REDUCING THE ORDER PICKING PROCESS TIME

How can Asyad Express company reduce its fulfilment center's order picking time by more than 30%

Graduation report

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Preface

This research is my graduation thesis project, it was done to fulfill the graduation and competencies requirements of the logistics engineering course of HZ university. I am honored to deliver this graduation thesis on shortening the order picking procedure at Asyad Express fulfillment facility. This project reflects the pinnacle of my academic career, demonstrating my devotion and enthusiasm for logistics engineering. This thesis has been a tough but rewarding experience that has allowed me to explore further into the subject matter and add to the current body of knowledge.

Throughout the course of this research, I received invaluable assistance from Mr. Mohammed Al-Kindi, my thesis advisor Mr. Max Walravens, and my fulfilment team colleagues, who guided me in determining the direction and caliber of this work. I am appreciative of their knowledge and encouragement, which have been crucial to my development as a researcher as well as the respondents who provided me with valuable information that I wouldn’t be able to have this much insight without them.

I'm hopeful that this thesis will be a valuable contribution to the company, inspiring additional research and development and I hope that it's enough to show whether the graduation requirements are achieved or not.

Thank you,

Mohamed Albusaidi

Muscat, May 22,2023.

Summary

This is a summary of this problem-solving research to gain a quick insight into all key findings and discussions. This research aims to answer the main question which is "How to reduce the order picking process time in the fulfillment center of Asyad Express in Muscat with 30% compared to the current situation by the end of 2023?" The reason is because there is a noticeable order volume increase and it is affecting the order fulfillment performance where customers' orders are delayed, leading to dissatisfaction by them. Adding to this, it is affecting the company departments themselves and delays their operations.

Therefore, in terms of the research sequence, first there is an investigation into this problem to reach the aim of this research starting by conducting a literature review about order picking and investigating similar cases to the one at hand. Followed by a well defining of the problem and its impact and how does the current situation look like leading to deeper insights. Then the process performance measurements are calculated by using the collected data from warehouse management system, Gemba walk, interviews, and work sampling to be able to notice bottlenecks which then are analyzed by Pareto chart to determine the high priorities which have the biggest impact on the problem which then are visualized into fishbone leading to a smoother analysis by 5Whys root cause analysis for the issues. Then, potential improvements are proposed, and an implementation plan is defined into Gantt chart using (Plan-Do-Check-Act) method. The last part of the result chapter is the future situation description where the improvements are examined and compared to the current situation. Lastly, the discussion, conclusion, and recommendations are presented.

Regarding the performance measurements it is noticed that both percentages of orders requiring material handling and wrong picked orders are leading to high wasted time. Furthermore, by using a warehouse layout and routes analysis using a spaghetti diagram, it is noticed that fast-moving goods are not located in the right locations, some are far, and some are on high shelves which cannot be reached easily leading to longer travel time and insufficient picking paths. These issues have been analyzed to reach the root causes which are poor storage assignment, routing, and picking methods due to zone policy and time availability to optimize them.

Regarding to the improvements, the After finding the right root causes, two potential improvements are proposed taking both literature review and company objectives into consideration. These improvements are applying the "mid-point-Pick-by-scan" method which is a combination between a routing and a picking policy as it's connected to each other. Which makes the picking process faster using Honeywell devices and orders are assigned according to mid-points locations as pickers only pick halfway the aisle only leading to short checking and travel time. The second improvement is applying ABC storage assignment per zone and per shelf which lead to a shorter travel time and reducing fast-moving goods that need additional material handlings.

The proposed improvements are examined to check whether they are effective and highly contribute to solving the issue or not. A scenario has been determined and each step time is measured and then doing the same thing for the same scenario but for future situation to make a comparison between them where the outcomes are a reduction on the travel time from 17 seconds to 4 seconds and less checking time with eliminated steps leads to an overall reduction on the process time by 39% which is from 74 minutes to 29 minutes on average. Therefore, the research question has been answered and the aim is achieved that the process time is reduced by more than 30% compared to the current situation.

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Abbreviations List

Number	Abbreviation	Referring to
1	DC	Distribution Center
2	SEM	Small to medium-sized enterprise
3	COD	Cash on delivery
4	SKU	Stock keeping unit
5	FCFS	First-come-first serve
6	FDG	Focus group discussion
7	FMEA	Failure modes and effects analysis
8	PDCA	Plan, Do, Check, Act method
9	QDA	Software for scanning and analyzing transcripts
10	WMS	Warehouse management system
11	DMAIC	Define, Measure, Analyze, Improve, Control
12	3PL	Third party logistics, and it refers on this research to the main warehouse
13	TC	Temperature control, refers to the fulfilment center
14	PS	Pallet store
15	VOB	Voice of business
16	LM	Last mile
17	ASN	Advanced shipment notice
18	AEX	Asyad Express
19	R. T	Real Time
20	RPN	Risk Priority Number

1. Introduction

This chapter provides an introduction. Background information, problem definition, and research goals are given. The main research question and sub-questions are then formulated. The report's scope and limitations are then addressed. Then lastly the report's function and reading instruction are described.

1.1 Company Background

Nowadays, distribution centers (DC) and fulfillment centers in the modern supply chain cannot be overstated. It is crucial that the DCs fulfill their duty of getting the right products to the right clients at the right time and at the right price. For many manufacturers DCs are regarded as a front-end for customer service (Simchi-Levi & Kaminsky, 2000). Regarding to this, Asyad Express (AEX) which is a logistics company based in Oman that has a partnership with Oman post offers a modern and agile domestic express delivery.

AEX relies on a strong local network and six distribution centers strategically situated around the nation to provide effective and rapid door-to-door delivery capabilities to any area of Oman within 48 hours. AEX deliver customer's essential papers and goods swiftly, securely, and effectively, from developing small to medium-sized enterprises to established multinational firms in a broad variety of industrial sectors including e-Commerce, manufacturing, services, and finance. In addition to quick shipping, AEX provides value-added optional extras such as cash on delivery and Returns, as well as a complete choice of packaging alternatives. This research is based on its main fulfilment center, which is in Muscat. The fulfillment space inside this building is over 1200 m2 and the total warehouse space is more than 3500 m2.

1.2 Problem statement and research aim

As more businesses seek to reduce expenses and boost warehouse and distribution center efficiency, picking has come under growing attention. Order picking - extracting goods from storage in response to a particular client request - is the most labor-intensive function in manual warehouses and the most capital-intensive operation in automated warehouses. Because of this, order picking is seen as the top priority for efficiency improvements by warehouse experts (Dekker, De Koster, Roodbergen, & Van Kalleveen, 2004). This implies that order picking is critical since it is a component of the process of fulfilling client orders. The order picking process's speed and efficiency may impact the delivery time of a client's order, which can affect customer satisfaction. To fulfill consumer orders promptly and properly, this process must be streamlined.

Due to the importance of order picking within the fulfillment center of AEX, it has been noticed that the order picking process takes a long time consequently the workers could not meet the set deadlines most of the times. Due to the elevated working pressure, process time measurements have not yet been performed. In addition, the process is performed randomly and without following specific walking paths resulting in increased expenses and consumer dissatisfaction. Therefore, the objective of this graduation research is to provide a deep analysis of the current situation and measurements that must be done in order to fix this and provide a strategic solution and systematic recommendations to AEX to optimize their order picking process by reducing the process lead time so that orders can be filled more quickly, reduce the time needed to select orders, reduce walk time, and collect products through the most efficient path.

1.3 Research Main and Sub questions

Regarding to the described problem, the main question of this graduation research can be formulated as follows: ***"How to reduce the order picking process time in the fulfilment center of Asyad Express in Muscat with 30% compared to the current situation by the end of 2023?"***. By saying improve, it's meant to make the best use of all literature and company sources and make this process efficient as much as possible, the 30% was chosen to be more specific and set a target in terms of measurements, a higher percentage may conflict with the workers working pressure and their ability to cope with change, it may conflicts as well with the research time period , targeted period and available sources. Therefore, 30% is more logical. The main question can be further divided into the following sub questions:

- How does the current situation of order picking process of Asyad Express look like?
  - This sub-question is important to define the current situation and having process performance measurements leading to a better understanding of the case.
- What are the root causes that lead to order picking taking a long time?
  - Important to find the bottlenecks and the root cause of the problem.
- What are the potential improvements to make the picking order process faster?
  - Essential to propose improvements which will solve the problem and conducting an implementation plan.
- What will the future situation look like after implementing the improvements with consideration of measurements?
  - Essential to analyze the proposed improvements and measure the how sufficient they are.

1.4 Scope and restrictions

Scope in:

- The research only focusses on the picking order process from start to end.
- The main fulfillment center layout is covered to illustrate the current situation.
- The research considers the order pickers paths.
- The research is based only on the main fulfillment center.
- The data, interviews, and survey's respondents are only from the main fulfilment center itself.

Scope out:

- The research is not focusing on other fulfilment center processes.
- The research does not cover the specification and information of ordered products.
- Other distribution and fulfillment centers are not covered.
- The orders history or orders to be picked are not all of them covered, only samples of them.
- There is no logistics concept mentioned as it is general, and it does not have a big impact whether on the findings or on improvements decisions. As the current situation analysis and related interview and meetings are enough.

1.5 Research function

This research provides current situation analysis and solutions to AEX to fix the main problem by using the literature review in the next chapter and the followed chapter, chapter 3, the multiple tools and strategic methods that are used for analysis, then chapter 4 is the research structure and planning followed by chapter 5 where all of the analysis and results are conducted, then the discussion, conclusion, recommendations, bibliography, appendixes are conducted sequentially.

2. Theoretical Framework

This chapter gives the theoretical framework for this research, which is used subsequently in the analysis of the outcomes. As a result, the many features of order picking process are outlined theoretically, and they are investigated in depth with the help of several reliable sources. This part is potentially addressing the sub questions of this research report and provides insight into the main topic of this research report.

2.1 Order picking concept and methods

The order-picking process in warehouses is the focus of this part. This framework has the potential to reduce order-picking costs and cycle time without affecting service quality. Understanding the components of order picking, such as travel time, item picking, and related activities, as well as investigating research areas such as warehouse layout design, order batching, storage assignment, and picker routing, is beneficial for optimizing warehouse operations.

According to (Tompkins, White, Bozer, & Tanchoco, 2010), the order-picking process, defined as the process of retrieving items from storage locations in response to a specific customer request and it's the most tedious and expensive task in a typical warehouse, accounting for up to 55% of total warehouse operating expenses; it also affects service quality. Consequently, it is crucial to reduce order-picking expenses and cycle time.

The time required to pick an order may be broken down into three components: time spent traveling between products, time spent picking items, and remaining activities. The fact that about 50% of overall order-picking time is spent on traveling as described by (Tompkins, White, Bozer, & Tanchoco, 2010). From another perspective, Order picking involves the process of clustering and scheduling the customer orders, assigning stock on locations to order lines, releasing orders to the floor, picking the articles from storage locations and the disposal of the picked articles as stated by (de Koster, Le-Duc, & Jan Roodbergen, 2006).

The most common objective of order-picking systems is to maximize the service level subject to resource constraints such as labor, machines, and capital (Ashayeri & Goetschalckx, 1989). By considering the importance of order picking, (Zulj, Glock, Grosse, & Schneider, 2018) explain that order-picking processes can be distinguished into four main research areas: warehouse layout design, order batching, storage assignment, and picker routing and it can be described as follow:

Warehouse layout:

In the context of order picking, (Tompkins, White, Bozer, & Tanchoco, 2010) state that the layout design concerns two sub-problems: the layout of the facility containing the order-picking system and the layout within the order-picking system. The first problem is usually called the facility layout problem; it concerns the decision of where to locate various departments (receiving, picking, storage, sorting, and shipping, etc.).

It is often carried out by considering the active relationship between the departments. Furthermore, (Zulj, Glock, Grosse, & Schneider, 2018) described more about the warehouse layouts and it's characteristics as the design of the warehouse layout takes into account the characteristics of the order-picking system, such as the mechanization level (manual, mechanized, semi-automated, automated), the location of receiving, picking, storage, sorting, and shipping areas, and the layout of the order-picking system, i.e. the location of the depot, the size of the picking area, racking (flow racks, pallet racks, or shelves), and equipment usage (picking trucks, picking carts).

Rectangular warehouse designs with parallel aisles are quite common. Here, the layout choice pertains to the number of blocks, the number and size of aisles and cross aisles inside each block, and the number of blocks. A few strategies address non-standard warehouse layouts such as flying-V, fishbone, and U-shaped designs. Lastly, (Tompkins, White, Bozer, & Tanchoco, 2010) noted a common objective about travel distance in relation of warehouses which is minimizing the handling cost, which in many cases is represented by a linear function of the travel distance.

Order batching methods:

According to (Zulj, Glock, Grosse, & Schneider, 2018), If the number of items per customer order is small, the total travel distance can be reduced by consolidating a set of customer orders into a single picking tour. Order batching groups customer orders to picking orders (batches) such that the total length of all tours through a warehouse is minimized. Related to this topic, (Tompkins, White, Bozer, & Tanchoco, 2010) explain that by increasing the number of orders (and therefore items) picked by an order picker during a picking tour, the travel time per pick can be reduced. A natural group of orders to put into a batch is single-line orders.

Single line orders can be batch by small zones in the warehouse to further reduce travel time. when an order is assigned to more than one picker, the effort needed to reestablish order integrity is significantly increased. The additional cost of sortation must be evaluated with respect to the travel time saved by batch picking. The order batching strategies described by (Tompkins, White, Bozer, & Tanchoco, 2010) are:

- Discrete (order) picking: One person picks one order, one line (product) at a time.
- Batch picking: One picker picks a group of orders (batch) at the same time, one line at a time.
- Zone picking: The total pick area is organized into distinct sections (zones), with one person assigned to each zone. The picker assigned to each zone picks all the lines, for each order, which are located within that zone.
- Wave picking: This method is like discrete picking in that one picker picks one order, one line at a time. The difference is that a selected group of orders is scheduled to be picked during a specific planning period.
- Zone-batch picking: Each picker is assigned a zone and will pick a part of one or more orders, depending on which lines are stocked in the assigned zones.
- Zone-wave picking: Each picker is assigned a zone and picks all lines for all orders stocked in the assigned zone, one order at a time, with multiple scheduling periods per shift.

Storage and layout:

There are various strategies for assigning items to storage locations in the warehouse. Common strategies are random storage, dedicated storage, and class-based storage, A random storage strategy arbitrarily assigns items to storage locations. This strategy aims to maximize storage-space utilization, but often results in long travel times. Dedicated storage assigns items to fixed storage locations based on item characteristics, such as demand frequency, weight, or measurements or the cube-per-order index, i.e., the ratio of the stock volume to the demand frequency. Dedicated storage leads to a lower degree of storage-space utilization, but often reduces travel time as compared to random storage. Class-based storage first groups items into classes and then assigns classes to dedicated areas of the warehouse which is referring to ABC analysis. (Zulj, Glock, Grosse, & Schneider, 2018).

Routing methods:

The objective of a routing policy is to sequence the items on the pick list to ensure a 'good' route through the warehouse that minimizes the total travel distance. A good routing policy should not only induce short total travel distance, but it should also help the picker visualize the next location and how to travel there most directly as stated by (Bartholdi & Hackman, 2014).

There are several routing methods developed and used in practice. They range from the very simple to the slightly more complex. These methods are described by (Bartholdi & Hackman, 2014) who state that the performance of these heuristics depends on the operating conditions of the system under study due to their definitions. The simplest routing heuristic is the S-shape policy. When this policy is used, the order picker enters every aisle where an item must be picked and traverses the entire aisle. Aisles where nothing must be picked are skipped.

An exception is made for the last aisle visited in case the number of aisles to be visited is odd. In that case a return travel is performed in the last aisle visited. Another very simple routing heuristic is Return policy. The order-picker enters and leaves aisles containing item(s) to be picked from the front aisle. A Midpoint routing policy, also one simple heuristic, looks like a return method on two halves of a warehouse. Only the first and last aisle visited are traversed entirely. Similarly, to the last heuristic, with Largest Gap policy all aisles that contain even one item to be picked are also left at the same side as they were entered, except the first and last visited which are traversed entirely.

The gap represents the separation between any two adjacent picks, between the first pick in the aisle and front aisle, or between the last pick in the aisle and the back aisle. According to (Zulj, Glock, Grosse, & Schneider, 2018), If the largest gap is between two adjacent picks, the picker performs a return route from both ends of the aisle. Otherwise, a return route from either the front or back aisle is used. The largest gap is therefore the portion of the aisle that the order picker does not traverse. This policy is a slightly more complex routing heuristic than the first three mentioned. The resulting route is somehow similar, but definitely at least equal or better than the route defined by Midpoint policy in all possible situations (see figure 2.1.1).

While (Rosenthal & Ratliff, 1983) mention that two relatively new policies have been developed which are Composite policy and Combined policy. Composite routing heuristic combines features of the S-shape and Return heuristics, minimizing travel distance between the farthest picks in two adjacent aisles for each aisle individually. Combined heuristics is also a combination of S-shape and Return policies, but a small component of dynamic programming gives it the possibility to look one aisle ahead. The decision about return or traversal route in the aisle depends not only on minimized travel in that aisle, but also on a better starting point for the next aisle. This in turn leads to a better overall result than Composite heuristic. All routing policies described above by their definitions have some restrictions for creating a route.

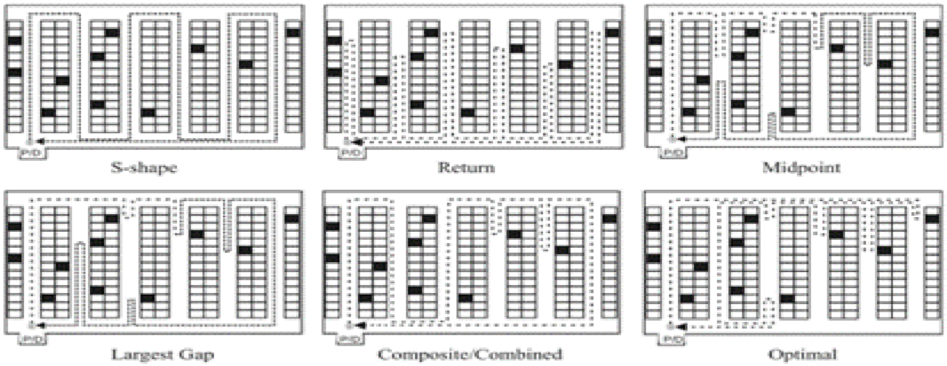

Figure 1. Examples of routes using several routing heuristics and an optimal algorithm (Bartholdi & Hackman, 2014).

The sources reviewed in this part provide valuable perspectives on various aspects of order picking. (Tompkins, White, Bozer, & Tanchoco, 2010) emphasize the significance of warehouse layout design and its impact on order picking, addressing both facility layout and layout within the order-picking system. On the other hand, (Zulj, Glock, Grosse, & Schneider, 2018) delve into various research areas, including warehouse layout characteristics, order batching, storage assignment, and picker routing. While (Tompkins et al, 2010) offer insights into travel distance and handling cost optimization, (Zulj et al, 2018) provide a broader perspective by encompassing multiple research dimensions. By synthesizing these sources, a comprehensive approach to order picking can be developed, optimizing travel time, storage utilization, and overall efficiency. This research aims to leverage these insights to enhance operational performance and customer satisfaction in order fulfillment centers.

2.2 Order picking planning problems & combination between them

This part describes the order picking planning problem that might lead to inefficient order picking process, then the main planning problems are combined together to have a deeper insight and a better understanding of the impact of each one of them which contributes on making brainstorming and decisions on the result chapter leading to a more sufficient research question answer.

2.2.1 Order picking planning problems

This section introduces the order picking planning problems and their crucial role in the efficiency of order fulfillment processes as these issues are essential for optimizing warehouse management and improving overall performance. This section explores the relevance of order picking planning problems and provides an overview of the key sectors and problems identified by different researchers that is leading to a better understanding of the main issues that might affect the order picking process.

