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Picking Process Improvement: The case of a company in the sporting goods retail sector

Dinis Filipe Lapão Garcia

Master in Management of Services and Technology

Supervisor:
Professor Teresa Sofia Grilo, Department of Marketing, Operations and Management,
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Department of Marketing, Operations and Management

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Resumo

Apesar de, com a Covid-19, algumas atividades ligadas ao desporto terem sido temporariamente afetadas, a pandemia veio reforçar a importância da atividade física para uma vida saudável, resultando numa maior prática de desporto tanto a nível formal como informal, que já vinham a ganhar cada vez mais adesão em Portugal. Dito isto, as empresas nos setores de atividades ligadas à prática desportiva devem estar preparadas para esta realidade.

Os mercados são cada vez mais competitivos, é fundamental rever e melhorar os processos de uma forma contínua e sistemática. Order picking é um dos processos que mais exige este esforço, pois é um dos processos que implica mais horas de trabalho e tem um impacto direto na qualidade e eficiência de toda a cadeia de abastecimento. Este é claramente o caso no centro logístico da Empresa X, mais concretamente na área dos artigos volumosos. Neste sentido, o presente estudo foca-se em encontrar estratégias apropriadas que permitam melhorar este processo.

Tendo em conta este objetivo, e com base na revisão de literatura, foi usada uma abordagem de Business Process Improvement (BPI). Como parte integrante desta abordagem, e também como consequência da revisão de literatura, foi proposta uma solução de melhoria que passa pela substituição do atual método de *pick-by-label* por *pick-by-tablet* juntamente com tecnologia RFID como método de confirmação.

Todas as análises efetuadas permitem concluir que esta proposta poderá representar melhorias significativas no que diz respeito à eficiência e eficácia do processo, indo assim de encontro aos objetivos estabelecidos para o projeto.

Palavras-chave: Setor retalhista de artigos desportivos, *Business Process Improvement,* Eficiência, Eficácia, *Picking, Pick-by-tablet*

JEL Classification System: L15; L67

Abstract

Although, with Covid-19, some sports-related activities were temporarily affected, the pandemic reinforced the importance of physical activity for a healthy life, resulting in a greater practice of sports both formally and informally, which had already been gaining more and more adherence in Portugal. Having said this, companies in the sports-related activity sectors must be prepared for this reality.

Markets are increasingly competitive, it is essential to revise and improve processes in a continuous and systematic way. Order picking is one of the processes that most requires this effort, as it is one of the processes that involves more working hours and has a direct impact on the quality and efficiency of the entire supply chain. This is clearly the case at the logistics centre of Company X, particularly in the area of bulky items. In this sense, this study focuses on finding appropriate strategies to improve this process.

With this objective in mind, and based on the literature review, a Business Process Improvement (BPI) approach was used. As an integral part of this approach, and also as a consequence of the literature review, it was proposed an improvement solution that involves the replacement of the current pick-by-label method with pick-by-tablet combined with RFID technology as a confirmation method.

All the analyses performed lead to the conclusion that this proposal may represent significant improvements in terms of process efficiency and effectiveness, thus meeting the objectives established for the project.

Keywords: Sporting goods retail sector, Business Process Improvement, Efficiency, Effectiveness, Picking, Pick-by-tablet

JEL Classification System: L15; L67

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Glossary

BPI - Business Process Improvement

BPM - Business Process Management

CMD - Cart-Mounted Display

ERP - Enterprise Resource Planning

HMD - Head-Mounted Display

HUD - Head-Up Display

IDS - ISCTE Discovery Service

KPI - Key Performance Indicator

PI - Performance Indicator

RFID - Radio Frequency Identification

SKU - Stock Keeping Unit

1. Introduction

This chapter aims to present the challenge at hand as well as its context. This project is developed in the scope of the sporting goods retail sector, more specifically in the logistics supply centre of the company where the study will be conducted - Company X. The description of the problem and its context, as well as a brief analysis of the sector, will serve as a basis to highlight the possible practical and scientific relevance of this project. In this respect, this chapter also presents the research question as well as the objectives and methodology followed. Finally, a brief presentation of the project structure is also included.

1.1. Context

The sports sector has assumed great relevance in the international arena, namely at the level of the Sustainable Development Goals established by the United Nations and the World Health Organisation, due to the important role it plays in promoting the health of the population (PWC, 2021). Moreover, the World Tourism Organisation recognises the relevance that the segment "Sports Tourism" has been assuming in the context of this sector. As per PWC (2021) in Portugal, one of the objectives of the Government Programme set out in the State Budget 2021 is to place Portugal among the 15 countries with more physical and sporting activity in the European Union (EU) by 2030.

Sports practice had been showing a very positive trend in recent years in Portugal, however, the COVID-19 pandemic had some impacts on this evolution. As an example, according to the National Institute of Statistics (NIS) (*INE - Instituto Nacional de Estatística*) (2021) in the last decade, the number of practitioners registered in sports federations had been following a positive trend, rising from 513,005 in 2009 to 688,894 in 2019. However, in 2020, contrary to the upward trend of recent years, this number dropped to 589,901, largely due to the COVID-19 pandemic and the restrictions associated with it.

Based on data from the Bank of Portugal (*Banco de Portugal*), NIS, and the EU, PWC (2021) estimated the economic relevance of the sports sector on the national economy as well as the impact of COVID-19 on it. In 2019, it is estimated that the sector (in its broad definition, i.e., considering all sports activities corresponding to the classification of economic activities (CEA) (*CAE - Classificação das Atividades Económicas*) 931; the activities, products and services needed as inputs to make and/or produce sport; and also, all economic activities and products that incorporate sport in their production processes) generated a Gross Value Added (GVA) of 4,210 million euros and 133 thousand jobs, translating into a weight of 2.3% in GVA and 2.8% in jobs in the national economy. In 2020, it is estimated that the sector (in its broad definition) generated a GVA of 3,695 million euros and 117 thousand jobs. This translates into an estimated drop of around 12% in both cases. For 2021, a partial

recovery of the sector is expected, but it will still be far from the pre-COVID figures. In 2021, considering two evolution scenarios (base and adverse scenarios), it is estimated that the sector (in its broad definition) will generate a GVA between 3,765 and 3,851 million euros, and between 119 and 122 thousand jobs, which would mean a growth between 2 and 4% compared to 2020.

The important idea to retain here is that despite the negative impacts of COVID-19 on the sports sector in terms of the number of practitioners at federated level, the number of jobs, among other things; this is a sector that had been showing a quite positive evolution in the pre-pandemic years. In addition, the COVID-19 pandemic raised awareness about the importance of physical activity and sports for health (PWC, 2021). Thus, with the improvement of the pandemic context, it is expected a significant increase in physical activity practice in various segments (both formal and informal), higher than in the pre-pandemic context (PWC, 2021). Having said this, companies in the sports-related activity sectors should be alert and prepared for this growth of activity.

Furthermore, in today's global economic environment, customers' expectations have increased and therefore businesses are actively looking for competitive advantages by delivering excellent service (Ciancio, 2018). According to Thatte et al. (2013), today's supply chains are expected to respond rapidly, effectively, and efficiently to changes in order to sustain, succeed and create competitive advantages in increasingly competitive markets. It is, therefore, essential to focus on time, flexibility, and speed of response. These conditions emphasise the need to revise and improve business processes on a continuous basis (Adesola & Baines, 2005), by reducing or eliminating waste throughout the processes and making them as efficient as possible (Widodo et al., 2021).

These challenges are posed to the sector as a whole, and also more specifically to Company X, which will be the focus of this project. Company X operates, as mentioned, in the sporting goods retail sector. This investigation takes place in its logistics supply centre responsible for the Portuguese market (i.e., responsible for receiving items from suppliers, storing and organising them and then supplying all the company's retail shops as well as online customers, in Portugal). This centre is divided into different areas where different teams operate according to the typology of items they are in charge of. Each team is responsible for various processes in their respective area, including the reception of items, picking, and stock management.

During the first weeks of contact with the company and its different teams and processes, with the aim of better understanding its needs, its strategic objectives, as well as its main areas and respective processes, it was concluded that the area with the greatest potential and need for improvement is the area of bulky items, more specifically in the picking process. Through an initial observation of the processes and conversations with employees and the people in charge of this area, it was possible to identify some factors that justify this conclusion, namely:

- Despite efforts, there are still many inefficiencies in the process and picking errors.

- This is a process that represents a major part of the team's working hours.
- As it mainly deals with heavy items, it is a very exhausting process for pickers if it is not efficient.
- It is a process that is of pivotal importance for the speed of response to orders.

It is therefore crucial for Company X to find ways to make this process more efficient and effective. While recognising this, the company does not want to change the warehouse layout, the picking routes, the picking type or the storage assignment policies, as it considers that its strategies at these levels are well suited to the needs of the process given the resources available. Following this line of thought, this project will focus primarily on analysing, adapting, and implementing appropriate strategies (given the company's requirements) to improve the picking process in the area of bulky items at the logistics supply centre of Company X, with the aim of increasing its efficiency and effectiveness.

1.2. Research Question

On the basis of the context described previously, the research question of this project is:

"How can the picking process in the area of bulky items at the logistics supply centre of Company X be improved so as to increase its efficiency and effectiveness?"

1.3. Objectives

As mentioned above, and according to the research question, the primary objective of this project is to improve the picking process in the area of bulky items at the logistics supply centre of Company X - a company operating in the sporting goods retail sector, by analysing, adapting, and implementing appropriate strategies to increase its efficiency and effectiveness.

To better answer the research question and in order to have a clearer idea of the path to follow, some specific objectives were defined:

- Observe, map and analyse the *"as is"* of the process.
- Characterise the process in terms of objectives and current performance.
- Identify wastes, inefficiencies and opportunities for improvement in the process.
- Propose appropriate solutions for the identified shortcomings in order to improve the process.
- Plan the improvement and design it.
- Assess the designed improvement to verify if it conforms to the planned goals.
- Provide suggestions for implementing the proposed solution.
- Compare the "as is" process with the "to be" process in terms of performance.

1.4. Methodology

The main steps of this approach are carried out in a sequential manner, and are as follows:

- Initialisation
- Selection
- Design
- Recommendations for Implementation
- Evaluation

Manage Change and Establish Top Management Support are also part of the proposed methodology but these are carried out throughout the entire project.

1.5. Structure

This project is structured as follows:

Chapter 1 - Introduction: In this chapter, the context of the investigation is described, the research question is formulated, as well as the objectives, the adopted methodology and the project structure.

Chapter 2 - Literature Review: In this chapter, a review of scientific documents on the concepts and themes under study is made to support the proposal presented in the introduction. The chapter starts by introducing basic concepts regarding business processes. After that, the importance of finding ways to improve business processes in a structured and systematic way is highlighted, where the different strategies mentioned in the literature for this purpose are analysed. In this follow-up, it was concluded that the focus would be on a BPI (Business Process Improvement) approach, with this concept being further explored as well as the different strategies for applying it. Moving closer to the research question and the established objectives, strategies related to the improvement of the picking process were then analysed.

Chapter 3 - Methodology: This chapter describes in detail how the research is conducted, as well as its different steps and the methods used in each one.

Chapter 4 - Case Study: In this chapter, a brief introduction of the company and the context of the problem is given, and then the different steps described in the methodology are applied.

Chapter 5 - Conclusions: Here the main findings of the research are presented, with the objectives and research question answered. The limitations of this project and recommendations for future improvements are also presented.

2. Literature Review

This chapter aims to present the theoretical basis that will support the development of the project. Given the context and the research question described previously, this literature review is based on the following key concepts: process; business process; improving business processes; Business Process Improvement (BPI); BPI methodologies and frameworks; BPI tools and techniques; lean; BPI in the retail context; picking; picking process improvement. The databases used for this literature review were EBSCO-host (here: IDS – ISCTE Discovery Service) and Scopus.

2.1. Business Processes

2.1.1. Process and Business Process

Before addressing the very issue of process improvement, it is important to clarify some key concepts in order to better understand their meanings and scopes.

The term *process* has been addressed and interpreted by different authors and from different perspectives, however, a commonly recognised definition is: "The transformation of inputs into outputs; the inputs can be resources or requirements, whilst the outputs can be products or results. The outputs may or may not add value and could be an input to another process" (Harrington, 1991, as cited in Adesola & Baines, 2005, p. 38).

In turn, the term *business process* results from the application of the process concept to a commercial organisation (Adesola & Baines, 2005). In this case, several specific definitions have become widely adopted in the literature. Tinnilä (1995), briefly summarises the concept of business process as being a set of logically related tasks that make use of the organisation's resources to achieve specified results in support of the organisation's objectives.

From these definitions, it can be understood that order picking in the area of bulky items in the logistics supply centre of Company X is a business process; being its improvement the aim of this project, in order to increase its efficiency and effectiveness.

2.1.2. Improving Business Processes

Business environments are more and more complex. Companies must be increasingly fast and flexible, undergoing significant changes in order to respond to pressures exerted by customer expectations, new technologies, and increasing global competition. To stay competitive in these dynamic business environments, companies need to revise and improve their business processes in a continuous and structured way (Adesola & Baines, 2005; Yousfi et al., 2019).

According to Yousfi et al. (2019), there are at least four reasons to work towards improving business processes. First, processes are designed by humans and humans are not perfect, therefore

processes may often have defects. Second, organisations tend to improve organically over time; being that, if they do not undergo any improvement, their processes will lag behind the competition and their performance will gradually deteriorate. Third, the context around organisations is also continuously evolving; new competitors may enter the market delivering the same products or services with better conditions for customers, customer preferences are continuously changing, and so forth. Fourth, regardless of the economic environment, organisations endeavour to improve business processes; when in good shape, improvement is undertaken as a reaction to an expansion, which often happens in the form of mergers or acquisitions, as these can result in partially redundant processes; on the other hand, when in bad shape, companies strive for efficient business processes since the companies operating the most efficient processes typically survive while the others tend to lose ground.

As per Harmon (2014), there are several different ways to improve business processes, such as process improvement, process redesign, business process management (BPM), and process automation. Following the definitions provided by Harmon (2014, p. xxxii), "*process improvement* refers to relatively minor, specific changes that one makes in an existing business process."; the author adds that "on occasion, special process improvement efforts are required to get everyone focused on improving a specific process". In turn, "*process redesign* refers to a major effort that is undertaken to significantly improve an existing process or to create a new business process". As for *business process management (BPM)* in its most generic sense refers to "how business managers organise and control processes". Finally, "*process automation* refers to the use of computers and software applications to assist employees or to replace employees in the performance of a business process.", which can be useful in process improvement, process redesign or BPM initiatives.

Another concept that is important to clarify is the concept of *business process reengineering*. In the literature, the terms business process improvement, business process redesign, and business process reengineering often lead to confusion (Zellner, 2013). Zellner (2013) stresses that the difference lies in the degree of implied change: whereas business process reengineering is perceived as more radical change, business process improvement is seen as incremental/evolutionary. Furthermore, according to Valiris and Glykas (1999), both reengineering and process improvement are included in the definition of redesign.

However, the terms business process redesign and business process reengineering are sometimes used interchangeably since most practitioners do not tend to make sharp distinctions between these concepts and often use the term "BPR" when referring to them (Limam Mansar & Reijers, 2007). In this regard, it means dropping the existing processes and starting afresh and is described as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance such as costs, quality and speed" (Hammer &

Champy, 1993, as cited in van der Aalst & van Hee, 1995, p. 37). This approach would imply major changes in the company both at the process level and possibly at the strategic level. This is not the purpose of this project, therefore, and considering the concepts presented and discussed above, the focus will be on business process improvement (BPI), which is a well-established methodology, and one of the most renowned approaches, that supports organisations in improving processes in a continuous and structured way (Kashfi & Aliee, 2020; Widodo et al., 2021).

2.2. Business Process Improvement (BPI)

Business process improvement has been a matter of concern since the origins of business processes, and it has been pursued consciously or unconsciously by business owners and/or managers (Yousfi et al., 2019).

The term *business process improvement (BPI)* was originally coined by James Harrington in 1991 (as cited in Kashfi & Aliee, 2020). It does not have a universally accepted definition, yet it is often regarded as "a methodology that is designed to bring step-function improvements in administrative and support processes using approaches such as process benchmarking, process redesign, and process reengineering" (Harrington et al., 1997, as cited in Adesola & Baines, 2005, p. 39). In a more generic and simplistic way, BPI can be referred to as "any process-based changes, minor or major, to move from an as-is process to its to-be version" (Yousfi et al., 2019, p. 3), where this "to-be version" would, ideally, be an improved version of the process.

The BPI methodology is a structured approach that supports the simplification and streamlining of business processes, leading to the efficient and effective use of resources, and has three main objectives (Zairi, 1997): increasing the effectiveness of the processes (producing the desired results); increasing the efficiency of the processes (minimising/optimising the use of resources); increasing the flexibility of the processes (ability to successfully respond to the ever-changing customer and business needs).

In conclusion, although there is no single universally accepted definition for the concept of BPI, one can say that its purpose is quite straightforward and that there is a clear need to apply it in a systematic and deliberate manner in order to succeed. Following on from this, several frameworks and methodologies have been developed for implementing BPI, which will be explored in the next subsection.

2.2.1. Methodologies and Frameworks

As mentioned above, several methodologies and frameworks regarding BPI have been developed over the years, which testifies the importance that has been given to this concept. It is important to have a

look at the different methodologies and frameworks that exist, as well as the different procedures and steps that are presented in each one. In this way, it is possible to understand the most important insights from a comprehensive perspective and achieve a complete and robust methodology.

In this regard, Curatolo et al. (2014) performed a comprehensive systematic literature review in order to identify the main activities that usually characterise a BPI procedure model. The goal of the search was to select papers in which a structured BPI approach with a procedure model was described. After analysing all the results with this purpose in mind, 13 papers were selected (Adesola & Baines, 2005; Bisson & Folk, 2000; Hallström, 2001; Khan et al., 2007; Kumar et al., 2006; Lee & Chuah, 2001; McAdam, 1996; McAdam & McIntyre, 1997; Paper, 1998; Povey, 1998; Rohleder & Silver, 1997; Semih et al., 2008; Varghese, 2004).

For each paper, the authors analysed the details of each activity described in the procedure model to identify those activities mentioned in at least 50 per cent of the papers reviewed. With this analysis, the authors arrived at 11 activities that they identified as being the characteristic activities of BPI. Further, in order to structure their analytical framework, Curatolo et al. (2014) provided a brief description of these 11 activities based on the different insights from the papers reviewed and divided them into two categories: core operational activities and support activities (details about each activity can be found in Annexe A).

The core operational activities are those directly linked to the process, these are: select a process to improve, understand the selected process, measure, improve, and implement. These activities should be performed in a planned pattern in order to improve a process, as follows: select a process to improve → understand the selected process → measure → analyse → improve → implement.

On the other hand, the support activities are activities that are, as well, essential for the success of the BPI approach, however, these must be carried out on a continuous basis to ensure the success of the ongoing improvement projects and the perpetuation of the improvement projects that have already been realised. These activities are: understand the environment, establish top management support, organise a project team, manage change, and monitor.

The authors further suggest elaborating a method based on the 11 characteristic activities identified. These activities would form the procedure model of the approach; for each activity, the techniques, the roles and the results should be defined, and an information model should describe the relationships between these elements.

This goes in line with Zellner (2011), who identified the five mandatory elements of a method:

- Procedure model: order of activities to be fulfilled when employing the method.
- Technique: way of generating results; supports an activity.
- Results: an artefact (e.g., a document) created by an activity.

- Role: the one who carries out the activity and is responsible for it.
- Information model: consists of the above-described elements and their relationships.

According to Zellner (2011), despite BPI being a much-discussed and studied topic, the act of improving still seems to be a black box, since most of the existing approaches do not effectively focus on how the improvement procedure can be supported or carried out methodologically to reduce uncertainty on the path from the as-is to the to-be. To this end, the author argues that a method can be a significant solution to provide this required support in a structured way, as it is a goal-oriented systematic approach.

The paper from Curatolo et al. (2014) provides an excellent overview of the different existing methods and approaches. In addition, it provides an interpretation of the approaches analysed and proposes a set of what the authors identified as the characteristic activities of BPI, suggesting, ultimately, elaborating a method (in accordance with Zellner (2011)) based on these same activities.

Nonetheless, the literature review for this study was based on a search conducted in 2012. Therefore, it was decided to perform a systematic literature review from that year onwards in order to understand whether different methodologies and approaches have emerged more recently that can be used to complement this research. For this purpose, it was used the same data collection strategy, which was inspired by Zellner (2011). The objective was to find relevant literature that dealt with a structured way of improving business processes through BPI (e.g., procedures, guidelines, techniques, or methods). The search words were limited to "business process improvement" in the title or abstract or subject terms. As this is a topic that is heavily addressed in the literature, another limitation added was the reference to terms rooted in method, approach, framework or procedure in the abstract (using truncation techniques). The search was limited to peer-reviewed academic journals and conference materials in order to ensure the highest quality, and, finally, the language was limited to English. The database used was EBSCO-host (here: IDS) as it provides access to a wide variety of quality and reliable sources (see search results in Annexe B).

This search, conducted in November 2021, led to a total of 97 results. Within this total, 21 duplicates were identified, leaving 76 papers to analyse further. The next step was to analyse the title, the abstract, and, if needed, the full text of these papers in order to verify the ones in which a structured BPI approach with a procedure model was described. Finally, after this analysis, 16 papers were found to comply with the mentioned criteria. Details about the authors and main activities/stages mentioned in the respective methodologies can be found in Annexe C.

From the analysis of the selected papers, it can be concluded that mostly they refer to applications in cases in specific contexts (fast-moving consumer goods (Radosevic et al., 2013); investment management (Ou-Yang & Tsai, 2014); automotive industry (Noori & Latifi, 2018; Swarnakar & Vinodh, 2016); computer-based administrative work (Widodo et al., 2021)) and/or to the use of innovative

approaches for BPI (Big Data based Decision Support Systems (Vera-Baquero et al., 2014, 2015); an approach on knowledge-intensive business processes (Manfreda et al., 2015); process mining (Djedovic et al., 2017); meta-modelling (Johannsen & Fill, 2017); agile (Martins & Zacarias, 2017); digital technologies (Denner et al., 2018); simulation technique (Mehdouani et al., 2019); object-process methodology (Casebolt et al., 2020); complex network analysis (Fakorede & Davies, 2021)). Either way, it can be observed that the proposed methodologies/frameworks are based on, or derived from, the more traditional approaches covered quite comprehensively by Curatolo et al. (2014), as mentioned earlier, proving that this paper provides a sound foundation for conducting a BPI initiative.

In one of the more recent studies, analysed in the systematic literature review, it was also presented a BPI framework that seems to go very much in line with the considerations of Zellner (2011) outlined earlier, as it indicates the path from the as-is to the to-be in a quite systematic and structured way. This framework was proposed by Widodo et al. (2021) and is summarised in the table below.

Table 2.1 BPI framework proposed by Widodo et al. (2021)

Steps	**Activities performed**
Initialisation	Current practice observation → Current practice interview → Business process mapping → Analyse current performance → Current resources statement
Selection	Flowchart analysis → Identify waste → Find the cause → Propose solutions → Select the most feasible proposed solutions to be implemented → Improvement Plan
Design	Design the proposed solution → Trial test the designed improvement to verify if it conforms to the improvement plan → Confirm and prepare the designed improvement for the beta version
Implementation	Create implementation plan → Monitor implementation → Measure performances → Determine if there are any necessary changes (or unnecessary changes) to be made in the beta version
Evaluation	Evaluate the performance of the beta version solution with the key performance indicators (KPIs) → Recreate process flowchart (new version) → Performance improvement evidence (by analysing the results from the performance evaluation and comparing the current process map to the beta version improvement process map) → Approve by analysing the current process and the beta version in terms of improvement. If necessary, the beta version will be redesigned to reflect the desired improvement → Bring Beta version to live version → Document the improvement

In conclusion, in order to have a methodology as robust and complete as possible, as well as with high methodological maturity, the proposal is to draw on the studies from Curatolo et al. (2014) and Widodo et al. (2021), with particular focus on the structure proposed by the latter.

2.2.2. Tools and Techniques

There are several tools and techniques to support each of the activities/stages in the BPI process. Also in this regard, Curatolo et al. (2014) provide an insightful contribution. Based on the papers analysed in their literature review of Lean approaches in hospital settings aiming at BPI, the authors gathered a

set of the main tools and techniques that were used to support each of the characteristic activities of BPI. These are depicted in the table below.

Table 2.2 Main techniques supporting the characteristic activities of BPI (Curatolo et al., 2014)

Activities	Tools and techniques				
Understand the environment	Voice of the customer	Surveys	Voice of the business		
Establish top management support	-				
Organise a project team	Team charter				
Manage change	Training	Continual and open communication			
Monitor	Follow up plan				
Select a process to improve	Project selection criteria				
Understand the selected process	SIPOC (Supplier-Input-Process-Output-Client)	Process mapping or value stream mapping	Gemba walk (or direct observation)	Spaghetti diagrams	
Measure	Time studies	Data collection	Critical to quality flowdown (CTQ)		
Analyse	Pareto charts	Root cause analysis	Statistical analysis	Ishikawa diagrams	Eight categories of waste
Improve	Brainstorming	5S	Visual management	Flow	Standardisation
Implement	Implementation plan	Pilot study			

It is important to mention that, although this set of techniques is based on a literature review of approaches in hospital settings, they are generic BPI and/or Lean techniques that have their roots in manufacturing industries and that can be successfully adapted and applied in other contexts and sectors (Curatolo et al., 2014).

All the techniques and tools mentioned in the framework proposed by Widodo et al. (2021) are covered by or directly related to the techniques presented in Table 2.2. In this framework, special emphasis is placed on the use of the seven-waste framework (which can also be considered a Lean technique) during the selection step. The concept of Lean within BPI is of particular interest here as this is an approach that goes very much in line with the objectives of reducing waste and increasing efficiency that have been established for this project, as will be further discussed in the next subsection.

Lean within BPI

The term *Lean production* or *Lean manufacturing* was first coined in 1988 by Krafcik (1988), a student of the Massachusetts Institute of Technology (MIT). The Lean approach focuses on waste elimination and continuous improvement with a high level of employee involvement (Curatolo et al., 2014). It was the result of the description and enrichment of the Toyota Production System formulated by Ohno

(1988) and became popular through the bestselling book *The machine that changed the world* (Womack et al., 1991). From here it was widely adopted by many automakers and later by other manufacturing industries. Later, Womack and Jones further refined the concept of Lean by describing the five Lean principles in another book called *Lean thinking* (Womack & Jones, 1996). With these principles, Lean evolved towards a customer-centric approach and was adopted by various service sectors such as education, banking and financial services, airlines, hotels, restaurants and healthcare (Suárez-Barraza et al., 2012).

According to Curatolo et al. (2014) when looking at the five Lean principles (identify the value stream, create flow by eliminating waste, respond to customer pull, understand value from the customer's viewpoint, and pursue perfection) defined by Womack and Jones (1996) and the Lean critical success factors (business plan and vision organisational structure, top management support, project management, change management, effective communication education and training, and monitoring and evaluation of performance) defined by Näslund (2008), it can be noted that these are closely related to the 11 characteristic activities of BPI. That said, it can be concluded that Lean and BPI have much in common and that a BPI procedure model including a Lean approach would probably be well suited in light of the stated objectives.

