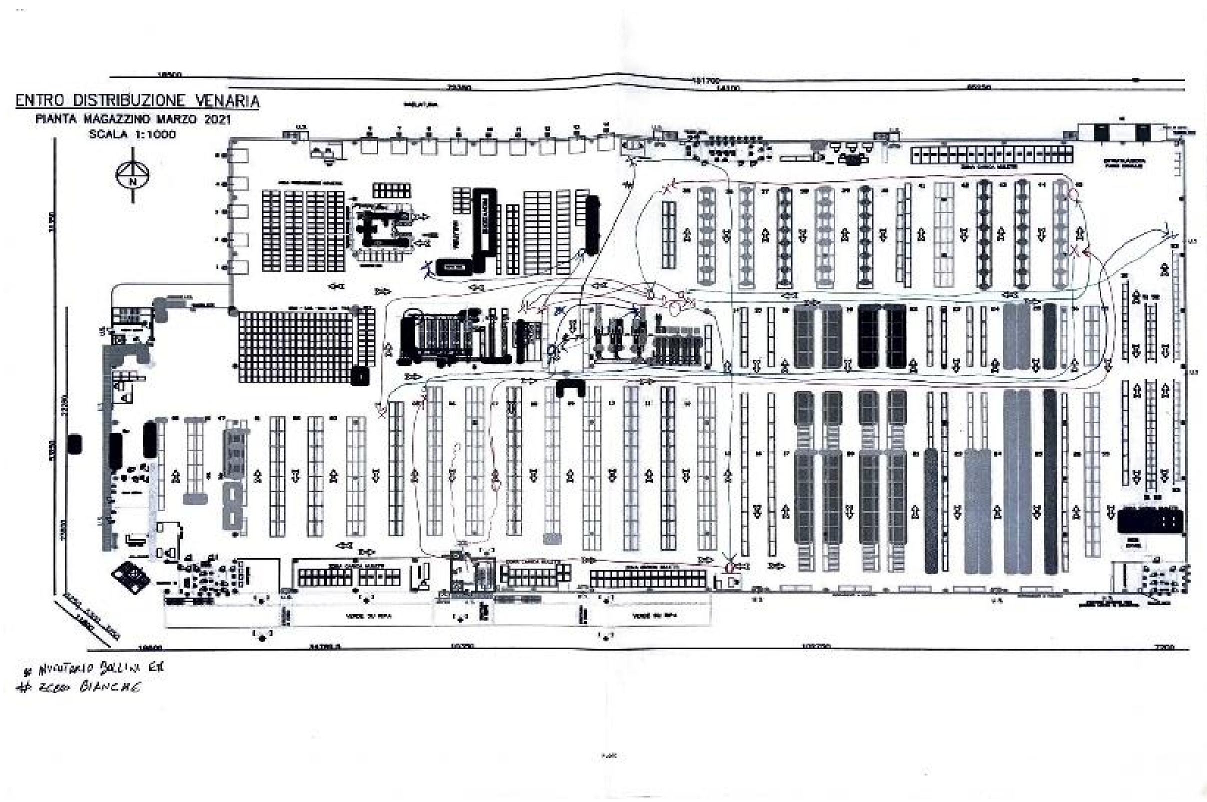


Figure 2 - Spaghetti chart 2

In the charts the different colors show the four types of trips:

- Red – Pallet trip
- Blue – Box trip
- Black – Label trip
- Green – Empty trip

The objective was to identify the primary consumption points across the warehouse, namely, the packing stations distributed along the shop floor. In total, 18 distinct consumption points were identified, each with different usage profiles and replenishment needs, each one with different features. The baseline condition revealed a lack of standardized routes, with the water spider frequently walking back and forth in a reactive manner, resulting in idle time, unnecessary travel, and inconsistent service levels.

A classification of consumable materials was conducted, as shown in the table below.