The low performance efficiency of order picking is usually because of problems on the planning of the order picking process, according to (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022) these planning problems can be divided into three main sectors which are:

- Strategic
- Tactical
- Operational

While (de Koster, Le-Duc, & Jan Roodbergen, 2006) state that to manage order picking operations, warehouse managers are faced with four order picking planning problems which are:

- Storage location assignment (i.e., determining the physical location where incoming products are stored).
- Order batching (i.e., rules defining which orders to combine in each pick tour)
- Zone picking (i.e., dividing the order picking area into smaller zones and allowing order pickers to retrieve items from a single zone)
- Routing (i.e., the order in which the items on the pick list are retrieved) are critical to the success of a warehouse management system.

In fact, both the three sectors and the four sectors' concepts are close to each other and have similar context. The three sectors mentioned by (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022) are:

strategic:

- Storage rack configuration: Given the size or capacity needs of the pick area, determining the width and height of storage racks, as well as the length and breadth of pick aisles and cross-aisles as defined by (Thomas, Lisa, & D. Meller, 2015).
- Technical equipment selection: The use of technical instruments such as material handling equipment and picking by voice to make picking easier (De Vries, Jelle, De Koster, & Daan Stam, 2016).
- Depot location: Choosing the number of depots and the location of the pick-up and delivery points for each pick tour (Pablo, Gomez-Montoya, Munuzuri, Cortes, & Correa-Espinal, 2017).

Tactical:

- Zone location: How to divide the order select area into zones as the number of zones, the location of zones and the zone shape (Jane, Chin-Chia, & Laih, 2005).
- Zone assignment: How to assign items to select zones based on product characteristics as size, weight, safety, and temperature requirements or demand characteristics as customer type (Jane & Chin-Chia, 2000).
- Zone picking: Customer orders are routed via all pick zones, which might be concurrent or sequential (Parikh, Pratik, & Russell, 2008).
- Sorting: Consolidating and sorting products, either during the pick tour (sort-while-pick) or after picking (pick-and-sort) (Van Nieuwenhuyse, Inneke, & De Koster, 2009).
- Replenishment: Choosing how and when to replenish storage areas in the order pick area (Gagliardi, Philippe, Ruiz, & Renaud, 2008).
- Storage assignment: Rules for assigning items to storage sites or (turnover-based) storage classes (Brynzer & Johansson, 1996)

Operational:

- Resource planning: determining the resource level and dispersing available resources among order pick regions (Van Gils, Teun, Ramaekers, Caris, & Cools, 2017).
- Workload planning: Which customer orders should be retrieved and when (Vanheusden, et al., 2020).

- Order batching: Rules for combining client orders in each pick tour (Henn, Sebastian, & Wascher, Tabu search heuristics for the order batching problem in manual order picking systems, 2012).
- Picker routing: The order in which storage sites should be reached in each pick tour to recover all goods on a pick list (Van Gils, et al., 2019).
- Job assignment: Choosing the order in which orders/batches of orders are obtained, as well as assigning these orders (batches of orders) to the available pickers (Henn & Sebastian, 2015).

Related to the four elements stated by (de Koster, Le-Duc, & Jan Roodbergen, 2006), Routing, batching, and storage assignment were covered in the previous subchapter; however, for a more in-depth background, the following is a summary of policies for the four most important order choosing planning problems:

Storage policies (Guo, X, Yu, De Koster, & R.B.M, 2016; Yu, et al., 2015) **:**

- Random: The storage sites for each stock keeping unit (SKU) are picked at random from among all available vacant spaces.
- Within-aisle: The SKUs in a single pick aisle correspond to the same storage class based on turnover.
- Across-aisle: Each storage class is separated by many pick aisles.
- Diagonal: The placement of storage classes is determined by the distance to the depot.
- Perimeter: The storage classes are positioned on the warehouse's edge.

Batching policies (de Koster, Le-Duc, & Jan Roodbergen, 2006; Henn, et al., 2012)**:**

- Priority rule based: Based on their priority, orders are allocated to pick lists (e.g., first-come-first-serve (FCFS)).
- Seed based: The generation of batches begins with the selection of an initial seed order (e.g., the smallest order), followed by the addition of unassigned client orders to the seed order in accordance with an order congruency rule (e.g., add an order such that the number of additional pick locations is minimal).
- Savings based: Pick lists are created based on the distance reductions that may be realized by merging many client orders into a single route.
- Metaheuristic: A collection of rules for the development of heuristic optimization methods for order batching.
- Exact algorithm: The order batching issue is optimally resolved utilizing techniques such as branch-and-bound.

Zoning policies (Jane, Chin-Chia, & Laih, 2005; Petersen & C.G, Considerations in order picking zone configuration, 2002)**:**

- Product properties assignment: Products are allocated to zones according to their physical characteristics, such as size and weight.
- Demand properties assignment: Products are allocated to zones depending on demand characteristics, including client type and order frequency.

Routing policies (Roodbergen, K.J, De Koster, & R.B.M, 2001; Scholz, et al., 2016; Theys, et al., 2010)**:**

- Aisle-by-aisle: Each order picker traverses the whole length of each pick aisle having at least one pick site.

- Traversal: Each order picker crosses the whole length of every sub-aisle (i.e., the portion of a pick aisle that is contained inside one warehouse block) having at least one pick site.
- Return: Each order selector enters and exits every pick aisle with at least one pick location from the same end.
- Midpoint: Each order picker only enters a pick aisle halfway and exits at the same end.
- Largest Gap: Each order picker enters a pick aisle only as far as the beginning of the widest gap inside the aisle and exits from the same end. The widest gap is the greatest distance between any two adjacent pick sites inside a single aisle, or the greatest distance between an aisle end and a pick location.
- Metaheuristic: A collection of rules for the development of heuristic routing optimization algorithms.
- Exact algorithm: The order picker routing issue is optimally handled utilizing techniques such as branch-and-bound.

In summary, the theoretical framework on order picking planning problems encompasses the works of various researchers. In comparing the works (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022) and (de Koster, Le-Duc, & Jan Roodbergen, 2006), similarities and differences emerge regarding the understanding of order picking planning problems. Both studies acknowledge the importance of storage assignment and order batching in achieving efficient warehouse operations. However, (Vanheusden et al, 2022) introduce the additional dimensions of strategic, tactical, and operational sectors, covering aspects such as storage rack configuration, technical equipment selection, zone picking, and resource planning. In contrast, (de Koster et al, 2006) focus on the specific challenges of storage assignment, order batching, zone picking, and picker routing. Despite these variations, both perspectives underscore the significance of optimizing order picking processes for effective warehouse management.

2.2.2 Combination of the order picking planning problems

Understanding the combination of order picking planning problems mentioned in the previous part is highly relevant to the research focused on reducing picking time in warehouse operations. By exploring the interactions between these problems, such as storage location assignment, order batching, picker routing, zone picking, and zoning, valuable insights can be gained into improving the overall efficiency of the picking process. By analyzing the joint effects of these planning issues, it is easy to identify key factors that contribute to time-saving opportunities and develop targeted strategies to minimize picking time, ultimately addressing the main research question.

Interactions are defined as the combined effect of two or more planning problems on a performance goal. These interactions can be investigated by considering multiple policies (i.e., solution methods or techniques for organizing a planning problem) for each planning problem and analyzing the effect of these policies on order picking performance (Gils, et al., 2018).

1) **The joint effect of storage location assignment and order batching on order picking performance is significant.**

In contrast to the storage–batching interaction, the relevance of the storage location assignment–routing relationship is less uniformly discussed in articles examining the storage location assignment–routing relationship. In a constrained factorial context, consisting of a limited number of studied policies, it is determined that storage site assignment and routing are unrelated (Chackelson, et al., 2013; Ho, et al., 2008; Ho, Y.C, Tseng, & Y.Y, 2006). Other publications, however, do discover a statistically significant interaction between the storage and route planning challenges in single-block warehouses (Manzini, et al., 2007; Petersen, C.G, Schmenner, & R.W, 1999). and in multiple block warehouses (Theys, et al., 2010). When creating order picker routes, these studies take information about the location of fast-moving goods into consideration. As a result, as next part indicates, the efficiency of routing rules is likely to be dependent on the storage location assignment strategy used (Gils, et al., 2018).

2) **The joint effect of storage location assignment and picker routing on order picking performance is significant.**

Numerous publications examining the combination of batching and routing strategies demonstrate that these planning issues are unrelated (Ho, Y.C, Tseng, & Y.Y, 2006; Ho, et al., 2008), whereas other research has shown considerable performance gains from combining batching and routing. Furthermore, combining route construction while constructing batches leads in significant performance gains as compared to handling the planning difficulties sequentially (Chackelson, et al., 2013). This is because the performance of the formed batch is mostly determined by the length of the established route. As a result, next part defines that there is a considerable interaction between the batching and route planning difficulties (Gils, et al., 2018).

3) **The joint effect of order batching and picker routing on order picking performance is significant.**

Zone picking operations, in conjunction with other order picking planning issues, have received little study attention so far (Gils, et al., 2018), Regardless of its significance in order choosing system performance (Petersen & C.G, 2002), the relationship between zone size and storage site assignment planning difficulties has been studied, although research provide contradictory conclusions about the relevance of the relationship (de Koster, Le-Duc, & Jan Roodbergen, 2006; Petersen & C.G, 2002). Because the zone size determines the number of aisles inside each order picking zone, the zone size is predicted to have a substantial impact on the efficiency of storage site assignment. Furthermore, the combined impact of zone assignment and storage site assignment has yet to be studied. Pick densities in the order picking area are affected by both zone assignment regulations and storage site assignment policies (Gils, et al., 2018). As a result, the zone selection planning issue and the storage site assignment planning problem are likely to be closely associated they are described in next part.

4) **The joint effect of storage location assignment and zone picking on order picking performance is significant.**

Just like the relationship between storage location assignment and zoning, research on the relationship between order batching and zoning is limited. The batching and zoning problems are discovered to be associated by simply comparing whether to batch (FCFS batching) and adjusting the number of zones or not (Petersen & C.G, 2000; Yu, M., De Koster, & R.B.M, 2009). More complex batching regulations are predicted to lessen the impact of zoning on order picking performance since these batching rules enable order pickers to avoid traveling across the full order picking region. Furthermore, storage zone assignment and batching affect the density of picking operations; hence, as indicated in the next part, we predict the zone picking and batching planning problems to be significantly connected (Gils, et al., 2018).

5) **The joint effect of order batching and zone picking on order picking performance is significant.**

Finally, the combined impact of the zone choosing, and route planning issues is unclear currently. It's expected that both planning difficulties will be considerably connected because zoning choices have a considerable influence on the distribution of pick density throughout the order picking region and the efficiency of routing policies is dictated by the distribution of pick densities as described on the next part (Gils, et al., 2018)

6) **The joint effect of zone picking and picker routing on order picking performance is significant.**

The best routing strategy outperforms all specialized routing heuristics combined with all zone choosing approaches. Because routing policies only determine the sequence of SKUs on the pick list, or because SKUs on the pick list are distributed over the order picking area in the same way for all routing policies, the average route length differences between routing policies grow as the pick area of a pick tour grows: By reducing the number of zones, the impacts of the routing rules are somewhat enhanced (Gils, et al., 2018).

A comparison of the sources reveals both similarities and differences in the findings regarding the combination of order picking planning problems. (Gils, et al., 2018) emphasize the significant joint effect of storage location assignment and order batching on picking performance. While other studies (Chackelson et al., 2013; Ho et al., 2008, 2006) suggest an unrelated relationship between storage location assignment and routing, others (Manzini et al., 2007; Petersen et al., 1999; Theys et al., 2010) discover a statistically significant interaction, particularly in single-block and multiple-block warehouses. Additionally, the impact of order batching and picker routing varies across different research findings. While other studies (Ho et al., 2006, 2008) indicate no association, others (Chackelson et al., 2013) highlight considerable performance gains from combining these planning issues. By understanding these diverse perspectives, it becomes evident that the field of reducing picking time involves nuanced complexities and differing viewpoints, necessitating further investigation to establish a comprehensive understanding.

2.3 Practical factors that affect order picking performance and its impact

The practical factors that influence order picking performance are highly relevant to addressing the research question and improving operational efficiency. This section provides valuable insights into the negative impacts of practical factors, such as efficiency, storage capacity, service levels, accidents, and worker well-being. Understanding and accounting for these factors helps optimize order picking processes and reduce picking time, contributing to enhanced warehouse operations.

According to (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022), the practical factors can be divided into four main sectors (see figure 2). These factors represent the negative impact either on efficiency, storage capacity, service level, accidents, and worker well- being, and each of these impacts are caused by practical factors on modelling order picking problems and how to account for the practical factors in existing solution algorithms. (Gils, et al., 2018) state that the order-picking efficiency, storage capacity, service levels, accident rates, and employee well-being were all influenced by the practical aspects described by (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022). Furthermore, an important thing is noted by (Gils, et al., 2018) who explain that efficiency means making the most effective use of resources; as the below practical factors, with the least amount of wasted time and effort.

According to (Gils, et al., 2018), system factors are defined as generally existing attributes of order picking systems in practice that are typically fixed in the short term due to strategic decisions such as layout design and system selection. However, the tactical and operational planning problems should account for system factors to benefit from these strategic decisions. The following system factors can be identified: high-level storage, pick vehicle properties, picker blocking, resource constraint and safety constraint. Humans are the central actors, especially in manual order picking systems. Furthermore, according to (Grosse, Eric , Christoph , Mohamed, & Neumann, 2015) ,the incorporation of human factors in order picking planning is highly relevant in practice and order pickers may pick the wrong product or an incorrect number of these products. These mistakes can have a significant impact on order picking performance, resulting in delivery delays, financial losses, and lower customer satisfaction.

	Efficiency	Storage capacity	Service level	Accidents	Worker well-being
System factors					
High-level storage	•	•			
Pick vehicle properties	•				
Picker blocking	•			•	•
Resource constraint			•		
Safety constraint	•			•	
Human factors					
Physical	•				•
Mental	•				
Perceptual	•		•		
Psychosocial	•		•		•
Picker skills	•		•		
Product and order factors					
Product properties	•	•	•		
Precedence constraint	•		•	•	
Due time constraint			•		
Workload equity	•		•		•
Real-time order arrival	•		•		
Product returns	•	•			
Inventory factors					
Inventory availability	•		•		
Obsolete inventory	•	•			
Scattered storage	•	•			

Figure 2. Impact of each practical factor on order picking performance measures (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022).

Product and order factors contain practical factors related to the type of products that are collected and specific order information. Solution algorithms ignoring these factors related to both orders and products often provide solutions that lack effectiveness since they are mostly infeasible in practice. Consequently, these models overestimate the real order picking performance. Products are retrieved from storage locations to fulfil customer orders. Nowadays, warehouses experience a large variety of products, varying demand for those products, and have numerous ways of determining where products should be stored. The practical factors related to storage issues are categorized as inventory factors as described by (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022)

Notable differences and similarities emerge when comparing the findings of various researchers regarding the practical factors that affect order picking performance. (Gils, et al., 2018) emphasize the impact of practical aspects on efficiency, storage capacity, service levels, accidents, and worker well-being. (Vanheusden, Van Gils, Ramaekers, Cornelissens, & Caris, 2022) categorize these factors into four main sectors. Despite variations in emphasis and categorization. While the researchers share a common understanding of the significance of practical factors, differences can be observed in the specific factors they focus on and the depth of analysis. By considering the collective findings, we gain a comprehensive understanding of the practical aspects that impact order picking performance and can develop effective strategies to optimize warehouse operations.

2.4 Improvements to optimize order picking lead time and efficiency

The quest for improved order picking lead time and efficiency has led researchers to explore various solutions and strategies. This section highlights the findings of two real case studies conducted by different researchers. The first study examines the operations of a tool and garden equipment supplier called Ankor, focusing on storage assignment and routing regulations. The second study focuses on a wholesaler and importer of spare parts and tools, aiming to optimize the order picking process to reduce costs. By delving into these case studies, valuable insights can be gained on effective improvements for order picking performance which helps on answering the research question.

Regarding to the first case study, it was done by (Dekker, De Koster, Roodbergen, & Van Kalleveen, 2004) who summarized the research of Ankor warehouse which is always under pressure to increase its efficiency while dealing with various special requirements in order picking, such as retrieving heavier things first to avoid damage to other, breakable products.

A study has been done to this company and its aim was to find an appropriate mix of storage assignment (assigning items to storage locations) and routing (determining the order in which products should be retrieved from storage to fulfill consumer demand) regulations for Ankor's circumstance. Within the Ankor case study, conventional problem-solving strategies to address this issue have been utilized, overcoming the unique aspects of Ankor's operations. The average route length in the order-picking procedure have been reduced by 31% by focusing on the routing and storage assignment and analyze the operations and layout deeply then choose that best method that fits to the analysis as Ankor adopted a new storage and routing technique by doing a combination of ABC and seasonal demand because of the research (Dekker, De Koster, Roodbergen, & Van Kalleveen, 2004).With Ankor’s traditional methods, travel, picking, and administration time consumed 76 percent of the total time. Reducing travel time makes picking time a higher percentage of the total time, which calls for attempts to reduce picking time as well.

Ankor has reduced picking time by adopting scanners with a shorter response time than the old scanners, which could take several seconds to confirm picks, by picking individual units rather than packages containing several units that had to be unpacked at receiving, and by calculating box sizes accurately, saving on packing time by the pickers. Since the study, Ankor has increased the number of products it carries from 18,000 to 19,000 and the percentage of picks in the tools area from 68 to 80 percent (tools take less pick time than gardening equipment).

Because of all these changes, Ankor reduced the number of pickers it employs from 20 in 2001 to 12 to 15 (depending on demand peaks) in 2002, which saves the company about 140,000 dollars. It is difficult to determine how much of this reduction to attribute to the new storage and picking policies. They played an important role, but the order-picking and administration times also improved as a side effect of this research. Often in practice, thoroughly examining a process highlights opportunities for improvement. All improvements led to a reduction in the number of order pickers of more than 25 percent as stated by (Dekker, De Koster, Roodbergen, & Van Kalleveen, 2004).

While according to (Sinisalo, 2016), who did a case study for a company which is a wholesaler and importer for spare parts, accessories and tools for passenger cars and utility vehicles. This company is affected by the high costs of the warehouse operations, and it decides to optimize its order picking process as much as possible to minimize the costs and make the customers satisfied at the same time. The result of the recommended improvements to optimize the order picking process have been described as the following figure:

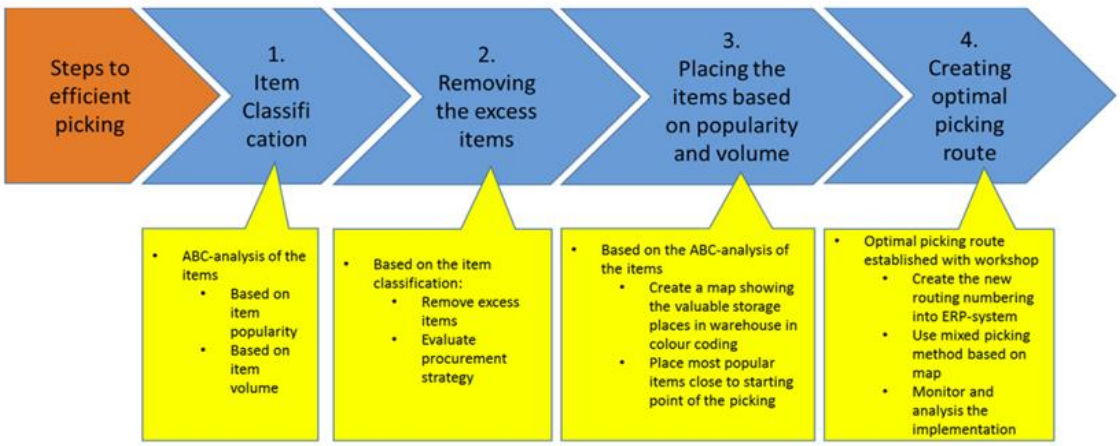

Figure 3. Proposed Improvement plan to the order picking (Sinisalo, 2016)

And as (Sinisalo, 2016) states each part can be described as follows:

1) Begin item categorization promptly and maximize the classification's potential. Classification of items is essential to enhancing the efficiency of the order picking process. Categorization of an item also acts as a basis for several additional activities since most improvement processes are logically dependent on this classification.