This is indeed the case in the framework proposed by Widodo et al. (2021). As mentioned earlier, the authors implement the concept of the seven-waste framework during the selection step of their BPI framework. This is a Lean thinking technique aimed at identifying and eliminating waste in order to increase process efficiency and reduce costs for the company (Widodo et al., 2021). The seven wastes are transport, inventory, motion, waiting, overproduction, overprocessing and defects (Ohno, 1988). This approach also has its origins in the Toyota Production System being widely spread to other manufacturing industries and successfully adapted and used in other sectors and industries (Widodo et al., 2021).

In conclusion, Lean is an approach that seems to be particularly relevant within BPI, especially when considering the objectives of reducing waste and increasing process efficiency. This conclusion further reinforces the importance of the studies from Curatolo et al. (2014) and Widodo et al. (2021) as both of them include Lean thinking in their approach to BPI.

2.2.3. BPI in the Retail Context

BPI has been increasingly used and successfully implemented in a growing number of different sectors and industry categories, such as manufacturing, healthcare, tourism, telecommunications, and education (Widodo et al., 2021). This phenomenon indicates that organisations, across different sectors, are actively seeking to improve their processes in a structured and methodical way in order to survive and thrive in increasingly competitive environments. The retail sector is a sector with a dynamic

nature and where competition is increasingly high (Moghdeb et al., 2011). It is therefore understood that, particularly in this sector, it is essential that BPI is not only applied, but rather implemented in a systematic way.

In order to understand what has been done in this regard in the context under consideration, a systematic literature review was conducted. For this, it was also used the database EBSCO-host (here: IDS). When searching for terms related to the sporting goods retail sector combined with terms related to BPI it was not possible to find any relevant results, for this reason, it was decided to extend the search to the retail sector in general. The search words were limited to words rooted in retail (using truncation techniques) in the title or abstract or subject terms, and "business process improvement" in the whole text (since restricting only to the same fields mentioned would overly limit the results). The search, conducted in November 2021, was limited to peer-reviewed academic journals and conference materials in order to ensure the highest quality, and the language was limited to English, leading to a total of 32 results (see search results in Annexe D). Within these, 2 duplicates were identified, leaving 30 papers to analyse. After analysing the title, the abstract, and, if needed, the full text of these papers, to identify the ones addressing BPI in the retail context, 6 papers were selected. Details about their authors, approaches and main conclusions can be found in Annexe E.

By analysing these papers and their main findings, some important conclusions can be drawn:

- BPI approaches have proven to be relevant and successful in the retail context.
- Knowledge sharing and learning behaviours (Law & Ngai, 2008) as well as the alignment of key stakeholders (Moghdeb et al., 2011) are of utmost importance for the success of BPI initiatives.
- Despite increasingly advanced technologies and systems, the decisive component for success continues to be the human component, as these technologies and systems leverage knowledge sharing and collaboration between the different workers (Marjanovic & Roose, 2011).
- A particularly effective way of implementing BPI within the retail context is through a Lean approach (Madhani, 2020a, 2020b).

These conclusions not only corroborate and reinforce the path that has been followed so far but may also contribute to the robustness of the methodology of this project.

2.3. Picking Process

There is no doubt that the conclusions and insights outlined in the section above are relevant to the context and the problem at hand. However, none of the papers analysed in the literature review of BPI in the retail sector focuses specifically on improving the picking process. For this reason, and to more

closely address the problem and the specific objectives, a review of basic concepts and strategies aimed at improving the picking process should be carried out, as well as a search for practical applications that may reinforce and contribute to the proposed methodology, particularly to suggest potential solutions for improvement in the selection step of the same.

2.3.1. Picking Process Improvement

There are various strategies that can be followed to improve the picking process, aiming at greater efficiency and effectiveness (de Carvalho et al., 2020; Rushton et al., 2014). These strategies may involve: redefining the layout; redefining picking routes; redefining the picking type; redefining the storage assignment policies; implementing information technologies.

The most commonly used strategies when dealing with heavy/bulky items relate to the warehouse layout (e.g., Hu et al. (2009)), the storage assignment of items (e.g., Dekker et al. (2004); Elbert and Muller (2017); Kutzelnigg (2011); Žulj et al. (2018)), and the picking routes (e.g., Dekker et al.(2004); Elbert and Muller (2017); Hu et al. (2009); Žulj et al. (2018)). However, as mentioned in the introduction, Company X does not intend to make changes to the warehouse layout, picking routes, picking type or storage assignment policies. Therefore, from this point onwards, the focus will be on concepts related to the use of information technologies to improve the efficiency and effectiveness of the picking process.

Information Technologies in Order Picking

Information technologies play a key role in the efficiency and effectiveness of the picking process. These can assist with tasks such as reading which location to go, reading how many items to pick, confirming that the picker is at the right location and/or picking the correct items, and advising the system of any shortages at the pick face (Rushton et al., 2014). According to Rushton et al. (2014), there are several alternative methods used in order picking, supported by different technologies and different levels of complexity in information systems: paper pick lists, pick-by-label, barcodes, radio data terminals, pick-by-light, put-to-light, radio frequency identification (RFID), voice technology (pick-by-voice), and vision technology (related to this is pick-by-HUD (head-up display) (Baumann, 2013; Guo et al., 2014, 2015)); these latter authors also explored pick-by-CMD (cart-mounted display).

- *Paper pick lists* - These are printed by the computer system and list all the SKUs to be picked, as well as their location and the quantities required. These are usually listed in the sequence they should be picked according to the picking route used. The picker picks the items, annotating on the list the confirmation of their pick and any discrepancies (e.g., due to shortages at the pick face). As per Baumann (2013), the major advantages of paper pick lists

are the low investment costs and their high flexibility if the warehouse layout needs to be changed; on the other hand, the biggest disadvantage is the high error rate.

- *Pick-by-label* - In this method, the pick list is composed of a series of labels glued on a sheet, printed in the sequence in which the items are to be picked. When picking, the picker glues each label to the respective item and informs the system in case any shortages are identified at the pick face. According to Spee (as cited in Baumann, 2013) the error rates are better than for paper pick lists but higher than for paperless picking systems.
- *Barcodes* – With this method barcodes may be placed at each location and the picker then scans this code to confirm that he/she is at the correct location before picking the item. Another option is to have a barcode on each item; in this case, the picker has to scan each code (or one code per SKU picked) at the moment he/she picks the items. This second scenario provides a more accurate control than the first one, as it also allows to identify reception or replenishment errors (i.e., when the wrong items have been placed in a picking location).
- *Radio data terminals* - These can provide online communication between specific warehouse workstations and warehouse management systems. The terminals can be truck-mounted, waist-mounted, or wrist-mounted on pickers. They are commonly combined with RFID or barcode scanners, in which case they are referred to as *mobile scanning devices* (Baumann, 2013). Normally, the next pick location and the required quantities are shown in text to the picker. The picker confirms the pick by scanning the corresponding label and then the next instructions are shown automatically. Baumann (2013) states that when compared to paper-based picking solutions, this method reduces the chance of errors, yet it is not one of the most agile methods due to the scanning process.
- *Pick-by-light* - In this method, each picking location is equipped with a computer-controlled LED panel. These panels indicate the next picking location and the quantities required to satisfy the order[1]. This method can yield high picking rates and very high levels of accuracy. However, pick-by-light systems require a high initial investment and are, therefore, in most cases, only viable in areas with smaller items and high turnover rates (Baumann, 2013).
- *Put-to-light* – This method is similar to pick-by-light, and is normally used in batch picking (lights may be mounted under or over the different order bins indicating where to put the items) or in the sortation process (a picker may perform a batch pick and then return to an

[1] A common application of this technology is to have a tote bin, representing a customer order, being taken by conveyor to a designated area of the warehouse; the barcode on the tote bin is scanned and the appropriate LED panels illuminate, displaying the quantities of items to be picked for all the SKUs required for that order; once the items have been picked, the picker presses a cancel button and then uses the conveyor to move the bin to the next zone; this process continues until the order is completed.

area of sorting shelves, with each compartment representing a customer order; when scanning a particular item, LED panels light up, showing the quantities required for each customer order).

- *RFID* - This method employs technology that enables automatic identification by using radio frequency tags, data readers and integrating software. Boxes or items are fitted with RFID tags, and the picking accuracy is confirmed by reading these tags at the time of picking (using an appropriate RFID reader for the context in question). The reader captures the data and sends it to the software, which can then interface with other logistics information systems. An RFID tag can contain substantial amounts of data, can be read via proximity not requiring line-of-sight, is fully automated and virtually error-free, which, combined with falling implementation costs, justifies the potential of this technology.
- *Voice technology* - With this technology, the picker hears the instructions (e.g., location and quantities) from the system through a headset. The picker then picks the required items and confirms the pick by speaking into the headset microphone. Often, the picker has to repeat a check digit located at each location to ensure that the items have been picked from the correct location. As with pick-by-light, this method frees the picker's hands allowing high productivity while maintaining high levels of accuracy.
- *Vision technology and pick-by-HUD* - The picker wears a headset incorporating a HUD (e.g., Google Glass (Guo et al., 2015)), which provides, visually, the information for the next pick, guiding the picker. This may even, in some cases, direct the picker to the exact location by means of arrows or tunnels on the display (using augmented reality (Guo et al., 2015)). The confirmation of the pick can be done by an integrated camera reading the item code, barcode or location number and/or by the picker interacting with the system by voice.
- *Pick-by-CMD* - This method emerged from the research of Baumann (2013), which revealed that a graphical version of the paper pick list performed significantly better than the traditional pick list. This graphical representation is shown on a display mounted on the picking cart to guide the picker (Guo et al., 2014). In some cases, it is done via a high-resolution display (Guo et al., 2015), as in *pick-by-tablet* (Baumann, 2013).

Ludwig et al. (2007) conducted a field study in auto-parts after-market distribution centres to compare the performance of different picking methods. This study revealed that when using handheld devices with item-level barcode scanning, a picking accuracy of 99.8% was achieved, while for picking with voice technology this accuracy was slightly lower (99.55%). This is explained by the fact that, with voice technology, the check was of the location rather than of the item itself, and as such, this method was more vulnerable whenever upstream events (e.g., reception or replenishment errors) resulted in

the wrong items being in the picking location, which, when using the barcode scanning devices, was automatically detected by scanning the item. Nevertheless, both these methods were associated with substantially higher picking accuracy than when paper pick lists were used (96.5%). On the other hand, voice technology allowed for a 17% improvement in productivity over the handheld barcode scanning technology, since, among other factors, with this method location checking can be done in parallel with the travelling and picking tasks.

Battini et al. (2015) compared different paperless picking systems (barcodes handheld, RFID tags handheld, voice picking, traditional pick-by-light, and RFID pick-by-light (combining traditional pick-by-light with RFID technology)) both from a technological and economic point of view, in two different warehouse configurations: a low-level picking warehouse (composed of different racks and aisles), and multilevel picking shelving. The results show that for the low-level picking warehouse with a medium to low number of picks per hour the best solutions are the handheld (both with barcodes and RFID tags) and the voice picking system, while the RFID pick-by-light is the best when the number of picks per hour is high. In the case of multilevel picking shelving, the most convenient technology is the RFID pick-by-light system for almost all the numbers of picks per hour.

Fager et al. (2019) studied the extent to which the type of picking information system (in this case: pick-by-paper, pick-by-light, pick-by-voice, and pick-by-HUD combined with an RFID reading bracelet for confirmation) impacts the time-efficiency of kit preparation when confirmations are required, considering both single-kit and batch preparation and also the picking density of the picking area. The results reveal that with single-kit preparation and high picking density, pick-by-HUD and pick-by-light are the most time-efficient choices; with single-kit preparation and low picking density, pick-by-light showed to be the better choice in terms of time-efficiency. On the other hand, for batch preparation, the most time-efficient choice was found to be pick-by-paper, regardless of the picking density.

Guo et al. (2014) evaluated, through a laboratory experiment, order picking assisted by four different methods (HUD, CMD, pick-by-light, and paper pick list). The findings suggest that pick-by-HUD and pick-by-CMD are superior, on all metrics evaluated (accuracy, error types, speed, workload, and user preferences), to pick-by-paper and pick-by-light. Being that, on the whole, pick-by-paper was the worst-performing method and pick-by-HUD the best-performing method. It was also noted that the differences between HUD and CMD were not significant to indicate that HUD is better than CMD.

Thomas et al. (2018) compared pick-by-HUD with wearable RFID verification to pick-by-light with button verification, pick-by-paper with barcode verification, and pick-by-paper with no verification. The results revealed that pick-by-HUD with RFID verification allows faster picking and provides the lowest error rate; this method also showed better results in terms of workload and overall user preferences.

Baumann (2013) explored two studies and their respective results. In one of these studies, four picking methods (text-based paper picking, audio (voice) picking, graphical paper picking, and pick-by-HMD (head-mounted display, in this case equivalent to HUD)) were compared in a high density picking environment. The results revealed that the method using the HMD is the one that provides the best performance in terms of picking speed and accuracy, virtually eliminating errors. The other study also evaluated four picking methods (pick-by-light, pick-by-HMD, pick-by-tablet, and pick-by-paper) in an assembly line of an automobile manufacturer with experienced workers under normal working conditions. Even though quantitative evaluations were excluded in this study, due to stakeholder restrictions at the plant, it was possible to draw several significant observations: pick-by-tablet and pick-by-HMD performed better than pick-by-paper and close to pick-by-light (the method usually used in this concrete setup) in terms of picking accuracy and speed; user feedback and acceptance for pick-by-tablet were much better than for pick-by-paper and pick-by-HMD and comparable to the normally used pick-by-light. As pick-by-tablet compares quite favourably to pick-by-light in terms of investment costs (especially in picking zones with many pick locations) and shows similar performance, the author argues that it could be used beneficially in many picking scenarios.

From the analyses carried out in these studies, it can be concluded that the introduction or improvement of information technologies in the picking process can bring significant performance gains, particularly in terms of picking efficiency and effectiveness, which is in line with the objectives of this project.

2.4. Conclusions

As has been suggested throughout the literature review and in accordance with the pre-established objectives, the focus of this project will be the improvement of the picking process in the area of bulky items at the logistics supply centre of Company X through a BPI methodology. Following on from this, and as also mentioned in the course of the literature review, two studies have been identified that are considered to be solid foundations for the development of a robust BPI methodology, with all the research carried out supporting and justifying their appropriateness.

Therefore, and in order to present a sound approach to the proposed problem, the BPI methodology to be used in this project will be essentially grounded on the framework proposed by Widodo et al. (2021) being further enriched by the insights from Curatolo et al. (2014). Being that, taking into account the company's requirements and the literature review carried out, the use of information technologies to improve the efficiency and effectiveness of the picking process seems to be an appropriate approach to follow in the selection step of this methodology in order to propose a potential solution for improvement, although no studies have been found in similar settings to the case under study.

3. Methodology

3.1. Research Methodology

This investigation is descriptive as it describes the various procedures of the division under study. The research is based on mixed methods, particularly with a convergent parallel design. This will be done using qualitative and quantitative data obtained through: different forms of observation, which allow a detailed and genuine description of the processes; archival records and documentation provided by the company; interviews (unstructured and semi-structured) with process owners and managers; and questionnaires.

3.2. Case Study Framework

As mentioned earlier, the BPI framework that will be used in this project is fundamentally based on the framework proposed by Widodo et al. (2021). This approach covers most of the characteristic activities of BPI identified by Curatolo et al. (2014), with the exception of "understand the environment", "select a process to improve", "establish top management support", "organise a project team", and "manage change". It is, therefore, considered relevant to complement the framework with these activities. Nonetheless, the case study framework will not include the activities "understand the environment" and "select a process to improve" (as these have already been carried out in order to realise the research question and objectives of the project), as well as "organise a project team" (as it is not possible to assign people from the company exclusively to this improvement project). Furthermore, as it is anticipated that implementation will not be possible during the course of the project, the fourth step will be "Recommendations for Implementation" instead of "Implementation". Accordingly, the proposed BPI framework that will be used as the research design for this project is as follows:

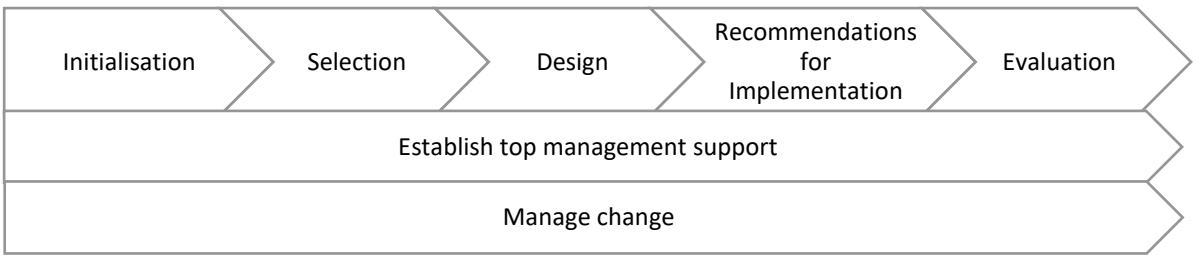

Figure 3.1 Case study framework

3.2.1. Manage Change and Establish Top Management Support

The activities manage change and establish top management support stem from the paper of Curatolo et al. (2014). These should be carried out on a continuous basis throughout the entire project.

According to the authors, the activity manage change is intended to facilitate the understanding and implementation of the new process for the operators. Accordingly, it involves communicating the changes that are undertaken during the project and training staff to use the new process.

In turn, the establish top management support activity is crucial to ensure that the project is in line with the objectives of the company. To this end, it is suggested to actively involve top management throughout the different phases of the project in order to guarantee its success.

3.2.2. Initialisation

The purpose of the initialisation step is to have a comprehensive understanding of the current picking process. At this stage, the objectives are to create a current process map and to understand the current performance.

To gain information about the current picking process, two activities will be carried out: current practice observation and current practice interview. Current practice observation will be done through direct observation and participant observation; documenting all the steps in the process and highlighting the most important remarks arising from the close observation of the pickers during the execution of their tasks and from directly participating in the process in real context. Current practice interview involves conducting unstructured and semi-structured interviews with the pickers and the team leader. These interviews will serve to better understand all the steps of the picking process and to get information about “why it is as it is”, available resources, future conditions and key performance indicators (KPIs). These interviews and discussions will also be fundamental to have the insights of those who execute the process daily in order to better identify wastes and weaknesses in the process and then propose adequate solutions to improve its efficiency.

This information, complemented with information from archival records and documentation provided by the company, will then be used for the process mapping, which will be done using the Bizagi software. After this, the current process performance should be analysed taking into account the KPIs, and the resource availability will be identified in the current resource statement which will then also be taken into account to propose the improvement solution.

Lastly, and in order to validate all the information, a brief meeting will be held with the team leader.

3.2.3. Selection

The aim of the selection step is to create an improvement plan based on an appropriate proposed improvement solution. In order to achieve this objective, some activities should be carried out.

Firstly, a thorough analysis of the process flowchart performed in the initialisation step will be conducted and the seven-waste framework will be used to identify waste in the process. In this regard, the different types of waste mentioned in this framework will be described so that they can be applied to the identification of waste in the case under study. In this follow-up, the different activities of the process will be analysed in order to identify any potential waste associated with them, and then, these wastes will be categorised according to their suitability within the seven-waste framework.

Based on the information obtained from the flowchart analysis and waste identification, the main problems in the process will then be identified, as well as their respective causes, which will be addressed in a structured and systematic way using fishbone diagrams (also known as Ishikawa diagrams - one of the techniques mentioned in Curatolo et al. (2014)). Here will also be identified performance indicators related to these causes that will later serve to assess the impact of the proposed improvement solution.

Having done this, the improvement solution will be proposed. This proposed solution will take into account all the analyses carried out earlier in this step, the available resources and the potential use of information technologies for improving the efficiency and effectiveness of the picking process mentioned in the literature review. In this phase, the insights gained from experiencing and analysing the picking process in the other teams of the logistics centre will also be taken into consideration as a form of benchmarking (one of the strategies mentioned by Curatolo et al. (2014) for the core operational activity of BPI “Improve”).

Lastly, an improvement plan will be drafted including the activities in which the proposed solution will have a material impact, as well as the desired function for these activities and the tools required to fulfil this function.

3.2.4. Design

The objective in the design step is to create a beta version of the improvement solution in order to realise the improvement plan.

For this purpose, firstly the improvement plan resulting from the selection step, together with the observations from the benchmarking done in the other teams of the logistics centre, will be used as the basis for the design of the proposed solution (which will be done by mapping the “to be” process using, as well, the Bizagi software). Secondly, this designed improvement will be analysed against the improvement plan in order to ensure that it meets the expectations. Finally, if this proposed solution

conforms to the improvement plan, it will be stated as the beta version or prototype version (the improved design of the current practice).

In order to confirm all these steps and the appropriateness of the improved design, a short meeting will be held with the team leader.

3.2.5. Recommendations for Implementation

As previously mentioned it is anticipated that it will not be possible to implement the proposed solution during the course of the project. For this reason, in this step, the objective is to provide some guiding recommendations for the implementation taking into account the methodology proposed by Widodo et al. (2021).

According to the authors, the implementation should be carried out to ensure that the beta version can perform in real conditions. For this purpose, three activities are key: create an implementation plan, monitor implementation, and measure performance. The focus of the implementation plan is on how the beta version can be implemented for testing purposes (as it is essential to first test the solution on a small scale), whereas the focus of monitor implementation is on closely monitoring the real practice of the beta version. The performance of the beta version should then be measured using the identified performance indicators and, based on this, it is determined whether there are any necessary changes to be made to the beta version.

3.2.6. Evaluation

The purpose of the evaluation step is to compare the beta version to the current practice, illustrating the outcomes of the improvement.

The performance indicators mentioned in the selection step will serve as a basis for this comparison. Since it will not be possible to effectively implement the proposed solution during the course of the project, this comparison will be made based on actual measurements for the “as is” process and expected values (based on all the analyses carried out) for the “to be” process. These measurements will be made directly by the project author, for those indicators for which information is available or which can be measured by observation. On the other hand, in the event that, for some indicators, it is not possible to make these measurements by observation (for reasons of time or practicality), these will be made by the pickers, in which case the author will develop the necessary forms to be filled in by the pickers for such measurements. Based on the results, each indicator will be analysed in detail.

These results and analyses will then be considered as a whole in order to evaluate the concrete potential for improvement in the process with the implementation of the proposed solution.

4. Case Study

This chapter presents in detail the application of the methodology described in the previous chapter to the particular case under study. Firstly, a brief presentation of the company and the setting in which the case study takes place will be made. Then the steps of the methodology will be followed in their respective sequence so as to have a structured and grounded investigation.

4.1. Company X

Company X operates, as previously mentioned, in the sporting goods retail sector. This case study takes place in its logistics supply centre responsible for the Portuguese market (i.e., responsible for receiving items from suppliers, storing and organising them and then supplying all the company's retail shops as well as online customers, in Portugal). This centre is divided into different areas where different teams operate according to the typology of items they are in charge of. Each team is responsible for various processes in their respective area, including the reception of items, picking, and stock management.

This project is centred on the team in charge of bulky items (i.e., large, heavy, and/or uneven items), more specifically on the picking process, for the reasons already mentioned. Since the picking process for online orders (e-commerce) is currently being overhauled, this case study is primarily focused on the picking process for the orders of the physical shops.

Currently, in this process, the *warehouse layout* (Annexe F) used is the *broken flow (or U-flow)*, as the receiving and shipment take place on the same side of the warehouse. The warehouse is arranged in parallel picking aisles, with a cross-aisle in the middle (this cross-aisle does not contain storage locations, but can be used to change aisles if needed and possible) (for details on warehouse layout refer to: de Carvalho et al. (2020) and Rushton et al. (2014)).

As for the *picking route*, it is used the *S-shape (or traversal)* policy as if it was a single-block warehouse. This routing policy means that the picker enters an aisle from one end and leaves from the other, being the aisle traversed entirely, and from the last visited aisle the picker returns to the depot; in this case, it has a single traffic direction. This method is employed because items are arranged in a specific order in the warehouse aisles to better assemble the order given the particular characteristics of the items (for details on picking routes refer to: de Koster et al. (2007) and Petersen II and Schmenner (1999)).

Regarding the *picking type*, the method used is *picking by order*, where the picker takes one order and travels through the whole warehouse until all the items of the order have been picked. In addition, orders are released in waves every morning and afternoon to better control the flow of goods and the allocation of staff, according to the outgoing vehicle schedule – *wave picking* (for details on picking types refer to: de Carvalho et al. (2020) and Rushton et al. (2014)).

As for the *storage assignment policies*, the method currently used can be referred to as the *mixed location method* or *class-based storage*. The storage area is subdivided into zones and the items are allocated to a zone according to some predefined criteria (fixed location); within each zone, the items are stored in any available location (random location). In this case, the most important criteria for determining which items correspond to each zone are the weight and size of the items, although there are other relevant criteria, such as the type of items and their use. These zones are mainly organised by aisles, and within each zone, the operators try to respect these criteria as much as possible when storing the items, despite the fact that there are no fixed locations. By following this method, it is possible to better assemble the order on the pallet (since, according to the criteria used, the heavier and larger items are placed at the bottom, while the lighter and smaller items are placed at the top), allowing, at the same time, better use of space and greater flexibility due to the fact that there are no fixed locations (for details on storage assignment policies refer to: de Carvalho et al. (2020), de Koster et al.(2007), and Gu et al.(2007)).

4.2. Manage Change and Establish Top Management Support

Before moving on to the sequential steps of the methodology it is important to make reference to manage change and establish top management support. Regarding manage change, this involved open communication with all team members about the project objectives throughout all the steps of the project; this way it was possible to have the contribution and alignment of everyone in the different stages, and keep them motivated by feeling they were contributing to something meaningful[2]. To establish top management support, some meetings were held, mainly at the beginning of the project, to define and align objectives; during the course of the project, this support was maintained through constant communication and weekly planning with the team leader.

4.3. Initialisation

As mentioned in the methodology, in the initialisation step the objectives are to create a current process map and to understand the current process performance. To reach these objectives some activities must be carried out, divided into the following three subsections.

4.3.1. Current Practice Observation and Interview

The first activity in the initialisation step is *current practice observation*. Activities related to the picking process were observed between October 2021 and February 2022. In this period the observation

[2] It should be noted that the issue of training pickers to use the new process has not been addressed here since it has not yet been implemented. However, as will be understood later, the proposed solution already exists in other teams in the logistics centre, so most team members have already had contact or even experience in working with it, thus facilitating this adaptation process.

methods altered between direct observation of the pickers' activity and observation by effectively participating in the process as a team member, going through all the stages of the process.