Category	Material	Notes / Typical Use
Boxes & Lids	S1 Box	Small-size box
	S1 Lid	Matching lid for S1 box
	S2 Box	Medium-small box
	S3 Box	Medium-large box
	S2-S3 Lid	Universal lid for S2 & S3 boxes
	S4 Box	Large box
	S4 Lid	Matching lid for S4 box
	MGA Box	Extra-large "MGA" box (oversize items)
	MGA Lid	Matching lid for MGA box
Pallets	Euro-pallet (EUR-1)	Standard 1200 × 800 mm wooden pallet
	MGA Pallet	2200 × 800 mm wooden pallet
Labels	Barcode label	Standard barcode stickers
	Colored label	Colored stickers for inbound priority
	Printer label stock	Label for dedicated printers

Table 1 - Consumables inventory

The difficulty was to estimate the consumption for each material, since they were not informatically tracked, regarding boxes, lids and labels. Another difficulty came from the aim of the company to recycle the empty boxes coming from the stocking stations. Regarding the pallets instead, they are always the same pallets circulating in the warehouse, so there is not an effective consumption (some pallets are used to ship materials, but they come back after few days, allowing the warehouse to maintain a standard average number of pallets.

A key initial challenge in applying the lean framework was the absence of measurable and repeatable replenishment cycles. In the pre-intervention state, the water spider operated in a fully reactive manner, deciding on a case-by-case basis which stations to replenish and when, based solely on perceived urgency or informal operator requests. As a result, it was impossible to extract reliable data on replenishment frequencies, delivery patterns, or task duration. This lack of standardization not only obstructed any form of performance measurement, but also made the process highly dependent on individual knowledge, leading to inefficiencies and inconsistent service levels across the warehouse. Another important task that occupies lot of water spider time is the collection of empty pallets around the shop floor. The water spider goes to the picking area and collects the empty pallets where all the material has been picked by the operators, then places them in the appropriate station. This task is critical since it is difficult to revise and improve; for safety reasons, pickers are not allowed to leave empty pallets in the aisles to make them more visible, nor are they permitted to carry them to the replenishment station themselves. At the same time, the pallets cannot remain in the picking bins for too long, as new material needs to be stored there. To bring structure to the process, a lean-based redesign was implemented, anchored in the principles of visual control and standard work. The system relies on static visual signals positioned directly at the consumption points. These included numerical and colored labels placed on shelving units to indicate the remaining quantity of consumables. A three-level indicator was used: a green zone indicating sufficient stock, a yellow warning threshold, and a red line identifying the refill trigger point. When the stock level reached the red line, the water spider could immediately recognize the need for replenishment. This setup enabled real-time monitoring of consumption and allowed the water spider to plan the next delivery sequence based on actual material status observed during their route.

This approach was reinforced by the application of 5S principles in both the replenishment and consumption zones. Each material was assigned a defined storage location, clearly labeled and accessible, with floor markings and visual indicators used to identify pallets storage points. Visual management was also adopted to reduce cognitive load and support intuitive navigation for the water spider during each route. These improvements enhanced the visibility of inventory status and reduced unnecessary searching or decision-making time.

Regarding the structural layout, no stations were changed since it was observed that they already were in the best position based on their utility [Figure 5]. It was difficult to move other materials to create new stations on the warehouse; the priority of the site was to create more ergonomic picking points for materials over place new stations for consumables.