2) Through item categorization, the case firm may also tackle the challenge of eliminating long-unsold surplus products. This activity may save money by reducing item handling expenses, which can be accomplished by eliminating unsold products. In addition, the liberated space from the unsold things may be used for new popular items, which may generate a greater profit than the unsold ones. In addition, reducing unnecessary products may make the warehouse more organized, allowing pickers to pick things up more efficiently and saving time.

3) Evaluating the procurement plan is vital for decreasing the case company's inventory levels. Without review of the procurement plan, the instance company's inventory levels may rise to unmanageable levels over time. Capital connected to surplus inventory might be withdrawn and employed for other purposes to increase the example company's current profitability. The case

company's order-picking procedure might be made more efficient by reducing inventory levels. As there are fewer products in the warehouse, they are dispersed across a smaller space. The less area must be traversed during order picking, the shorter the distance the pickers must go. Therefore, the procedure will be faster and more effective.

4) If things are kept in storage according to their popularity, order pickers' routes might be made even more efficient. By putting the most popular goods nearer to the beginning of the picking process, the total distance the pickers must travel may be reduced. During the present picking process of the case firm, most of the picking takes place across the warehouse, which is around 18,000 square meters in size. If popular products are arranged in an area of 10,000 square meters, the pickers' journey distance might be cut in half compared to when things are distributed at random.

5) The new, more efficient picking route should be implemented. It also eliminates problems with enlargement part picking by splitting the enlargement portion into three zones for selecting. A new picking route is insufficient to increase the efficiency of the case company's picking process since the products must be arranged in the warehouse according to their popularity. To increase the efficiency of the selection process, this research suggests putting commodities in the warehouse according to their popularity. This would result in a shorter distance for pickers to go inside the warehouse than is now the case, since the routes used for picking up popular products are traveled more often and so need to be shortened.

This section studies conducted by (Dekker, De Koster, Roodbergen, & Van Kalleveen, 2004) and (Sinisalo, 2016) provide distinct perspectives on optimizing order picking lead time and efficiency. The Ankor study of (Dekker, et al., 2004) highlights the impact of storage assignment and routing techniques, leading to significant reductions in average route length and overall picking time. On the other hand, the case study of (Sinisalo, 2016) emphasizes the importance of item categorization, inventory level evaluation, and efficient picking routes to enhance the overall efficiency of the process. Despite the differences in the specific recommendations because each of them depends on its situation, both studies underscore the significance of tailored improvements to optimize order picking performance and reduce costs for companies operating in diverse industries.

2.6 Conceptual Model

The main important things that are related to affecting the order picking process either time or efficiency are summarized from the theoretical framework on the following conceptual model.

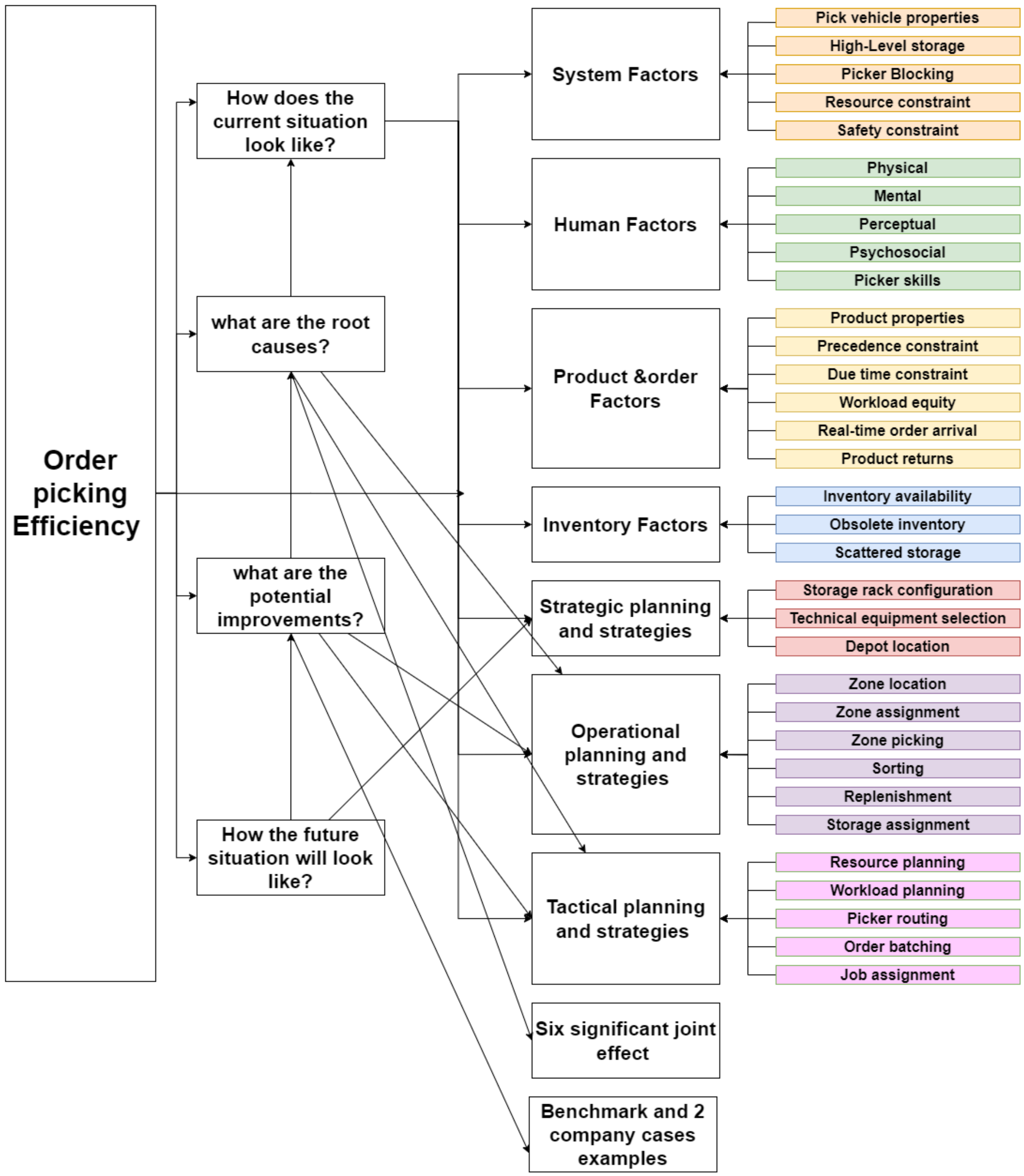

Figure 4. Conceptual Model

3. Research Method

In this chapter, the whole research type is discussed and then an explanation of the research type of each sub-question of this research and methods of data collection and analyzing of each of them. Lastly, the validity and reliability are discussed.

3.1 General Research type

This research requires interviews with employees and managers as a high volume of data and insights need to be collected in order to achieve the research aim. Wide-ranging information is evaluated using tests of performance measurements by work sampling, figures, and research. The history and current data report evaluations are needed too. This research uses a qualitative approach, with a quantitative component, as qualitative approach gives a deeper insight about the process and the applied policies while the quantitative approach gives an insight on process performance measurements. Focusing on the quality and depth of qualitative data maintains it detailed. This allows qualitative research to use small samples to get rich insights.

This method clarifies the dynamics. Qualitative techniques including descriptive method (Bell & Waters, 2014). This study will use descriptive research since it is accurate and objective. A qualitative research design may study many components using different approaches. In the quantitative research section, the data will be collected by physical observations and the data records, then monitor and analyze the history of these collected data as well.

3.2 Research methods

This section will provide an overview of the research type and data collecting and analyzing methods of each sub-question with motivation of how these methods will be performed.

3.2.1 How does the current situation of order picking process of Asyad Express look like?

The current situation defining includes the description of the process, defining the problem, the negative impacts, and order picking performance measurements. To define the current situation efficiently, a combination of qualitative and quantitative research will be done, related to the qualitative research, to clarify the current situation and a better understanding an in-depth interview with the fulfilment manager will be done that will be transcript and using QDA minor.

The questions for the interview will be prepared carefully in advance and it will be open questions, there will be some deeper questions that may occur during the interview. These questions can be found on appendix 6. The interview will be recorded to avoid errors while transcribing it. The transcript will be provided in appendix 7. To analyze the interview content, a program called QDA minor will be used where the common things of the interview can be labeled which gives a better overview and efficient analyzing result. The screenshots of QDA using will be illustrated on appendix 5.

Then, because the number of workers is not high, a survey would not be reasonable and helpful as instead it's better to have a focus group discussion (FGD) which will be made to gain more advanced insight from different perspectives of fulfilment center workers. Then an observation will be made by doing a Gemba walk (Kollenburg, 2019) and experiencing the process by self and doing process time and performance measurements by using both historical data which will be analyzed in Excel file and the findings will be represented on the result chapter as well as using a stopwatch to measure the process time while following the pickers. After gaining the insight and related data from these sources, the gained information will be first compared to each other and then described and then visualized by using different tools as process mapping with all details and specifications, using Swimlane and flow chart. With comparison with the first section of the literature review of the order picking process concept and methods, to clarify what literature methods matches the strategy and order picking process of AEX.

Using the company database and warehouse management system (WMS), all the related reports will be considered. A sample of the orders will be taken in terms of measurements and analysis. This samples and other measurements as process time, distances, travel time, order volume, accuracy rate and other related measurements will be recorded in an Excel file and then visualized into Diagrams, Bar, and pie charts to provide an overview of the collected data and measurements with combination of the existed company data if founded.

3.2.2 What are the root causes that lead to order picking taking a long time?

After answering the previous sub-question, all the data needed for analyzing is already collected, here is the time of analyzing the collected data, first is to analyze the interviews and FGD's then analyze the collected data from samples, measurements done on previous sub question and Gemba walk using the done Excel file. The factors that have been found will be analyzed by Pareto chart to determine the 20% of them that has an effect on 80% of the process as there are multiple factors and some are not having a big impact on the issue as well as considering the research available time it's not possible to focus on all factors, therefore, Pareto analysis is a useful tool to distinguish the top factors that need to be focused on. After analyzing all the data from different methods, all the bottlenecks and causes that are found will be visualized using a fish bone diagram (cause and affects analysis) to give a better overall insight with all possible causes and effects as well as according to (Kollenburg, 2019) the Fishbone Diagram stands out as a better tool than others for problem analysis and root cause identification due to its visual representation, comprehensive approach, facilitation of brainstorming, cause-and-effect analysis, and problem prioritization capabilities.

After visualizing the overall causes, it is time to know the root causes of these visualized causes, and this is by using the 5 whys root causes analysis method. In terms there were certain things that unclear and prevents reaching the root cause either because of the company sources access limitations or anything else, an extra interview will be made to investigate more. The founded causes and root causes will then be related to the literature review to compare it and have more insight.

3.2.3 What are the potential improvements to make the picking order process faster?

Now all of the root causes are clear, so this sub-question, will come up with an strategic solutions and efficient improvements based on the root causes, for this sub-question it will be a qualitative research as to use all of the literature review, and have a meeting with the manager and workers to discuss with them different alternatives in order to choose the best of them from the point of view of the employees where it can be accepted and make sure they can cope with change and at the same time from the point of view of the analyzed data. This approach makes it easier to get a comfortable discussion with different employees and gain a faster insight with different perspectives instead of just making an interview with the manager or certain employee which will take more effort and time regarding to scheduling and preparing for questions as well as in terms of improvements, interview can give a limited points of view whether the proposed improvements are sufficient or not. This will be followed by an implementation plan for the improvements using a combination of Plan-DO-Check-Act (PDCA) and Gantt chart.

3.2.4 What will the future situation look like after implementing the improvements with consideration of measurements?

To make the suggested improvements more relevant, this sub-question will answer how the future situation will look like. So, the future situation will be described, and the new or eliminated process will be designed, the future situation process mapping will be visualized by a flow chart as its preferred over other tools due to their visual representation, comprehensive overview, simplified communication, and identification of bottlenecks. Then there will be calculations of time future situation process performance followed by a comparison between the current and future situations. Then a risk analysis and failure modes and effect analysis (FMEA) will be used to know the risks when implementing the improvements. This is important to be able to control the potential risks that might occur during implementations well as to think in advance about how to deal with them to avoid any delays later. In terms of whether there are any further recommendations, it will be described in the recommendations chapter.

3.4 Validity and Reliability

In terms of doing research. One of the most important things is to be aware that the collected data is valid and reliable enough to have an efficient result and acceptance (Bell & Waters, 2014). In terms of validity, the whole data that will be extracted from the company database or from self-measurements will be double checked, and the questions which will be asked in the interviews and FGDs is prepared in advance strategically and logically. This interview will be recorded and transcribed on appendix 7, and the questions can be found on appendix 6, therefore, all these tasks contribute to increasing the validity of this research.

In terms of the Theoretical framework which then used as a pack up for the result chapter are all gathered from a valid and trusted sites and citations that include the direct data and knowledge that leads to the facts and true theory (Bell & Waters, 2014). When selecting sources from Google Scholar and library books references, much time was spent to find the best reliable and valid sites to search from, as can be seen in the theoretical framework that the sources have been mentioned, and most of them are case studies written by experienced authors in these fields. In terms of internal validity (Kollenburg, 2019), both qualitative and quantitative research will be performed using interviews, survey and FGDs for qualitative and Gemba walk, observations, process performance measurements and historical data for quantitative. Because there are certain questions that need a qualitative research technique, in this case open interviews, to be answered. And there are problems that need a quantitative approach since numerous figures and computations must be studied and displayed using various programs such as Excel to reach an answer.

A Gantt chart have been done on the planning phase for this research with all tasks and phases that need to be covered, within this chart a meeting with the company supervisor will be held after each phase to discuss the progress and check the work whether it's valid or not, for the same reason, a meeting with the Hz university supervisor will be done as well.

Finally in terms of reliability (Bell & Waters, 2014), it will be assured by asking the same sort of questions to different respondents, which implies that the findings will be less reliant on chance. Respondents' replies will not be influenced by others since they will be questioned independently. For the collected data and measurements from investigating the workers' picking paths and taking order samples, it will be done from two to three times to ensure that the gained results are close to each other. This also increases reliability, which is a condition for the validity of this research.

3.5 Methodologies summary

The below figure gives a clearer overview of all methods will be used:

PDCA	DMAIC	sub questions	elements	research approach	research type	data collection methods	visualizing/ analyzing methods
PLAN	Define	current situation	problem description	Desk and field	qualitative	interview, picking &process time observations -Gemba walk	5W1H , QDA
			problem negative effects description			Survey	VOB
			Description of the policy and procedure			interviews, FGDs, picking &process time observations & Gemba walk, company documents & records	Swimlane, flow chart, using Literature review
	Measure		measurements of current process performance	Desk and field	qualitative & quantitative	historical data records, Time and Motion Studies, work sampling, WMS database and picking &process time observations	calculations , visualizing by suitable charts, graphs, tables and diagrams & Spaghetti diagram for path visualization
		root cause analysis	main bottlenecks based on the measurements				pareto analysis
	Analyze		analysis of the bottlenecks causes	Desk and field	qualitative & quantitative	Interviews, FGDs, historical data records, Time and Motion Studies, picking &process time observations, work sampling, WMS database	fishbone diagram
			root cause analysis				5 WHYs
DO	Improve	Potential improvements	identify improvements	Desk	qualitative	Interviews, database	PDCA , Gantt chart
			implementation plan				
		Future situation	future situation description	Desk	qualitative	interviews & database	flow chart
			future situation performance measurements	field	qualitative & quantitative	process simulation/ pilot testing if possible, Manager Feedback	calculations , tables
CHECK	Control		comparison between future and current situation				
ACT			risk management & KPIs	Desk			FMEA & KPIs matrix

Figure 5. Methodologies summary

4. Results

In this chapter, the focus is on presenting the research findings pertaining to the order picking process in the case company's fulfillment center. This chapter is structured to firstly provide a description of the current situation and bottlenecks, followed by a thorough analyzation of root causes. Subsequently, the potential improvements and implementation plan will be discussed, highlighting their impact. Lastly, the envisioned future state of the order picking process will be outlined. Through data analysis from field observations, interviews, and process measurements, key challenges affecting lead time and customer satisfaction will be identified. The forthcoming sections will delve into each aspect in more detail, presenting the research findings and their implications.

4.1 Current situation

This subchapter presents the current order picking process. It identifies the research problem, discusses its negative consequences on productivity and process lead time, and investigates policies, procedures, and process mapping to visualize workflow and identify inefficiencies. Process performance measurements will be provided which then will reveal the bottlenecks. This subchapter serves as a foundation for further analysis and improvement initiatives, providing a clear understanding of the current state of the order picking process.

4.1.1 Problem identification

In this section the problem will be identified by using the information gathered from the meeting and interviews and the gathered data from Gemba walk observations. The gathered data outcome will be structured on this section by using the 5W1H method which identifies the problem clearly and taking different aspects into consideration by answering the following questions:

- Who is involved in the order picking process?
- What exactly is the problem and what can be seen?
- Where does the problem occur?
- When did the problem start?
- Which objects are affected by the problem?
- How does the problem develop and how much damage has it already caused?

WHO: Starting with the first question. The order picking process can be affected directly by the workers and pickers, as they have a direct interaction with the process and any decision or action, they take it affects the process and its lead time, either by what path the pickers choose to pick the order or by the action or mistakes done by them. Factors as skills and workers motivation and workload distribution between the workers may affect the process as well. Furthermore, the managers are also involved as the instructions given by them to the pickers decide whether the process works good or not. The case company's clients who are storing their goods on the company's fulfillment center are also involved, as the information accuracy and type of goods as well as the order timing and special order requested by them can delay and affect the picking process. The last mile(LM) team and transportation department are also involved, part of the picked orders will be handed to LM and the other part to transportation based on order address. The order picking times is limited depending on the driver's departure times for delivery as these departure times are part of a big network of the whole country and these drivers are taking with them Oman post orders as well and distribute it daily to other provinces. This means that the driver's departure times cannot be scheduled to fit the fulfilment center orders time and picking process, instead the orders and picking process is timed to fit the departure times.

WHAT: The order picking process which takes a long lead time is becoming more serious issue by time since the order volume is getting higher year by year, fewer orders can be processed within a given time frame, limiting the overall output and efficiency of the operation which leads to dissatisfaction by the clients due to the delays, adding to this, as what have been seen by Gemba walk, most of the workers shift time was spent on the order picking process, they are picking the orders without a certain route , while if the order picking process became shorter and time is saved, the workers can then focus on other tasks as inventory accuracy and efficiency. Beside these Lengthy order picking times disrupt the overall flow and efficiency of the fulfillment center. It creates bottlenecks, congestion, and inefficiencies in other related processes, such as packing, shipping, and inventory management. Not only on the processes itself but also on other departments as the stamp department who sometimes need the stored stamps urgently as well as LM and transportation department.

WHERE: The company building contains six warehouses/ stores, this party logistics (3PL) warehouse, temperature control warehouse (fulfilment center), mezzanine, 2 stamps stores and one special client store. In fact, the order picking issue occurs on all of warehouses except the 3PL warehouse as it's different and managed differently as it provides another type of service compared to the fulfilment center, the mezzanine is new and still empty but it will have the same process as the fulfillment center so this research can be useful for future mezzanine research, and the stores are private and containing a high value items and considered as an exceptional case. So, the focus will be only on the fulfilment center where the highest percentage of the issue occurs as it is the most place that has a workload and more optimum data to be gathered.