The second activity in the initialisation step is *current practice interview*. Here semi-structured interviews were conducted individually with two pickers and the team leader, a script (Annexe G) was created to guide the interviews, but there was freedom and flexibility to address other issues that arose during the conversations. Throughout this phase, there were also more informal conversations with members of the team that can be considered as unstructured interviews. These interviews revealed several important aspects:

- The picking process itself has not been thoroughly reviewed for quite some time. What has been done are some adjustments, mainly at the level of the *mass plan* (allocation of items in the warehouse) in order to increase the efficiency of the process, mainly by facilitating the assembly of the orders on the *pallets/magnums*[3], safeguarding, as well, the quality and transport of more sensitive items. With the latest changes in the *mass plan* there was an increase in productivity but there are still some time-consuming activities and picking errors[4].
- Often more time is wasted on activities that are not picking itself, but are part of the picking process (e.g., printing and organising the picking lists; doing the invoicing and reading the RFID of the items; having to make adjustments in the system due to the identification of errors; correcting errors only detected at the end of the process; etc.). During the picking itself, the most time-consuming activities, especially for those with less experience, are confirming the item for picking and assembling the orders on the pallets/magnums, since it involves dealing with boxes and items with varying weights and dimensions.
- The process activities continue to be carried out as they are due to lack of time to think about the issues, accommodation, and habituation to the process as it is done. Furthermore, it has been difficult to find better solutions, as the process must always be adjusted according to the needs, which vary.
- The most important KPIs in the picking process are *quality* (% of picking errors) and *productivity* (more precisely, the average no. of *"colis"*[5] "made" per picker per hour), which is,

[3] Pellets are the commonly used European wooden pallets; magnums are foldable large containers.

[4] It is considered a picking error when it is sent to a shop: a wrong item; a missing item; an extra/missing unit of a given item.

[5] Colis is the name given to a label, with a barcode, that identifies an item or a group of items for picking, with the same item code that are in the same location for picking in the warehouse (these items are, of course, equal). When printing the list with the order (referred to as *"rafal"* - a digital request made by a certain shop that is transformed into a physical flow in order to be prepared), this list has the various colis of the same order. The number of colis for a given order represents the number of locations the picker will have to go to complete the order. For example, if a certain order has 50 colis it means that the picker will have to go through 50 locations to complete the order. However, the number of items can be, and often is, greater than the

naturally, influenced by the processing time in each activity of the picking process. Here, was also mentioned the importance of issues such as the pickers' safety and well-being, waste and reuse of resources, although these are not direct indicators of process performance.

4.3.2. Picking Process Description and Mapping

The third activity in the initialisation step is mapping the process. This was done using the information gathered in the two previous activities and also by consulting documents provided by Company X in order to, for example, confirm certain specific terms.

For a better understanding of the process mapping (Figure 4.1 (overall process) and Annexe H (sub-processes)), the picking process will now be described in detail (to assist the reading, an arrow is placed before each Yes or No question). Before starting to describe the process itself, it is important to mention that each team member doing picking moves around the warehouse on a forklift. In addition, and in order for the mapping to be feasible and logical, an assumption was made: when there are missing items/quantities on the pallet/magnum (when verifying whether the invoice is closed (A9.1), or during the compliance check in the RFID reading (A12)), these will either fit on the current pallet/magnum or on a single new pallet/magnum (with no need for more than one new pallet/magnum). It is important to note that this assumption is reasonable since, when these errors occur, the number of missing items/quantities is always relatively low.

The process starts with one of the team members extracting, from the company´s ERP (Enterprise Resource Planning) system, the information about the orders from the shops (A0). After this, prints the rafal lists of these orders, and places them in the proper order on the table (A1). Currently, this process is done manually on a computer at the team's meeting point in the warehouse. This process is done taking into account the loading plan (dispatch times of the trucks of each shop), and the person who is doing this puts these same times on the top of the rafal of the respective shop and places them in order on the adjacent table so that priority is given to the shops with the closest dispatch times. Each rafal corresponds to a single order from a particular shop, so it can be understood that the picking method used is picking by order, as mentioned before.

The picker takes one rafal from the table (complying with the order of priority), analyses the rafal (A2), and, taking into account the typology[6] and quantities of the items in it, as well as the fact that there are shops that do not accept shipping in magnums, decides whether picking should be done using a pallet or a magnum, and fetches what considers to be the most appropriate (A3).

number of colis, since in most cases the order includes more than one item with the same code in the same location for picking (equal items).

[6] The type of items that normally justify doing the picking using a magnum are mainly heavy but not particularly large items, items that are difficult to fit on a pallet, or items whose quality may be affected if they are not well packed.

In the rafal, the colis are organised according to the warehouse aisles, so that the picker has the smoothest possible path. This path has a picking logic so that it starts with the heavier and larger items, to be at the bottom, and ends with the lighter items, in order to facilitate the assembly of the orders on the pallet/magnum (the aisles in the warehouse are organised accordingly – see Annexe F). However, based on own experience, the picker may decide to pick a certain item before another so as to better assemble the items on the pallet/magnum, but always taking this path into account; or, for example, when the typology and quantities of the items in the order indicate that it should be done using a magnum, the picker starts in the aisles where the items to be placed in the magnum are, following the normal path from here, and, if necessary and possible, finishes by placing the remaining items on top of the already closed magnum (if these items are too heavy the picker should fetch a new pallet/magnum to place them on).

The colis labels indicate the location in the warehouse, the *"contenant"*[7], the code and the quantities of the items to be picked. Therefore, the picker moves to the location indicated on the colis of the next item to be picked (A4) and confirms all these elements (A5). → Are the required quantities of the item available for picking in the indicated location? If yes, the picker moves on to *sub-process A6*; if not, the picker goes to the system to check if there are other locations where this item is available (A5.1). → Are the required quantities of the item available in other location(s)[8]? If not, the picker acknowledges, in the system, the item as undeliverable and makes the necessary adjustments (A5.1a) so that the physical quantities of the item correspond to the quantities registered in the system, and moves on to the next decision node; if yes, the picker makes the necessary adjustments in the system (A5.1b1), for the same reasons, moves to that location(s), confirms all the elements mentioned previously (A5.1b2), and moves on to *sub-process A6*.

Sub-process A6: → Is picking being done using a magnum? If not (meaning it's being done on a pallet), the picker places the item(s)/box(es) on the pallet (A6a1) and glues the respective colis on them (A6a2) in a visible manner so that these can later be more easily read for invoicing; if yes, the picker places the item(s)/box(es) in the magnum (A6b1), and glues the respective colis on the outside of the magnum (not on the item(s)/box(es)) (A6b2). → Was(were) the item(s) picked from a box? If not, the sub-process is over; if yes → Is the box, from which the item(s) was(were) taken, empty? If not, the sub-process is over; if yes, the picker cuts and flattens the box, and leaves it in the recycling bin (A6.1).

After *A6* or *A5.1a*, there are three possibilities. This happens because picking can be done in the normal sequence of the order (standard picking), or it can be done due to the identification of missing

[7] Contenant is a code that identifies a certain set of items (with the same item code) upon their reception at the warehouse.

[8] Here, it is assumed that the picker confirms the physical existence of the required quantities of the item in these location(s).

colis/item(s) when checking if the invoice is closed (in A9.1), or due to the identification of missing quantities of items during the compliance check in the RFID reading (in A12). For now, the way forward is standard picking.

→ Is the rafal list finished (there are no more colis of the order to pick) or is the pallet/magnum full (no more items can be placed on it)? If not, the picker moves to the location of the next item to be picked (A4); if yes, the picker goes to the invoicing and pallet filming area (A7), enters the company's ERP system on the computer (A8) and reads (invoices), with a manual scanner, the barcodes of all the colis on the pallet/magnum (A9).

→ Is the rafal list finished? If not (meaning that the pallet/magnum is full), the picker moves on to activity *A10*; if yes, the picker verifies if the invoice is closed (A9.1). → Is the invoice closed (all the colis of the rafal have been successfully read (invoiced))? If yes, the picker moves on to activity *A10*; if not, the picker checks which colis is(are) missing (A9.1.1).

Here, there are three possibilities (not exclusive): the missing colis is(are) on previous pallet(s)/magnum(s) of the order (path (a)); the missing colis is(are) on the current pallet/magnum but the colis has(have) not been read (invoiced) (path (b)); the missing colis is(are) neither on the current nor on previous pallets/magnums of the order (path (c)). If it is the first case, the picker fetches the pallet(s)/magnum(s) and reads (invoices) the missing colis (A9.1.1a1); then, the picker merges the *UATs*[9] into one[10]*,* prints it, scans on the RFID (no errors will be identified here because this verification had already been done for all other items on this pallet/magnum, with the missing items being now confirmed by the picker), and glues the new UAT(s) on the respective pallet(s)/magnum(s) (A9.1.1a2)); after that, the picker returns the pallet(s)/magnum(s) to the respective area of the shipping dock (A9.1.1a3). If it is the second case, the picker reads (invoices) the missing colis on the current pallet/magnum (A9.1.1b). If it is the third case → Is it possible to place the item(s) on the current pallet/magnum? If yes, the picker moves to the location of the next item to be picked (A4) and follows the path until *sub-process A6*; at the branching point, the picker follows the path "picking due to the identification of missing colis/item(s) when checking if the invoice was closed"; → Have all the missing items been picked? If not, the picker moves to the location of the next item to be picked (A4); if yes, the picker goes to the invoicing and pallet filming area (A9.1.1c1) and, in the system, reads (invoices) the missing colis (A9.1.1c2). If it is not possible to place the item(s) on the current pallet/magnum, the picker moves on to activity *A10,* and goes through all the following activities with the current pallet/magnum; when reaching the last decision point, as the order is not yet completed, the picker

[9] UAT (*Unidade a Transportar*) - Association of the various colis that are on a pallet/magnum into a single unit (label), which will later be dispatched by the quayside team.

[10] When the picker reads (invoices) the missing colis, a new UAT is created. But, since the item(s) corresponding to these colis are on the same pallet/magnum (which already had a UAT without the missing colis), these two UATs must be merged into a single one, corresponding to that pallet/magnum.

fetches a new pallet/magnum (A3) and follows the same path as is followed if the item(s) can be placed on the current pallet/magnum (detailed above).

Thereafter, the picker prints the UAT of the pallet/magnum (A10), and moves on to *sub-process A11*: → Is it necessary to film the pallet/magnum[11]? If yes, the picker films the pallet/magnum (this is done automatically by a proper machine) and activates the items' RFID reading (done by a static RFID reader that is in this area) (A11a); if not, the picker activates the items' RFID reading (A11b). After *A11*, the picker checks the conformity between the RFID reading and the quantities of items on the pallet/magnum[12] (A12). → Is everything in conformity (the quantities of the items on the pallet/magnum correspond to the quantities registered in the UAT)?

If not everything is in conformity in A12 → Are there extra quantities of items on the pallet/magnum? If not, the picker moves on to activity *A12b*; if yes: *sub-process A12a*: the picker checks which item(s) is(are) in excess (A12a1). → Is it necessary to remove the film from the pallet/magnum? If not, the picker moves on to activity *A12a2*; if yes, the picker removes the film from the pallet/magnum (A12a1.1) and moves on to activity *A12a2*. Then, the picker leaves the extra quantities in the respective location(s) from which they were picked (A12a2). After *A12a*, → Are there quantities of items missing on the pallet/magnum? If not, the picker returns to *sub-process A11* and proceeds with the normal path; if yes, the picker moves on to activity *A12b*. In this activity, the picker checks which item(s) is(are) missing (A12b). → Is it possible to place the item(s) on the current pallet/magnum?

If it is possible to place the item(s) on the current pallet/magnum → Is it necessary to remove the film from the pallet/magnum? If not, the picker moves on to activity *A4*; if yes, the picker removes the film from the pallet/magnum (A12ba1.1) and moves on to activity *A4*; then, the picker follows the path between activity *A4* and *sub-process A6*; at the branching point, the picker follows the path "picking due to the identification of missing quantities of items in the RFID reading"; → Have all the missing items been picked? If not, the picker moves to the location of the next item to be picked (A4); if yes → Is it a new pallet/magnum? If not (which is the case here), the picker goes to the invoicing and pallet filming area (A12ba2), moves on to *sub-process A11* and proceeds with the normal path[13].

[11] When the pallet has only few items that are not at risk of being lost or damaged it is not necessary to film it. Also, when the order is fully completed inside a magnum it is not necessary to film, but when items are placed on top of the closed magnum it is also important to film them so that they are well secured.

[12] Here it is important to note that the RFID reader only reads the quantities of items whose codes are associated with the colis pertaining to the UAT at hand. In addition, there are some items that the RFID reader usually struggles to read, therefore the compliance between the quantities of items on the pallet/magnum and the quantities registered in the UAT (displayed on the RFID reader's monitor) must often be verified by the picker on his/her own without having 100% confirmation from the RFID reader.

[13] If it is not a new pallet/magnum it implies that the pallet/magnum is full or that the rafal list is finished, since a pallet/magnum only goes to the filming and RFID reading area if one of these two conditions is true. Thus, and since the correct UAT of this pallet/magnum is already printed, the picker moves directly to *sub-process*

If it is not possible to place the item(s) on the current pallet/magnum after A12b: *sub-process A12bb*: the picker creates a new UAT for the current pallet/magnum without the colis concerned (A12bb1). → Is it necessary to take any item(s) from the current pallet/magnum[14]? If not, the sub-process is over; if yes → Is it necessary to remove the film from the pallet/magnum? If not, the picker takes the item(s) from the pallet/magnum (A12bb1.2) and the sub-process is over; if yes, the picker removes the film from the pallet/magnum (A12bb1.1), takes the item(s) from the pallet/magnum (A12bb1.2) and the sub-process is over. After *A12bb*, the picker returns to *sub-process A11* and proceeds with the normal path; when reaching the last decision point, as the order is not yet completed, the picker fetches a new pallet/magnum (A3) and follows the same path as is followed if the item(s) can be placed on the current pallet/magnum (explained in the previous paragraph) until the decision point → Is it a new pallet/magnum? If yes (which is the case here) → Is the rafal list finished or is the pallet/magnum full? If yes, the picker goes to the invoicing and pallet filming area (A7) and proceeds with the normal path; if not, the picker moves to the location of the next item to be picked (A4) and proceeds the path as standard picking.

If everything is in conformity in A12, the picker glues the UAT on the pallet/magnum and leaves it in the corresponding area of the shipping dock (A13).

If the order is completed, i.e., the invoice is closed (in A9.1) and everything is in conformity (in A12), the process is over; otherwise, the picker fetches a new pallet/magnum (A3) and repeats the process described until the order is completed.

The process mapping and description is complex and difficult to follow at certain points in the process. However, this is a consequence of the complexity and the number of "ifs" that exist in the process itself. In this sense, it was considered important to reflect all these details in the mapping in order to make it as close as possible to reality, so that it serves not only as an analytical tool at this stage of the project, but also as a potential future improvement tool based on process standardisation and documentation.

A11. For the above conditions to be met, it is assumed that if the pallet/magnum is full when reaching the RFID reading area, even if some extra space is made available on it when there are extra quantities of items to be returned, this space will either not be sufficient for or will be filled again by the missing quantities of items (if there are any).

[14] Let's imagine that a colis is associated to 2 units of the item X, but in the pallet/magnum there is only one unit. In this case, since it is not possible to place the missing unit on the current pallet/magnum, it is necessary to take the unit that is on the current pallet/magnum and place the two units of the item X on a new pallet/magnum. This happens because the units/items associated to the same colis should not be shipped in different UATs.

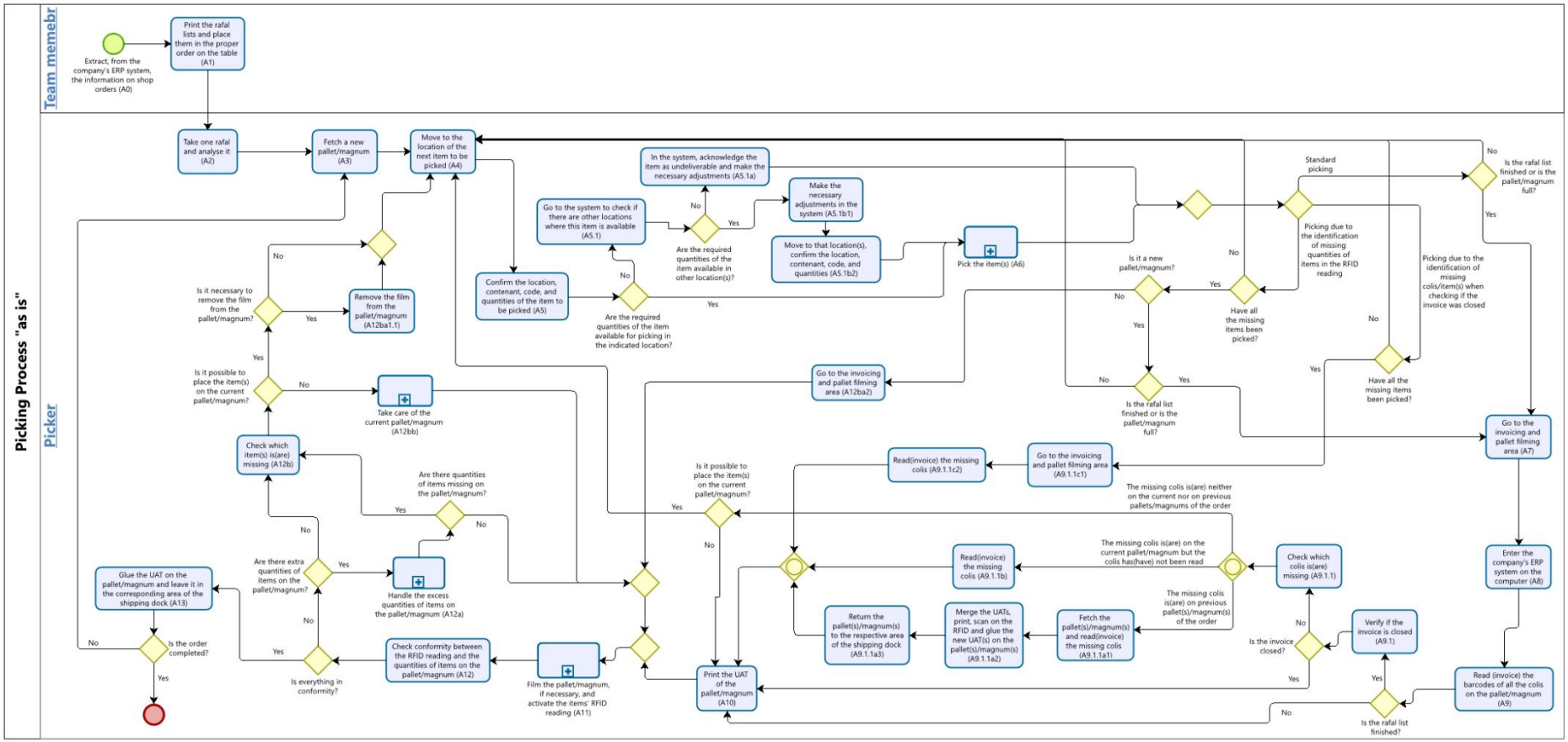

Figure 4.1 Process mapping “as is”

4.3.3. Current Performance Analysis and Resource Statement

After mapping the business process, it is important to understand the current performance and resource availability. With regard to the current performance of the process, the two KPIs highlighted earlier were considered: *quality* (% of picking errors) and *productivity* (average no. of colis per picker per hour). Concerning quality, data provided by the company for the month of April 2022 was analysed, according to which, in this month, 112 picking errors were reported out of a total of 128,140 items picked, representing a percentage of picking errors of approximately 0.09%. As for productivity, based on data provided by the company regarding the first two months of 2022, and further clarifications with the team leader, it was possible to conclude that, currently, the average productivity is around 45 colis per picker per hour.

Regarding the current resource availability, this is set out in the table below.

Table 4.1 Current resources statement

Resources	Description
People	The author; team members (pickers); team leader
Tools	AS400 (company's ERP system); forklifts; tablets + portable printers*; static RFID reader; film wrapping machine; items' RFID tags
Time	Until 31 October 2022

* Tablets and portable printers are currently being used, in the team, for e-commerce order picking

4.4. Selection

As stated in the methodology, the ultimate objective in the selection step is to create an improvement plan based on an appropriate proposed improvement solution. Towards this end, this step is divided into four subsections: flowchart analysis and waste identification, main problems and corresponding causes, proposed improvement solution, and improvement plan.

4.4.1. Flowchart Analysis and Waste Identification

According to the seven-waste framework, there are seven recognised wastes: transport, inventory, motion, waiting, overproduction, overprocessing and defects. As mentioned in the literature review, although this approach has its origins in the Toyota Production System, it is widely spread to other manufacturing industries and successfully adapted and used in other sectors and industries. To better understand the suitability of this framework for the context at hand, it is important to first clarify what each of these wastes refers to, not only in manufacturing but also in other contexts (Table 4.2), as both can apply to the case under study.

Table 4.2 The seven wastes of the Toyota Production System and its suitability for non-manufacturing contexts (adapted from Ohno (1988), and Widodo et al. (2021))

Waste	Description (manufacturing context)	Office/non-manufacturing context
Transport (W1)	Unnecessary movement/handling of resources (materials, tools or equipment)	Manual transferring or moving data; switching between tasks too often; interruptions
Inventory (W2)	Holding excessive inventory	Files waiting to be worked on; unused records in a database; obsolete files
Motion (W3)	Unnecessary or excessive movements or steps performed by the worker	Extra effort to find objects or information; walking and reaching to get materials; searching for files; sifting through inventory to find what is needed; excess mouse clicks; double entry of data
Waiting (W4)	Worker or equipment/machine idle; waiting for people, equipment, materials, or information	Wating on documents; having files waiting for review; ineffective meetings; waiting for the computer/system to load
Overproduction (W5)	Producing more than the customer or the process needs/requires	Making extra copies; providing more information than needed; providing a service before the customer is ready
Overprocessing (W6)	Non-value added activities in process; refers to doing more work, adding more components, or having more steps than what is required	Manual work; unnecessary steps/activities; redundant or repeated activities
Defects (W7)	The production of a defective product or parts; will require either reworking or scrapping	Wrong data used to input, deliver or present to the end customer, or for subsequent activities in the process

By using the information obtained during the current practice observation and interview, and by analysing the process mapping, it is possible to identify the potential existence of these wastes in the different activities of the process. The waste analysis is summarised in Table 4.3, where the "X" indicates the wastes that were identified during each activity/sub-process.

Table 4.3 Waste identification for process activities

Activity/sub-process	W1	W3	W4	W6	W7
A1	X	X	X	X	
A5		X			X
A5.1 + A5.1a	X	X		X	X
A5.1+A5.1b1 + A5.1b2	X	X		X	X
A6a1/A6b1	X	X		X	
A6a2/A6b2	X	X		X	
A9 + A9.1	X	X		X	X
A9.1.1 to A10*	X	X		X	
A12		X		X	X
A12a to A12*	X	X		X	
A12b to A12*	X	X		X	

*This includes all activities/sub-processes between the first and the last mentioned, excluding A10 in the first case and including A12 in the other two cases. For instance, in the first case, it could be: A9.1.1 + A4 + A5 + A6 + A9.1.1c1 + A9.1.1c2. Or, in the latter case, it could be: A12b + A12ba1.1 + A4 + A5 + A6 + A12ba2 + A11 + A12. These represent repeated, redundant or non-value added activities.

4.4.2. Main Problems and Corresponding Causes

With the insights gained during the current practice observation and interview, along with the analysis of the process mapping, and with the further contribution of the seven-waste framework, it was possible to identify the main problems of the process, as well as their causes. In order to identify the causes and sub-causes in a more structured and systematic way, another tool was also used: fishbone diagrams (Annexe I). The two major problems identified were the lack of effectiveness in supplying the shops and inefficiencies in the process. Table 4.4 and Table 4.5 show, for each of these problems, their causes (for more details on the causes and sub-causes of these problems, see Annexe I) and associated waste, as well as the corresponding performance indicators (PIs). These performance indicators also reflect the impact of these factors and will be analysed further on (in the *Evaluation step*).

Table 4.4 Problem - Lack of effectiveness in supplying the shops

Causes	Waste	Indicators
The required quantities of the item are neither available for picking in the indicated location nor in other locations (A5.1a)	W7	No. of times an item is acknowledged as undeliverable (PI1)
Items shipped by mistake or in over/under quantities	W7	No. of picking errors (over/under quantities or items shipped by mistake) (PI2)

Table 4.5 Problem - Inefficiencies in the process

Causes	Waste	Indicators
Manual tasks (in A1)	W1; W3; W4; W6	Time spent on activity A1 (PI3); paper consumption (PI4)
The required quantities of the item are not available for picking in the indicated location	W1; W3; W6; W7	No. of times the required quantities of the item are not available for picking in the indicated location (PI5); time spent on activities A5.1 + A5.1a or A5.1 + A5.1b1 + A5.1b2 (PI6)
Difficulties in placing and adjusting the arrangement of the items on the pallet/magnum (in A6a1/A6b1)	W1; W3; W6	Time spent on activity A6a1/A6b1 (PI7)
The picker has to glue the colis on the respective item(s)/box(es)/magnum (in A6a2/A6b2)	W1; W3; W6	Time spent on activity A6a2/A6b2 (PI8)
The picker needs to read (invoice) the colis, one by one, manually (in A9)	W1; W3; W6; W7	Time spent on activity A9 (PI9)
Identification that the invoice is not closed, at the end of the rafal (in A9.1)	W1; W3; W6; W7	No. of times the invoice is not closed at the end of the rafal (PI10); resulting waste of time (due to repeated, redundant or non-value added activities) (PI11)
The picker has to confirm, on his/her own, the compliance between the quantities of items on the pallet/magnum and the quantities registered in the UAT (in A12)	W3; W6; W7	Time spent on activity A12 (PI12)
Identification of extra/missing quantities of items on the pallet/magnum during the compliance check in the RFID reading (in A12)	W1; W3; W6; W7	No. of times that an error in quantities is detected during the compliance check in the RFID reading (PI13); resulting waste of time (due to repeated, redundant or non-value added activities) (PI14)

4.4.3. Proposed Improvement Solution

The proposed improvement solution is based on the combination of some of the information technologies mentioned in the literature review, namely pick-by-CMD (more specifically pick-by-tablet) combined with RFID technology as a confirmation method (using portable RFID reading plates), replacing, in this way, the current method of pick-by-label. The tablet (which will be fitted on the forklift) has all the information integrated in real-time with the company's ERP system and the RFID reading plates are connected to the tablet via Bluetooth (for an illustration of the material used for this solution see Figure 7.8, Annexe J).

This solution is inspired by the picking method used in other teams in the logistics centre and was devised for two main reasons:

- By confronting the analysis of the main problems of the process and their respective causes with the benchmarking carried out, by observing and experiencing the picking process in these other teams, it was possible to realise that a picking method identical to the one employed in these teams meets exactly the causes identified, reducing or even eliminating their impact (as will be explored in the following sections, especially in *Evaluation*).
- As can be seen in Table 7.8 (Annexe K), the percentage of items (sent to shops) whose RFID is confirmed is much higher when using the portable RFID reading plates than when using the static readers, increasing control and reducing the permeability to error. In addition, Company X is going to robotise the picking process in the teams of non-bulky items. Therefore, this solution allows not only to fully exploit the potential of the resources already available in the team (such as RFID technology), but also to reuse the resources that will no longer be used by other teams (such as portable RFID reading plates, more tablets and portable printers, and even manual pallet jacks, if necessary).

In this way, this solution allows to meet the objectives of improving the efficiency and effectiveness of the process without the need for further investment.