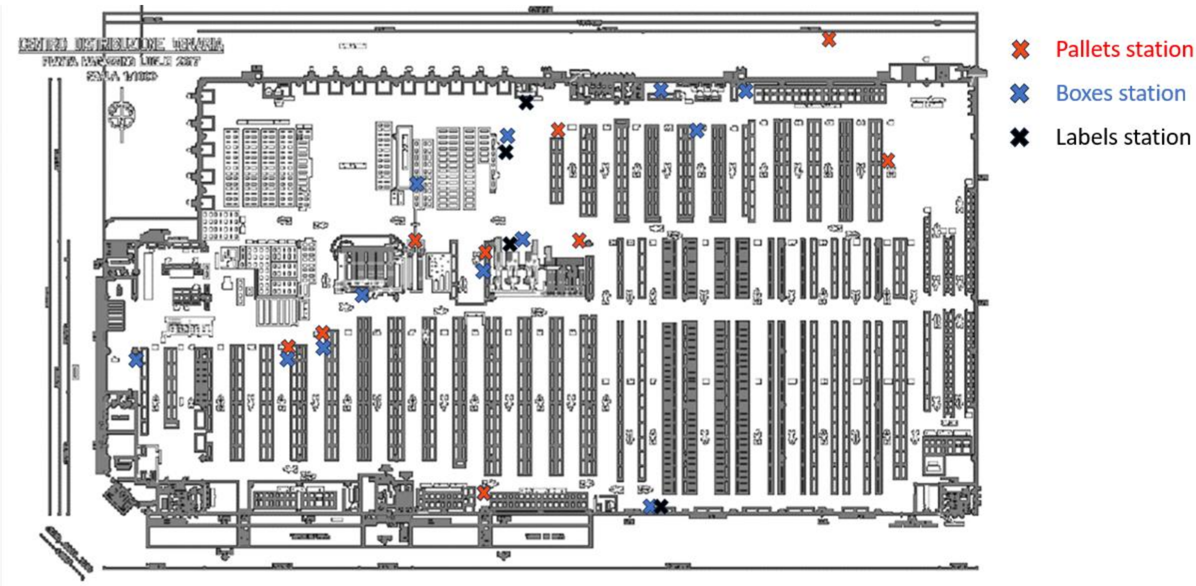


Figure 3 - Structural layout

Due to the inherent variability in workload and order peaks across shifts, the implementation relied on a hybrid replenishment logic. While a baseline route was established with defined loops and time windows, real-time kanban signals allowed the water spider to dynamically adjust their sequence or deviate as needed to address priority requests. This hybrid model balanced structure with responsiveness, supporting stability without compromising flexibility.

In parallel with the implementation of visual kanban signals, it was also necessary to categorize the different workstation types and group the consumable materials accordingly, in order to further streamline replenishment logic and ensure consistency across delivery cycles. First it was necessary to group boxes and leads in one big category, since the replenishment of a station can be done all at once and involve all types of boxes and lids, and the consumption rate of a station can be considered as a whole one. The only exception is the MGA boxes and lids that are part only of one of the stations that in the following lines will be categorized as B4.

For boxes we distinguish four groups, for each one is calculated an average daily consumption and replenishment, with the cadence based on 14 h 30 min of work (2 shifts of 7 h 15 min):

- B1 - Central hub: the single, large-capacity buffer at the picker start-area that both feeds outbound operators and serves as the take-off point for the water-spider. It carries ≈ 6200 boxes per shift-day and, given its 2000-box capacity, requires 3 full replenishments a day (≈ 4 h 50 min cadence).
- B2 - High consumption: three replenishment shelves located close to the picking area. Each holds 90 boxes and is emptied about three times per day, i.e. ≈ 2700 boxes and so 3 replenishments per station (≈ 1 h 27 min cadence).
- B3 – Inbound: a 300-box location in the receiving area that absorbs an average of 1200 boxes per day; its capacity triggers 4 replenishments (one every 3 h 38 min).
- B4 - Low consumption: seven scattered points with low, steady demand. Their 90-box slot is topped up once per shift-day, so only 1 replenishment is needed.

For pallets three logical buckets are distinguished:

- P1 - Picking pallets: four outbound lanes staged with completed orders. With the loading rule of 10 boxes per pallet, each lane handles ≈ 125 pallets per day; at 10-pallet capacity that equates to 13 replenishments per lane (≈ 1 h 07 min cadence).
- P2 - MGA pallets: one internal supply lane consuming ≈ 44 pallets; with a capacity of 10 it needs 4 replenishments a day.
- P3 - Inbound pallets: one pallet lane linked to receiving; ≈ 58 pallets, hence 6 replenishments.

We also have to add a category for the labels (it will be called L1) that contributes for only one replenishment a day, since a labels' roll lasts for very long so the picker changes it very rarely. Besides this the activity that occupies most of the water spider's time is the collection of empty pallets. As mentioned before the water spider has to collect all the empty pallets in the picking area, this activity consumes an average of 15 minutes every hour. This activity was difficult to implement, because there isn't the possibility to implement visual boards in the aisles to help the water spider find the empty pallets and, even if it would be doable, the water spider still had to go through the corridors and search for the signals.

An average of 5 minutes per task has been calculated, resulting in a workload of 74% (see table below).

Component	**Value**
Total tasks / day	86
Operating time	14h 30min
Tasks / hour	5.93
Minutes / hour spent on tasks (5 min x tasks)	29.7 min

Empty-pallet collection	15 min/h
Total busy minutes/hour	44.7 min
Water spider utilisation	74 %

Table 2 - Water spider workload

This workload can be considered a positive outcome since it leaves time that can be used for two other types of activities. The first includes all related support activities, like movements of the pallets that stand outside or cutting the carton needed for specific type of deliveries. The second refers to the priority activities that must be carried out in order to maintain a dynamic and adaptable nature of the process. The variability of each task must also be considered, so the 26% that is off the water spider utilization cover also a possible dilation of some tasks.