WHEN: This problem has been noticed recently, less than a year, because the AEX company is not old, it was established in 2019, by time the management changes, the clients who use the company service are changing, the company is getting more bigger and known which lead to higher workload and order volumes. Although the company used to maintain and try to control this change, recently it became more noticed, and the situation worsened. There is no action that has been taken to deal with this problem yet as in the last years, the company has been working on other projects and the management layers have been changed a few times, taking into consideration the time and workload as well.

WHICH: Beside the customer satisfaction, orders accuracy, operational efficiency and productivity, there are no physical objects effected by the issue have been noticed.

HOW: The problem results in delayed order fulfillment, impacting promised delivery dates and customer service levels. According to customers' feedback they are experiencing frustration, dissatisfaction, and loss of trust in the company's ability to deliver orders in a timely manner. It creates bottlenecks and congestion in the fulfillment center. It disrupts the overall flow of operations as well causing inefficiencies in other processes and hinders the overall operational performance. In addition, it contributes to increased labor costs. More time spent on picking orders means higher labor expenses, reducing the profitability of the operation and inefficiencies in the picking process may also result in additional costs associated with errors, rework, and returns.

Finally, by taking what can this issue cause and what it has already caused into account, this research issue will become even more serious if there is no action taken, as the company are expecting to grow by near future and its expecting to make contracts with new clients especially for the new mezzanine which will make the workload even higher.

4.1.2 Negative effects of the problem

The previous section presents the problem identification according to the interview and observations and it has mentioned some of the damage that this issue caused. To make this more relevant and considering different dimensions of the issue impact, as the customers information and their complains are private it is not possible to reach them, but some of the clients are some of the company departments itself, beside the clients the issue impacts other departments processes causing bottlenecks. Therefore, it is much wiser to conduct a small survey and send it to employees from different departments to determine the impact of this issue into other business departments including departments who are storing items on the fulfilment center, the survey outcome will be presented by using voice of business (VOB) method.

The survey was very simple just to get fast responses and to have a background of the impact, there are three main questions were asked which are:

1) What is your department name?
2) Out of ten, how bad is the order fulfilment speed affecting your work within your department?
3) How did the order fulfilment speed affect your department?

It can be noticed that the employees haven't been asked about the long lead time of order picking process itself, as they don't know what is behind the curtain, they don't know the speed of order picking process, or receiving order or sorting and packaging, they only know the order fulfillment in general which is what they receive.so they were asked about the speed of order fulfilment even without mentioning if it really takes long time or not, this allows the respondents to give honest responds and gives the possibility to take any positive responds into account.

The survey was sent to four employees of each department (only the average of each department responds will be presented), the LM, transportation, stamps, and Oman post operations departments. The outcome of the survey is represented in the following table which clarifies that these departments are really suffering from delayed order fulfillments.

Table 1. VOB Survey result

Question 1	Question 2	Question 3 (summary)
Last mile department	7	- Delays on starting their operations. - Affects productivity. - Receiving items with wrong labelling. - Pressure by management to increase efficiency.
Transportation department	8	- Affects the driver's departure times. - Affects productivity & efficiency. - Did not meet customer delivery time commitments. - Unfair workload distribution, some shifts get a lot of orders and some less due to order delays.

Stamps department	7	- Sometimes cannot meet clients' orders on time. - As stamps are picked sheet by sheet and sometimes, they can be small pieces the number of errors is high. - Sometimes an urgent letter that needs a certain type of stamp is required, any delay in urgent orders costs a lot.
Oman post operation department	6	- Some of the operation tools, cloths, boots are stored on the fulfilment center, sometimes the operators cannot start their shift unless they meet the safety rules, as wearing boots for instance, delay on getting this item will delay the operator work.

4.1.3 Policy and Procedure

This section will present first the work policy of orders fulfilment and focus more on the order picking process and how it is applied by using the outcome of the interview, FGDs and observations. The outcome will be presented by using the theoretical background. Therefore, this section will explain the company's elements described in the theoretical background, fulfillment Centre layout, strategic, tactical & operational plans, order batching method, storage assignment and routing method. Following by a description of the order picking process.

4.1.3.1 Policies

Due to privacy purposes, not all the policies are mentioned, only some of the policies which have a direct relation to the order picking process will be presented which are as follows:

- Stock is easily accessible and identified through SKU label.
- Stacking only according to allowed stacking limits; to avoid any damage material and endanger personnel.
- Goods are stored based on categories.
- Any order without advanced shipment notice (ASN) created in advance will not be received.
- New stock should be put on the shelf in a proper way to avoid falling and using the maximum space possible.
- Stock total weight should not exceed the shelf max load.
- All items should be labeled with the SKU and barcode (QR code is not accepted).
- New stock should be put on the shelf in a proper way to avoid falling and using the maximum space possible.
- Picking routes should be well organized to avoid conflicts and minimize wasted movements.
- Picking should be based on picking instructions.
- Customized packing to be done in accordance with client's standards.
- Every pick should be performed against WMS order.
- Orders should be placed in the Packing Stations.

These policies might affect the order picking process if it is not done in the right way, therefore, these policies will be examined and measured whether it's done correctly or not. Only the policies which are not done correctly will be presented later in the performance measurements section.

4.1.3.2 Fulfilment center layout

Before presenting the fulfilment center layout itself, it is much wiser to illustrate the whole operation plan, this gives better understanding of other operation department locations that are connected to the fulfilment center as the LM and transportation departments and how far are them. Also, it shows the gates and clarifies that the fulfilment packaging areas and desks where the WMS is used are outside the fulfilment area. Each number shown on the layout below will be determined to which area it refers and then the fulfilment layout will be presented itself.

Table 2. Building Layout areas references

1: Fulfilment Center	**6: Last Mile**
2: PS (3PL warehouse)	7: Transportation
3: Mezzanine	8: Fulfilment Center Packing area
4: customs	9: Fulfilment Center Desks
5: Oman Post operations	Grean areas: Gates

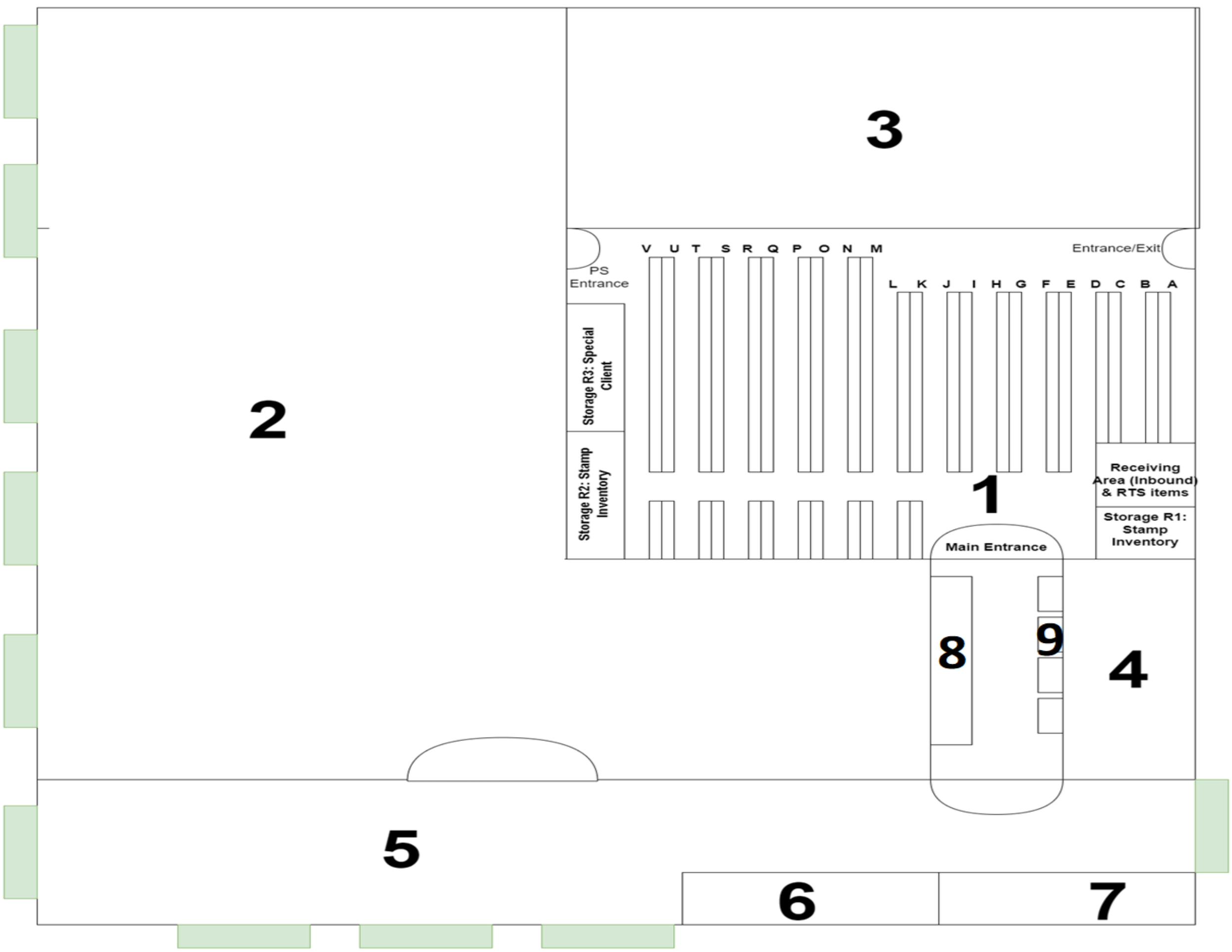

Figure 6. Company layout overview

The following Layout represents the fulfilment center layout, the racks are labeled from A to V, each rack has six rows, all the shaves are coded and labeled. Regarding shelves labels and locations name, if the shelf is located on rack E on the first column and the first row, the location name will be "TC-E01-A". AS Tc represents the fulfilment center area, E is the rack location, one represents the rack's column number and A represents the rack's row. This makes it very easy for the pickers to understand the locations and find them quickly. The area highlighted by yellow represents the closest points to the desks and packing area while the highlighted in red are the far ones. More details about the picking processes, aisles, racks height and shelves sizes and all related measurements will be discussed in the next section.

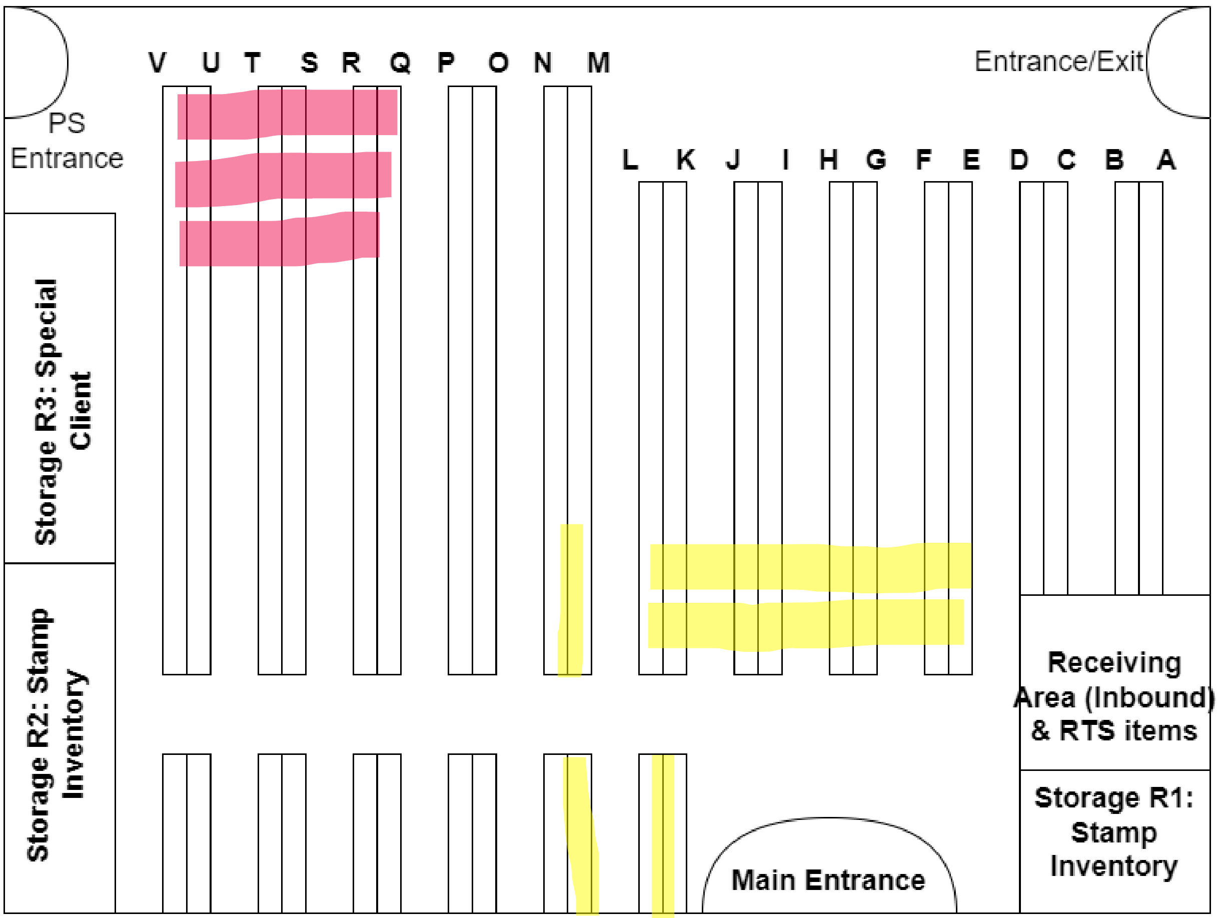

Figure 7. Fulfilment Center layout

4.1.3.3 Fulfilment center work Plans

Strategic plan:

- Storage rack configuration:
    - Temperature control center (TC) space: over 1200 m2
    - Number of shelves locations: 1711
    - Racks are labeled from A to V, each rack has six rows.
    - Racks height: 3 m
    - Storage shelves sizes: 90*45*54 cm
    - Pick aisles breadth: 1 m.

  - Cross-aisles breadth: 1.8 m

- Technical equipment selection: there is no technical equipment used for the picking process.
- As which can be noticed on the layout, the number of columns per rack is different, so the following table shows how many columns per rack:

Table 3. Number of columns per rack

RACK	TOTAL COLUMNS	RACK	TOTAL COLUMNS
A	6	**L**	21
B	6	**M**	21
C	6	**N**	21
D	9	**O**	21
E	11	**P**	21
F	13	**Q**	21
G	14	**R**	21
H	14	**S**	21
I	14	**T**	21
J	14	**U**	21
K	17	**V**	21

Tactical plan:

- Zone assignment & location:

Table 4. zones areas and product categories

LOCATION	ZONES
	Products categorization.
A-B	Documents.
C-D	Perfumes.
E	Medicine.
F-G	Stamp.
H-K	Accessories.
L-O	Cosmetics.
P-S	Food
T-V	Store (fulfillment resources).

- Zone picking using product properties assignment policy, the products are classified into categories according to its types as the above table, the customer orders are routed via all pick zones sequentially. As if zone 1 is rack A & B, zone 2 is rack C & D first the picker will pick sequentially from zone 1 then from 2.
- Sorting: after the pick tour which is not included on the process of picking (pick-while-sort).
- Replenishment: there is no replenishment unless the client delivered a new stock as an inbound.

Operational plan:

- Resource planning: there is no resources or equipment are used, the pickers get a paper of packing list, and they start to pick manually, the only resource they use while picking is the trollies which, there is no shortage of trollies, instead there is more than needed as some are just stored on the receiving area. The sixth rows of each rack are always empty for safety reasons, so it is not utilized. The first four rows can be reached easily, there are 2 ladders available if needed for heavy items stored on the fourth rows or fifth rows of the rack.
- Workload planning: the customer orders might be retrieved if there is no ASN, no clear data, no remaining stock.
- Job assignment: assigning orders to pickers is done by distributing the work fairly to the available pickers, assigning job is according to the clients ID for instance if there are 3 clients and each clients made 10 orders and there are 3 pickers available, each one of them will handle one client orders.

4.1.3.4 Storage assignment method

The client rents a whole shelf to store his goods, the rented shelf place is determined depending on the client type of product according to the above zone table, as for instance chemicals and medicines cannot be stored with food items in the same place. Then whenever the client brings a stock of that product it will be stored on that rented shelf.

4.1.3.5 Order batching method

There is no batching method applied from those mentioned on theoretical framework, the current method is the orders are picked in 3 batches according to the following schedule:

Table 5. Batching schedule

Batch	From	To	Remarks
First Batch	8:30	9:30	Muscat shipments
Second Batch	12:00	13:00	All shipments
Third Batch	16:00	17:00	All shipments

The first batch is the most important one as all the picked orders are only for Muscat shipments, the capital city of Oman where the fulfillment center is located. 70% of the orders are considered Muscat shipments. So, the most workload is for these shipments which are picked on the first batch. If the order is for Muscat shipment the client must make the order before 8:00, then at 8:30 the pick list is printed and all orders for Muscat shipment will be picked. Then deliver it to the LM after 9:30 to deliver it on the same day. If there is no time to pick all the received Muscat orders on the first batch, it will be picked on the second batch but then it will not be delivered the same day.

The company is not really fixed on the timing of the second batch and the third batch as the orders can pick through the day at any time because of the increasing order volume and workload as well as orders will be delivered on the next day after picking and packing them. The first batch timing cannot be easily changed because it's connected to the transportation and LM drivers' departure times as the drivers are taking with them both items that will be delivered door to door and items that are delivered to Oman post offices where then the customer pick his postal from.

All the drivers' times and routes of different cities are scheduled accurately and connected to each other, any change or delay may affect the whole chain. This means that the focus will be on the first batch as the highest order volume is there as well as it is limited to a driver's schedule, the orders need to be collected within one hour from 8:30 to 9:30 so no Muscat orders will be left for the second batch which will be delivered on the next day. Although the focus will be on the first batch but making it possible to handle the first batch order volume within less than one hour will be applicable as well for the other batches which even contain lower order volumes.

4.1.3.6 Routing method

There are no routing methods applied, the pickers are moving randomly according to the picking list SKU's sequence locations. Later this will be measured whether it is really having a big impact percentage on the process or not comparing to other founded factors.

4.1.3.7 Order picking process map

Before presenting the order picking process map itself, the order fulfillment Swimlane will be illustrated to have a clear overview of the whole process starting by clients making orders and ending by handing orders to LM team. This Swimlane will not provide all the steps details, instead only the main steps will be shown to get a simple understanding of the process. Then the order picking part will be presented using a flow chart process mapping method for in-depth details.