With this solution, the picking information will be presented in a graphical and intuitive manner (for an illustrative example see Figure 7.9, Annexe L) on the tablet. With this information the picker moves to the indicated location and, before placing the item(s) on the pallet/magnum, reads, with the RFID reading plate, the RFID of the item(s). By doing this, the tablet automatically indicates if everything is correct (correct item and quantities). Everything being correct, the picker confirms the pick on the tablet and places the item(s) on the pallet/magnum. By confirming the pick on the tablet, the item(s) are automatically invoiced and then the information for the next pick is displayed, according to the picking route, until the order is completed. The whole picking process with the proposed solution will be further detailed in the section *Improvement Design*.

4.4.4. Improvement Plan

The improvement plan based on this solution is presented in the table below. This includes the activities in which the proposed solution will have a concrete impact, as well as the desired function for these activities and the tools needed to accomplish that.

Table 4.6 Improvement plan

Activity	Desired function	Tools
A1	No longer necessary; done automatically	Tablet
A6a2/A6b2	No longer necessary	Tablet
A9 and A9.1	No longer necessary; done automatically	Tablet
A9.1.1 to A10*	No longer necessary	Tablet
A11	No longer necessary to activate the RFID reading here; done at the time of picking	RFID reading plate
A12	No longer necessary; done automatically	Tablet + RFID reading plate
A12a to A12*	No longer necessary	Tablet + RFID reading plate
A12b to A12*	No longer necessary	Tablet + RFID reading plate

* This includes all activities/sub-processes between the first and the last mentioned, excluding A10 in the first case and including A12 in the other two cases. For instance, in the first case, it could be: A9.1.1 + A9.1.1a1 + A9.1.1a2 + A9.1.1a3. Or, in the latter case, it could be: A12a + A12b + A12bb + A11 + A12 + A13 + A3 + (…). These represent repeated, redundant or non-value added activities.

4.5. Design

As mentioned in the methodology, in the design step, the goal is to create a beta version of the proposed solution that meets the improvement plan described in the previous section. Accordingly, the "to be" process was first designed (via process mapping) and explained considering the proposed solution, being then assessed to understand if it accomplishes the improvement plan, i.e., if it can be considered as the beta version.

4.5.1. Improvement Design

The "to be" process mapping is depicted in Figure 4.2 (overall process) and Annexe M (sub-processes).

The process starts with one of the team members extracting, from the company's ERP system, the information about the orders from the shops into the tablet software.

After this, the picker selects, on the tablet, the shop whose order is to be prepared (complying with the order of priority). Then, the picker analyses the rafal (on the tablet) and, taking into account the same factors mentioned in the process mapping "as is", decides whether picking should be done using a pallet or a magnum, and fetches what considers to be the most appropriate.

As mentioned before, on the tablet the picker has all the information needed to do the picking (just like in the process mapping "as is" with the colis labels), being that this information is also organised according to the warehouse aisles, so that the picker has the smoothest possible path (as described for the process mapping "as is"). Therefore, the picker moves to the location of the next item to be picked and confirms the location, contenant, code, and quantities required.

→ Are the required quantities of the item available for picking in the indicated location? If yes, the picker scans the RFID of the item(s) with the portable RFID reading plate; if not, the picker goes to the system to check if there are other locations where this item is available. → Are the required quantities of the item available in other location(s)? If not, the picker acknowledges, in the system, the item as undeliverable and makes the necessary adjustments so that the physical quantities of the item correspond to the quantities registered in the system, and moves on to the next decision node; if yes, the picker makes the necessary adjustments in the system, for the same reasons, moves to that location(s), confirms all the elements mentioned previously, and scans the RFID of the item(s) with the portable RFID reading plate.

→ Is everything correct[15]? If yes, the picker moves on to *sub-process "pick and invoice the item(s)"*; if not, the picker reconfirms the location, contenant, code, and quantities of the item to be picked and follows the same steps until everything is correct in this decision node.

Sub-process "pick and invoice the item(s)": the picker places the item(s)/box(es) on the pallet/magnum and confirms, on the tablet, the picking of the item(s)[16]. → Was(were) the item(s) picked from a box? If not, the sub-process is over; if yes → Is the box, from which the item(s) was(were) taken, empty? If not, the sub-process is over; if yes, the picker cuts and flattens the box, and leaves it in the recycling bin.

→ Is the rafal list finished or is the pallet/magnum full? If not, the picker moves to the location of the next item to be picked; if yes, the picker goes to the invoicing and pallet filming area and enters the company's ERP system on the computer. Here, the picker creates and prints the UAT of the pallet/magnum and moves on to *sub-process "film the pallet/magnum, if necessary"*: → Is it necessary to film the pallet/magnum? If yes, the picker films the pallet/magnum; if not, the sub-process is over.

Lastly, the picker glues the UAT on the pallet/magnum and leaves it in the corresponding area of the shipping dock. If the order is completed[17], the process is over; otherwise, the picker fetches a new pallet/magnum and repeats the process described until the order is completed.

4.5.2. Assess the Improvement Design

By analysing the improvement design, some important conclusions can be drawn:

- Once the information about the orders has been extracted to the tablet software, this information automatically appears organised on it, making activity A1 no longer necessary.

[15] By scanning the RFID of the item(s) with the RFID reading plate, it is indicated on the tablet whether it is the correct item and the correct quantities. It may happen that the plate, for some reason, cannot read the RFID of the item(s), in this case the picker has to confirm, personally, if everything is correct.

[16] By making this confirmation on the tablet, the item(s) are automatically invoiced.

[17] The picker can check this on the tablet.

- As picking is done by-tablet (and not by-labels), activities A6a2/A6b2 are no longer necessary.
- The invoicing of the items is done, by confirming the picking on the tablet, at the time they are picked, so activity A9 is no longer necessary. Furthermore, it is only possible to move on to the next item after confirming, on the tablet, the picking of the current item (invoicing it), thus it is impossible for the invoice not to be closed at the end of the rafal, consequently, activity A9.1 is also no longer necessary; the same applies to activities A9.1.1 to A10[18].
- As the items' RFID is read by the portable RFID reading plates at the time the items are picked, the activation of the items' RFID reading is no longer necessary in sub-process A11.
- Since the items' RFID is read, and consequently the correct item and quantities are confirmed, at the moment each item is picked, the conformity between the quantities of items registered in the UAT and the quantities of items on the pallet/magnum is always guaranteed, rendering activity A12 unnecessary.
- As a consequence of the previous point, if there is any mistake in the item or quantities, this is detected right at the time of picking and not at the end of the process, and so activities A12a to A12[18] and A12b to A12[18] are no longer necessary.

By looking at the aforementioned comments, it can be understood that the improvement design conforms to the improvement plan and therefore it is set as the *beta version*.

4.6. Recommendations for Implementation

As predicted in the methodology, it was not possible to implement the proposed solution during the course of the project. Therefore, the aim in this step is to provide some guiding recommendations for the implementation of the proposed solution taking into account the approach proposed by Widodo et al. (2021), which is outlined for this step in the methodology.

Accordingly, for the implementation stage in the case under review, it is suggested that the beta version of the proposed solution should first be tested by only a few pickers for a specific period of time (e.g., one month). During this period, the KPIs identified in this project should be closely monitored in order to understand if this solution really meets the desired and expected improvements; here the pickers should also point out, if they identify, any unanticipated gaps or weaknesses associated with the proposed solution. Based on this feedback, it should then be determined if the beta version of the proposed solution is suitable to work in real conditions or if it needs any adaptations or refinements before being implemented for the whole process.

[18] This includes all activities/sub-processes between the first and the last mentioned, excluding A10 in the first case and including A12 in the other two cases. For instance, in the first case, it could be: A9.1.1 + A10 + A11 + A12 + A13 + A3 + (…). Or, in the latter case, it could be: A12a + A11 + A12. These represent repeated, redundant or non-value added activities.

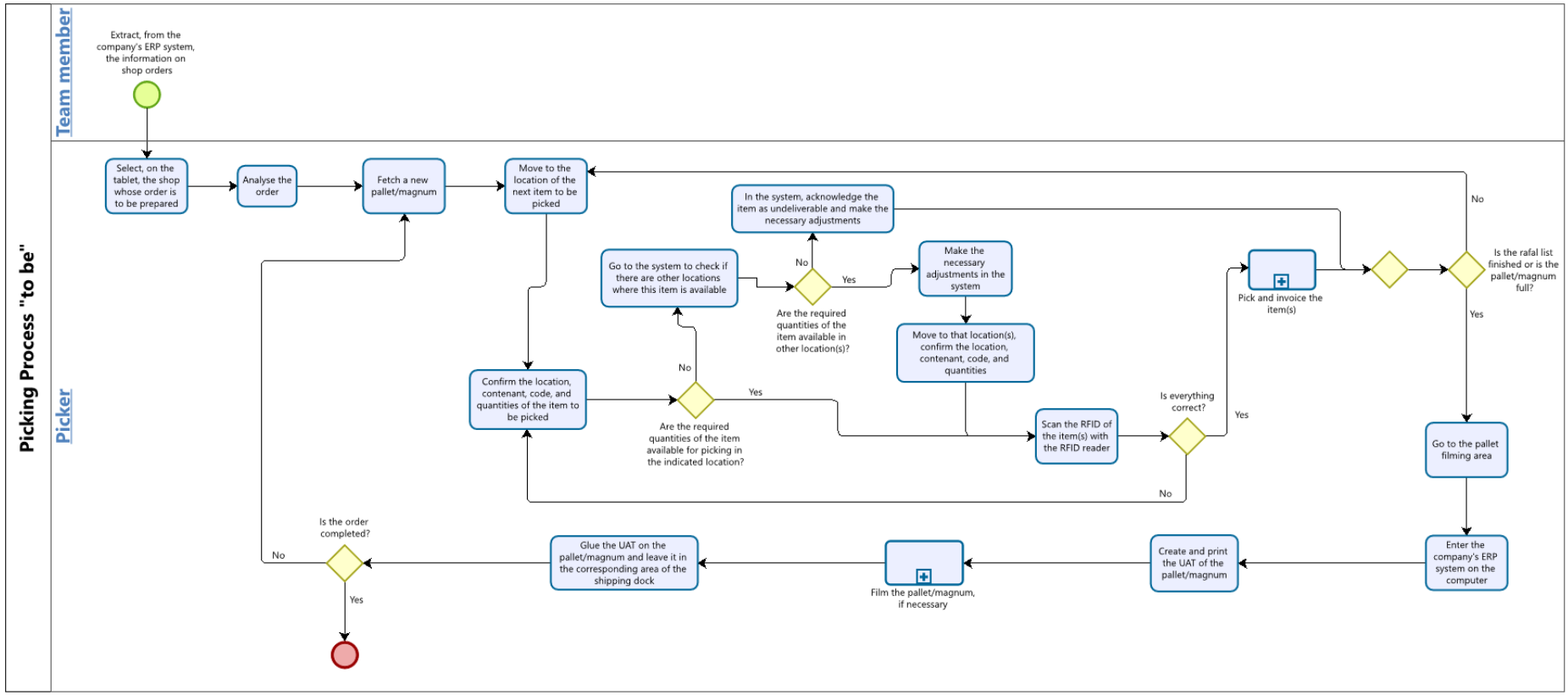

Figure 4.2 Process mapping “to be”

4.7. Evaluation

As mentioned in the methodology, the aim of the evaluation step is to compare the "as is" process with the "to be" process, considering the proposed solution. This way, it will also be possible to better visualise the potential improvements that may stem from this proposal once it was not possible to implement it during the timeframe of this project. In order to realise this objective, part of the indicators mentioned in Table 4.4 and Table 4.5 were measured for the "as is" process and then analysed in order to understand, in practice, the potential improvements that can be brought about by the proposed solution in the "to be" process.

4.7.1. Measurement and Analysis of Performance Indicators

Firstly, it is important to mention which indicators were measured and why, as well as how they were measured. Accordingly, the following table details how the indicators for which measurement was deemed relevant were measured.

Table 4.7 Indicator measurement procedure

Indicator	How it was measured*
PI1, PI5, PI10, and PI13	Measured directly by the pickers using the spreadsheet (Annexe N) developed by the author (in the month of April 2022)
PI2	Measured using the available data on picking errors (in the month of April 2022)
PI3 and PI4	Measured directly by the person carrying out activity A1, also using the spreadsheet (Annexe N) developed by the author (in the last week of April 2022)
PI8	Measured by the author through direct participation in the process (in the current practice observation phase)
PI9 and PI12	Measured by the author, through direct observation of the pickers performing activities A9 and A12 (for five different days, in April and May 2022)

* For these measurements, it was decided to use periods of the months of April and May since, according to the team leader, these are months of average picking activity (neither particularly high nor low) and are therefore good representatives of the big picture. The measurement periods for each indicator were also decided together with the team leader taking into account their variability and frequency of occurrence. Being those with lower frequency and higher variability measured over a longer period of time than those with higher frequency and lower variability.

The direct measurement of indicators PI6, PI11 and PI14 is not worthwhile as these refer to a variable number of activities, the duration of which also varies greatly, depending on the context (such as the type and number of errors identified, or the type of items being handled). A good way to assess the impact of these indicators is to look at indicators PI5, PI10 and PI13, respectively. This is because the higher PI5, PI10 and PI13 are, the greater the impact of PI6, PI11 and PI14, respectively, since the latter are a consequence of the former. Another indicator that was not measured is PI7. In this case, it is an indicator that varies greatly according to the order and the type of items being handled; moreover, the cause to which it refers is considered inherent to the process and, consequently, this indicator will not be affected by the proposed solution, so its measurement is not significant.

The procedure and the outcomes of the measurement and analysis of the performance indicators are presented below and summarised in Table 4.12.

PI1 - No. of times an item is acknowledged as undeliverable

As already understood, an item is acknowledged as undeliverable when it is not available for picking in any warehouse location and therefore it is not possible to satisfy the order. According to the data records made during the month of April 2022, pickers faced this situation 58 times (for more details see Table 7.9, Annexe N).

For this indicator, it was not possible to make an exact estimate for the "to be" due to lack of data. However, it is expected that with the proposed solution the number of picking errors will decrease considerably (explained in detail in: *PI2 - No. of picking errors*), and consequently the number of times an item is acknowledged as undeliverable should also decrease, since, as can be noted in Table 7.9 (Annexe N), the main reason for the occurrence of this problem is picking errors.

PI2 - No. of picking errors

As mentioned earlier in this project, according to data provided by the company, in the month of April 2022, there were 112 picking errors[19] reported out of a total of 128,140 items picked, which represents a percentage of picking errors of approximately 0.09%.

For this indicator it was also not possible to make an exact estimate for the "to be" since there is no concrete data regarding the reduction in the number of picking errors with the implementation of this method, for example in the other teams of the logistics centre. Therefore, and in order to have a better understanding of the real impact of the proposed solution with regard to picking errors, it was decided to conduct a short questionnaire (using Google Forms) to the company's employees (Annexe O). First there was a brief introduction explaining the topic and the purpose of the questionnaire, and then some questions, the results of which are described and analysed below:

- The first two questions served to limit the respondents to the target population and to characterise the sample. A total of 24 responses were obtained. To the question "Were you in the Logistics Centre before this picking method was implemented?" 15 (62.5%) answered "No" (for whom the questionnaire ended) and 9 (37.5%) answered "Yes" (for whom the questionnaire continued) (Figure 7.12, Annexe O). To the question "Do you have picking experience before and after the implementation of this method?" the 9 answered "Yes"[20] (Figure 7.13, Annexe O), and so all moved on to the next questions.

[19] This number of picking errors recorded is highly dependent on the reporting of these errors by the shops, which is often not done, so it is believed that the real number of picking errors is higher.

[20] Although it seems like a small sample, it is considered representative since, according to the team leader, there are very few employees with this experience still in the logistics centre.

- The answers to the third question “How was picking done before?” (Figure 7.14, Annexe O) indicate that previously in the other teams the picking method used was similar to the one currently used in the team under study, which supports the appropriateness of this analogy.
- Finally, the last question “How do you evaluate the impact of the introduction of the picking method (tablet + portable RFID plate) with regard to the reduction of the number of picking errors?” had a scale between 1 - *Nil* and 5 - *Extremely significant*. Of the 9 respondents, 1 answered: “2 - *Not very significant*”, 2 answered: “3 – *Significant*”, 4 answered: “4 - *Quite significant*”, and 2 answered: “5 - *Extremely significant*” (Figure 7.15, Annexe O).

The analysis of Table 7.8 (Annexe K) had already shown that there is a strong potential for improvement, regarding the number of picking errors, by using the proposed picking method in comparison to the one currently used. The answers to this questionnaire corroborate this idea and reveal that this solution may actually have a positive impact on this indicator, as it has already had in other teams in the past. Therefore, it is expected that with the proposed solution the number of picking errors will decrease considerably.

PI3 - Time spent on activity A1

According to the measurements taken (see Table 7.10, Annexe N), for each day in the last week of April 2022 (from 24 to 30), it can be observed that the time spent on activity A1 varies between 50 and 60 minutes per day, with a total of 6 hours and 20 minutes in the analysed week. This time does not depend so much on the number of colis but rather on the number of rafal lists; this number does not vary much from week to week, since it depends on the number of orders from shops, which is relatively stable from week to week. Thus, these figures can be seen as a good representation for other weeks.

With the proposed solution, activity A1 no longer exists, so these times will be saved. In the case of this particular week, there would be a saving of 6 hours and 20 minutes.

PI4 - Paper consumption

For this indicator, the data presented in Table 7.10 (Annexe N) was also used. It can be seen that in the last week of April 2022, were printed (consumed) 219 rafal lists corresponding to 7320 colis labels.

As can be easily understood, with the proposed solution, this paper consumption is eliminated.

PI5 - No. of times the required quantities of the item are not available for picking in the indicated location

According to the data records made during the month of April, pickers encountered this scenario 76 times (see Table 7.11, Annexe N).

For this indicator, it was also not possible to make an exact estimate for the "to be" due to lack of data. However, as explained in detail in: *PI2 - No. of picking errors,* it is expected that with the proposed solution the number of picking errors will decrease considerably, and consequently the number of times the required quantities of the item are not available for picking in the indicated location should also decrease, since, as can be noted in Table 7.11 (Annexe N), the main reason for the occurrence of this problem is picking errors.

As mentioned above, this indicator is a good proxy for indicator PI6, since the greater PI5, the greater the time spent on activities A5.1 and A5.1a, or on activities A5.1, A5.1b1 and A5.1b2 (PI6). This is because these activities are only necessary if the required quantities of the item are not available for picking in the indicated location. Therefore, as the number of times this happens (PI5) is expected to decrease with the proposed solution, it is also expected that less time will be spent on these activities (PI6).

PI8 - Time spent on activity A6a2/A6b2

This indicator was gauged by the author during the current practice observation phase by directly participating in the process. During this phase, it was observed that this activity takes between 1 to 3 seconds, with little variation. With the proposed solution, activity A6a2/A6b2 is no longer necessary and therefore this time (here referred to as Y) will be saved.

With the proposed solution, however, there is an additional time spent to read the RFID of the items with the RFID reading plate and to invoice them (confirming their picking on the tablet). Based on initial experience, when participating in the picking of other teams in the logistics centre where the method proposed in the solution was used, it was possible to note that the time to perform these two aforementioned activities is very similar to the time spent on activity A6a2/A6b2, also varying between 1 and 3 seconds, with little variation. Furthermore, the movement that will be necessary to pass the RFID reading plate through the item(s) to read the RFID (in the "to be" process) is very similar to the movement currently necessary to glue the colis on the item(s)/box(es)/magnum; and for each colis label glued in the "as is" process there is one RFID reading and one invoicing in the "to be" process. That said, this time was considered to be equivalent to the time spent on activity A6a2/A6b2, i.e., Y[21].

Since, with the proposed solution, the time that is saved with activity A6a2/A6b2 is used in the new activities herein described, these times are considered to cancel each other out, as it is possible to confirm in Table 4.12.

[21] It is important to mention that this assumption was clarified and confirmed with the team leader.

PI9 - Time spent on activity A9

The measurement of this indicator was done by the author through direct observation of the pickers performing this activity (A9). For this purpose, activity A9 was observed during five different days (26 April, 2, 6, 11 and 12 May 2022). These measurements were made on five different days of the week, across three different weeks and at different times of the day, in order to cover as much diversity as possible of orders and pickers performing the activity, so as to have a sample as reliable as possible. This indicator was measured randomly for 86 pallets and 41 magnums, totalling 127 measurements (see Table 7.14, Annexe P).

As it was not possible to measure this indicator for all the pallets/magnums on the days in question, it was necessary to extrapolate the values. During this analysis, it was observed that this indicator has a direct relationship with the number of colis to be invoiced. However, a difference was noted depending on whether it is a pallet or a magnum. This is explained by the fact that if all the colis are glued on a magnum, their invoicing is faster than if they are glued on the different boxes on a pallet. The results of this analysis, based on the data collected, are presented in the table below.

Table 4.8 PI9 - Analysis of the data collected

Pallet/Magnum	Sum of no. of colis	Sum of time (hh:mm:ss)	Average sec/colis
Magnum	1313	00:32:16	**1.47**
Pallet	1348	00:48:38	**2.16**
Grand Total	**2661**	**01:20:54**	**1.82**

In this case, the company's databases only provide the total number of pallets + magnums sent per day, so it is not possible to know exactly how many pallets and how many magnums were sent on the days analysed. Therefore, it was decided to calculate the minimum and maximum time that is currently spent on this activity; the minimum considering that everything is sent in magnums and the maximum considering that everything is sent on pallets; it was also calculated the time taking into account the average time per colis of the 127 measurements (in this case, it is assumed that the ratio between pallets and magnums in reality is the same as in the collected data).

Based on this information, and to quantify the current situation, the data for the last week of April 2022 was considered[22], during which 7320 colis were invoiced. Using this value, the minimum, average, and maximum time spent on activity A9 in this week are shown in the table below.

[22] Since it is not possible to know (through the company's databases) exactly how many pallets and magnums were sent on the days of the measurements, nor how many colis were on each pallet/magnum (only knowing the total for the day) it would be indifferent to use the data from these days or from others. For this reason, it was decided to use the data for a full week. The week considered was the last week of April 2022, since, as mentioned before, it is a week of a good period to represent the overall situation, and it has also been used previously for other indicators.

Table 4.9 PI9 - Estimated time spent on activity A9 in the last week of April 2022

	Minimum	Average	Maximum
Time* (hh:mm:ss)	02:59:53	03:42:33	04:24:06

* $Time = 7320 \times \text{average sec/colis}$ (1)

With the proposed solution, activity A9 is no longer necessary, so this time would be saved.

PI10 - No. of times the invoice is not closed at the end of the rafal

As per the data records made during the month of April, pickers faced this problem 12 times (see Table 7.12, Annexe N). With the proposed solution, items are invoiced by confirming their picking on the tablet at the time they are picked, and the information for the next pick is only displayed after this confirmation, with no risk of skipping the invoicing of any item. Therefore, in the "to be" process this problem no longer occurs.

As mentioned earlier, this indicator is a good proxy for indicator PI11, since the greater PI10, the greater the time spent on repeated, redundant or non-value added activities (referred to as "A9.1.1 to A10" in Table 4.3) (PI11). This is because these activities are only necessary if the invoice is not closed at the end of the rafal. That said, and since this problem no longer occurs in the "to be" process, the time spent on these activities (PI11) is saved.

PI12 - Time spent on activity A12

As with indicator PI9, the measurement of this indicator was done by the author through direct observation of the pickers performing this activity (A12). For this purpose, activity A12 was also observed during five different days (26 April, 2, 6, 11 and 12 May 2022). As mentioned for indicator PI9, these measurements were made on five different days of the week, across three different weeks and at different times of the day, in order to cover as much diversity as possible of orders and pickers performing the activity, so as to have a sample as reliable as possible. This indicator was also measured randomly for 86 pallets and 41 magnums, totalling 127 measurements (these measurements, together with other data obtained from the company's databases, can be seen in Table 7.15, Annexe Q).

It was also not possible to measure PI12 for all the pallets/magnums on the days in question, so it was necessary to extrapolate the values for this indicator as well. In this case, it was observed that this indicator is not impacted by whether it is pallet or magnum, however, it can be influenced by several other factors, these being: the total number of items on the pallet/magnum, the total number of items not read, the number of different items, and the number of different items not read.

It was therefore decided to explore, on the basis of the data collected, the relationship between these factors and PI12 by analysing the linear regressions using Excel's Analysis ToolPak. With this analysis, it was noted that looking at each variable in separate, the one with the greatest impact on

PI12 is the number of different items not read. However, during the measurements and also by analysing the data it was understood that the other variables may also be important in explaining the behaviour of PI12.

Consequently, it was decided to analyse the multiple linear regression with these four variables as the independent variables of the model, with PI12 as the dependent variable. The Regression Statistics and ANOVA outputs in Table 7.16 and Table 7.17 (Annexe R) indicate that there is a strong and precise relationship between the independent variables and the dependent variable (Multiple R, R Square, and Adjusted R Square really close to 1, and a relatively low Standard Error), and that the model as a whole is statistically significant (Significance F < 0.05). However, as can be seen in Table 7.18 (Annexe R), the P-value for the independent variable "No. of items not read" is greater than 0.05, which means that this variable is not statistically significant as a predictor of the dependent variable (PI12), in this model.

Hence, it was decided to analyse the multiple linear regression considering only the other three variables (No. of items, count of different items, and count of different items not read) as independent variables of the model, with PI12 as the dependent variable. Also in this case, the Regression Statistics and ANOVA outputs in Table 7.19 and Table 7.20 (Annexe S) indicate that there is a strong and precise relationship between the independent variables and the dependent variable (Multiple R, R Square, and Adjusted R Square really close to 1, and a relatively low Standard Error), and that the model as a whole is statistically significant (Significance F < 0.05). In this model, the P-values for all the independent variables are well below 0.05, as shown in Table 7.21 (Annexe S), so these three variables are statistically significant. Accordingly, this was the multiple regression model used to extrapolate the values of PI12. To build the equation for this model, the values of the coefficients for the different variables, presented in Table 7.21 (Annexe S), were used, resulting in the following equation: (2)

$$Time\ (in\ seconds) = 0.0379898432127889 \times no.of\ items + 0.415273714962573 \times count\ of\ different\ items + 10.1723136460258 \times count\ of\ different\ items\ not\ read + 3.12877446378763$$

For this purpose, the necessary data regarding the pallets/magnums for which measurements were not taken on the days in question were collected from the company's databases. Data for 14 and 15 May 2022 has also been added in order to cover all seven different days of the week in this analysis. Therefore, the days for which data were collected were, in April: the 26th (Tuesday), in May: the 2nd (Monday), the 6th (Friday), the 11th (Wednesday), the 12th (Thursday), the 14th (Saturday) and the 15th (Sunday). Using equation (2) it was possible to estimate PI12 for each of these pallets/magnums (for details on these data, see Table 7.22, Annexe T). As, in this case, it was possible to obtain the necessary data for the pallets/magnums for which measurements were not made on the analysed days, it was decided to use the data from the days of the measurements and from two other days (which, as mentioned above, together constitute a full week) to estimate the time spent on activity

A12 (PI12). Accordingly, the estimations for PI12 for these seven days (a full week) are presented in the table below.

Table 4.10 PI12 - Estimated time spent on activity A12 for a full week

Estimated PI12[a] (hh:mm:ss)	Measured PI12[b] (hh:mm:ss)	Total (hh:mm:ss)
02:48:34	01:16:34	04:05:08

[a] Estimates, for the pallets/magnums for which PI12 was not measured, using the multiple linear regression equation mentioned.