After this a cycle loop was established, with every hour starting with the pallet collection and ending with the buffer time. Three loops were individuated.

Cycle A	
Clock (min)	**Task**
00 – 15	Empty-pallet collection
15 – 20	P1
20 – 25	P1
25 – 30	P1
30 – 35	B3
35 – 40	P2
40 – 45	B2
45 – 60	15-min free buffer

Table 3 - Cycle A

Cycle B	
Clock (min)	**Task**
00 – 15	Empty-pallet collection
15 – 20	P1
20 – 25	P1
25 – 30	P1
30 – 35	P3
35 – 40	B2
40 – 45	B2
45 – 60	15-min free buffer

Table 4 - Cycle B

Cycle C	
Clock (min)	**Task**
00 – 15	Empty-pallet collection
15 – 20	P1
20 – 25	P1
25 – 30	P1
30 – 35	B1
35 – 40	B2
40 – 45	B4
45 – 60	15-min free buffer

Table 5 - Cycle C

From here, we can check that the planned supplied meets the required replenishment a day leaving space for adjustments.

Family	Required /day	Supplied /day
P1 – Picking pallets	52	52
B1 – Central hub	3	3
B2 – High consumption	9	10
B3 – Inbound boxes	4	4
B4 – Low consumption	7	7
P2 – MGA pallets	4	4
P3 – Inbound pallets	6	6
L-1 – Labels	1	1

Table 6 - Daily check

4.3 Results and operational insights

Beyond the direct improvements in task execution, the implementation of the standardized framework contributed to broader strategic goals within the distribution center. By stabilizing internal logistics flows, the company laid the groundwork for a more reliable and scalable operational model. In particular, the increased predictability of replenishment processes enabled a better alignment with outbound priorities, reduced last-minute expedites, and improved the service level toward stations. The nature of the activity flow makes it difficult to find KPIs to monitor in order to see the effectiveness of the implementation of the new method, but some measurements can be taken. The application proposed in the previous paragraph estimates that the water spider has to complete 6 tasks per hour, plus the pallet collection; results show that after 2 weeks the average was at 7.2 task/h. Considering that the 15 minutes buffer per hour is proposed for adding special requests based on daily demand variability and for occasional tasks, this result can be considered acceptable. The number of interventions completed before a stockout occurred was considered a proxy for the system's anticipatory effectiveness. In the reactive model, stockouts were frequent and often required urgent restocking. After the implementation, the water spider was able to fulfill more replenishment tasks before actual depletion occurred, indicating that the visual system supported earlier detection of needs and improved the reliability of supply. The reduction in urgent calls and delivery rework not only streamlined the water spider's route, but also enabled indirect gains in picker productivity, as operators no longer had to pause their tasks to request missing materials.

From a qualitative perspective, the introduction of a standardized replenishment framework brought noticeable improvements in the organization and execution of daily logistics activities. Prior to the intervention, the absence of clearly defined procedures made the water spider's work heavily reliant on informal communication and personal judgment, which in turn introduced inconsistencies across shifts and operators, and very frequently operators had to call the water spider to face emergencies, so it had to interrupt his actual activity, refill where it was needed, and then go back to his original task, causing a double waste, for him and for the operators. Following the implementation, both water spider personnel and warehouse operators reported an increased sense of clarity and predictability in daily operations.

One of the most frequently cited benefits by warehouse staff was the increased transparency in material availability. The visual kanban indicators allowed operators to intuitively recognize the refill status of consumables without needing to interrupt their workflow or issue verbal requests. This reduction in interruptions and clarification exchanges contributed to smoother coordination and improved mutual understanding between the water spider and workstation users. Supervisors also observed a decline in last-minute emergencies and stockouts, particularly in high-volume areas, which was attributed to earlier detection of needs and more reliable task execution.