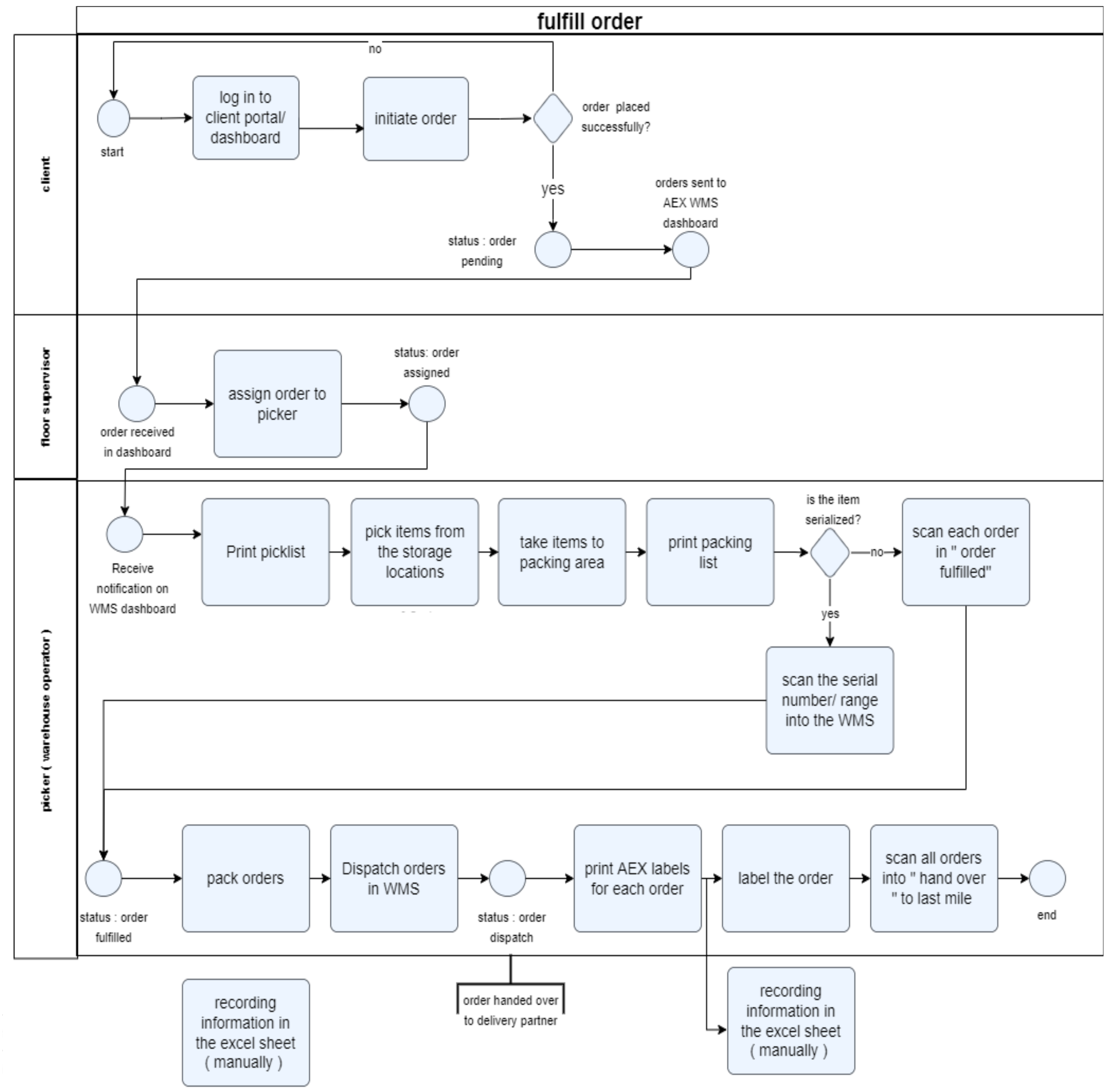

Figure 8. Order fulfilment process SwimLane

After presenting the Swimlane that describes how the client creates the orders which then will be received, picked and packed and then hand it to the LM team to be delivered to the customers, the flow chart below illustrated the steps of order picking process, the process starts by receiving the order from the client and the process will not be considered done until the orders statues on the WMS changed from assigned to fulfilled and it can't be fulfilled if the items are wrong so the workers must check the items first as it's described on the chert. The time of each process step will be measured in the next section.

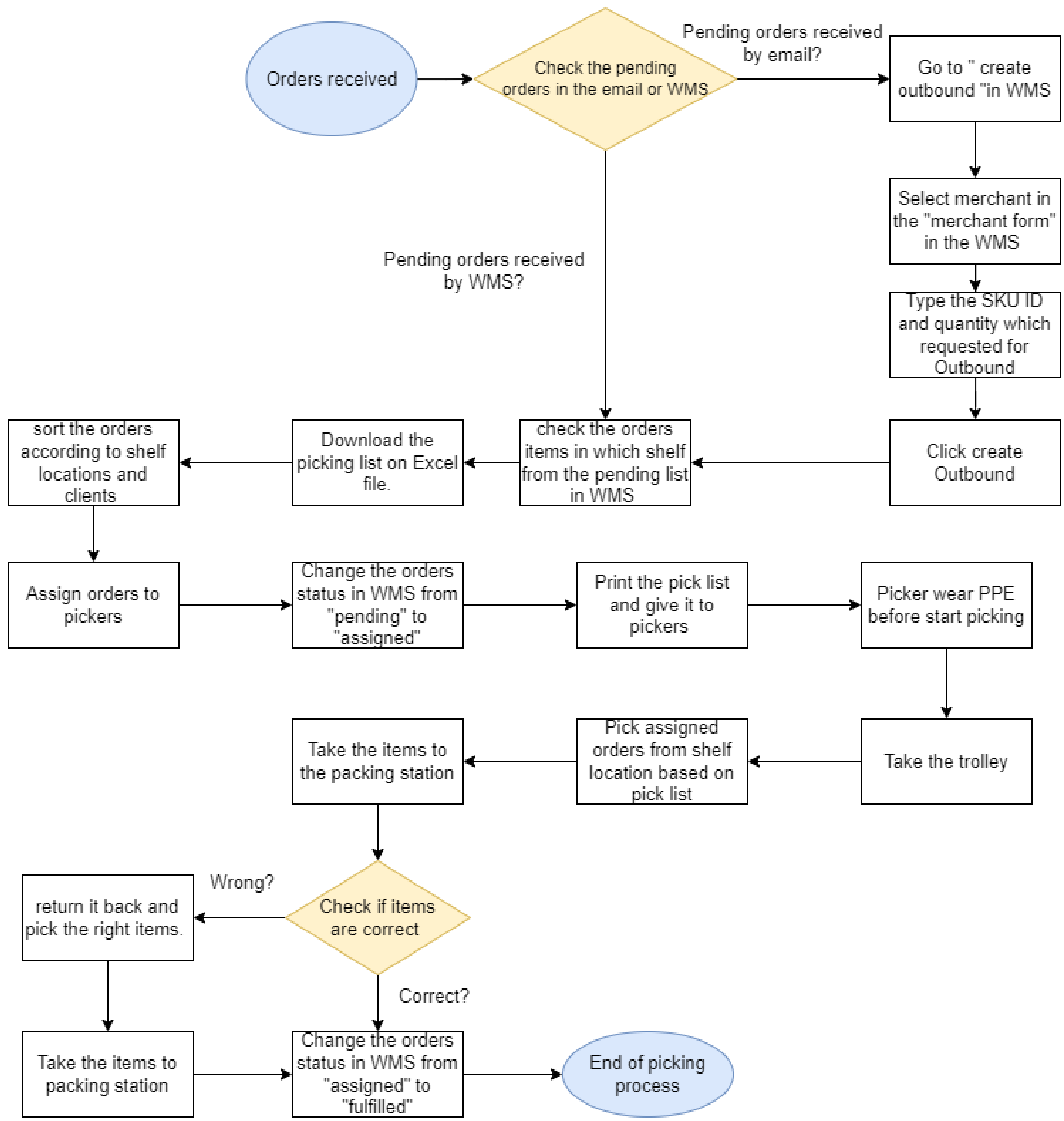

Figure 9. Current situation order picking process flow chart

4.1.4 Order picking performance measurements

After describing the current situation in detail and addressing most of its elements to maximize comprehension and gain a thorough understanding, this section will examine the order picking process's primary measurements to clarify the performance and efficiency rate of the order picking as well as its duration. These measurements were selected based on the previously specified policies and the theoretical background of the most important factors to consider, combining them with what was observed during the Gemba walk and acquired through interviews with employees. This section examines the following measurements, which are depicted by charts and graphs:

Table 6. Performance measurements

1) Order volume.	5) Travel time
2) Order complexity.	6) Order picking Processing time.
3) Accuracy rate.	7) Pick density.
4) Picking path performance.	

A portion of the collected database for these measurements was extracted from the WMS, while the remaining portion was collected by work sampling, monitoring the process, and Gemba walk as there are no records on WMS for some measurements. Even for the WMS database, an additional step was taken to take samples and monitor the process to determine if the data is identical to increase validation. As evidence and for a better comprehension of the type of data used to derive the results of these diagrams and charts, screenshots examples of collected data will be provided in the appendices.

4.1.4.1 Order volume

The below table determines the types of measurements of this part and its outcome, the taken database timeframe is from 1/4/2022 to 1/4/2023 except for the yearly change measurement which is from April 2020 to April 2023:

Table 7. order volumes

Average daily first batch order volume	178 orders
Average daily first batch quantity volume	436 pieces
Average 2&3 batch order volume	105 orders
Average 2&3 batch quantity volume	206 pieces
Average daily order volume	283 orders
Average daily picked SKU quantity volume	642 pieces

It's clear that the first batch volume is higher than second and third batch together, the reason of this that the first batch is all for the orders that will be shipped within Muscat province which is basically the place where more than quarter of the country population live as well as most of the company's client's businesses are located in Muscat, this leads to a high order volume from this place which will be handled on the first batch.

The line chart below illustrates the average order and quantity volume trends over the past 12 months starting from April 2022 to April 2023. It is obvious that the order and quantity volume is increasing over time as discussed earlier. The reason for this is the company is not as old as it was established five years

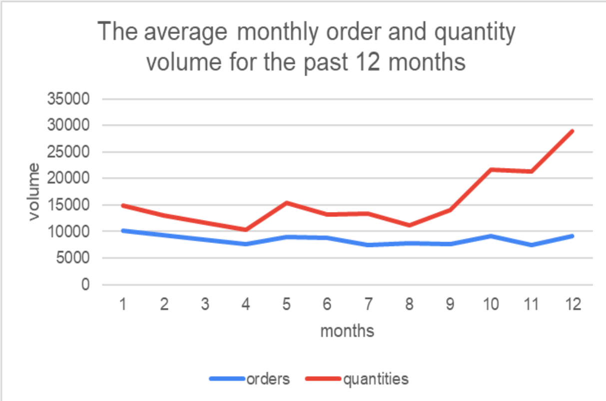

Figure 11. The average monthly order and quantity volume

Figure 10 Average yearly change in order and quantity volumes

ago, and it is growing over time and contracting with more and more new clients. Some clients have fast-moving goods with high volumes. it can be noticed as well that the red line is rising on the past 12 months quantity volume chart, while the blue line is only slightly rising and almost stable, the reason of that is most orders contain multiple quantities, in terms on seasonal demand the client might set one order with many quantities that has been increased due to seasonality. The above bar chart shows the average number of orders and quantity volume for each year from 2020 to 2023 with the trend line shown. The volume is increasing over time, which proves the reasons mentioned above.

4.1.4.2 Order complexity

This measurement will determine the percentage of orders complex orders and compare it with the standard orders, as complex order requires additional time to be picked. Adding to this, it will help to determine where the focus will be, as if the complex orders percentage is significantly higher than the standard orders the focus of reducing lead time will be on complex orders so then the improvement result can be higher and vice versa. There are two complex order types founded which are the orders that contains items located on a high shelf location and requires a ladder to reach them (will be defined as type 1) and the orders that contain items require an additional item to be picked as brochures or the packing material of the client itself (will be defined as type 2). Otherwise, all the rest items can be reached easily, and it does not require additional actions as there is no heavy items or big size items stored on the TC has been discussed earlier on zones part, items are small and light as food ingredients, medicines, and accessories and so on.

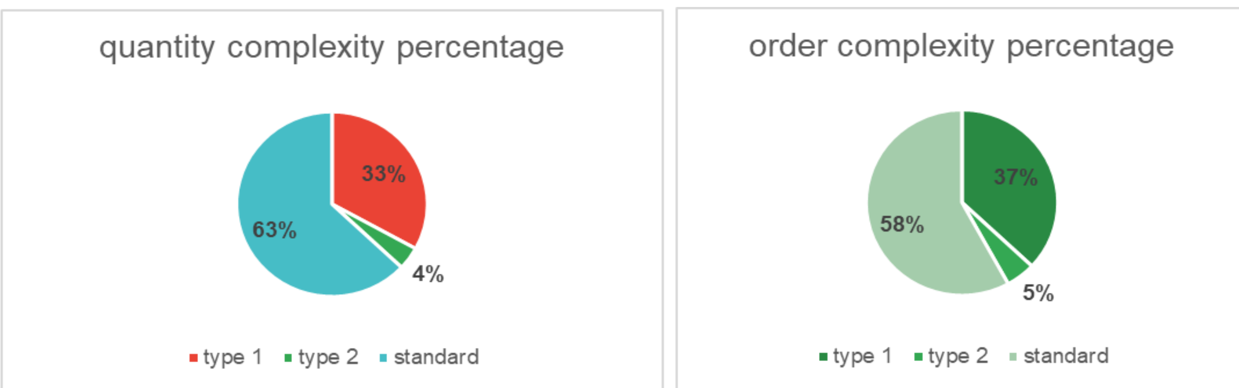

Figure 12. Complexity percentage pie chart of orders and quantities

The above pie charts show the percentage of average daily orders and quantity of each type. It is obvious that the standard orders are 58% of the total daily orders and the quantities are 63%, type 1 still considered high as it's more than the half of the standard orders and type 2 orders considered low, so the only focus will be on both the standard orders and type 1 orders.

4.1.4.3 Accuracy rate

This measurement will determine the volume and percentage of the items or orders that are picked incorrectly which then will be returned to the shelf locations and the right items will be picked which will take an additional time that is considered as a wasted time. The pie chart below shows the percentage of both wrong picked orders and correct picked orders out of the total average daily picked orders. It is clear that the accuracy rate of correct orders is 83% while the error rate is 17%.the main reason that there is a high incorrect picking is because the process is done manually and there is a human error as well as similar products with unnoticeable differences as size or similar SKU codes with only one number difference.

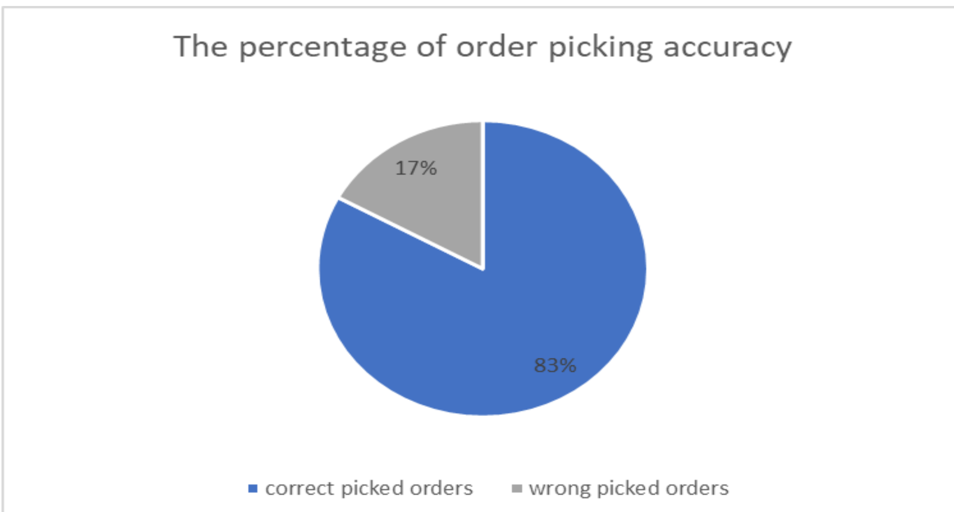

Figure 13. pie chart of order picking accuracy percentage

4.1.4.4 Picking path performance

In terms of picking path, this is highly related to the pickers. The fulfilment center has 6 pickers, but it can be only assigning 2 pickers for each batch because the workers have a schedule of the task that they need to do and there is a high workload as there in order need to be picked from the other warehouses and stores as well as receiving inbound, packing, dispatching, cycle counts and inventory management tasks. Therefore, only 2 pickers for each batch and the rest pickers are sent to help other workers with other tasks. As has been discussed with the fulfilment manager, the company is currently developing new projects and wants to save money as much as possible to be invested in these projects. Therefore, the company do not want to spend money for additional workers and their wages as they are trying to manage the tasks with the available workers and in case there is a seasonal demand or an increase in workload, the company hires workers only for the needed hours to lower costs.

As there is 6 pickers and three batches; two for each batch, the data has been collected by monitoring each picker separately, so 6 picking paths of the 6 pickers were monitored daily for one week which is 5 working days by just writing the starting point and the location the pickers went sequentially until the picking tour ends. Then all the picking paths are visualized on the spaghetti diagram below which is in total 30 picking paths (6 paths per day, in 5 days its 30 in total and all are visualized):

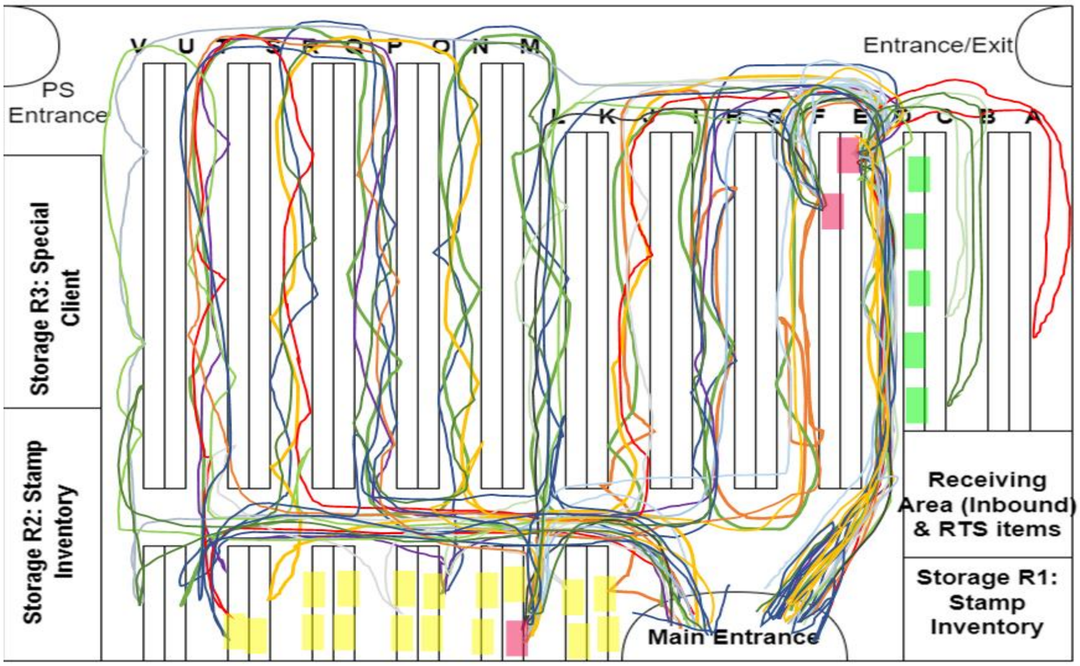

Figure 14. Spaghetti Diagram of picking routes

The aim of this diagram is not to monitor each path, it's only to have a fast glance on the area that has more picking pressure, that's why its visualized on a simple way. It is clear from the Spaghetti diagram that there are some shelf locations which contain fast moving goods as it's almost that in every picking tour these locations are visited. These locations are highlighted in red on the diagram which are in rack E, F &M. This can be easily noticed by looking into the locations areas where there is a high density of lines compared to other locations.

Furthermore, the locations highlighted in yellow are close to the entrance but there is little flow. It is obvious as well that the aisle between D and E is one of the most visited aisles but there are no items picked from rack D which is highlighted in green. All these highlighted things lead to low picking path efficiency. These issues will be described later in the bottlenecks section.

During data collection it was noticed that the pickers have almost similar movements, after investigation it was clear that the pickers are following the sequence of the picking list no matter if it is a shorter route or not. The picking list orders locations are sorted sequentially according to the rack label starting from "A" ending by "V," in some cases, some pickers don't follow the exact picking list sequence as they find a faster route, but this happens rarely compared to how many times they are following the picking list. The reason they are following the picking list is that there are too many orders, and they do not want to confuse as going to rack M for instance then N then return to M, they prefer to end each rack order then move to the next.