[b] Actual measurements (for the pallets/magnums for which PI12 was measured).

With the proposed solution, activity A12 is no longer necessary, so this time would be saved.

PI13 - No. of times that an error in quantities is detected during the compliance check in the RFID reading

According to data records made during the month of April 2022, pickers experienced this situation 5 times (Table 7.13, Annexe N). With the proposed solution, the RFID reading is done at the time the items are picked. Therefore, if there is any error, the system alerts automatically, without the risk of detecting errors in the quantities of items only at the end of the process. As a result, in the "to be" process this problem is eliminated.

As previously mentioned, this indicator is a good proxy for PI14, since the greater PI13, the greater the time spent on repeated, redundant or non-value added activities (referred to as "A12a to A12" and "A12b to A12" in Table 4.3) (PI14). This is because these activities are only necessary if an error in quantities is detected during the compliance check in the RFID reading. Consequently, and since in the "to be" process this problem no longer arises, the time spent on these activities (PI14) is saved.

4.7.2. Savings Assessment and Performance Improvement Overview

Based on the indicators that were actually measured and estimated, an estimate of total savings will now be made (both in terms of time and money). According to data provided by the company, the cost of a box with 12,000 colis labels is 30.24€, and the average cost/hour of a picker is 12.60€. Based on this, the calculations for the total costs associated with indicators PI3, PI4, PI9, and PI12 for an average picking week can be seen in the table below.

Table 4.11 Cost, associated with indicators PI3, PI4, PI9, and PI12, for one week of average picking

PI3	PI9	PI12	Total (hh:mm:ss)	Associated cost	PI4 cost of 7320 colis	Total Cost	
06:20:00	02:59:53	04:05:08	13:25:01	169 €	18 €*	187 €	**Min**
	03:42:33		14:07:41	178 €		196 €	**Av**
	04:24:06		14:49:14	187 €		205 €	**Max**

$$* \cong (30.24 \div 12000) \times 7320 \quad (3)$$

Accordingly, with the proposed solution, in one week of average picking there will be savings, with indicators PI3, PI9, and PI12 (considering, for instance, the average value for PI9) of about 14:07:41 (hh:mm:ss). In terms of economic savings, by adding to the cost of these hours the cost of the colis labels consumed (PI4), the savings would amount to 196€ per week, which generalising to a 52-week year totals 10,192€. These savings are quite significant, and it is also important to note that this is an underestimate, since although these are the indicators that will be most impacted by the proposed solution, there are also savings associated with other indicators, as described earlier in this chapter.

Through this analysis, together with the analysis of Table 4.12 and Table 4.13, it can be concluded that the proposed solution will allow the reduction of much of the wastes identified, this will have a positive impact on most of the performance indicators analysed and consequently, as they are directly related to these, on the two KPIs (quality and productivity) identified in *Initialisation*. All in all, it can be concluded that the proposed solution contributes positively to the objective of improving the process with the aim of increasing its efficiency and effectiveness.

Table 4.12 Summary of measurement and analysis of performance indicators

Indicator	As is	To be	Estimated savings	Notes
PI1	58	(a)	58 - (a)	In an average picking month
PI2	112	(a)	112 - (a)	In an average picking month
PI3	06:20:00	0	06:20:00	In an average picking week
PI4	7320 colis labels	0	7320 colis labels	In an average picking week
PI5	76	(a)	76 - (a)	In an average picking month
PI6	(b)	(a)	(b) - (a)	Proxied on the basis of the previous indicator
PI7	(b)	(b)	0	Not affected by the proposed solution
PI8	Y	Y	0	See the explanation given in PI8
PI9	Min - 02:59:53; Average - 03:42:33 Max - 04:24:06;	0	Min - 02:59:53; Average - 03:42:33 Max - 04:24:06;	In an average picking week
PI10	12	0	12	In an average picking month
PI11	(b)	0	(b)	Proxied on the basis of the previous indicator
PI12	04:05:08	0	04:05:08	In an average picking week
PI13	5	0	5	In an average picking month
PI14	(b)	0	(b)	Proxied on the basis of the previous indicator

(a) It was not possible to make an exact estimate, but it is expected that with the proposed solution there will be a reduction.
(b) Not measured.

Table 4.13 Waste reduction with the proposed solution

Activity/sub-process	W1	W3	W4	W6	W7
A1					
A5		X			X
A5.1 + A5.1a	X	X		X	X
A5.1+A5.1b1 + A5.1b2	X	X		X	X
A6a1/A6b1	X	X		X	
A6a2/A6b2					
A9 + A9.1					
A9.1.1 to A10					
A12					
A12a to A12					
A12b to A12					

Notes:

X	Waste remains the same
X	Waste reduced
	Waste eliminated

5. Conclusions

This investigation was conducted in the team of bulky items in the logistics supply centre responsible for the Portuguese market of Company X, a company operating in the sporting goods retail sector.

The overall aim of the project was to answer the research question: *"How can the picking process in the area of bulky items at the logistics supply centre of Company X be improved so as to increase its efficiency and effectiveness?"*.

From the literature analysed, it was possible to understand the importance of having a clear focus on process improvement to achieve success, especially in increasingly competitive and demanding sectors, such as the sector under consideration. However, for this success to be sustainable, this focus on process improvement must be carried out in a systematic and well-structured way, which highlights the importance of a BPI methodology. Therefore, in this follow-up, the literature review also focused on looking for studies that would provide solid foundations for the development of a BPI approach for this project.

Order picking is one of the processes that deserves this focus, as it is one of the processes that demands more working hours and directly impacts the quality and efficiency of the entire supply chain. This is clearly the case within the area under study in the logistics centre of Company X and so it was imperative to seek strategies that could meet the objectives of improving the efficiency and effectiveness of the picking process in this area.

In the literature, several strategies were found with this objective in mind. Following this literature review, and given the particular characteristics of the case and the company's requirements, it was concluded that a possible approach could involve strategies concerning the use of information technologies to improve the efficiency and effectiveness of the picking process.

The outlined BPI approach was then applied to the case study, where its different stages were followed on a step-by-step basis. First, the process was observed and characterised in detail. Then, it was carefully analysed in order to identify the main problems and the respective causes. Based on these analyses and on the strategies identified in the literature review, a solution and the respective improvement plan were then proposed. The next step was the design and description of the "to be" process considering the proposed solution; this improvement design was then confronted with the improvement plan in order to verify if it meets the established improvement objectives. In the next step, and as it was not possible to implement the proposed solution during the project, some guiding recommendations for the implementation phase were provided. Finally, several indicators were measured and analysed to better quantify the potential impact in terms of process improvement that may arise from the proposed solution.

The proposed solution is to replace the current pick-by-label method with pick-by-tablet combined with RFID technology as a confirmation method (using portable RFID reading plates). Through the analysis of the "as is" and "to be" process maps, as well as the analysis of the different performance indicators identified, it can be concluded that, with the proposed solution, the process becomes not only simpler and easier to understand but also more efficient and effective, responding to the pre-established objectives.

These improvements will save time and other resources which in turn can mean economic savings. However, it should be noted that these savings do not have to be reflected directly in money, as the working hours saved in the picking process can be applied to further improve the same and/or other processes, thus fostering a culture of continuous improvement, enhancing as well employee satisfaction and overall well-being.

The proposed solution was the one that was considered to best meet the objectives and characteristics of the project as well as the company's requirements. Nevertheless, other potential strategies could be suggested to improve the process in question. For example: *batch picking* for smaller orders (which could also be applied for e-commerce); standardise the possibility to use both traffic directions on the picking route (as space allows) and to use the central cross-aisle to change aisles if advantageous (this last strategy is already applied by most pickers but is not standardised, and in theory there is still only one traffic direction).

The project, however, has some potential limitations. In the systematic literature reviews, having limited the search terms to "business process improvement" may have generated some limitations in the results since, as observed in the literature, some authors use the terms business process improvement, business process reengineering, business process redesign and sometimes even business process management interchangeably. Another limitation is the fact that it was not possible to implement the proposed solution during the course of the project. As a consequence of the previous limitation, it was not possible to truly quantify the impact of the proposed solution on some of the indicators analysed. Furthermore, it was not possible to consider all cases for the measurement of indicators for the "as is" process, therefore some estimates had to be made by approximation.

This investigation was carried out in the specific context of the picking process in the bulky items area in the logistics supply centre of Company X; however, the methodology followed can be adapted and generalised to other contexts with similar objectives. As future work, it is recommended to check the potential impact of the other strategies, suggested above, with the aim of improving the picking process under analysis. It may also be interesting to analyse the potential of other strategies related to the picking route and the storage of items in the warehouse, which, despite not having been considered interesting by the company in the present setting, may emerge as sources of improvements in the future and can always be combined with the solution proposed in this project.

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7. Annexes

Annexe A

The following tables display the description of the 11 characteristic activities of BPI identified by Curatolo et al. (2014), divided into core operational activities and support activities.

Table 7.1 BPI core operational activities identified by Curatolo et al. (2014)

Activity	Description
Select a process to improve	It is suggested that the user select the process to improve based on the process performance, the process impact on the customers' needs, or the objectives and strategy of the organisation.
Understand the selected process	To understand a process, it is suggested to collect information among operators, clearly define the process characteristics and objectives, and map it graphically, when possible.
Measure	Collect data in order to measure the process performance.
Analyse	To analyse the process, it is suggested to identify the activities with non-added value, as well as the shortcomings related to the selected process (bottlenecks, lack of efficacy or efficiency, etc.).
Improve	The actions suggested for improving a process are benchmarking, streamlining the process by eliminating redundant activities and waste, as well as assessing the need for new technologies. It is also suggested to represent the improvement on a future state map.
Implement	To implement the improvement, it is suggested to plan this implementation of the new process in advance. It is also sometimes suggested to conduct a pilot test before the implementation.

Table 7.2 BPI support activities identified by Curatolo et al. (2014)

Activity	Description
Understand the environment	It is important to understand the environment of the organisation before moving on to the following BPI activities. This activity can be defined by one or more actions such as: identifying the strategic objectives of the organisation, understanding the main business processes of the organisation, understanding employees' and/or customers' needs, and analysing the competition.
Establish top management support	It is suggested to actively involve top management in order to ensure the success of the approach.
Organise a project team	This activity involves selecting the project team, training team members on BPI basics and planning the team's work. The team should be composed of members actively involved in the different stages of the selected process.
Manage change	This activity is intended to facilitate the understanding and implementation of the new process for the operators. In this way, this activity involves communicating the changes that have been undertaken and training the staff to use the new process.
Monitor	This activity includes identifying performance indicators, collecting data and monitoring these indicators. A new BPI project should be carried out if a problem is identified. By doing so, continuous improvement is accomplished. This activity enables the existence of the new process and its quality to be assured.

Annexe B

The table below presents the search results of the systematic literature review of BPI methodologies/frameworks.

Table 7.3 Search results of the systematic literature review of BPI methodologies and frameworks

Search	
Database	EBSCO-host (here: IDS)
Search terms	TI "business process improvement" OR SU "business process improvement" OR AB "business process improvement" AND AB (method* OR approach* OR framework* OR procedure*)
Limitations	Peer-Reviewed academic journals and conference materials; Date Published: 01/01/2012 onwards; Language: English
Results	97
Duplicates	21
Overall	76
Selected papers	16

Annexe C

The following table lists the papers selected in the systematic literature review of BPI methodologies and the respective main activities/stages.

Table 7.4 Papers selected in the systematic literature review of BPI methodologies and frameworks

Author(s)	Activities/stages					
(Radosevic et al., 2013)	Planning of reengineering	Analysis of identified process	Redesign of process	Obtaining resources	Implementation	Continuous process improvement
(Ou-Yang & Tsai, 2014)	Planning	As-is Session	Involve Others	Should-be Session	Implementation	
(Vera-Baquero et al., 2014, 2015)	Definition	Configuration	Execution	Control	Diagnosis	Improvement
(Bradford & Gerard, 2015)	Identify goals and objectives	Compile process inventory; select a process	Define and understand the process	Analyse and measure the process	Improve the process	Continuous improvement
(Manfreda et al., 2015)	Initiating the project	Modelling existing processes	Analysing current processes	Formulating proposals for improvements		
(Swarnakar & Vinodh, 2016)	Define	Measure	Analyse	Improve	Control	
(Djedovic et al., 2017)	Business process governance	Managing changes and BPM innovation	Process modeling and analysis	Implementation	Control and measurement of business processes	
(Johannsen & Fill, 2017)	Define	Measure	Analyse	Improve	Control	
(Martins & Zacarias, 2017)	Business Process Discovery		Business Process Change			
(Denner et al., 2018)	Selection and modelling of business process	Preselection of suitable digital technologies	Inclusion of further evaluation perspectives	Final assessment of digital technologies		
(Noori & Latifi, 2018)	Define	Measure	Analysis	Change Management	Improve	Control
(Mehdouani et al., 2019)	Process identification	Process design	Process analysis	Process redesign	Process implementation	Process execution & control
(Casebolt et al., 2020)	Decomposition		Rationalisation		Optimisation	
(Fakorede & Davies, 2021)	Initiation	Analysis	Re-engineering	Implementation	Evaluation	
(Widodo et al., 2021)	Initialisation	Selection	Design	Implementation	Evaluation	

Annexe D

The table below presents the search results of the systematic literature review of BPI in the retail context.

Table 7.5 Search results of the systematic literature review of BPI in the retail context

Search	
Database	EBSCO-host (here: IDS)
Search terms	(TI retail* OR SU retail* OR AB retail*) AND "business process improvement"
Limitations	Peer-Reviewed academic journals and conference materials; Language: English
Results	32
Duplicates	2
Overall	30
Selected papers	6

Annexe E

The following table lists the papers selected in the systematic literature review of BPI in the retail context as well as the respective approaches and main conclusions.

Table 7.6 Papers selected in the systematic literature review of BPI in the retail context

Author(s)	Methodology/approach	Main conclusions
(Law & Ngai, 2008)	The authors collected data from multinational and Hong Kong-listed manufacturing, and wholesale or retailing firms to assess the impact of knowledge sharing and learning behaviours on organisational performance, on BPI and on its product and service offerings, as well as the impact of BPI on organisational performance and on the product and service offerings of a firm.	Through this research, the authors hypothesised and evidenced that: Knowledge sharing and learning behaviours positively contribute to BPI, to organisations' product and service offerings, and ultimately to organisational performance; BPI positively contributes to the organisational performance, and has positive impacts on the capability of a firm to offer products and services to meet customers' changing needs and preferences.
(Corinna Cagliano et al., 2011)	The system dynamics (SD) methodology was used to model warehouse operations in the distribution centre of a leading fast fashion vertical retailer. The case study includes a detailed analysis of the relationships between the flow of items through the warehouse, staffing, inventory management policy, and order processing tasks to understand how different sourcing and resource utilisation policies affect the operational performance dynamics of warehouse processes.	Flexible staffing, outsourcing of selected warehouse operations (in this case item count), and sourcing from reliable manufacturers may result in important performance improvements (cost savings, reduced inventory, and shorter warehouse lead times) for centralised warehousing.
(Marjanovic & Roose, 2011)	This research aims to critically analyse an innovative approach to Business Intelligence (BI) and Business Process Management (BPM) integration, achieved through BI-enabled BPI, founded in human-centred Knowledge Management (KM). The analysis is based on theoretical frameworks found in the related disciplines of BPM, BI and KM, and, as an illustrative example, was implemented by a large retail company in Australia.	The key to the success of BI-enabled BPI is not in technology and technical integration between BI and BPM systems but is related to the people component (i.e., HR policies that need to be redesigned to enable the ongoing co-evolution of BI technology and human practices); BI system is changing the nature of human work, turning individual decision-makers into collaborating knowledge workers; BI-enabled BPI requires new approaches to performance management of processes and people involved.

Author(s)	Methodology/approach	Main conclusions
(Moghdeb et al., 2011)	The authors presented a case study of a BPI project in a major Australian retail organisation to gain insights into how to achieve higher levels of improvement in BPI initiatives. Two theoretical lenses (stakeholder theory and organisational capabilities theory) were used to reveal which factors could lead to higher levels of business process improvement.	The issues preventing this organisation from achieving its goals were mainly social rather than organisational in nature. While executives were dedicated to making the organisation more business process-aware, some key stakeholders resisted adopting this vision (the alignment of key stakeholder requirements impacts the level of improvement); other than directly impacting the level of improvement, BPI organisational capabilities were used to achieve the alignment of key stakeholder requirements; the alignment among the requirements of key stakeholders in BPI initiatives would improve if they are fed-back with the improvement results while the improvement project is in progress, which in turn assists in achieving higher levels of improvement, and so on. In conclusion, the findings reveal that improvement depends on continuously revisited cyclical, not linear, stakeholders' alignment process, and persistent development of BPI organisational-specific capabilities.
(Madhani, 2020a, 2020b)	The research provides a clear roadmap for Lean Six Sigma (LSS) deployment in the retail industry. It develops the retail LSS synergy framework as well as the financial evaluation metrics and highlights that LSS deployment positively affects the business performance of retailers. By using these frameworks, the research also discusses illustrative examples to highlight the success of LSS implementation by retailers.	The deployment of LSS benefits the retail industry immensely as it mitigates many challenges faced by retailers. With LSS initiatives, traditional retail operations are transformed to represent greater cost efficiency and customer effectiveness in operations (as illustrated in the examples provided), thereby helping to build sustainable competitive advantages.

Annexe F

The figure below illustrates the warehouse layout.

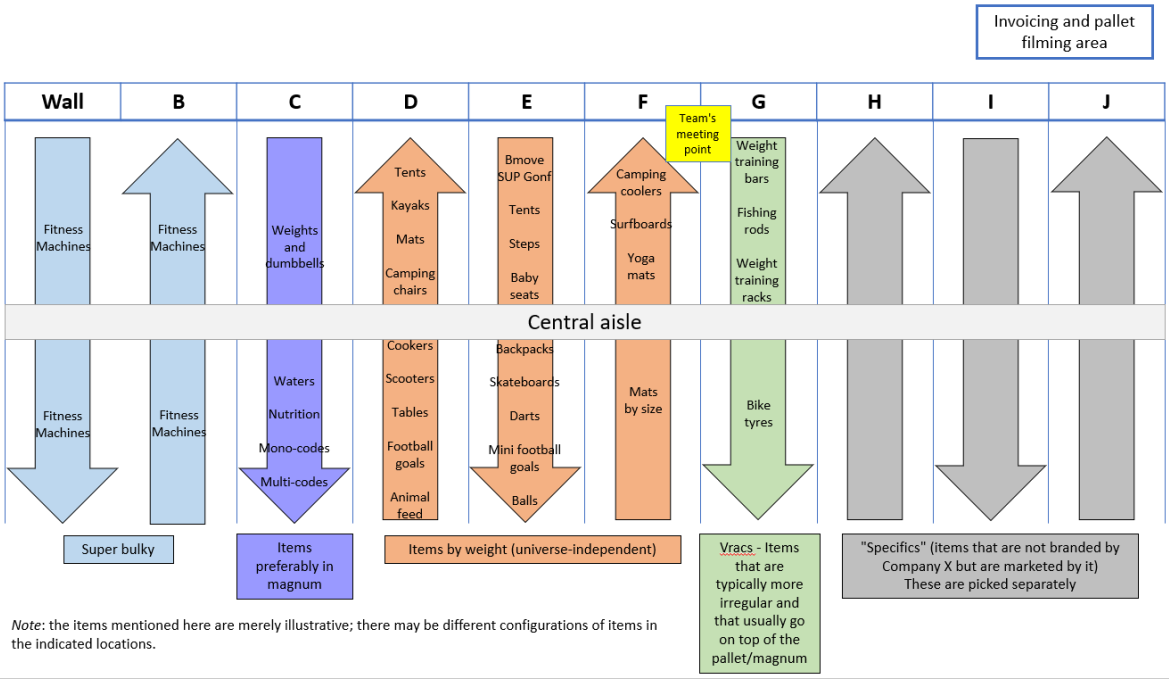

Figure 7.1 Warehouse layout

Annexe G

The table below presents the script for the semi-structured interviews.

Table 7.7 Script for the semi-structured interviews

How long ago was the picking process reviewed?
What do you think of the performance of the picking process currently?
Which activities or steps in the process do you think create the most delays and difficulties?
Why do you think these activities continue to be done as they are today?
What do you think can be done to improve given the circumstances and resources available?
Which performance indicators do you consider the most important to improve in the picking process?

Annexe H

The following figures provide details of the sub-processes present in the process mapping “as is”.

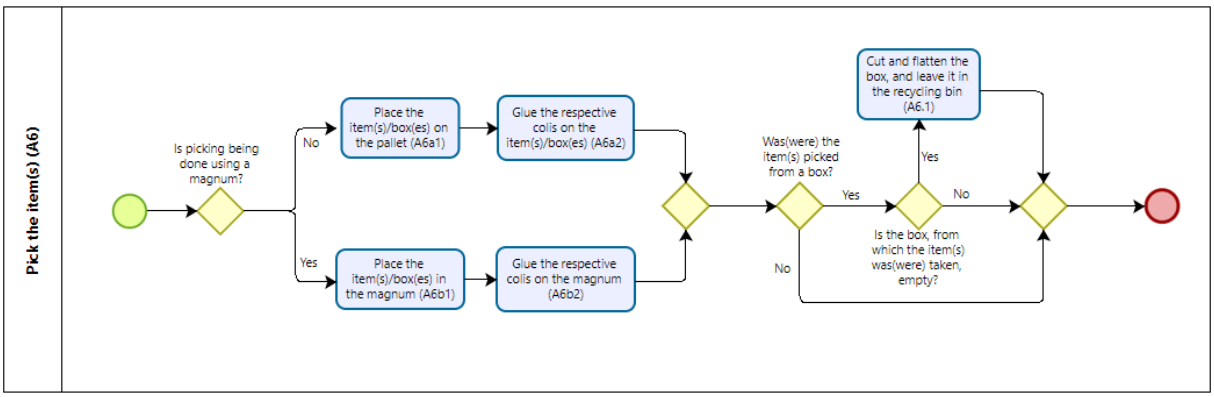

Figure 7.2 Sub-process A6: pick the item(s)

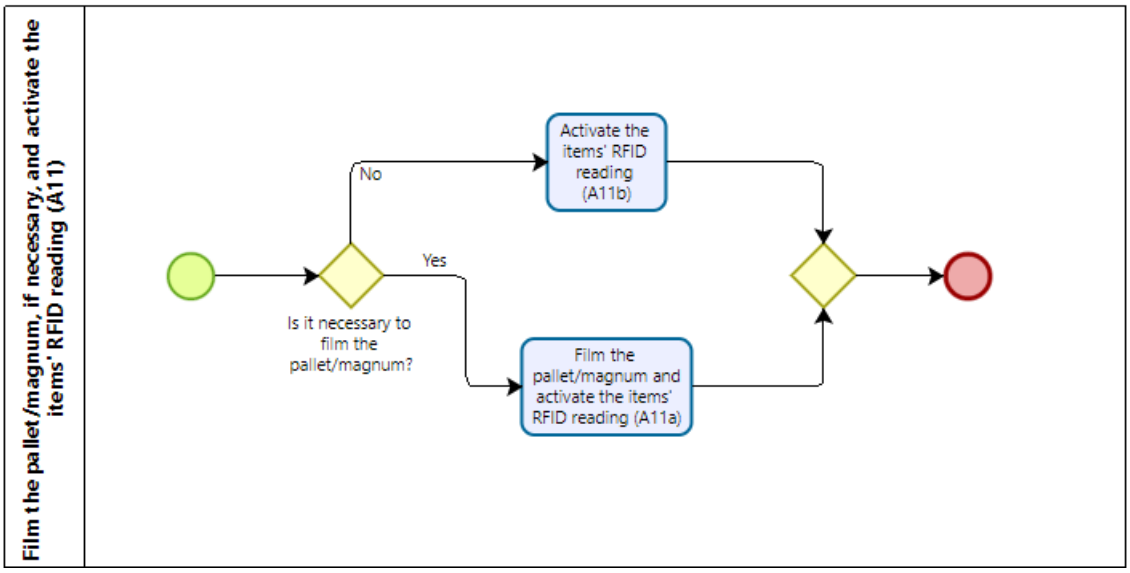

Figure 7.3 Sub-process A11: film the pallet/magnum, if necessary, and activate the items’ RFID reading

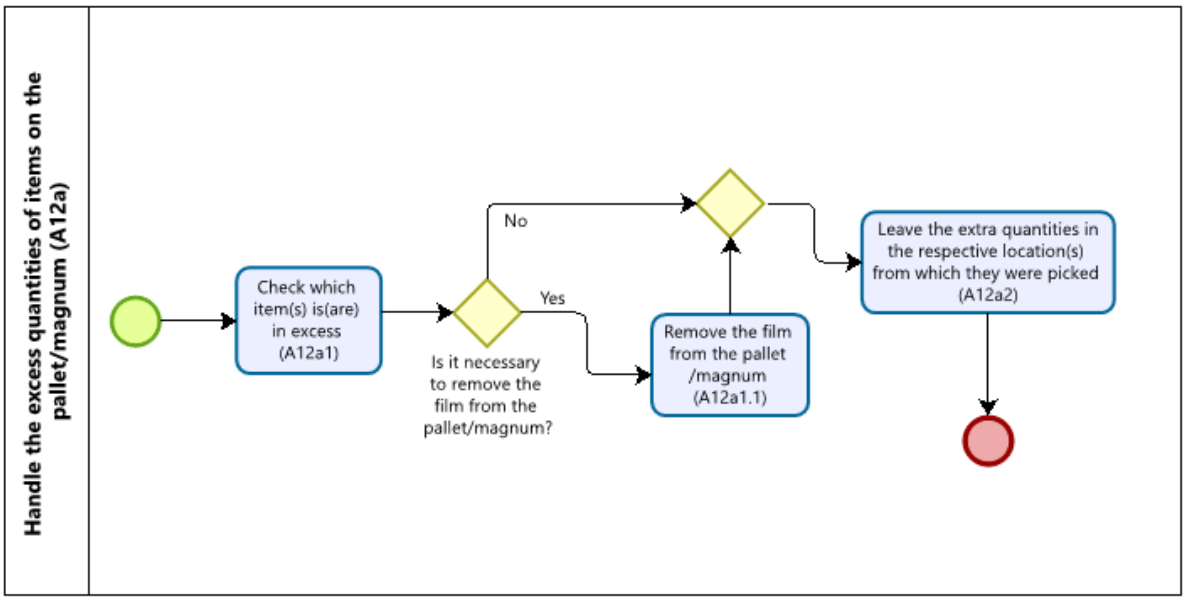

Figure 7.4 Sub-process A12a: handle the excess quantities of items on the pallet/magnum

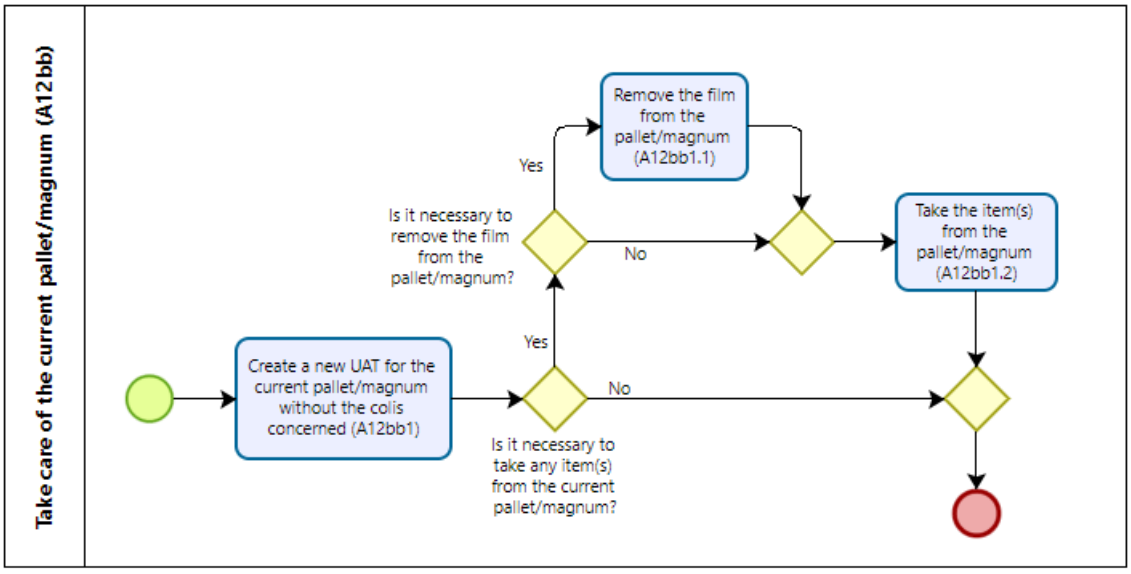

Figure 7.5 Sub-process A12bb: take care of the current pallet/magnum

Annexe I

The following figures represent the fishbone diagrams for the main problems identified, with the respective causes and sub-causes.