Furthermore, the introduction of simple, repeatable visual signals aligned with 5S principles led to a more organized and ergonomic environment. Material drop-off points were consistently respected, floor markings helped delimit paths and storage zones, and disorder caused by leftover packaging or misplaced supplies was notably reduced. These seemingly small changes had a cumulative effect on daily performance, especially in peak workload periods, when the ability to rely on a structured process proved crucial, but show that the process is not perfect, and lots of improvements can be done. Nonetheless, the implementation also encountered some resistance and operational challenges. A number of operators initially struggled to fully trust the kanban system, particularly in workstations where consumption was highly variable. In such cases, they were hesitant to rely exclusively on visual triggers, fearing delayed responses or material shortages. A request from other operators was to give the water spider a walkie talkie to permit the team leader to call him when needed, but this suggestion was discarded for two reasons: because it was considered unnecessary and because the over usage of it would have been stressful for the water spider. The concern was gradually addressed through targeted on-the-job coaching and clarification of how the hybrid logic, combining structured loops and reactive flexibility, ensured continuity even in volatile demand situations. Another critical insight emerged regarding the learning curve associated with the new process. Although the visual tools were simple and self-explanatory by design, their correct use still required a short adaptation period. During the initial implementation phase, water spider operators required supervision not only to interpret kanban signals correctly but, more importantly, to internalize and follow the newly established predefined paths. In fact, the most challenging aspect of the transition was learning to execute deliveries according to a fixed sequence of activities, rather than acting reactively based on immediate needs or proximity. This shift demanded a change in mindset: from a flexible, on-demand model to a more disciplined and structured routine. At first, operators tended to deviate from the assigned loop to address perceived urgencies, which risked disrupting the logic of workload balancing and route optimization. Only after repeated reinforcement the new habit take hold, and time can only help to consolidate it. The effectiveness of the framework suggests its replicability across other distribution centers facing similar challenges. The combination of standardized paths, visual triggers, and workload balancing mechanisms proved robust enough to be adapted to varying demand conditions, offering a structured solution to a commonly under-addressed logistical gap.

5 Conclusions

In conclusion, the structured application of the lean-based framework to the internal replenishment process led to tangible improvements in both performance and operational clarity. Quantitative data confirmed a reduction in unnecessary movements, shorter lead times, and increased delivery consistency, while qualitative observations highlighted improved coordination, better material availability, and reduced cognitive load on operators. Crucially, the introduction of standardized delivery loops and visual signals not only enhanced efficiency but also laid the foundation for a more stable and replicable process. Although some adaptations were necessary to align the framework with the specific dynamics of the warehouse, particularly in balancing standardization with flexibility, the resulting system proved effective in supporting lean objectives without compromising responsiveness.

These findings demonstrate that, even in distribution environments characterized by variability and decentralization, the water spider role can be transformed into a structured, value-generating function through targeted lean methodology. What was once an informal task guided mainly by operator experience and intuition was formalized into a repeatable, visually controlled process that promotes flow, reduces waste, and supports continuous improvement.

This thesis also highlights the broader organizational benefits of lean standardization in logistics. By clearly defining responsibilities, sequencing activities, and introducing visual management tools, coordination between water spiders and picking operators was significantly improved. The visibility of material needs and replenishment priorities allowed for faster responses and fewer interruptions, thereby improving overall service levels.

Nonetheless, the work presented some limitations. Due to the absence of an initial standardized system, reliable historical data was absent, which restricted pre and post intervention comparisons. In addition, while the proposed method is generalizable in principle, its application may require specific tailoring depending on physical layout constraints, technological infrastructure, material variety and consumptions and team maturity. The informal nature of some supporting activities, such as pallet handling, also poses a challenge for complete standardization.

Looking ahead, several areas for future development emerge. Firstly, integrating digital kanban tools or warehouse management systems (WMS) with mobile devices could enhance signal collection and route planning in real time. Secondly, expanding the framework to include exception handling, returnable packaging flows, or data-driven workload balancing would further reinforce its robustness. Finally, embedding continuous training and operator feedback mechanisms can ensure that the process remains flexible, human-centric, and adaptable to evolving operational needs.

Ultimately, this thesis confirms that the application of lean thinking to internal logistics processes, when rigorously structured and thoughtfully adapted, can yield meaningful operational gains, despite the contrast between lean rigorous structure and logistic variability. The case of the water spider at Schneider Electric demonstrates that, even in dynamic and complex warehouse environments, lean principles such as standard work, visual control, and flow orientation remain powerful tools for driving efficiency, resilience, and organizational learning.

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