4.1.4.5 Travel time measurement

As there are 2 pickers per batch a sample of 15 orders with different shelf locations from each picker were taken to do this measurement, in total 30 samples. The route that each picker takes while picking the order was recorded, then the distance was measured from location to the other based on the route, the velocity of the pickers is 1 second per 50 cm, according to these data the average distance was determined, and then average travel time was calculated. The collected database and calculations of this measurement will be found on appendix 1 as a screenshot, the outcome of the calculation is that the average travel time of order picking process per shelf location is 17 seconds.

4.1.4.6 Order picking processing time

The fulfillment process consists of order receiving, picking the order, sorting, packing and then handing it to LM. Most of the time spent fulfilling the order is on the picking process. Adding to this, other processes are simple and do not take time as well as it is not within the scope of this research. The focus will be on order picking itself so the order fulfilment cycle time will not be considered.

A sample of 100 orders were taken by recording the starting time of the picking process and the ending time for each order. Then the duration of each process was extracted, and the average time was determined. The following table determines the average time taken in seconds within each process step for one order that contains only one SKU quantity, the total processing time for this is 268 seconds.

Table 8. Current situation average standard order picking step times

step No	Process step	Av. Time (s)
1	check WMS pending orders	26
2	check the orders items shelf locations	23
3	download picking list on Excel file	9
4	add up together the quantities of the same client and same SKU but different order by using Pivot table	36
5	sort the orders according to shelf location	8
6	divide orders and prepare it in a pick list form to assign it to pickers	16
7	change the statue in WMS from pending to assigned	6
8	print two pick lists for the 2 pickers	32
9	give the pick lists to pickers	5
10	picker wear PEE	11
11	picker move to receiving area to take the trolly	14
12	picker check the order location on pick list	3
13	picker move to the shelf location with the trolly	17
14	picker search for the item by checking SKU code	9
15	Picker picks the items and put them on the trolly	2
16	picker check the picked quantity	1
17	picker take the trolly to the packing station	41
18	checking the order SKU/quantity/condition if correct	2
19	change the statue in WMS from assigned to fulfilled	6
Total time		267

The above table represents the standard process. It can be noticed that average travel time between locations is 17 while when going to packing area its 41 the reason is because usually the picking trip ends by picking from far locations bason on picklist. This process can be taken for a further complex scenario which requires an additional step either because some orders require a ladder to be picked which is kept on the location where it was used lastly or either because there are some orders are picked incorrectly and need to be returned and both takes an additional time. The following tables represents the average time for these additional steps:

Table 9. Current situation average additional material handling steps time

step No	Process step	Av. Time (s)
20	searching for the ladder	96
21	pick the ladder	3
22	take it to the next shelf location	17
23	go back to previous shelf location and pick the trolly	17
24	take the trolly to next location where the ladder is	17
25	climb the ladder	4
26	get down from the ladder	4
Total time		158

For the following table. there are no steps defined for picking the trolly because while correcting the orders the pickers are using a different type of trolly which is small located at the same place where the picker is on the packing area and if the quantity is low then the picker take the items by hand.

Table 10. Current situation average orders correction steps time

step No	Process step	Av. Time (s)
27	take the picklist and check the wrong picked item's location	3
28	Pick the items from packing area	4
29	take the items to the location	17
30	put the items on the shelf	2
31	pick the right items	2
32	check SKU code and quantity	3
33	take them to the packing station	17
Total time		48

From the above three tables, it can be noticed that the average time of every process step is highlighted into different colors, each color represents a certain thing, this is defined on the following table:

Table 11. steps references

color code	referring to	standard table total time (s)	additional handling material table total time (s)	orders correction table total time (s)
yellow	steps that are fixed, the time is fixed	233	96	17
green	refers to average travel time between shelf locations, it changes depending on the number of different shelf locations per pick list (standardly 17 seconds for each shelf location)	17	51	17
orange	time changes depending on the number of orders per picklist (standardly each order 12 seconds)	12	-	3
blue	time changes depending on the quantity per order (standardly for each SKU item 5 seconds)	5	-	11
Red	this time change depending on the number of row 5 and 6 shelf locations per picklist (11 seconds for each shelf location)	-	11	-

As the total time of standard piking process is 268 and the additional time for material handling is 149 then in total it can be 417, the additional time here is almost 36% of the taken time this percentage will be used later pick density measurement.

From the previous tables it can be noticed that there are many variations and scenarios. Therefore, a formula of the average order picking processing time has been determined by taking all the described variations into consideration. All the table measurements and even the calculation that can be done using this formula are only for the "average" times as in reality there is a possibility that it can be more or less, but most of the measurements will be close to the calculated average. To increase the validation of this formula, a picking complex scenario will be examined and described by measuring the real time it takes as well as by using the formula to calculate its duration then both outcomes will be compared to each other (table 12). The formula is as follows:

(1) Average standard order picking process time (s) = 233 + (17 * number of locations per picklist) + (12 * number of orders per picklist) + (5 * quantity per order * number of orders)

If there are any additional steps required, it's necessary to use one of these formulas or both depending on the required steps:

(2) Average time (s) required for using handling material = 96 + (51 * number of row 5&6 location per picklist) + (11 * number of row 5&6 location per picklist)

(3) Average time (s) required for order correction = 17+ (17 * number of wrong orders locations per picklist) + (3* number of wrong orders) + (11 * quantity per wrong order * number of wrong orders)

If formula 2 or 3 are used, or both, the next step is to add all the formula's results together:

(4) Final Average order picking process time = formula 1 result + formula 2 result if required + formula 3 result if required

4.1.4.7 Pick density

This measurement will determine how many items can be picked per hour, as what have been discussed on the order complexity measurement, 37% of the daily orders requires additional handling material and the additional time for these orders as been discusses on the above section is 36%. As well as what has been discussed on the accuracy rate measurement that the wrong picked items are 17% of the daily orders.

This means that 37% of the one-hour time will be spent on orders with additional time of using material handling which will be 22.2 minutes, but what is needed is the net additional time of the whole time spent on picking this type of orders which can be done by taking 36% out of the 22.2 minutes which will be 8 minutes. As well as 17% of the remaining time from the one-hour time will be spent on correcting the wrong picked items and the rest percentage, which will be 10.2, therefore the net remaining time after deducting the wasted time on additional steps will be 41.8 minutes.

As been discussed on order volume measurement part, the most the average number of orders of the first batch which has the most important one and contained the highest workload is 178 orders, the orders are divided within 2 pickers per batch so each picklist will contain around 89 orders. These 89 orders need to be picked during the first batch schedule which is one hour from 8:30 to 9:30.

A sample of 100 picking list was taken to extract from the average number of orders per picklist, average number of locations (normally the number of locations are same as the number of orders, as if there is an order has 2 different SKU from different locations it will be considered as two orders on the picking list and it will be sorted later when the process ends) and the average number of quantities per order. The outcomes were as follows:

- average percentage of locations per picklist is 30% of the orders per picklist, because there can be multiple orders that have the same location but different SKUs therefore as the number of orders must be 89, the number of different locations will be around 27.
- The average number of quantities per order is 3.

by using the formula number one discussed on previous section and by using the above data and considering the order processing time is 42,5 minutes, average number of orders that can be picked in one hour will be 63. This means that around 26 orders out of the 89 will be delayed. This is a high percentage which is around 29% of delayed orders. Therefore, this makes sure that by achieving the goal of this research which is reducing the process lead time by at least 30%, the 29% delayed will be solved and orders will be picked during the batch schedule.

For a clearer understanding of the most discussed measurements, the following table represents the average scenario of the first batch picking process based on all the above section's averages measurements, it's clear that the final average time is around 74 minutes while it supposed to picked within 60 minutes, this means there is an additional time by 24% that need to be reduced.

Table 12. average current situation scenario with total process time measurements

measurements and calculations	result	remarks	R. T
av number of orders per picklist	89	as discussed on order volume measurement	91
number of locations per picklist	27	as discussed, its 30% of orders number	29
av quantity per order	3	as discussed, its 3 pieces per order on average	3
number of row 5&6 location per picklist	10	as discussed on complex order measurements, orders require additional handling are 37% of the total orders, which will be 33 orders, as the number of locations is 30% of orders number then it will be (30%*33=10)	8
number of wrong orders	15	as discussed on accuracy rate measurement, wrong picked orders are 17% of the total orders, which will be 15 orders	13
number of wrong orders locations per picklist	5	number of locations (30%*15 =4.5, apx.5)	3
quantity per wrong order	3	as discussed, its 3 pieces per order on average	2
formula 1 result	3095	around 52 minutes	-
formula 2 result	716	around12 minutes	-
formula 3 result	642	almost 11 minutes	-
Final Average order picking process time	4453	around 74 minutes	4357

To increase the validity of this scenario, a real measurements of 1 week (5 working days) order picking process of only the first batch has been don which is in total 5 picking tours that have been measured by following one picker and using a stopwatch, it is done by measuring the total real picking process time during the first batch picking tour as well as recording each picklist variations for the whole week, then as the average of the collected database was taken which is illustrated on the last column of the above table (highlighted in blue), it can be noticed that the real time 4357 seconds and the calculated time using the formulas 4453 seconds are close to each other which proves that these averages calculations are valid.

The above scenario is based on average calculations of each step and each measurement of the whole process based on historical data and collected data during work sampling. So, this scenario will be used for any next calculations.

4.2 Root causes analysis

After taking all the needed measurements and pointing the issue places, this section will determine which aspects of the process time need to be focused on by using a pareto chart, following be describing the bottlenecks and visualize the causes and effects into a fishbone diagram. Then, all of the causes will be analyzed using root cause analysis.

4.2.1 Bottlenecks

From the previous section most of the related measurements were discussed. Therefore, there have been some issues determined which cause a delay in order picking and additional required time, as this research questions focuses on reducing the order picking process time, by using the above measurements outcomes, the bottlenecks of each time type will be determined separately. The time measurement types discussed earlier are as follows:

- Fixed time
- Unfixed time:
    - Travel time
    - Picking time
    - Checking time
    - Wasted time due handling or orders correction.

As the main purpose of this research is reducing time, the above time types have a long duration, so it needs to be reduced, to know where the focus need to be, a pareto chart 20/80 have been done to determine which time types are affecting the process more. The below table is conducted by using previous section measurements and scenario, the total picking time has been categorized into 6 categories according to the above fix and unfixed time types as shown on the table, then each time of each category has been calculated out of the total average picking time as for instance the total checking time have been determined out of the total picking time then the percentages and the cumulative have been calculated to be able to use the Pareto chart.

Table 13. current situation total average percentage of each time type

Time type/categories (from the average scenario described earlier)	total time (s)	% of total time	cumulative
checking time	2049	37%	37%
total travel time	1071	20%	57%
additional correction steps time	746	14%	71%
additional handling steps time	648	12%	83%
direct picking items from shelf time	624	11%	94%
fixed time	329	6%	100%

From the above table the following Pareto chart has been created:

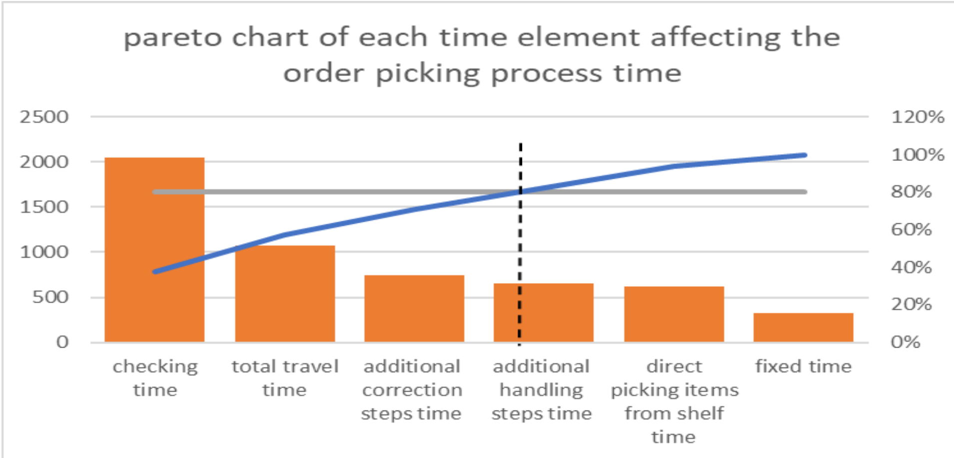

Figure 15. Pareto chart

It can be noticed from the chart that the first 4 bars from the left are the high priority to be considered while picking and fixed time are the least important as they do not have a big impact on the process time. Therefore, only the bottlenecks of checking, travel, and both additional times are determined by what have been noticed on all the performance measurements outcomes which was done based on work sampling, historical data, Gemba walk and interviews. The bottlenecks are as follows:

1) Time is wasted on using additional handling material:
   34% of the daily orders are picked from shelves located on the fifth and sixth rack rows, which need to be reached by a ladder, this requires an additional time to search for the ladder and take it to reach the location. In this part there is additional time that is considered a waste and there is additional handling time that is considered as a requirement. It does not matter to distinguish that as the aim is to minimize the percentage of orders require material handling as 34% is high comparing to the number of shelf location of row 1 to 4, this high percentage means that the fast-moving goods located on high locations due to zones are high volume. If for instance according to ABC the fast-moving goods are located on close and easily accessed locations and only C items are located on high shelves, then the ladder will be used rarely. According to the analysis 82% out of the 34% are fast moving goods which are located close but on high locations because of the zone policy. B is 16% and C is 2%. Therefore, all 34% will be considered a waste as the aim of this is to reduce the time taken on using additional handling.

2) Time is wasted on correcting wrong picked items:
   The wrong picked items are 17% out of the daily picked orders, this requires an additional time to take the wrong items back to the TC and pick the right items and take it to packing area. This percentage needs to be reduced as it has both additional wasted travel time and checking time.

3) The covered distances are very high leading to high average of travel time:
   The average travel time is 17 seconds which is a high average when considering the TC size and the different locations frequency, as there are certain locations are visited a lot, so the Go-and-return route is duplicated many times for the same route in a daily term. As well as there is the picking rate from some close locations is low.

4) Insufficient order picking paths:
   There are a wasted movements when the pickers follow the picklist sequence as there can be a better route, as for instance if the picklist has the following locations from 2 racks which are on the same aisle, sequentially sorted on picklist by the rack letter then the rack number as L01, L010, M05. It is logical that the optimum path is L01, M05 then L010. As M05 is in the middle between L01, L010 but on the opposite side then the picker does not have to come back again to it.
   The picker is following the picklist as it contains a big amount of orders volume, and the picklist can be on multiple pages so normally if the picker skips the picklist sequence the rate of error can be increase and some orders might be forgotten to be picked. There are reasons that the company did not improve this will be represented in root causes analysis later.

5) Manual picklist data verification:
   The pickers need to verify each order location and each SKU code before picking the item, this verification and checking is done manually using the picklist which make the checking time too long as if there is a quantity of 100 SKU, the checking time for each SKU will be duplicated 100 times as each item needs to be checked. This checking and verification process is done to ensure that the location is right, and the SKUs are not placed on other wrong location, as well as to ensure that the SKU code is right as the one on the picklist so both the right SKU will be picked, and the code is verified to ignore any issue or error for next times.

   Although this is done regularly but some pickers still rushing themselves to finish the picking process fast so they don't check the complete SKU code which explains why there is some wrong picked orders, as for instance there might be 2 SKUs with the exact same code except one number is different, normally these SKUs are the same product but with different size, color, or flavor.

4.2.2 Cause and Effect diagram

After describing all the founded bottlenecks, these bottlenecks represent as causes that makes the process lead time longer, so the fishbone diagram below represents all these issues with determining the effect of each one for a better overview between the cause and the effect:

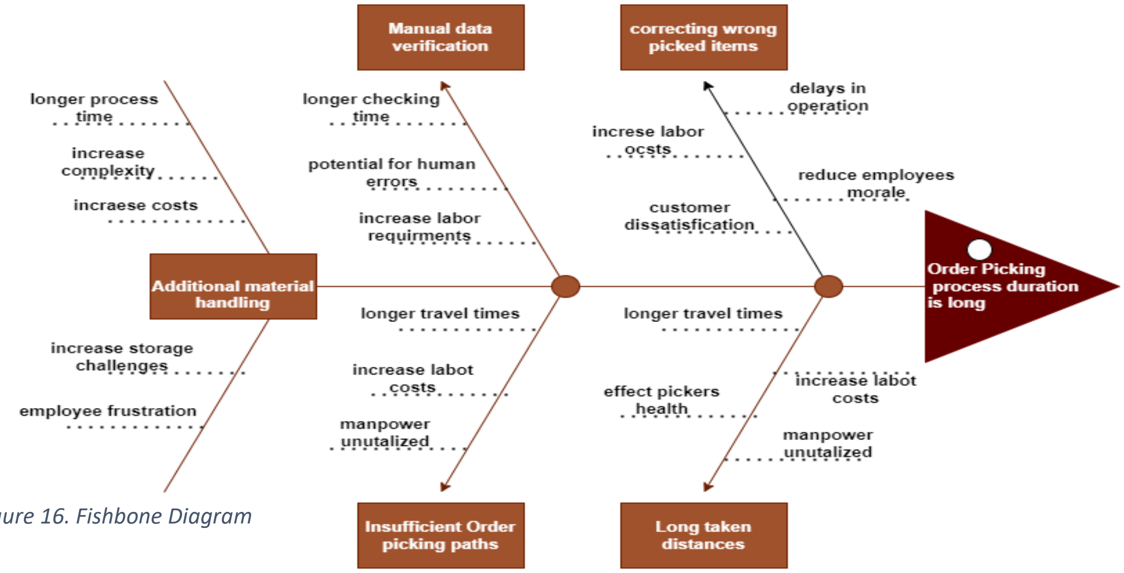

Figure 16. Fishbone Diagram

4.2.3 Root cause analysis

According to the Pareto analysis, both additional times, travel time and checking time need to be reduced, the reason of this that these times can't reach to a 0%, it only can be reduced as logically there will be still a travel time and checking time, so being satisfied with only reducing one of them will not be sufficient. As the scope is wide and there are multiple time types that need to be reduced, there will be multiple bottlenecks and causes as well.

These bottlenecks are related to time so there will be similar causes expected. So, the approach will be first by determining all noticed bottlenecks related to the described time types, then narrowing it by conducting only 2 whys out of the 5 whys root cause analysis for each bottleneck, then the similar causes will be furtherly analyzed by the rest 3 whys.

the similar causes of these bottlenecks. Following by conducting the 5 whys root cause analysis for these common causes.

1) Long wasted time:
- Time is wasted on using additional handling material.
    - W1: high percentage of daily orders containing items located in high shelves locations.
    - W2: poor storage assignment method as there is ineffective placement or allocation of fast-moving goods.
- Time is wasted on correcting wrong picked items.
    - W1: Because pickers confuse while picking similar SKU that can be different in size, color or even in 1 number of the SKU code.
    - W2: Poor picking method

2) Long travel time:
- The covered distances are very high leading to high average of travel time:
    - W1: because there are low order picks from close locations and from D rack which is frequently passed by while some far locations contain fast moving goods (highlighted in Spaghetti diagram).
    - W2: poor storage assignment method as there is ineffective placement or allocation of fast-moving goods.
- Insufficient order picking paths:
    - W1: because pickers follow the picking list locations sequence.
    - W2: Poor routing method which does not consider distances lengths.

3) Long checking time:
- Manual picklist data verification leads to long checking time.
    - W1: Although there is an error rate, pickers spent time comparing locations and SKU codes on picklist to the ones on the shelves.
    - W2: Poor picking method that does not consider taken checking time and error possibility.