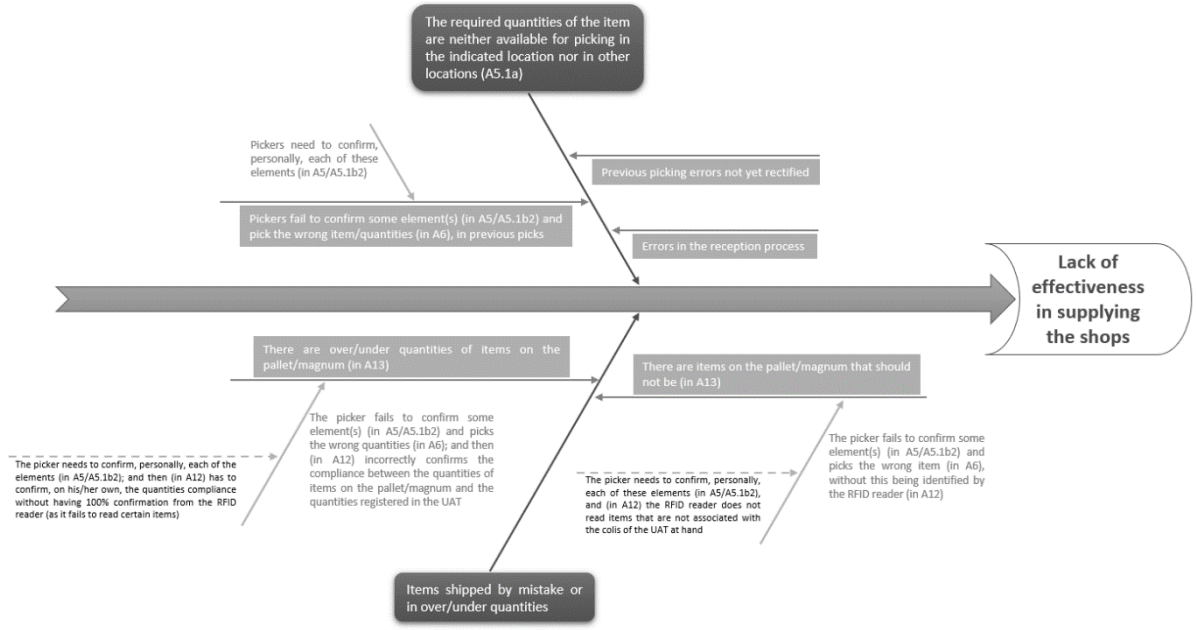

Figure 7.6 Fishbone diagram for the problem: lack of effectiveness in supplying the shops

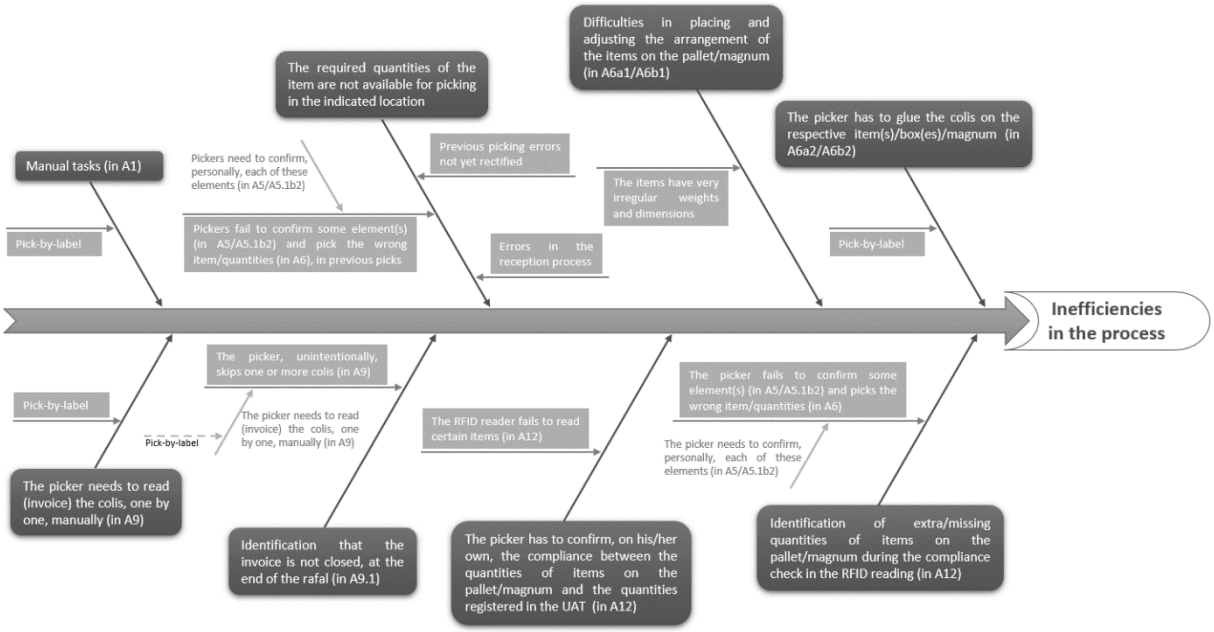

Figure 7.7 Fishbone diagram for the problem: inefficiencies in the process

Annexe J

The following figure shows the material required for the proposed solution.

Figure 7.8 Material required for the proposed solution

Annexe K

The following table shows, for each team of the logistics centre, the percentage of items (sent to shops) whose RFID was confirmed.

Table 7.8 Percentage of items (sent to shops) whose RFID was confirmed, by team

Team	% of RFID confirmed*
Water	98.53
Adventure	98.64
Hiking	98.22
Fitness	98.80
Colrun	98.09
Quay	83.33
Bulky	84.49

Teams using portable RFID reading plates

Teams using the static RFID reader

* These figures relate to the first eight months of 2022.

Annexe L

The following figure is an illustrative example of the graphical display of information on the tablet; providing information about the location of the next item to be picked, the item code, the contenant, the quantities to be picked, the quantities of the item already scanned on the RFID plate, and the total number of items already picked/to be picked.

Figure 7.9 Illustrative example of the graphical display of information on the tablet

Annexe M

The following figures provide details of the sub-processes present in the process mapping “to be”.

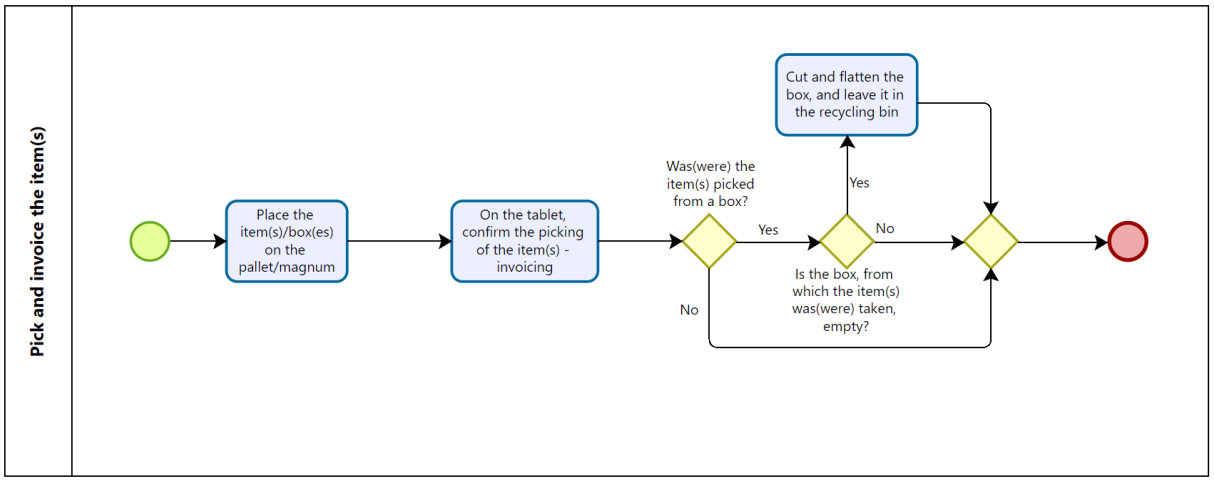

Figure 7.10 Sub-process: pick and invoice the item(s)

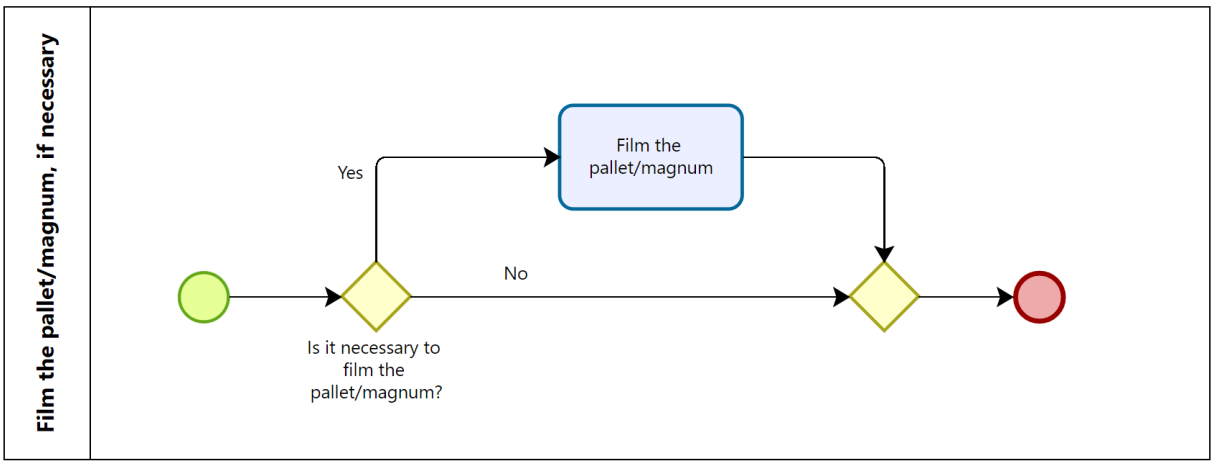

Figure 7.11 Sub-process: film the pallet/magnum, if necessary

Annexe N

The following tables contain the records made by the pickers in the spreadsheet, developed and shared by the author, for the indicators measured by them.

Table 7.9 PI1 - Collected data

PI1 - No. of times an item is acknowledged as undeliverable		
Registration/Counting	**Reason**	**Date**
X	Reception error	01/04/2022
X	Picking error	02/04/2022
X	Picking error	02/04/2022
X	Picking error	02/04/2022
X	Picking error	03/04/2022
X	Picking error	03/04/2022
X	Picking error	04/04/2022
X	Picking error	05/04/2022
X	Picking error	05/04/2022
X	Picking error	06/04/2022
X	Picking error	06/04/2022
X	Picking error	06/04/2022
X	Picking error	06/04/2022
X	Picking error	06/04/2022
X	Picking error	07/04/2022
X	Picking error	07/04/2022
X	Picking error	07/04/2022
X	Picking error	08/04/2022
X	Picking error	08/04/2022
X	Picking error	08/04/2022
X	Picking error	09/04/2022
X	Picking error	10/04/2022
X	Picking error	10/04/2022
X	Picking error	11/04/2022
X	Picking error	11/04/2022
X	Picking error	12/04/2022
X	Picking error	12/04/2022
X	Picking error	13/04/2022
X	Picking error	13/04/2022
X	Picking error	13/04/2022
X	Picking error	14/04/2022
X	Reception error	14/04/2022
X	Picking error	15/04/2022
X	Picking error	15/04/2022
X	Picking error	15/04/2022
X	Picking error	15/04/2022
X	Picking error	16/04/2022
X	Picking error	17/04/2022
X	Picking error	19/04/2022

Registration/Counting	Reason	Date
X	Picking error	20/04/2022
X	Picking error	20/04/2022
X	Picking error	20/04/2022
X	Picking error	20/04/2022
X	Picking error	20/04/2022
X	Picking error	21/04/2022
X	Picking error	22/04/2022
X	Picking error	24/04/2022
X	Picking error	25/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Picking error	28/04/2022
X	Picking error	28/04/2022
X	Picking error	29/04/2022
X	Picking error	29/04/2022
X	Picking error	30/04/2022
Total		
58		

Table 7.10 PI3 & PI4 - Collected data

PI3 - Time spent on activity A1 & PI4 - Paper consumption			
Registration/Measurement (hh:mm:ss)	**No. of rafal lists**	**No. of colis**	**Date**
01:00:00	36	1374	24/04/2022
00:50:00	30	1284	25/04/2022
00:50:00	31	1352	26/04/2022
01:00:00	34	1232	27/04/2022
01:00:00	32	626	28/04/2022
00:50:00	29	705	29/04/2022
00:50:00	27	747	30/04/2022
Total			
06:20:00	**219**	**7320**	

Table 7.11 PI5 - Collected data

PI5 - No. of times the required quantities of the item are not available for picking in the indicated location		
Registration/Counting	**Reason**	**Date**
X	Reception error	01/04/2022
X	Picking error	01/04/2022
X	Picking error	02/04/2022
X	Picking error	02/04/2022
X	Picking error	02/04/2022
X	Picking error	03/04/2022
X	Picking error	03/04/2022
X	Picking error	03/04/2022
X	Picking error	04/04/2022
X	Picking error	04/04/2022
X	Picking error	04/04/2022
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X	Picking error	06/04/2022
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X	Picking error	08/04/2022
X	Picking error	08/04/2022
X	Picking error	08/04/2022
X	Picking error	08/04/2022
X	Picking error	09/04/2022
X	Picking error	09/04/2022
X	Picking error	09/04/2022
X	Picking error	10/04/2022
X	Picking error	10/04/2022
X	Picking error	11/04/2022
X	Picking error	11/04/2022
X	Picking error	12/04/2022
X	Picking error	12/04/2022
X	Picking error	12/04/2022
X	Picking error	13/04/2022
X	Picking error	13/04/2022
X	Picking error	13/04/2022
X	Picking error	14/04/2022
X	Reception error	14/04/2022
X	Picking error	14/04/2022

Registration/Counting	Reason	Date
X	Picking error	15/04/2022
X	Picking error	15/04/2022
X	Picking error	15/04/2022
X	Picking error	15/04/2022
X	Picking error	16/04/2022
X	Picking error	16/04/2022
X	Picking error	17/04/2022
X	Picking error	18/04/2022
X	Picking error	19/04/2022
X	Picking error	20/04/2022
X	Picking error	20/04/2022
X	Picking error	20/04/2022
X	Picking error	20/04/2022
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X	Picking error	21/04/2022
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X	Picking error	22/04/2022
X	Picking error	22/04/2022
X	Picking error	24/04/2022
X	Picking error	25/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Picking error	26/04/2022
X	Reception error	26/04/2022
X	Picking error	28/04/2022
X	Picking error	28/04/2022
X	Picking error	28/04/2022
X	Picking error	29/04/2022
X	Picking error	29/04/2022
X	Picking error	30/04/2022
Total		
76		

Table 7.12 PI10 - Collected data

PI10 - No. of times the invoice is not closed at the end of the rafal	
Registration/Counting	**Date**
X	01/04/2022
X	01/04/2022
X	04/04/2022
X	06/04/2022
X	09/04/2022
X	13/04/2022
X	19/04/2022
X	24/04/2022
X	26/04/2022
X	26/04/2022
X	26/04/2022
X	30/04/2022
Total	
12	

Table 7.13 PI13 - Collected data

PI13 - No. of times that an error in quantities is detected during the compliance check in the RFID reading	
Registration/Counting	**Date**
X	05/04/2022
X	07/04/2022
X	09/04/2022
X	13/04/2022
X	27/04/2022
Total	
5	

Annexe O

This annexe presents the results of the answers to the questionnaire made to the company's employees regarding the impact (in terms of picking errors) felt on other teams in the logistics centre, with the introduction of the picking method with tablet + portable RFID reading plate.

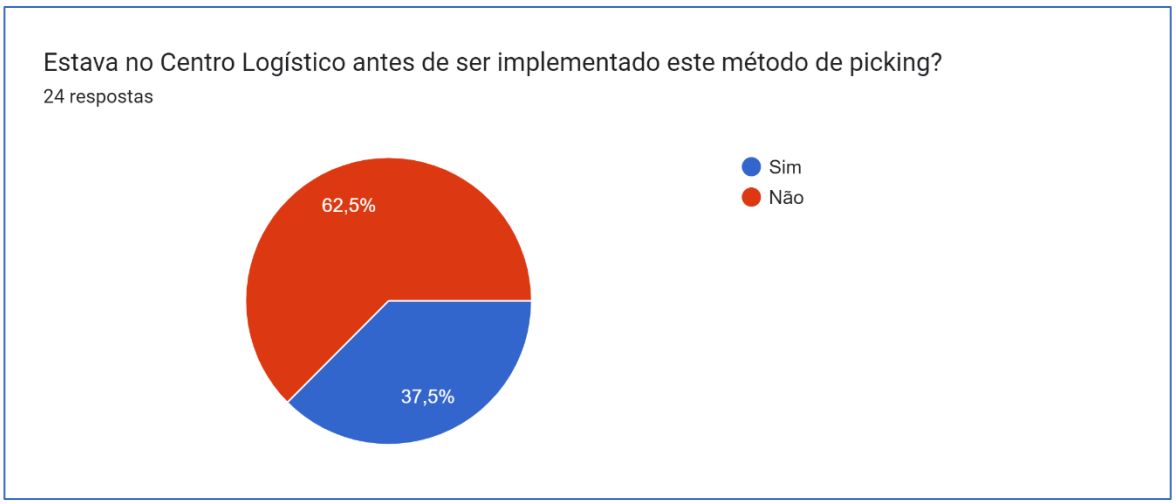

Figure 7.12 Results of the answers to the question "Were you in the Logistics Centre before this picking method was implemented?"

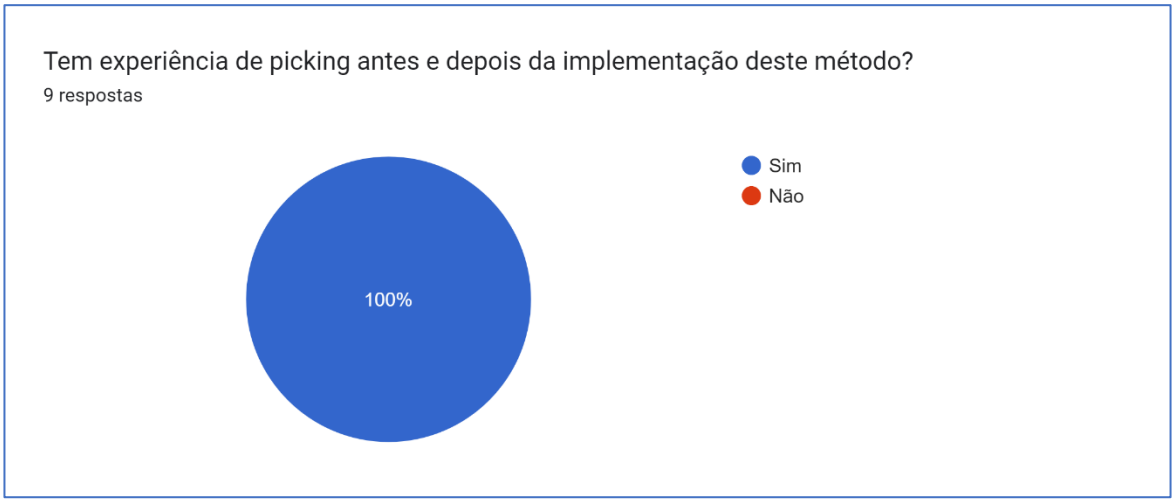

Figure 7.13 Results of the answers to the question "Do you have picking experience before and after the implementation of this method?"

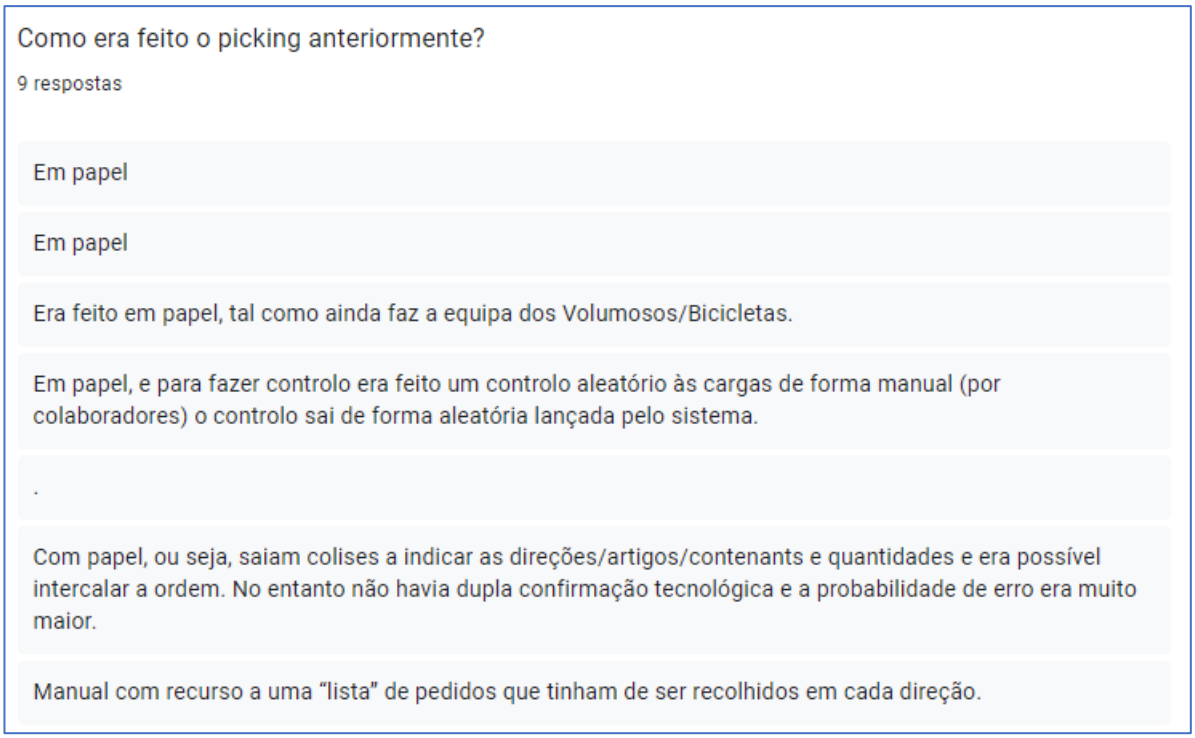

Figure 7.14 Results of the answers to the question "How was picking done before?"

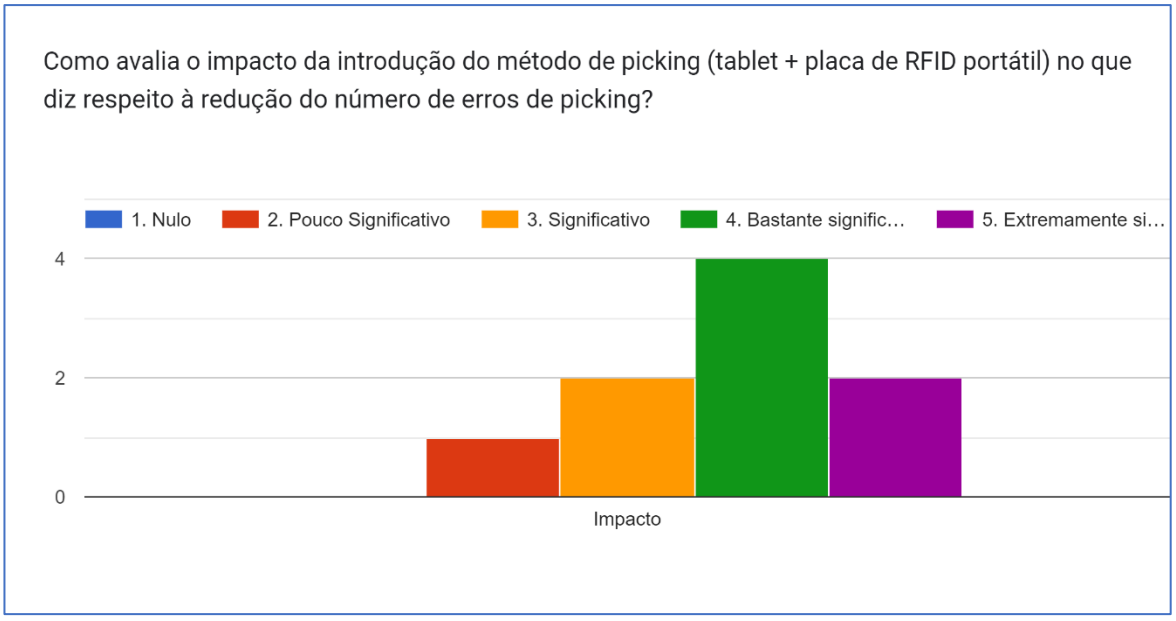

Figure 7.15 Results of the answers to the question "How do you evaluate the impact of the introduction of the picking method (tablet + portable RFID plate) with regard to the reduction of the number of picking errors?"

Annexe P

The following table presents the data that was collected for indicator PI9 – time spent on activity A9 (read (invoice) the barcodes of all the colis on the pallet/magnum).