It can be noticed that there are similar causes for some bottlenecks, as a conclusion there is only 3 main causes which are:

- Poor storage assignment method
- Poor picking method
- Poor routing method

So, to solve the issue according to Pareto chart, none of these causes can be ignored so there will be 3 root causes, but it is much easier to define the root causes of these 3 by completing the rest 3 whys analysis which is represented on the following figure:

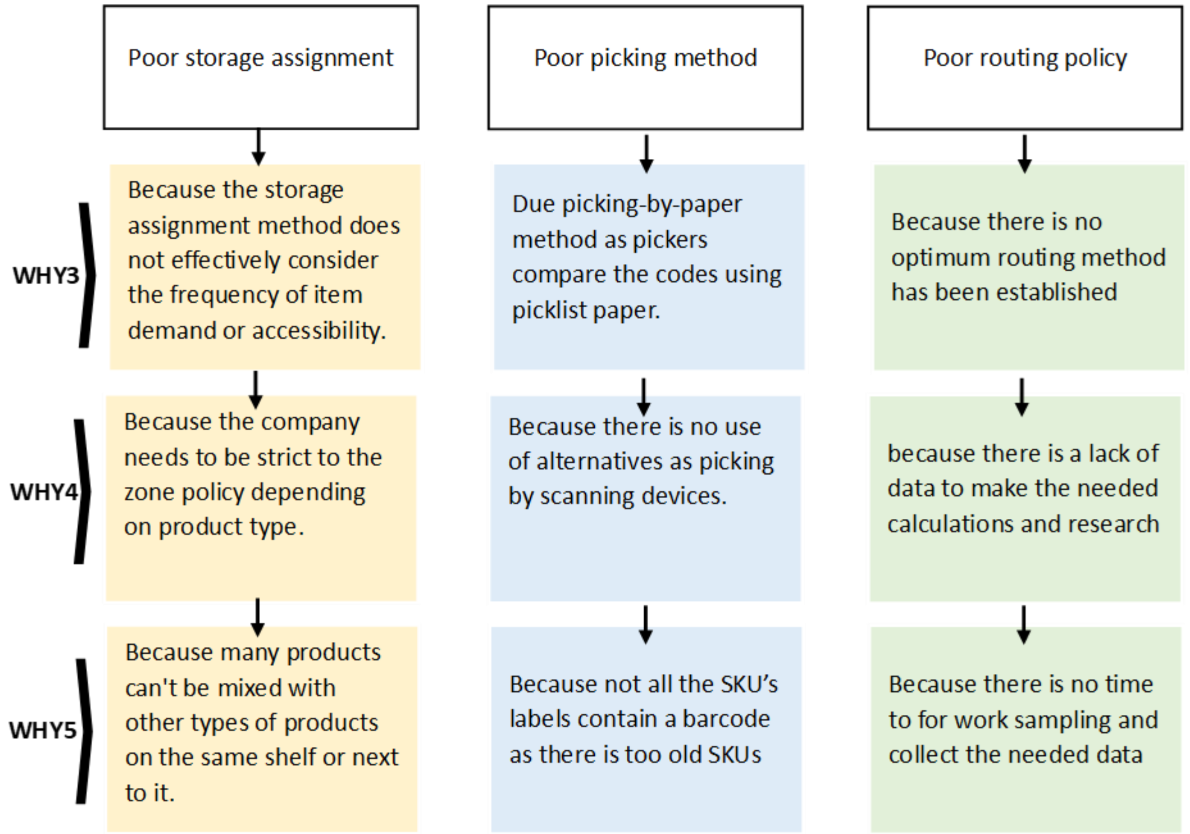

Figure 17. 5Whys root cause analysis

As a conclusion of the root cause analysis, there is there causes which are:

- Poor storage assignment due to zoning policy depending on product types.
- Poor picking method due to some SKUs unlabeled with barcodes which takes time to do it for the big number of quantities.
- Poor routing policy due to lack of routing planning, time, and data resources.

4.3 Potential improvements

This sub-chapter is where the research main question is answered, as there 3 root causes, there will be more than one solution to solve the issue and reach a more than 30% reduction of the process time. Proposing an improvement or solutions with high investment in new technology will be insufficient for the company as discussed with the manager, as the company wants to save money for its new planned projects as discussed earlier. Therefore, the improvements will be to the procedure and applied policies itself and if applicable looking for using low investment technologies that can be reached and provided easily.

This section will start by describing the potential improvement by proposing only 2 effective solutions which will have a big positive impact on the issue, any other recommendations will be mentioned later in the recommendations chapter. There will be an implementation plan for the 2 solutions after describing them, followed by the next chapter where the solutions will be tested and compared to the current situation.

4.3.1 Improvements

1) Apply “Pick-by-scan mid-pointly” method:

This improvement refers to a joint combination of routing method and picking policy. This will help to reduce the travel time, checking time and wasted time for errors or material handling. To make the improvement clearer, the picker uses a normal scan device while picking and checking and he only picks halfway the rack, as there are 2 pickers per batch, the other half will be covered by the second picker.

This can be done easily by first make sure that all of SKUs have a barcode as well as the shelf location label, has been discussed on the root causes some SKUs don’t have a barcode and it’s costing a lot of time to check them and create barcode labels, print them, and stick the labels on the items. In fact, the TC workers are printing a cycle time and expiry date for a part of the SKUs each day and they are doing cycle counts and expiry checks every day until the end of the month all the SKUs are checked and counted, then they start again on the next month and over and over.

By adding only one additional column to tick whether the SKU items have a barcode or not on the cycle counts or expiry date check list, all the SKUs will be checked by the end of the month while doing the cycle counts.

Then only 2 Honeywell scanner devices for the 2 pickers, which do not cost a high investment, will be connected directly to the WMS which can be done easily by the system controllers. So, when assigning orders from the WMS it will be transferred directly to the picker’s Honeywell device. The assigned orders for the 2 pickers will be as the below figure where the TC divide into 2 areas, any orders that has a location located on the green area will be assigned directly the first picker, and any order location is on the blue area will be assigned to the second picker directly from WMS. Honeywell device photos can be found on Appendix 2 and midpoint route example can be found in appendix 3.

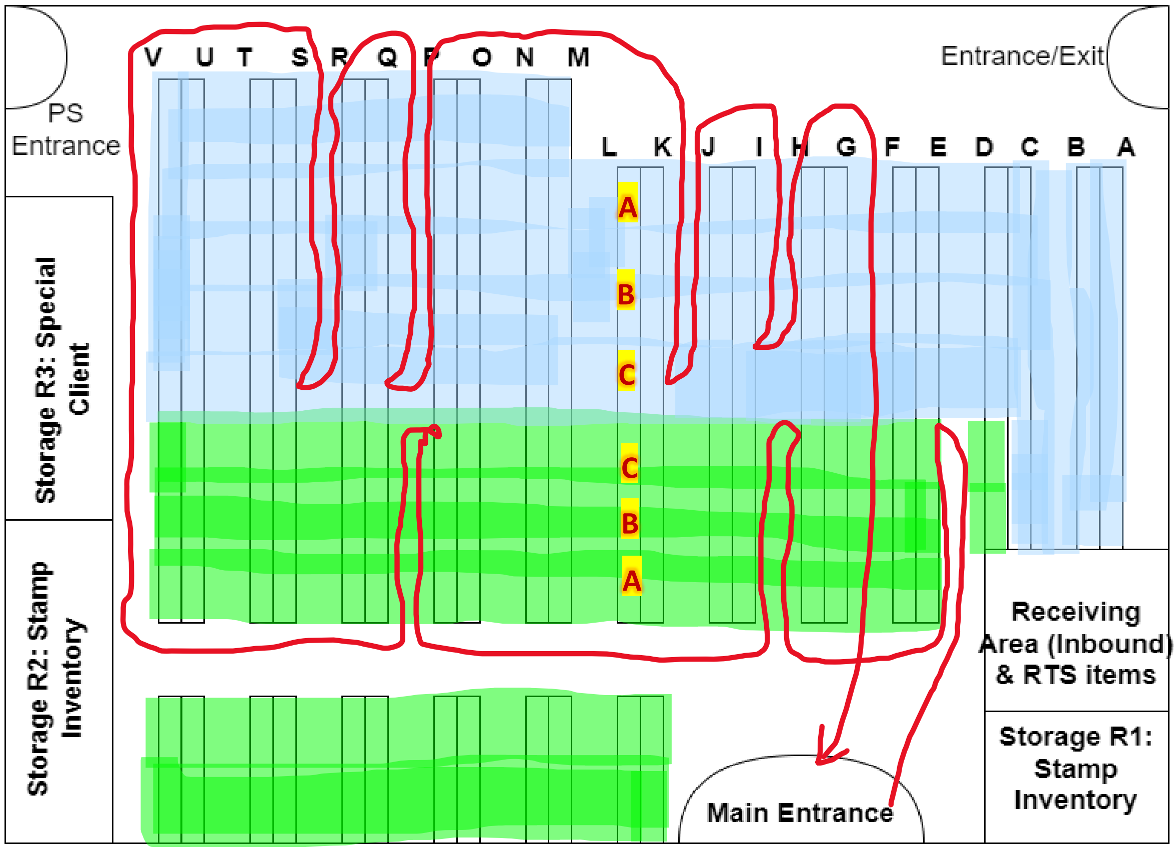

Figure 18. Midpoints areas

So, the midpoint policy is applied. There is a slight difference between the proposed mid-point policy and the real mid-point theory as described on theoretical framework, the red path on the above figure illustrates how the mid-point works as described on theoretical farmwork, it can be noticed the in this situation the same picker might visit the other half of the same row that he visits previously during his tour.

While the proposed mid-point policy aims to make the picker pick the orders only from shelves until only the middle of the rack without going later to pick from the other half of the row and without knowing that he needs to do that, as the picklist will be assigned directly in advance from WMS according to mid-points the picker will just follow the picklist locations as usual. So, it's more of splitting the whole warehouse into 2 picking zones, the green and the blue one as shown above, but the way that the warehouse is divided is according to the determined mid-point locations, therefore the time can be more effectively saved as there is 2 pickers and if the picker goes again to the same row but on the other half there will be some wasted movements as well as conflicting movements with the second picker.

The policy of sorting the orders from A to V sequentially and the picker follow the sequence can be applied here, although there is still a waste of movements but by midpoint it will reduce by halfas pickers do not have to walk through the while aisle then return. So, by applying midpoint the average travel time is expected to be reduced by half.

Then after assigning orders, the picker will receive a notification on the device, he will first click on the first order on the Honeywell screen, go to the location, scan the SKU barcode for each picked item, then scan the location barcode then directly move to the next order.

It can be noticed that the picker is scanning each picked item, so the device recognizes whether the picked item is correct or not as well as recognizing the picked quantity. If the picker picked more than required the device will notify him, as well as if the picker scanned the same item twice the device will make a sound notification, then the picker scan the shelf location which will means that all orders from this shelf has been picked, at the same time it verifies whether the SKUs are located on the same shelf as mentioned on the system or not. After scanning the shelf location if the picked quantity is less than required the device will make a notification meaning that the picker still not finished yet from this shelf location and there are still some quantities missing. Then the picker goes for the next shelf with the same process. That is how the mid-point pick-by-scan will work which will reduce both checking time and number of errors and travel time.

2) Apply ABC storage assignment method:

As it has been discussed earlier that the company are not applying ABC for the TC because if there is 2 fast moving SKUs but from a different product category it cannot be stored into one shelf, the zone policy assigned whole racks to the product categories. So, when the workers want to store a goods, they determine first the product category and then store the stock on any available shelf within that product category zone.

This improvement cannot be applied for the whole TC without taking the zones into consideration, so the ABC analysis storage assignment will be first done per zone, as if there is a fast-moving good within that zone is located at the end of the zone it will be moved at the beginning of the zone and vice versa. As what is happening with location E09 which is at the end of medicines zone in rack E, it's been discussed earlier on the spaghetti diagram that this location consists of fast-moving goods as the pick frequency from there is high, therefore this can be moved to E01 which is close to the entrance and packing station and so on.

After applying ABC analysis to all zones, an ABC analysis will be even done per shelf that includes multiple SKUs some of them more than 9 different products on one shelf with stacked quantity. So, for the green midpoint area the SKUs will be stored from the right to the left side of the shelf starting from fast moving to low moving goods on that shelf and well as in locations itself while for the blue area will be stored from left to right side. This is to maximize the benefits of the ABC storage assignment as its only done per zone, as well as it is a small step with small effect by in a long-term basis the counted saved travel time will be sufficient as well as it allows the pickers to find the item easily per shelf. By applying the ABC method, improvement, the travel time is expected to be reduced significantly.

On figure 18, the ABC letters colored in red represents where each category of ABC will be located, this is to avoid making all of the A category on green zone which makes more pressure on this zone. So, the ABC categories are divided evenly. The A category of blue zone is far away from the entrance or the starting point but in fact it's closer to the blue zone picker while picking from there as it's located at the beginning of the row.

4.3.2 Implementation plan

The implementation plan was done by a Gantt chart including all steps that need to be taken to implement the improvements, the phases steps are determined according to the PDCA method. Then on the next sub-chapter, these improvements will be analyzed or tested to calculate the positive impact by applying them and how much the time has been reduced. The table below represents the implementation phases described on the Gantt chart with defining to which element of PDCA it refers to:

Table 14. Gantt chart phases with PDCA elements

Phase Number	Phase	PDCA
1	Planning	Plan
2	Analysis and preparation	Plan
3	Design and Strategy	Plan
4	ABC storage assignment implementation	Do
5	Midpoint and pick-by-scan Implementation	Do
6	Training and Communication	Do
7	Go-Live and monitor and new methods	Check
8	Evaluation and adjustment	Act

The Gantt chart can be found in Appendix 4.

4.4 Future situation

This sub-chapter will represent a description of the future situation how it will look like by illustrating a future process map and discussing the changes, following by time measurements of the process if the improvements are implemented, Then, there will be a comparison between future situation performance with the current situation performance to determine whether the main goal of this research has been achieved or not and if there is a positive change and reduction on the process time by more than 30%.

4.4.1 Future situation description

By implementing the proposed potential improvements there will be many changes on the order picking process as some steps will be eliminated, the following flow chart represents the future situation process map:

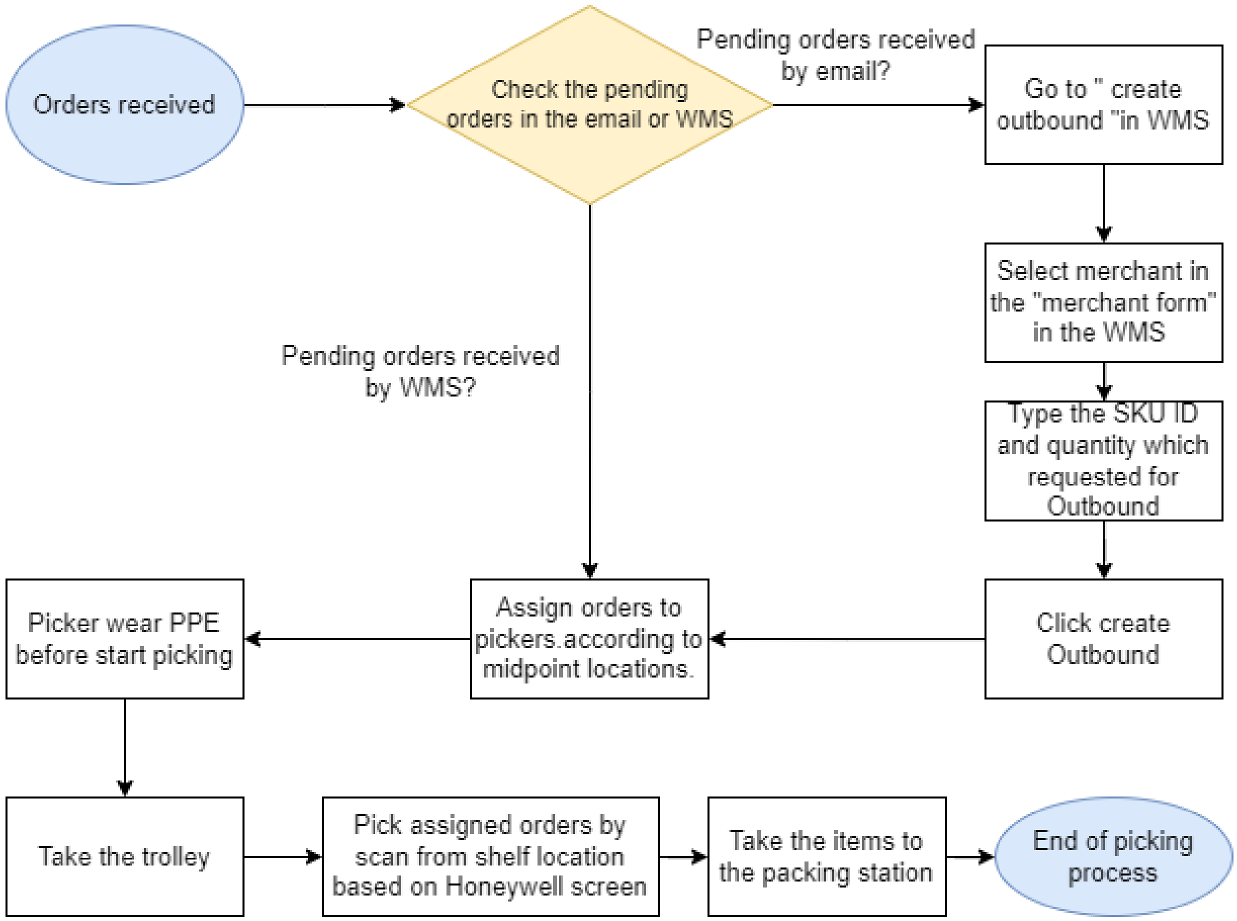

Figure 19. Future situation order picking process flow chart

It can be noticed that the process became smoother and shorter compared to the current situation as there are many steps that are eliminated, Therefore, the time that was spent on performing the eliminated steps will be saved. The following table describes the eliminated steps and the reason of that:

Table 15. eliminated process steps of future situation with the reasons.

Eliminated Step	Reason
check the orders items in which shelf from the pending list in WMS.	As Honeywell verifies location barcodes and as the system can assign orders automatically according to midpoint there is no need to check the orders and its locations
Download the picking list onto the Excel file.	There is no need for picklist anymore as orders transfers directly from WMS to the Honeywell
sort the orders according to shelf locations and clients.	Orders do not need to be sorted manually anymore as when the system divide the orders according to midpoint locations automatically, the locations will be sorted sequentially automatically as well so the picker receive the sorted orders on his Honeywell.
Change the orders status in WMS from "pending" to "assigned.”	When assigning orders to pickers and clicking approve, the orders will be sent to pickers Honeywell automatically according to midpoint locations and the status will automatically changes to assign when clicking the approve button.
Print the pick list and give it to pickers.	There is no need for printing picklist anymore
Check if items are correct.	as described earlier, the Honeywell gives a sound notification weather the picked quantity is higher or lower than required, as well as the picker scan the SKU of every picked item as well as the location barcode, there will be no wrong picks otherwise the Honeywell will not accept the picked quantities while picking and keep giving notification until the picker adjust the mistake.
Change the orders status in WMS from "assigned" to "fulfilled.”	When the picker ends picking from the last location on his Honeywell list, he will scan the location barcode meaning that he picked all the orders from that last shelf, so the status of his assigned orders will be changed to fulfilled.

4.4.2 Future situation order picking time measurements

First, this section will determine how much the average travel time will be, in order to determine this the ABC storage assignment analysis has been done, all of the SKU items has been analyzed and allocated in Excel file to locations depending on its ABC category. Each location has been measured to determine how far or how close it is to the packing area which makes it easier to allocate the SKUs to the locations depending on the ABC analysis. After applying the ABC analysis, it was found that 86% percents of products locations have been changed. The ABC analysis Excel file will not be shared for company privacy reasons.

The second step is that a real pending orders for the first batch was downloaded on Excel file, the orders on locations on the downloaded Excel file has been changed according to the new locations of ABC analysis, then all orders have been divided according to the midpoints locations, after dividing the orders it was sorted sequentially, then the distances taken to these new locations was measured, first the green highlighted area on the previous warehouse layout figure of midpoint locations has been tested then the blue one. This has been done for first batch orders for 5 days, so as there are two pickings per batch in total it is 10, 5 blue area and 5 green area.