Table 7.14 PI9 - Collected data

PI9 - Time spent on activity A9				
UAT	**Pallet/Magnum**	**No. of colis**	**Time (hh:mm:ss)**	**Date**
009000770343431	Pallet	3	00:00:07	26/04/2022
009000770343432	Magnum	24	00:00:33	26/04/2022
009000770343433	Pallet	6	00:00:14	26/04/2022
009000770343434	Magnum	27	00:00:42	26/04/2022
009000770343435	Magnum	17	00:00:27	26/04/2022
009000770343436	Pallet	3	00:00:06	26/04/2022
009000770343438	Pallet	25	00:00:50	26/04/2022
009000770343447	Magnum	15	00:00:23	26/04/2022
009000770343463	Magnum	17	00:00:25	26/04/2022
009000770343470	Magnum	25	00:00:40	26/04/2022
009000770343443	Pallet	15	00:00:33	26/04/2022
009000770343451	Magnum	23	00:00:30	26/04/2022
009000770343449	Pallet	24	00:01:00	26/04/2022
009000770343466	Pallet	14	00:00:30	26/04/2022
009000770343467	Pallet	15	00:00:37	26/04/2022
009000770343469	Magnum	25	00:00:36	26/04/2022
009000770343471	Pallet	18	00:00:38	26/04/2022
009000770343472	Magnum	4	00:00:06	26/04/2022
009000770343474	Pallet	29	00:01:10	26/04/2022
009000770343475	Magnum	24	00:00:32	26/04/2022
009000770343478	Pallet	13	00:00:26	26/04/2022
009000770343480	Pallet	20	00:00:48	26/04/2022
009000770343479	Magnum	43	00:00:57	26/04/2022
009000770343486	Magnum	42	00:01:04	26/04/2022
009000770343487	Pallet	23	00:00:52	26/04/2022
009000770343490	Pallet	10	00:00:25	26/04/2022
009000770343491	Pallet	26	00:00:52	26/04/2022
009000770343492	Pallet	14	00:00:27	26/04/2022
009000770343494	Pallet	9	00:00:20	26/04/2022
009000770343477	Pallet	3	00:00:06	26/04/2022
009000770343500	Magnum	11	00:00:16	26/04/2022
009000770343501	Pallet	8	00:00:20	26/04/2022
009000770344015	Pallet	14	00:00:28	02/05/2022
009000770344016	Pallet	12	00:00:30	02/05/2022
009000770344017	Pallet	14	00:00:28	02/05/2022
009000770344018	Magnum	35	00:00:46	02/05/2022
009000770344019	Pallet	8	00:00:16	02/05/2022
009000770344021	Pallet	17	00:00:37	02/05/2022
009000770344029	Pallet	17	00:00:34	02/05/2022

UAT	Pallet/Magnum	No. of colis	Time (hh:mm:ss)	Date
009000770344032	Pallet	20	00:00:50	02/05/2022
009000770344034	Magnum	47	00:01:14	02/05/2022
009000770344036	Pallet	18	00:00:38	02/05/2022
009000770344037	Pallet	19	00:00:37	02/05/2022
009000770344039	Magnum	48	00:01:17	02/05/2022
009000770344040	Magnum	31	00:00:50	02/05/2022
009000770344044	Pallet	30	00:00:58	02/05/2022
009000770344045	Magnum	38	00:00:50	02/05/2022
009000770344048	Pallet	33	00:01:06	02/05/2022
009000770344049	Pallet	19	00:00:47	02/05/2022
009000770344050	Magnum	23	00:00:37	02/05/2022
009000770344412	Pallet	20	00:00:41	06/05/2022
009000770344415	Pallet	7	00:00:15	06/05/2022
009000770344421	Magnum	28	00:00:39	06/05/2022
009000770344423	Pallet	9	00:00:19	06/05/2022
009000770344426	Magnum	10	00:00:16	06/05/2022
009000770344427	Magnum	20	00:00:26	06/05/2022
009000770344429	Pallet	10	00:00:20	06/05/2022
009000770344430	Pallet	18	00:00:38	06/05/2022
009000770344432	Pallet	4	00:00:10	06/05/2022
009000770344434	Pallet	17	00:00:41	06/05/2022
009000770344435	Magnum	18	00:00:26	06/05/2022
009000770344439	Pallet	6	00:00:13	06/05/2022
009000770344440	Pallet	18	00:00:45	06/05/2022
009000770344443	Pallet	9	00:00:19	06/05/2022
009000770344444	Pallet	15	00:00:34	06/05/2022
009000770344446	Magnum	20	00:00:27	06/05/2022
009000770344449	Pallet	20	00:00:39	06/05/2022
009000770344450	Magnum	26	00:00:36	06/05/2022
009000770344451	Pallet	22	00:00:43	06/05/2022
009000770344453	Pallet	5	00:00:12	06/05/2022
009000770344454	Pallet	12	00:00:27	06/05/2022
009000770344457	Pallet	18	00:00:39	06/05/2022
009000770344946	Pallet	12	00:00:30	11/05/2022
009000770344911	Magnum	43	00:01:02	11/05/2022
009000770344912	Pallet	13	00:00:26	11/05/2022
009000770344893	Pallet	14	00:00:34	11/05/2022
009000770344915	Pallet	9	00:00:19	11/05/2022
009000770344892	Pallet	15	00:00:35	11/05/2022
009000770344917	Magnum	28	00:00:46	11/05/2022
009000770344920	Pallet	2	00:00:05	11/05/2022
009000770344921	Magnum	54	00:01:16	11/05/2022
009000770344888	Pallet	14	00:00:30	11/05/2022
009000770344923	Pallet	21	00:00:46	11/05/2022
009000770344926	Pallet	20	00:00:44	11/05/2022
009000770344928	Pallet	9	00:00:20	11/05/2022

UAT	Pallet/Magnum	No. of colis	Time (hh:mm:ss)	Date
009000770344933	Magnum	27	00:00:45	11/05/2022
009000770344934	Magnum	43	00:01:04	11/05/2022
009000770344936	Magnum	43	00:01:02	11/05/2022
009000770344944	Pallet	19	00:00:41	11/05/2022
009000770344961	Pallet	18	00:00:35	11/05/2022
009000770344963	Pallet	18	00:00:40	11/05/2022
009000770344962	Magnum	26	00:00:39	11/05/2022
009000770344966	Pallet	14	00:00:29	11/05/2022
009000770344967	Pallet	27	00:00:53	11/05/2022
009000770344969	Magnum	48	00:01:06	11/05/2022
009000770344972	Pallet	13	00:00:26	11/05/2022
009000770344979	Pallet	32	00:01:08	11/05/2022
009000770344980	Pallet	24	00:00:46	11/05/2022
009000770344983	Pallet	3	00:00:07	11/05/2022
009000770344985	Pallet	26	00:00:52	11/05/2022
009000770344989	Pallet	9	00:00:21	11/05/2022
009000770344992	Pallet	25	00:00:55	11/05/2022
009000770344994	Magnum	68	00:01:41	11/05/2022
009000770345031	Magnum	28	00:00:40	12/05/2022
009000770345034	Pallet	23	00:00:51	12/05/2022
009000770345035	Pallet	15	00:00:32	12/05/2022
009000770345037	Pallet	20	00:00:42	12/05/2022
009000770345039	Pallet	19	00:00:37	12/05/2022
009000770345040	Pallet	9	00:00:22	12/05/2022
009000770345043	Magnum	28	00:00:44	12/05/2022
009000770345047	Pallet	5	00:00:10	12/05/2022
009000770345059	Magnum	27	00:00:39	12/05/2022
009000770345061	Pallet	6	00:00:12	12/05/2022
009000770345063	Pallet	11	00:00:25	12/05/2022
009000770345064	Magnum	66	00:01:31	12/05/2022
009000770345066	Pallet	20	00:00:49	12/05/2022
009000770345067	Pallet	18	00:00:35	12/05/2022
009000770345068	Pallet	16	00:00:32	12/05/2022
009000770345071	Magnum	46	00:01:11	12/05/2022
009000770345074	Pallet	20	00:00:43	12/05/2022
009000770345076	Pallet	18	00:00:35	12/05/2022
009000770345078	Magnum	50	00:01:22	12/05/2022
009000770345081	Pallet	21	00:00:48	12/05/2022
009000770345082	Pallet	22	00:00:54	12/05/2022
009000770345084	Magnum	47	00:01:13	12/05/2022
009000770345083	Pallet	9	00:00:21	12/05/2022
009000770345085	Pallet	30	00:01:03	12/05/2022
Total			**01:20:54**	

Annexe Q

The following table presents the data that was collected for indicator PI12 – time spent on activity A12 (check conformity between the RFID reading and the quantities of items on the pallet/magnum).

Table 7.15 PI12 - Collected data

PI12 – Time spent on activity A12								
UAT	**Pallet / Magnum**	**No. of items**	**No. of items read**	**No. of items not read**	**Count of different items**	**Count of different items not read**	**Time (hh:mm:ss)**	**Date**
00900077 0343431	Pallet	5	5	0	2	0	00:00:05	26/04/2022
00900077 0343432	Magnum	44	36	8	21	1	00:00:24	26/04/2022
00900077 0343433	Pallet	11	10	1	5	1	00:00:13	26/04/2022
00900077 0343434	Magnum	87	60	27	16	2	00:00:39	26/04/2022
00900077 0343435	Magnum	91	66	25	14	3	00:00:45	26/04/2022
00900077 0343436	Pallet	3	3	0	1	0	00:00:11	26/04/2022
00900077 0343438	Pallet	103	87	16	22	3	00:00:58	26/04/2022
00900077 0343447	Magnum	78	76	2	21	2	00:00:35	26/04/2022
00900077 0343463	Magnum	93	64	29	14	2	00:00:37	26/04/2022
00900077 0343470	Magnum	36	34	2	15	1	00:00:19	26/04/2022
00900077 0343443	Pallet	35	32	3	13	2	00:00:24	26/04/2022
00900077 0343451	Magnum	77	70	7	18	3	00:00:42	26/04/2022
00900077 0343449	Pallet	68	67	1	12	1	00:00:19	26/04/2022
00900077 0343466	Pallet	31	31	0	12	0	00:00:11	26/04/2022
00900077 0343467	Pallet	46	45	1	15	1	00:00:20	26/04/2022
00900077 0343469	Magnum	161	136	25	20	5	00:01:08	26/04/2022
00900077 0343471	Pallet	61	28	33	7	4	00:00:52	26/04/2022
00900077 0343472	Magnum	4	4	0	3	0	00:00:08	26/04/2022
00900077 0343474	Pallet	158	146	12	24	4	00:01:03	26/04/2022
00900077 0343475	Magnum	111	107	4	23	2	00:00:40	26/04/2022
00900077 0343478	Pallet	75	75	0	12	0	00:00:15	26/04/2022
00900077 0343480	Pallet	46	45	1	14	1	00:00:18	26/04/2022
00900077 0343479	Magnum	138	100	38	18	5	00:01:03	26/04/2022
00900077 0343486	Magnum	185	132	53	31	8	00:01:49	26/04/2022

UAT	Pallet / Magnum	No. of items	No. of items read	No. of items not read	Count of different items	Count of different items not read	Time (hh:mm:ss)	Date
00900077 0343487	Pallet	58	57	1	20	1	00:00:23	26/04/2022
00900077 0343490	Pallet	23	23	0	10	0	00:00:08	26/04/2022
00900077 0343491	Pallet	114	68	46	18	6	00:01:20	26/04/2022
00900077 0343492	Pallet	130	130	0	8	0	00:00:09	26/04/2022
00900077 0343494	Pallet	9	9	0	4	0	00:00:08	26/04/2022
00900077 0343477	Pallet	3	3	0	2	0	00:00:10	26/04/2022
00900077 0343500	Magnum	116	68	48	4	3	00:00:44	26/04/2022
00900077 0343501	Pallet	8	6	2	5	2	00:00:18	26/04/2022
00900077 0344015	Pallet	27	27	0	11	0	00:00:07	02/05/2022
00900077 0344016	Pallet	29	28	1	10	1	00:00:15	02/05/2022
00900077 0344017	Pallet	89	78	11	13	4	00:00:53	02/05/2022
00900077 0344018	Magnum	178	136	42	26	8	00:01:38	02/05/2022
00900077 0344019	Pallet	8	8	0	1	0	00:00:05	02/05/2022
00900077 0344021	Pallet	36	36	0	14	0	00:00:08	02/05/2022
00900077 0344029	Pallet	45	45	0	5	0	00:00:09	02/05/2022
00900077 0344032	Pallet	34	32	2	13	2	00:00:30	02/05/2022
00900077 0344034	Magnum	173	131	42	24	7	00:01:24	02/05/2022
00900077 0344036	Pallet	82	70	12	16	3	00:00:45	02/05/2022
00900077 0344037	Pallet	71	70	1	8	1	00:00:15	02/05/2022
00900077 0344039	Magnum	499	291	208	14	8	00:01:52	02/05/2022
00900077 0344040	Magnum	175	154	21	23	2	00:00:42	02/05/2022
00900077 0344044	Pallet	83	81	2	21	1	00:00:25	02/05/2022
00900077 0344045	Magnum	259	205	54	24	5	00:01:17	02/05/2022
00900077 0344048	Pallet	70	69	1	19	1	00:00:23	02/05/2022
00900077 0344049	Pallet	68	39	29	13	2	00:00:37	02/05/2022
00900077 0344050	Magnum	135	120	15	15	3	00:00:46	02/05/2022
00900077 0344412	Pallet	98	90	8	14	3	00:00:40	06/05/2022
00900077 0344415	Pallet	82	66	16	7	3	00:00:36	06/05/2022
00900077 0344421	Magnum	143	117	26	21	6	00:01:24	06/05/2022

UAT	Pallet / Magnum	No. of items	No. of items read	No. of items not read	Count of different items	Count of different items not read	Time (hh:mm:ss)	Date
00900077 0344423	Pallet	36	36	0	8	0	00:00:10	06/05/2022
00900077 0344426	Magnum	14	14	0	7	0	00:00:08	06/05/2022
00900077 0344427	Magnum	51	49	2	18	1	00:00:21	06/05/2022
00900077 0344429	Pallet	11	11	0	7	0	00:00:06	06/05/2022
00900077 0344430	Pallet	133	130	3	16	1	00:00:24	06/05/2022
00900077 0344432	Pallet	9	9	0	3	0	00:00:04	06/05/2022
00900077 0344434	Pallet	90	80	10	15	2	00:00:38	06/05/2022
00900077 0344435	Magnum	134	126	8	17	3	00:00:49	06/05/2022
00900077 0344439	Pallet	7	7	0	5	0	00:00:09	06/05/2022
00900077 0344440	Pallet	68	68	0	11	0	00:00:10	06/05/2022
00900077 0344443	Pallet	35	24	11	3	1	00:00:17	06/05/2022
00900077 0344444	Pallet	63	51	12	12	2	00:00:34	06/05/2022
00900077 0344446	Magnum	94	89	5	20	3	00:00:50	06/05/2022
00900077 0344449	Pallet	64	64	0	18	0	00:00:08	06/05/2022
00900077 0344450	Magnum	220	194	26	17	5	00:01:12	06/05/2022
00900077 0344451	Pallet	136	124	12	19	3	00:00:53	06/05/2022
00900077 0344453	Pallet	8	8	0	5	0	00:00:05	06/05/2022
00900077 0344454	Pallet	56	36	20	10	3	00:00:38	06/05/2022
00900077 0344457	Pallet	71	59	12	15	2	00:00:37	06/05/2022
00900077 0344946	Pallet	140	139	1	9	1	00:00:20	11/05/2022
00900077 0344911	Magnum	123	103	20	34	9	00:01:50	11/05/2022
00900077 0344912	Pallet	13	12	1	8	1	00:00:17	11/05/2022
00900077 0344893	Pallet	108	101	7	12	3	00:00:43	11/05/2022
00900077 0344915	Pallet	48	48	0	9	0	00:00:08	11/05/2022
00900077 0344892	Pallet	73	70	3	16	1	00:00:20	11/05/2022
00900077 0344917	Magnum	49	25	24	21	2	00:00:39	11/05/2022
00900077 0344920	Pallet	2	1	1	1	1	00:00:13	11/05/2022
00900077 0344921	Magnum	208	164	44	34	7	00:01:38	11/05/2022
00900077 0344888	Pallet	86	76	10	13	3	00:00:42	11/05/2022

UAT	Pallet / Magnum	No. of items	No. of items read	No. of items not read	Count of different items	Count of different items not read	Time (hh:mm:ss)	Date
00900077 0344923	Pallet	51	48	3	17	1	00:00:21	11/05/2022
00900077 0344926	Pallet	101	98	3	15	1	00:00:21	11/05/2022
00900077 0344928	Pallet	40	39	1	7	1	00:00:14	11/05/2022
00900077 0344933	Magnum	147	128	19	23	4	00:00:59	11/05/2022
00900077 0344934	Magnum	275	223	52	28	7	00:01:43	11/05/2022
00900077 0344936	Magnum	232	197	35	28	9	00:01:58	11/05/2022
00900077 0344944	Pallet	80	76	4	15	3	00:00:43	11/05/2022
00900077 0344961	Pallet	125	122	3	17	2	00:00:38	11/05/2022
00900077 0344963	Pallet	72	72	0	11	0	00:00:06	11/05/2022
00900077 0344962	Magnum	186	151	35	19	4	00:01:01	11/05/2022
00900077 0344966	Pallet	64	64	0	13	0	00:00:05	11/05/2022
00900077 0344967	Pallet	144	137	7	23	2	00:00:40	11/05/2022
00900077 0344969	Magnum	336	214	122	12	6	00:01:23	11/05/2022
00900077 0344972	Pallet	40	40	0	12	0	00:00:07	11/05/2022
00900077 0344979	Pallet	113	113	0	19	0	00:00:06	11/05/2022
00900077 0344980	Pallet	112	107	5	21	2	00:00:35	11/05/2022
00900077 0344983	Pallet	13	12	1	2	1	00:00:13	11/05/2022
00900077 0344985	Pallet	112	112	0	11	0	00:00:10	11/05/2022
00900077 0344989	Pallet	16	10	6	3	1	00:00:14	11/05/2022
00900077 0344992	Pallet	74	74	0	18	0	00:00:11	11/05/2022
00900077 0344994	Magnum	461	324	137	33	11	00:02:12	11/05/2022
00900077 0345031	Magnum	165	127	38	22	6	00:01:25	12/05/2022
00900077 0345034	Pallet	82	79	3	14	1	00:00:20	12/05/2022
00900077 0345035	Pallet	37	37	0	15	0	00:00:11	12/05/2022
00900077 0345037	Pallet	84	77	7	18	2	00:00:32	12/05/2022
00900077 0345039	Pallet	86	77	9	6	1	00:00:18	12/05/2022
00900077 0345040	Pallet	11	11	0	8	0	00:00:07	12/05/2022
00900077 0345043	Magnum	134	133	1	17	1	00:00:26	12/05/2022
00900077 0345047	Pallet	16	14	2	4	1	00:00:16	12/05/2022

UAT	Pallet / Magnum	No. of items	No. of items read	No. of items not read	Count of different items	Count of different items not read	Time (hh:mm:ss)	Date
00900077 0345059	Magnum	105	67	38	19	6	00:01:15	12/05/2022
00900077 0345061	Pallet	13	13	0	6	0	00:00:06	12/05/2022
00900077 0345063	Pallet	31	31	0	11	0	00:00:09	12/05/2022
00900077 0345064	Magnum	338	262	76	42	10	00:02:09	12/05/2022
00900077 0345066	Pallet	35	35	0	10	0	00:00:07	12/05/2022
00900077 0345067	Pallet	46	43	3	10	1	00:00:17	12/05/2022
00900077 0345068	Pallet	32	28	4	10	3	00:00:30	12/05/2022
00900077 0345071	Magnum	188	152	36	28	3	00:01:00	12/05/2022
00900077 0345074	Pallet	107	101	6	18	1	00:00:23	12/05/2022
00900077 0345076	Pallet	67	66	1	13	1	00:00:17	12/05/2022
00900077 0345078	Magnum	291	229	62	34	10	00:02:06	12/05/2022
00900077 0345081	Pallet	58	57	1	7	1	00:00:14	12/05/2022
00900077 0345082	Pallet	97	91	6	18	4	00:00:58	12/05/2022
00900077 0345084	Magnum	289	262	27	30	6	00:01:30	12/05/2022
00900077 0345083	Pallet	68	68	0	8	0	00:00:08	12/05/2022
00900077 0345085	Pallet	109	96	13	19	2	00:00:38	12/05/2022
Total							**01:16:34**	

Annexe R

The following tables present the results of the multiple linear regression analysis with PI12 as the dependent variable and four independent variables (No. of items, no. of items not read, count of different items and count of different items not read). It should be noted that, in order to facilitate the interpretation of the data, for this analysis the unit used for time was the second.

Table 7.16 Regression analysis with 4 independent variables - Regression statistics output

Regression Statistics	
Multiple R	0.992912082
R Square	0.985874403
Adjusted R Square	0.985411269
Standard Error	3.788170921
Observations	127

Table 7.17 Regression analysis with 4 independent variables - ANOVA output

ANOVA					
	df	**SS**	**MS**	**F**	**Significance F**
Regression	4	122189.4598	30547.36496	2128.700791	8.6443E-112
Residual	122	1750.72915	14.35023893		
Total	126	123940.189			

Table 7.18 Regression analysis with 4 independent variables - Coefficients output

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	3.090943181	0.734042091	4.210852782	4.89468E-05	1.637833547	4.544052816
No. of items	0.029929893	0.010445884	2.865233297	0.004908557	0.009251224	0.050608563
No. of items not read	0.029660305	0.028990673	1.023098193	0.308285831	(0.027729627)	0.087050237
Count of different items	0.460091016	0.076916146	5.981722204	2.26703E-08	0.307827823	0.612354208
Count of different items not read	10.04592872	0.272379102	36.88215665	5.214E-68	9.506727082	10.58513036

Annexe S

The tables below show the results of the multiple linear regression analysis with PI12 as the dependent variable and three independent variables (No. of items, count of different items, and count of different items not read). It should be noted that, in order to facilitate the interpretation of the data, for this analysis the unit used for time was the second.

Table 7.19 Regression analysis with 3 independent variables - Regression statistics output

Regression Statistics	
Multiple R	0.992851051
R Square	0.985753209
Adjusted R Square	0.985405726
Standard Error	3.78889045
Observations	127

Table 7.20 Regression analysis with 3 independent variables - ANOVA output

ANOVA					
	df	**SS**	**MS**	**F**	**Significance F**
Regression	3	122174.439	40724.813	2836.841044	2.5122E-113
Residual	123	1765.749974	14.35569084		
Total	126	123940.189			

Table 7.21 Regression analysis with 3 independent variables - Coefficients output

	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	3.128774464	0.733249389	4.266999071	3.91659E-05	1.677352257	4.580196671
No. of items	0.037989843	0.006860885	5.537163478	1.77321E-07	0.024409142	0.051570545
Count of different items	0.415273715	0.063235216	6.567127322	1.29303E-09	0.290103482	0.540443948
Count of different items not read	10.17231365	0.242801803	41.89554419	1.15902E-74	9.691702365	10.65292493

Annexe T

The following table shows the data collected from the company's databases, about the pallets/magnums for which measurements were not made on the days under analysis, necessary to extrapolate the values of PI12. As mentioned earlier, data for 14 and 15 May 2022 has also been added in order to cover all seven different days of the week in this analysis. Therefore, the days for which data were collected were, in April: the 26th (Tuesday), in May: the 2nd (Monday), the 6th (Friday), the 11th (Wednesday), the 12th (Thursday), the 14th (Saturday) and the 15th (Sunday). The values in the column "estimated PI12 (in seconds)" were obtained using the equation resulting from the multiple linear regression analysis with three independent variables:

(2)

$$Time\ (in\ seconds) = 0.0379898432127889 \times no.\ of\ items + 0.415273714962573 \times count\ of\ different\ items + 10.1723136460258 \times count\ of\ different\ items\ not\ read + 3.12877446378763$$

Table 7.22 PI12 - Data collected to estimate PI12

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
26/04/2022	009000770343440	8	4	0	5.09
26/04/2022	009000770343441	1	1	0	3.58
26/04/2022	009000770343442	1	1	0	3.58
26/04/2022	009000770343444	3	3	0	4.49
26/04/2022	009000770343445	102	8	1	20.50
26/04/2022	009000770343446	7	4	0	5.06
26/04/2022	009000770343452	2	1	0	3.62
26/04/2022	009000770343453	10	3	1	14.93
26/04/2022	009000770343454	1	1	0	3.58
26/04/2022	009000770343455	65	13	1	21.17
26/04/2022	009000770343457	8	2	0	4.26
26/04/2022	009000770343458	82	19	2	34.48
26/04/2022	009000770343459	133	20	0	16.49
26/04/2022	009000770343460	10	2	0	4.34
26/04/2022	009000770343461	10	5	1	15.76
26/04/2022	009000770343462	5	5	0	5.40
26/04/2022	009000770343464	3	3	0	4.49
26/04/2022	009000770343465	23	14	1	19.99
26/04/2022	009000770343468	1	1	0	3.58
26/04/2022	009000770343473	2	1	0	3.62
26/04/2022	009000770343476	12	7	0	6.49
26/04/2022	009000770343481	50	9	2	29.11
26/04/2022	009000770343482	12	7	0	6.49
26/04/2022	009000770343483	1	1	0	3.58

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
26/04/2022	009000770343484	19	6	1	16.51
26/04/2022	009000770343485	4	3	0	4.53
26/04/2022	009000770343488	2	2	0	4.04
26/04/2022	009000770343489	8	6	0	5.92
26/04/2022	009000770343493	2	1	0	3.62
26/04/2022	009000770343495	5	2	0	4.15
26/04/2022	009000770343496	11	6	0	6.04
26/04/2022	009000770343497	1	1	0	3.58
26/04/2022	009000770343498	2	2	0	4.04
26/04/2022	009000770343499	24	6	2	26.88
26/04/2022	009000770343502	13	7	0	6.53
26/04/2022	009000770343503	4	2	0	4.11
26/04/2022	009000770343504	13	3	0	4.87
26/04/2022	009000770343505	8	3	0	4.68
26/04/2022	009000770343506	6	4	0	5.02
26/04/2022	009000770343507	2	2	0	4.04
26/04/2022	009000770343508	4	3	0	4.53
26/04/2022	009000770343509	8	8	0	6.75
26/04/2022	009000770343510	92	24	3	47.11
26/04/2022	009000770343511	218	22	6	81.58
26/04/2022	009000770343512	327	20	8	105.24
26/04/2022	009000770343513	62	13	2	31.23
26/04/2022	009000770343514	31	9	0	8.04
26/04/2022	009000770343515	8	4	0	5.09
26/04/2022	009000770343516	13	8	0	6.94
26/04/2022	009000770343517	62	15	2	32.06
26/04/2022	009000770343518	26	5	0	6.19
26/04/2022	009000770343519	69	16	0	12.39
26/04/2022	009000770343520	6	5	0	5.43
26/04/2022	009000770343521	2	1	0	3.62
26/04/2022	009000770343522	97	4	1	18.65
26/04/2022	009000770343523	177	16	4	57.19
26/04/2022	009000770343524	113	4	0	9.08
02/05/2022	009000560055513	1	1	0	3.58
02/05/2022	009000770343977	18	5	1	16.06
02/05/2022	009000770343978	23	7	1	17.08
02/05/2022	009000770343979	14	6	0	6.15
02/05/2022	009000770343980	263	17	4	60.87
02/05/2022	009000770343981	337	19	3	54.34
02/05/2022	009000770343982	21	7	1	17.01
02/05/2022	009000770343983	27	9	1	18.06
02/05/2022	009000770343984	1	1	0	3.58
02/05/2022	009000770343985	24	4	1	15.87
02/05/2022	009000770343986	26	8	1	17.61

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
02/05/2022	009000770343987	191	24	4	61.04
02/05/2022	009000770343988	2	1	0	3.62
02/05/2022	009000770343989	295	21	4	63.75
02/05/2022	009000770343990	36	11	2	29.41
02/05/2022	009000770343991	6	3	0	4.60
02/05/2022	009000770343992	5	5	0	5.40
02/05/2022	009000770343993	66	13	2	31.38
02/05/2022	009000770343994	90	17	0	13.61
02/05/2022	009000770343995	7	5	0	5.47
02/05/2022	009000770343996	98	9	5	61.45
02/05/2022	009000770343997	13	8	1	17.12
02/05/2022	009000770343998	12	4	0	5.25
02/05/2022	009000770343999	22	14	2	30.12
02/05/2022	009000770344000	12	4	0	5.25
02/05/2022	009000770344001	45	16	0	11.48
02/05/2022	009000770344002	4	2	0	4.11
02/05/2022	009000770344003	42	10	0	8.88
02/05/2022	009000770344004	66	21	3	44.87
02/05/2022	009000770344005	18	10	0	7.97
02/05/2022	009000770344006	12	7	0	6.49
02/05/2022	009000770344007	39	6	0	7.10
02/05/2022	009000770344008	2	2	0	4.04
02/05/2022	009000770344009	6	1	0	3.77
02/05/2022	009000770344010	266	17	7	91.50
02/05/2022	009000770344011	7	4	0	5.06
02/05/2022	009000770344012	7	6	1	16.06
02/05/2022	009000770344013	109	13	2	33.01
02/05/2022	009000770344014	12	4	0	5.25
02/05/2022	009000770344020	7	4	1	15.23
02/05/2022	009000770344022	9	7	0	6.38
02/05/2022	009000770344023	5	4	0	4.98
02/05/2022	009000770344024	3	3	0	4.49
02/05/2022	009000770344025	151	13	3	44.78
02/05/2022	009000770344026	3	2	0	4.07
02/05/2022	009000770344027	3	2	0	4.07
02/05/2022	009000770344028	2	2	0	4.04
02/05/2022	009000770344030	1	1	0	3.58
02/05/2022	009000770344031	2	2	0	4.04
02/05/2022	009000770344033	5	3	0	4.56
02/05/2022	009000770344035	10	4	0	5.17
02/05/2022	009000770344038	8	5	0	5.51
02/05/2022	009000770344041	5	3	0	4.56
02/05/2022	009000770344042	3	2	0	4.07
02/05/2022	009000770344043	1	1	0	3.58

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
02/05/2022	009000770344046	5	4	0	4.98
02/05/2022	009000770344047	8	4	0	5.09
02/05/2022	009000770344051	14	7	0	6.57
02/05/2022	009000770344052	309	24	9	116.39
02/05/2022	009000770344053	107	11	0	11.76
02/05/2022	009000770344054	5	4	0	4.98
02/05/2022	009000770344055	276	17	2	41.02
02/05/2022	009000770344056	40	14	1	20.63
02/05/2022	009000770344057	4	2	0	4.11
02/05/2022	009000770344058	8	5	0	5.51
02/05/2022	009000770344059	116	26	2	38.68
02/05/2022	009000770344060	70	15	5	62.88
02/05/2022	009000770344061	55	7	0	8.13
02/05/2022	009000770344062	16	7	0	6.64
02/05/2022	009000770344063	11	9	0	7.28
02/05/2022	009000770344064	10	6	0	6.00
02/05/2022	009000770344066	2	2	0	4.04
02/05/2022	009000770344068	12	5	0	5.66
02/05/2022	009000770344069	52	14	2	31.26
02/05/2022	009000770344070	29	11	1	18.97
02/05/2022	009000770344071	6	5	0	5.43
02/05/2022	009000770344072	72	10	1	20.19
02/05/2022	009000770344073	7	5	0	5.47
02/05/2022	009000770344074	65	10	2	30.10
02/05/2022	009000770344075	147	18	0	16.19
02/05/2022	009000770344076	8	5	0	5.51
02/05/2022	009000770344077	3	3	0	4.49
02/05/2022	009000770344078	22	7	0	6.87
02/05/2022	009000770344079	5	4	0	4.98
02/05/2022	009000770344080	39	6	2	27.45
02/05/2022	009000770344081	4	2	0	4.11
02/05/2022	009000770344082	4	2	0	4.11
02/05/2022	009000770344083	13	7	1	16.70
02/05/2022	009000770344084	57	13	1	20.87
02/05/2022	009000770344085	207	29	7	94.24
02/05/2022	009000770344086	73	5	1	18.15
02/05/2022	009000770344087	2	1	0	3.62
02/05/2022	009000770344088	24	6	0	6.53
02/05/2022	009000770344089	2	2	0	4.04
06/05/2022	009000040893131	1	1	0	3.58
06/05/2022	009000770344413	5	3	1	14.74
06/05/2022	009000770344414	10	8	1	17.00
06/05/2022	009000770344416	1	1	0	3.58
06/05/2022	009000770344417	1	1	0	3.58

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
06/05/2022	009000770344418	7	5	0	5.47
06/05/2022	009000770344419	9	6	0	5.96
06/05/2022	009000770344420	6	4	0	5.02
06/05/2022	009000770344422	7	7	0	6.30
06/05/2022	009000770344424	1	1	0	3.58
06/05/2022	009000770344425	6	6	0	5.85
06/05/2022	009000770344428	8	4	1	15.27
06/05/2022	009000770344431	4	3	0	4.53
06/05/2022	009000770344433	35	19	2	32.69
06/05/2022	009000770344436	7	5	0	5.47
06/05/2022	009000770344437	1	1	0	3.58
06/05/2022	009000770344438	5	4	0	4.98
06/05/2022	009000770344441	4	2	0	4.11
06/05/2022	009000770344442	9	6	0	5.96
06/05/2022	009000770344445	1	1	0	3.58
06/05/2022	009000770344447	8	5	0	5.51
06/05/2022	009000770344448	4	3	0	4.53
06/05/2022	009000770344452	6	4	0	5.02
06/05/2022	009000770344455	5	4	0	4.98
06/05/2022	009000770344456	3	3	0	4.49
06/05/2022	009000770344458	10	9	0	7.25
06/05/2022	009000770344459	177	22	1	29.16
06/05/2022	009000770344460	46	13	1	20.45
06/05/2022	009000770344461	8	5	0	5.51
06/05/2022	009000770344462	104	9	1	20.99
06/05/2022	009000770344463	19	6	0	6.34
06/05/2022	009000770344464	6	4	0	5.02
06/05/2022	009000770344465	27	9	1	18.06
06/05/2022	009000770344466	5	3	0	4.56
06/05/2022	009000770344467	1	1	0	3.58
06/05/2022	009000770344468	53	9	1	19.05
06/05/2022	009000770344469	1	1	0	3.58
06/05/2022	009000770344470	23	4	1	15.84
06/05/2022	009000770344471	8	8	0	6.75
06/05/2022	009000770344472	199	14	2	36.85
06/05/2022	009000770344473	2	1	1	13.79
06/05/2022	009000770344474	8	5	1	15.68
06/05/2022	009000770344475	55	5	2	27.64
06/05/2022	009000770344476	11	8	0	6.87
06/05/2022	009000770344477	125	17	2	35.28
06/05/2022	009000770344478	127	14	0	13.77
06/05/2022	009000770344479	8	4	0	5.09
06/05/2022	009000770344480	4	3	0	4.53
06/05/2022	009000770344481	5	3	0	4.56

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
06/05/2022	009000770344482	8	5	0	5.51
06/05/2022	009000770344483	164	33	6	84.10
06/05/2022	009000770344484	5	3	1	14.74
06/05/2022	009000770344485	126	13	2	33.66
06/05/2022	009000770344486	22	10	0	8.12
06/05/2022	009000770344487	10	5	0	5.59
06/05/2022	009000770344488	30	4	2	26.27
06/05/2022	009000770344489	1	1	0	3.58
06/05/2022	009000770344490	95	22	4	56.56
06/05/2022	009000770344491	21	7	0	6.83
06/05/2022	009000770344492	53	5	1	17.39
06/05/2022	009000770344493	184	14	2	36.28
06/05/2022	009000770344494	7	4	1	15.23
06/05/2022	009000770344495	3	1	1	13.83
11/05/2022	009000770344886	8	5	0	5.51
11/05/2022	009000770344887	4	2	0	4.11
11/05/2022	009000770344889	147	25	3	49.61
11/05/2022	009000770344891	7	5	0	5.47
11/05/2022	009000770344894	82	18	2	34.06
11/05/2022	009000770344895	36	10	1	18.82
11/05/2022	009000770344896	182	19	2	38.28
11/05/2022	009000770344897	30	16	3	41.43
11/05/2022	009000770344898	26	11	0	8.68
11/05/2022	009000770344899	86	32	4	60.37
11/05/2022	009000770344900	11	4	0	5.21
11/05/2022	009000770344901	140	32	2	42.08
11/05/2022	009000770344902	11	6	1	16.21
11/05/2022	009000770344903	129	30	5	71.35
11/05/2022	009000770344904	44	4	1	16.63
11/05/2022	009000770344905	21	12	1	19.08
11/05/2022	009000770344906	36	11	0	9.06
11/05/2022	009000770344907	35	17	1	21.69
11/05/2022	009000770344908	40	7	2	27.90
11/05/2022	009000770344909	27	18	1	21.80
11/05/2022	009000770344910	9	7	0	6.38
11/05/2022	009000770344913	14	10	0	7.81
11/05/2022	009000770344914	1	1	0	3.58
11/05/2022	009000770344916	13	8	0	6.94
11/05/2022	009000770344918	10	8	0	6.83
11/05/2022	009000770344919	4	2	0	4.11
11/05/2022	009000770344922	116	22	4	57.36
11/05/2022	009000770344924	3	1	0	3.66
11/05/2022	009000770344925	8	6	0	5.92
11/05/2022	009000770344927	16	13	1	19.31

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
11/05/2022	009000770344929	13	8	0	6.94
11/05/2022	009000770344930	1	1	0	3.58
11/05/2022	009000770344931	25	10	0	8.23
11/05/2022	009000770344932	7	4	0	5.06
11/05/2022	009000770344935	45	15	1	21.24
11/05/2022	009000770344937	61	4	1	17.28
11/05/2022	009000770344938	171	13	3	45.54
11/05/2022	009000770344939	8	6	0	5.92
11/05/2022	009000770344940	1	1	0	3.58
11/05/2022	009000770344941	10	4	1	15.34
11/05/2022	009000770344942	11	7	0	6.45
11/05/2022	009000770344943	4	2	0	4.11
11/05/2022	009000770344945	105	20	2	35.77
11/05/2022	009000770344947	183	30	5	73.40
11/05/2022	009000770344948	8	6	0	5.92
11/05/2022	009000770344949	2	1	0	3.62
11/05/2022	009000770344950	11	9	0	7.28
11/05/2022	009000770344951	3	3	0	4.49
11/05/2022	009000770344952	10	6	0	6.00
11/05/2022	009000770344953	51	8	1	18.56
11/05/2022	009000770344954	31	4	1	16.14
11/05/2022	009000770344955	7	5	0	5.47
11/05/2022	009000770344956	32	1	1	14.93
11/05/2022	009000770344957	61	16	0	12.09
11/05/2022	009000770344958	10	5	0	5.59
11/05/2022	009000770344959	10	8	0	6.83
11/05/2022	009000770344960	9	5	0	5.55
11/05/2022	009000770344964	4	3	0	4.53
11/05/2022	009000770344965	8	6	0	5.92
11/05/2022	009000770344970	7	3	1	14.81
11/05/2022	009000770344971	108	3	1	18.65
11/05/2022	009000770344973	63	10	3	40.19
11/05/2022	009000770344974	10	8	0	6.83
11/05/2022	009000770344975	2	1	0	3.62
11/05/2022	009000770344976	1	1	0	3.58
11/05/2022	009000770344977	8	6	0	5.92
11/05/2022	009000770344978	12	8	0	6.91
11/05/2022	009000770344981	10	6	0	6.00
11/05/2022	009000770344982	10	9	0	7.25
11/05/2022	009000770344984	10	4	0	5.17
11/05/2022	009000770344986	10	6	0	6.00
11/05/2022	009000770344987	12	9	0	7.32
11/05/2022	009000770344988	14	6	1	16.32
11/05/2022	009000770344990	12	4	0	5.25

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
11/05/2022	009000770344991	14	7	0	6.57
11/05/2022	009000770344993	284	21	9	114.19
11/05/2022	009000770344995	10	7	0	6.42
11/05/2022	009000770344996	16	8	0	7.06
11/05/2022	009000770344997	14	9	1	17.57
11/05/2022	009000770344998	47	14	3	41.25
11/05/2022	009000770344999	216	28	4	63.65
11/05/2022	009000770345000	53	9	1	19.05
11/05/2022	009000770345001	139	22	5	68.41
11/05/2022	009000770345002	12	9	0	7.32
11/05/2022	009000770345003	285	27	10	126.89
11/05/2022	009000770345004	11	6	0	6.04
11/05/2022	009000770345005	5	2	2	24.49
11/05/2022	009000770345006	126	3	2	29.51
11/05/2022	009000770345007	53	16	2	32.13
11/05/2022	009000770345008	11	5	0	5.62
11/05/2022	009000770345009	72	16	5	63.37
11/05/2022	009000770345010	227	25	5	73.00
11/05/2022	009000770345012	8	3	0	4.68
11/05/2022	009000770345013	70	2	1	16.79
11/05/2022	009000770345014	28	10	1	18.52
11/05/2022	009000770345015	31	11	1	19.05
11/05/2022	009000770345016	54	7	2	28.43
11/05/2022	009000770345017	11	6	1	16.21
11/05/2022	009000770345018	54	15	1	21.58
11/05/2022	009000770345019	18	4	0	5.47
11/05/2022	009000770345020	3	3	0	4.49
12/05/2022	009000770345021	187	15	4	57.15
12/05/2022	009000770345022	133	9	2	32.26
12/05/2022	009000770345023	1	1	0	3.58
12/05/2022	009000770345024	60	4	2	27.41
12/05/2022	009000770345025	389	30	6	91.40
12/05/2022	009000770345026	144	24	2	38.91
12/05/2022	009000770345027	7	4	0	5.06
12/05/2022	009000770345028	65	9	1	19.51
12/05/2022	009000770345029	59	16	2	32.36
12/05/2022	009000770345030	11	8	0	6.87
12/05/2022	009000770345032	9	5	0	5.55
12/05/2022	009000770345033	9	5	0	5.55
12/05/2022	009000770345036	7	6	0	5.89
12/05/2022	009000770345038	11	7	0	6.45
12/05/2022	009000770345041	14	6	0	6.15
12/05/2022	009000770345042	10	5	0	5.59
12/05/2022	009000770345044	6	4	0	5.02

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
12/05/2022	009000770345045	63	18	1	23.17
12/05/2022	009000770345046	6	3	0	4.60
12/05/2022	009000770345048	5	3	0	4.56
12/05/2022	009000770345049	5	3	0	4.56
12/05/2022	009000770345050	12	8	0	6.91
12/05/2022	009000770345051	2	2	0	4.04
12/05/2022	009000770345052	50	8	1	18.52
12/05/2022	009000770345053	173	21	4	59.11
12/05/2022	009000770345054	5	5	0	5.40
12/05/2022	009000770345055	41	9	1	18.60
12/05/2022	009000770345056	8	4	1	15.27
12/05/2022	009000770345057	112	20	4	56.38
12/05/2022	009000770345058	9	4	1	15.30
12/05/2022	009000770345060	9	6	0	5.96
12/05/2022	009000770345062	11	8	1	17.04
12/05/2022	009000770345065	9	5	0	5.55
12/05/2022	009000770345069	10	7	0	6.42
12/05/2022	009000770345070	1	1	0	3.58
12/05/2022	009000770345072	12	8	0	6.91
12/05/2022	009000770345073	2	1	0	3.62
12/05/2022	009000770345075	7	6	0	5.89
12/05/2022	009000770345077	3	1	1	13.83
12/05/2022	009000770345079	3	2	0	4.07
12/05/2022	009000770345080	2	1	1	13.79
12/05/2022	009000770345086	5	1	0	3.73
12/05/2022	009000770345087	67	16	2	32.66
12/05/2022	009000770345088	160	27	6	81.45
12/05/2022	009000770345089	70	12	1	20.94
14/05/2022	009000770345159	11	6	0	6.04
14/05/2022	009000770345160	8	6	0	5.92
14/05/2022	009000770345161	3	2	0	4.07
14/05/2022	009000770345162	52	32	3	48.91
14/05/2022	009000770345163	127	19	1	26.02
14/05/2022	009000770345164	112	22	2	36.86
14/05/2022	009000770345165	27	4	0	5.82
14/05/2022	009000770345166	34	12	1	19.58
14/05/2022	009000770345167	4	2	0	4.11
14/05/2022	009000770345168	5	4	0	4.98
14/05/2022	009000770345169	5	5	0	5.40
14/05/2022	009000770345170	21	11	1	18.67
14/05/2022	009000770345172	26	6	1	16.78
14/05/2022	009000770345171	7	4	0	5.06
14/05/2022	009000770345173	4	3	0	4.53
14/05/2022	009000770345174	4	3	0	4.53

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
14/05/2022	009000770345175	93	16	3	43.82
14/05/2022	009000770345176	10	5	0	5.59
14/05/2022	009000770345177	97	15	1	23.22
14/05/2022	009000770345179	7	6	0	5.89
14/05/2022	009000770345178	39	14	1	20.60
14/05/2022	009000770345180	28	8	0	7.51
14/05/2022	009000770345181	73	11	2	30.81
14/05/2022	009000770345183	10	8	0	6.83
14/05/2022	009000770345182	9	4	0	5.13
14/05/2022	009000770345184	34	12	1	19.58
14/05/2022	009000770345185	29	10	0	8.38
14/05/2022	009000770345186	298	8	5	68.63
14/05/2022	009000770345188	16	6	1	16.40
14/05/2022	009000770345187	3	2	0	4.07
14/05/2022	009000770345189	94	15	2	33.27
14/05/2022	009000770345190	36	12	2	29.82
14/05/2022	009000770345191	30	6	0	6.76
14/05/2022	009000770345192	7	5	0	5.47
14/05/2022	009000770345193	110	16	1	24.12
14/05/2022	009000770345194	7	5	0	5.47
14/05/2022	009000770345195	6	4	0	5.02
14/05/2022	009000770345196	4	4	0	4.94
14/05/2022	009000770345197	187	27	5	72.31
14/05/2022	009000770345199	34	10	2	28.92
14/05/2022	009000770345198	147	12	3	44.21
14/05/2022	009000770345202	7	5	0	5.47
14/05/2022	009000770345200	4	3	0	4.53
14/05/2022	009000770345201	133	14	3	44.51
14/05/2022	009000770345204	33	7	3	37.81
14/05/2022	009000770345205	8	3	0	4.68
14/05/2022	009000770345207	1	1	0	3.58
14/05/2022	009000770345206	149	17	5	66.71
14/05/2022	009000770345203	3	3	0	4.49
14/05/2022	009000770345208	83	12	1	21.44
14/05/2022	009000770345209	9	6	0	5.96
14/05/2022	009000770345210	10	8	0	6.83
14/05/2022	009000770345211	2	2	0	4.04
14/05/2022	009000770345212	6	3	0	4.60
14/05/2022	009000770345213	64	12	1	20.72
14/05/2022	009000770345214	55	10	1	19.54
14/05/2022	009000770345215	10	4	0	5.17
14/05/2022	009000770345217	3	2	1	14.25
14/05/2022	009000770345218	48	11	1	19.69
14/05/2022	009000770345220	7	6	0	5.89

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
14/05/2022	009000770345219	17	10	0	7.93
14/05/2022	009000770345221	4	4	0	4.94
14/05/2022	009000770345222	49	12	2	30.32
14/05/2022	009000770345223	5	5	0	5.40
14/05/2022	009000770345224	8	5	0	5.51
14/05/2022	009000770345225	152	28	7	91.74
14/05/2022	009000770345226	7	6	0	5.89
14/05/2022	009000770345227	161	17	2	36.65
14/05/2022	009000770345228	6	3	0	4.60
14/05/2022	009000770345229	8	6	0	5.92
14/05/2022	009000770345231	50	17	2	32.43
14/05/2022	009000770345230	4	3	0	4.53
14/05/2022	009000770345232	9	6	0	5.96
14/05/2022	009000770345233	3	3	0	4.49
14/05/2022	009000770345234	56	14	0	11.07
14/05/2022	009000770345236	32	13	1	19.92
14/05/2022	009000770345235	100	11	2	31.84
14/05/2022	009000770345237	40	9	2	28.73
14/05/2022	009000770345238	11	7	0	6.45
14/05/2022	009000770345239	94	18	2	34.52
14/05/2022	009000770345240	49	9	0	8.73
15/05/2022	009000770345242	1	1	0	3.58
15/05/2022	009000770345243	132	4	3	40.32
15/05/2022	009000770345244	55	17	1	22.45
15/05/2022	009000770345245	123	31	5	71.54
15/05/2022	009000770345246	3	3	0	4.49
15/05/2022	009000770345247	230	23	3	51.93
15/05/2022	009000770345248	95	34	5	71.72
15/05/2022	009000770345251	22	7	1	17.04
15/05/2022	009000770345250	216	6	3	44.34
15/05/2022	009000770345252	9	6	1	16.13
15/05/2022	009000770345253	107	47	5	77.57
15/05/2022	009000770345254	21	9	1	17.84
15/05/2022	009000770345255	3	2	0	4.07
15/05/2022	009000770345256	18	9	1	17.72
15/05/2022	009000770345257	52	14	1	21.09
15/05/2022	009000770345258	21	8	2	27.59
15/05/2022	009000770345259	104	28	2	39.05
15/05/2022	009000770345260	58	25	1	25.89
15/05/2022	009000770345261	47	8	0	8.24
15/05/2022	009000770345262	7	5	0	5.47
15/05/2022	009000770345263	72	13	1	21.43
15/05/2022	009000770345264	3	2	0	4.07
15/05/2022	009000770345265	14	3	0	4.91

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
15/05/2022	009000770345266	1	1	0	3.58
15/05/2022	009000770345267	3	2	0	4.07
15/05/2022	009000770345268	315	19	6	84.02
15/05/2022	009000770345269	78	8	1	19.59
15/05/2022	009000770345270	2	2	0	4.04
15/05/2022	009000770345271	2	1	0	3.62
15/05/2022	009000770345272	3	3	0	4.49
15/05/2022	009000770345273	42	11	0	9.29
15/05/2022	009000770345275	3	2	0	4.07
15/05/2022	009000770345274	2	1	0	3.62
15/05/2022	009000770345276	140	22	4	58.27
15/05/2022	009000770345277	369	23	7	97.90
15/05/2022	009000770345278	6	4	0	5.02
15/05/2022	009000770345279	41	11	1	19.43
15/05/2022	009000770345280	119	13	1	23.22
15/05/2022	009000770345282	75	6	2	28.81
15/05/2022	009000770345281	99	9	3	41.14
15/05/2022	009000770345284	4	4	0	4.94
15/05/2022	009000770345283	16	12	1	18.89
15/05/2022	009000770345285	8	6	0	5.92
15/05/2022	009000770345287	16	4	0	5.40
15/05/2022	009000770345286	111	14	4	53.85
15/05/2022	009000770345288	36	9	2	28.58
15/05/2022	009000770345289	10	6	0	6.00
15/05/2022	009000770345290	94	11	4	51.96
15/05/2022	009000770345291	5	3	0	4.56
15/05/2022	009000770345292	6	5	0	5.43
15/05/2022	009000770345294	179	23	4	60.17
15/05/2022	009000770345296	26	3	0	5.36
15/05/2022	009000770345295	7	4	0	5.06
15/05/2022	009000770345293	294	24	6	85.30
15/05/2022	009000770345298	4	4	0	4.94
15/05/2022	009000770345297	41	3	2	26.28
15/05/2022	009000770345299	5	3	0	4.56
15/05/2022	009000770345300	9	7	0	6.38
15/05/2022	009000770345301	213	21	5	70.80
15/05/2022	009000770345302	2	1	0	3.62
15/05/2022	009000770345303	243	22	5	72.36
15/05/2022	009000770345304	666	20	9	128.29
15/05/2022	009000770345305	105	6	2	29.95
15/05/2022	009000770345306	7	5	0	5.47
15/05/2022	009000770345307	48	13	0	10.35
15/05/2022	009000770345308	7	5	0	5.47
15/05/2022	009000770345309	7	7	0	6.30

Date	UAT	No. of items	Count of different items	Count of different items not read	Estimated PI12 (in seconds)
15/05/2022	009000770345311	101	18	4	55.13
15/05/2022	009000770345310	8	3	0	4.68
15/05/2022	009000770345312	5	3	0	4.56
15/05/2022	009000770345314	79	13	1	21.70
15/05/2022	009000770345313	28	1	1	14.78
15/05/2022	009000770345315	12	9	0	7.32
15/05/2022	009000770345316	1	1	0	3.58
15/05/2022	009000770345317	11	8	0	6.87
15/05/2022	009000770345319	4	1	1	13.87
15/05/2022	009000770345318	135	15	7	85.69
15/05/2022	009000770345320	4	3	0	4.53
15/05/2022	009000770345321	91	15	2	33.16
15/05/2022	009000770345322	10	7	0	6.42
15/05/2022	009000770345323	4	3	0	4.53
15/05/2022	009000770345324	3	2	0	4.07
15/05/2022	009000770345325	41	10	0	8.84
15/05/2022	009000770345326	9	5	0	5.55
15/05/2022	009000770345327	253	23	5	73.15
15/05/2022	009000770345328	12	8	0	6.91
15/05/2022	009000770345331	169	16	3	46.71
15/05/2022	009000770345330	10	3	1	14.93
15/05/2022	009000770345332	28	4	0	5.85
15/05/2022	009000770345329	7	5	0	5.47
15/05/2022	009000770345333	4	3	0	4.53
15/05/2022	009000770345334	219	12	6	77.47
15/05/2022	009000770345335	10	8	0	6.83
15/05/2022	009000770345336	10	7	0	6.42
15/05/2022	009000770345337	3	2	0	4.07
15/05/2022	009000770345338	279	22	8	104.24
15/05/2022	009000770345339	9	4	0	5.13
15/05/2022	009000770345340	12	5	0	5.66
15/05/2022	009000770345341	8	2	1	14.44
15/05/2022	009000770345342	53	8	1	18.64
15/05/2022	009000770345343	16	8	0	7.06
15/05/2022	009000770345344	4	3	0	4.53
15/05/2022	009000770345345	11	8	0	6.87
15/05/2022	009000770345346	9	5	0	5.55
15/05/2022	009000770345348	16	6	0	6.23
15/05/2022	009000770345347	261	14	5	69.72
15/05/2022	009000770345349	4	2	0	4.11
15/05/2022	009000770345350	18	8	1	17.31
15/05/2022	009000770345351	10	5	0	5.59
15/05/2022	009000770345352	1	1	0	3.58
15/05/2022	009000560068883	2	1	0	3.62

Total estimated time spent on activity A12 (PI12) (in seconds)	**10113.69**
Total estimated time spent on activity A12 (PI12) (in hh:mm:ss)	**02:48:34**