The distance measurements are not done physically by considering the time available to conduct this research, but it was calculated using the warehouse, aisles, racks, and shelves measurements described previously. As for instance of the shelf length is 90 cm and shelf edge are 5cm in total 95, from shelf E05 to shelf E8 the distance on average will be 285 cm. in this way all distances have been calculated which then the average travel time has been determined which is 4 seconds.

The calculated average travel time is based on both midpoint method and ABC storage assignment, as ABC makes the locations closer depending on historical demand and picks frequency and the midpoint makes the pickers only go through halfway the aisle, the travel time has reduced by 24% from 17 to 4 seconds.

Regarding the ABC analysis, after categorizing each SKU whether it is an A, B or C, it was noticed that the percent of A SKUs located in rows 5&6 is 40% of the total row 5&6 SKUs before allocating it to the new locations. After allocating the SKUs to the new locations depending on its ABC category, it was noticed that the percentage of category “A” SKUs located in rows 5&6 is 11% of the total SKUs located there. So, there is a decrease of 30% which means that the wasted time due to additional material handling occurrence can be reduced by 30%.

As ABC storage assignment and midpoint methods has an impact only on travel time and additional material handling time which has been calculated, the Pick-by-scan method which has an impact on checking time and number of errors will be calculated. For both pick-by-scan impact calculations and total process time of future situation, the average time measurements defined on the current situation will be used and regenerated into the future situation conditions which will be as follows:

Table 16. Future situation standard average order picking steps time

step No	Process step	Av. Time (s)
1	Assign orders to pickers	16
2	picker wear PEE and take the Honeywell device	11
3	picker move to receiving area to take the trolly	14
4	picker check the location on Honeywell	3
5	picker move to the shelf location with the trolly	4
6	Picker directly checks the item and scan it to make sure it is right	3
7	Picker picks the item, scan it, and put them on the trolly	3
8	picker scan the location barcode	1
9	picker take the trolly to the packing station	41
Total time		96

It can be noticed that this average order picking process time was on the current situation 19 steps while on the future situation 19 steps was eliminated for the reasons discussed previously and left with only 8 same steps and one new step. The 8 steps time are the same as on the current situation except for step number 7 which is expected to be increase from 2 seconds to 3 seconds as there is an additional step there which is scan the item as well as step 5 where the average travel time has been decreased from 17 to 4. Scan devices are really fast, it takes only one send to scan any barcode. The new step which is number 8 is scanning the location barcode which takes 1 second. So, the total average standard future situation order picking time is 96 seconds.

Table 17. Future situation additional material handling steps time

step No	Process step	Av. Time (s)
20	searching for the ladder	96
21	pick the ladder	3
22	take it to the next shelf location	4
23	go back to previous shelf location and pick the trolly	4
24	take the trolly to next location where the ladder is	4
25	climb the ladder	4
26	get down from the ladder	4
Total time		158

The above table represents the time taken for orders that need a handling material, this table was discussed on the current situation, the only difference here is that the steps that contained travelling time which highlighted in green have been changed from 17 to 4 seconds.

As discussed earlier, by applying the pick-by-scan improvement, there will be no chance for wrong picks as the device directly notifies the picker while picking the wrong item, not at the end of the process where items are taken to packing are where the picker need to return for correction. Even if the item has expired, as soon as the picker scan the item, he will be notified that this item is expired, because before labeling the SKUs by the barcodes each barcode will be assigned to its SKU on the WMS so all data related to that SKU as expiry date will be linked to the barcode.

Using the above tables, the four described formulas will the change as they will be as follows:

(1) Average standard order picking process time (s) = 82 + (4 * number of locations per picklist) + (7 * number of orders per picklist) + (3* quantity per order * number of orders)

If there are any additional steps required, it is necessary to use the following formulas:

(2) Average time (s) required for using handling material = 96 + (12 * number of row 5&6 location per picklist) + (11 * number of row 5&6 location per picklist)

(3) Average time (s) required for order correction (there will be zero time spent on this as discussed)

(4) Final Average order picking process time = formula 1 result + formula 2 result if required + formula 3 result (0)

The average time required per picklist according to the future situation will be calculated by using the same average scenario described on the current situation which is as follows:

Table 18. Future situation order picking average scenario with time measurements.

measurements and calculations	result	remarks
av number of orders per picklist	89	as discussed on order volume measurement
number of locations per picklist	27	as discussed, its 30% of orders number
av quantity per order	3	as discussed, its 3 pieces per order on average
number of row 5&6 location per picklist	2	as discussed on complex order measurements, orders require additional handling are 37% of the total orders, and it can be reduced by 29% as discussed in future situation so it will be 8% which will be 7 orders, as the number of locations is 30% of orders number then it will be (30%*7=2)
formula 1 result	1614	around 27 minutes
formula 2 result	142	Around 2 minutes
formula 3 result	0	0 minutes
Final Average order picking process time	1756	around 29 minutes

4.4.3 Comparison between current and future situations

The following table represents the time spent on current and future situations based on the above tables, and shows how much time is saved as well as the percentage of time reduction:

Table 19. Process time comparison between future and current situations

time type	current situation	future situation	saved time	reduction in time percentage
standard picking time (m)	52	27	25	52%
material handling time (m)	12	2	10	17%
correction time (m)	11	0	11	0%
Total average time (m)	74	29	45	39%

As a conclusion, by implementing the proposed potential improvements, the order picking process time can be reduced by 39% which achieves the goal of this research and answers the main question where the reduction percentage is more than 30%.

4.4.4 Risk management analysis

This section will present the potential risks or issues that may occur when trying to implement the proposed improvements as they need to be maintained and control, the risk analysis will be by using the FMEA risk analysis method to have better project control management which contains risks events, chance of occurrence, impact, detection or recovery time and risks value which is the risk priority number (RPN). The followed scale to score the risks severity, occurrence and the detection which is as follows:

- (1-2) low possibilities to notice which not affect the improvements. (1-200)
- (3-4) less serious on noticing it by the management and might not affect the improvement. (300-400)
- (5-6) serious to the improvement where there is a possibility it cannot be implemented. (500-600)
- (7-8) high doubt about the improvement will not be implementing. (700-800)
- (9-10) Not possible to do the improvement implementation. (900-1000)

The numbers on the right side of the scale represents the RPN, as if the RPN is 200, then it refers to low possibilities to notice which not affect the improvements, the FMEA analysis is as follows:

improvement	risks	severity	occurrence	detection	RPN
ABC storage assignment	Inaccurate classification of products	7	3	6	126
	Insufficient data for accurate ABC analysis	8	2	7	112
Pick-by-scan	Insufficient training resulting in scanning inefficiencies	6	5	3	90
midpoint policy	Inadequate analysis of warehouse layout for optimal midpoint locations	5	1	2	10
general risks	Lack of flexibility in adapting to the changes	8	7	4	224
	non-approval from management/stockholders	9	5	5	255
	no available time to transitional, train and change	9	7	8	504

Table 20. FMEA risk analysis

This FMEA analysis helps on investigating which challenge is higher to occur and need to be handled as its obvious that all of the risks are on the safe side as some have low possibilities to notice which not affect the improvements and some less serious on noticing it by the management and might not affect the improvement as well, except one risks that contain a high RPN which is no available time to transitional, train and change. This risk is considered serious to the improvement where there is a possibility it cannot be implemented. This risk can be handled by first assigning someone sufficient to plan for it or the manager can do it by

self by following Kaizen method where working on the project 1-2 hours a day is better than doing nothing or working on it all on a short time. 1-2 hours a day means 30-60 hours a month and so on. So, then it is possible to develop a detailed project plan and prioritize essential training as well as engaging the stakeholders early.

Here is the end of the result chapter where the research question has been answered by clearly identifying the problem and the current situation following by current measurements and root cause analyses where poor storage assignment, routing and picking methods causes has been identified. Followed by a potential improvement for these causes by implementing both midpoint pick-by-scan and ABC analysis where then the implementation plan is described, and the future situation measurements and risk analysis have been calculated leading to a process time reduction of 39% of the current situation.

5. Discussion

This research is aiming to reduce the order picking process time to be able to deliver all orders and fulfill them on time, after describing the current situation and doing certain types of measurements the root causes were identified leading to make a better decision of what improvements can be proposed, all of these was done by taking the theoretical framework onto consideration. The 2 potential improvements that were proposed are “midpoint pick-by-scan” and “applying ABC storage assignment method”.

For a deeper discussion about the findings and the proposed potential improvements, it was mentioned that the company don’t have time to do Barcode labels for all SKUs, as they are preforming manually picking process, the managers thinks that why to waste time which is unavailable on a thing that they don’t need as the company don’t use barcodes. This can be due to a lack of awareness of the importance of using scanning devices and its impact on reducing the number of errors, making the process faster and smoother and reducing the time, which is the main aim.

In fact, the time availability discussion was solved by proposing that as the company is doing a daily cycle counts and expiry date check for all SKUs, they can add only one additional column on their checklists to point whether the item they are checking for cycle count or expiry date is labeled with barcode or not. This will take only 1-2 additional seconds for each item to be checked. Then they can label the identified items in a faster way. So, then the company can use scanners as Honeywell, this device is better than the normal handheld scanners as its smart and has a screen as well as its fast and takes even less than a second to response while scanning a barcode, in terms of investment the company needs only 2 scanners which will be used for each batch. This will not cost a high investment compared to the cost of labor and customer dissatisfaction the order picking process time leads to.

In terms to the midpoint policy, it can be done easily as the pickers don’t even need to be train, they can complete their regular picking policy that they used to, because the midpoint strategy will be done on the WMS by assigning the orders automatically to pickers according to the defined midpoints locations, so each picker will get a list of orders that has already been divided according to midpoints so they only keep picking from the locations on the list as used to. The discussion of why the sorting of the orders will not be changed as the orders will be sorted sequentially according to the rack location from “A to V”, because changing it needs a hard complex algorithm or a smart route optimization software which will be considered as a high investment while The sequence path will be accepted after applying the midpoint policy as the picker even he is following the sequence but he will go only to halfway the aisle as for instance there is an orders location sequentially sorted as from locations “E1, E6, F3”. It does not matter if the pickers follow “E1-F3-E6” or “E1-E6-F3” because whether there is an order on rack “F” location or not the picker will return passing by “F” locations and exit from the same place he enters according to midpoint policy.

Regarding to the ABC storage assignment method, this might take time to switch all the item’s locations and allocate them physically on the new locations depending to the ABC analysis, but it can be efficiently managed by a detailed and structured project and implementation plan as it will have a great positive impact on both short and long terms. The company was assuming that the company is not doing the ABC storage assignment because it needs to take safety policy into consideration and be strict to the zone policy as each SKU is allocated to a certain zone location depending on its product type, as for instance chemicals cannot be stored with food. This limitation has a big impact whether to apply ABC or not, but a thing is better than nothing and for at least a more efficient performance even if its low the ABC storage assignment can be done per zone separately and the per shelf. This been measured as after implementing this ABC analysis strategy 86% of SKUs locations have been changed meaning that there was a high percentage of "A" category items are located on far locations with the zone itself.

The risks related to these improvements are defined by using FMEA method where the tip prioritize risk was that the company might have no time for change an or train which leads to the possibility that these improvements might not be accepted, has been discussed for pick-by-scan can be none on a fast way for labeling SKUs but it does need time for training, the ABC storage assignment needs time to implement but it doesn't need a high training as workers will only switch the locations then just get back to the procedure of picking from the locations depending on picklist and the midpoint policy doesn't need a high effort or time as its only done on WMS and no training is required except for WMS users which can be done easily as there is only small differences on the process. Therefore, the highest effort will be on ABC time and Pick-by-scan training and implementation time. But considering the time that will be saved by applying them, it will be worth it to spend some time on implementing them to gain a more efficient performance and save both time and costs.

Limitations:

This section represents the limitations or challenges has been faced during data collection which are:

1) Sample limitations: in many positions of the result chapter, it was mentioned that work sampling or a sample of 100 for instance were taken, in fact due to the available time to conduct this research, the sample size could not be increased as it will take more time. Even the 100 taken sample of mentioned on the results chapter on different parts as a 100 sample of to record each process step average duration and a 100 sample of picking list to know average number of locations and quantities and so on.

All these 100 samples are in fact was taken at one time for the same samples and same picklists as all needed measurements and factors or data that need to be collected was planned from the beginning before starting the result chapter, then it was collected on one Excel file where then it was cleaned, and all needed data was extracted from it. When cleaning these samples all outliers that contain unrealistic numbers were eliminated as for instance all 90 orders have 1-5 quantities while there is only one order has 234 quantity which will strongly affect the average so its eliminated. Due to the time limit no more than 100 samples were taken.

As well as due to that the company is new and the WMS starts functioning only from 2020 then there is no old historical data. All the taken samples or the WMS historical data were within a maximum of oner year ago, as within April 2022 to April 2023, except for the average yearly change of order volume measurement. Taking a sample of more than a year as from 2021 would not be beneficial as during that time the company was even newer and applying different strategies and policies than now which makes the data vary from that year to the current year.

2) Selection basis: after collecting the historical data from WMS, it was cleaned and all outliers were eliminated as unrealistic numbers, data containing a high variation from others, orders that are picked but to be disposed was eliminated as well because its exceptional case and so on, this makes the data size smaller but gives ability to increase validity and reliability.

3) The data provided from the WMS was for standard database measurements such as distances, time measurements, locations pick frequency and many measurements the company do not have it, so it was a self-collected data. Which might contain a possible human error. But in fact, to check that the data has been tested by doing a measurement and compare it to what has been discussed on interviews and seen by Gemba walk as well as to any historical data for that if exists and vice versa, WMS database was compared to a real sample to check whether its right or not. But these actions and the availability of the data limit both data size and time available.

4) The company is very strict some of the data was private which couldn’t be shared for any reasons, and some data it’s private but it can be shared for trainees under a condition that it won’t be shared, it can only use for measurements and analysis, even the data of the WMS was provided hardly as it can’t be shared to an external email, and there is no email provided for trainees that haven’t graduated yet, after making discussions with the HR, they accepted the request of providing an email but it was after a long time which then the WMS data has been provided. Therefore, for the company privacy reasons there will be no dataset or excel files shared within this research, there will be some screenshots dataset examples on appendix 1.

6. Conclusion

This chapter will present the structure and final findings as well as the potential improvements of this research describing the strengths and the weaknesses in order to get a move insight following by a recommendation part where any further recommendation for implementing the potential improvements or control it will be determined.

The aim of this research is to reduce the order picking process time of AEX fulfilment center by at least 30% of the current situation time to be able to fulfil and deliver all batches orders on time and get the customers loyalty and satisfaction back. Starting by explaining the problem and the current situation, followed by the current situation performance measurements where the key findings were that 17% are wrong picker order and 34% are complex orders out of the daily average orders which takes an additional time as well as the travel time and checking time considered and most elements that are affecting the situation.

At the end of conducting the Pareto analysis, it was clear that all these four issues need to be managed to reduce the process time. Therefore, a root cause analysis has been done where 3 root causes were found, poor storage assignment, poor routing, and poor picking methods. This was clear during Gemba walk and the measurements outcomes, but these methods are poor because of zoning and time and resources availability.

Then to answer the research question and achieve the aim, 2 potential improvements were proposed, applying midpoint pick-by-scan, which is related to both joints' significates, and Ankor company case who solve the issue by using scanners, but a faster ones then already used, these has been mentioned on the theoretical framework, and the second improvement is applying ABC storage assignment methods which is related to the wholesaler company case mentioned on the theoretical framework who applied a lean and ABC analysis leading them to a great results.

So, by clearly understanding the theoretical framework it was easier to describe the company policies and procedures, as the structure and main elements of order picking as warehouse layout, routing, order batching, zoning and different picking methods and policies were all explained theoretically, the factors affecting the process are also explained. Therefore, deciding what type of measurements need to be taken was easier based on the available theory as well as when thinking of solutions by taking the two case companies into consideration.

The most significant strengths are that the research was conducted in accordance with a well-organized and efficient plan in order to identify the correct root causes, as interviews and self-observations, as well as survey and regular meetings, were conducted throughout all of the months spent on the company, process flow charts and graphs, and data reports were created, the majority of which were not provided ready on the system, and were then approved by the managers and employees to ensure accuracy. That was to get a general understanding and background on the company's processes, particularly those connected to the issue.

In addition, various approaches and lean six sigma tools such as the (DMAIC, refers to Define-Measure-Analyze-Improve-Control), 5W1H, VOB, graphs, tables, spaghetti diagram, and pareto chart, as well as fishbone, 5 whys, and FMEA analysis, were employed. All the features described above strengthen the data and solutions. Furthermore, the offered solutions have a significant influence on improving the order picking process and lowering its duration since they were provided in response to the correct root causes and do not need a large financial commitment or expensive expenditures.

On the other hand, the FMEA analysis shows that there are some weaknesses and problems. Right now, the company is busy with other projects, so they do not have time to do trainings and make changes to their order-picking process or policies. This takes time, and the staff needs to get used to the new changes. However, a suggestion has been made for how to manage and control this problem, this research solutions will be pending until the company has a time to study and check the solution and propose them to the top manager to get an approval.

As a conclusion, all of the above mentioned improvements has been tested and calculated based on a database that has been checked to increase its validity and reliability leading to a very big positive impact on the process by reducing the travel time from 17 seconds to 4 seconds and less checking time with eliminated steps as well as a reduction on wasted time due to material handling or due wrong picked orders which will not occur anymore, these reductions leads to an overall reduction on the process time by 39% which is from 74 minutes to 29 minutes on average. Therefore, the research question has been answered and the aim is achieved that the process time is reduced by more than 30% compared to the current situation.

7. Recommendations

This chapter represents the recommendations and additional small steps of improvements that can help more on solving the research issue.

- It is better to start implementing the ABC storage assignment first then the midpoint and pick-by-scan methods, so the locations have been already adjusted.
- For material handling, the ladder can always be stored on the receiving area to make it easier to find and reduce searching time instead of leaving it in the last time used place.
- There is further research that can be done by doing a work sampling or pilot testing of the future situation to measure the improvement in more detail and deeply.
- There can be further research as well of reducing other type of times which were not included in root causes as it is not determined with the pareto chart, this can raise the time reduction percentage.
- Lean methods and tools can be applied to the fulfillment center to reduce waste and improve efficiency.
- Start doing the action, start planning and proposing this to top managements to get approvals by following Kaizen method and work few hours each day to produce an efficient plan with deeper details.
- When implementing ABC storage assignment, collected data and analysis must be valid and reliable and checked many times to ignore mismatching and wrong allocations.
- Before implementing ABC analysis, it would be good to optimize space utilization so there can be more empty shelves per zone and fast-moving goods will then be even closer.

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Appendix 1: Database screenshots

Due to company privacy reasons, the database cannot be shared but here are some screenshots examples:

Note: the shelf location column is sorted sequentially based on the recored route

Order No	shelf location	distance (cm)
1	TC-E03-B	534
2	TC-E09-B	540
3	TC-E11-B	180
4	TC-F12-C	290
5	TC-G11-A	185
6	TC-H02-D	1270
7	TC-H09-A	630
8	TC-I05-A	460
9	TC-I11-C	750
10	TC-J01-A	1170
11	TC-K12-B	1090
12	TC-L02-B	1350
13	TC-M02-A	100
14	TC-M04-B	180
15	TC-M07-B	270

	client id	SKU name	SKU code	shelf code	shipment	date	year
1	IQF002	SHOPINKH/	SHOPINKH	TC-K06-A	Muscat	10/5/2023	2023
2	IQF002	ZAGLOU01	ZAGLOU01	TC-K06-B	Muscat	10/5/2023	2023
3	IQF002	HALIMNAJI	HALIMNAJ	TC-K07-A	Muscat	10/5/2023	2023
4	IQF002	STOREKE5N	STOREKE5	TC-K07-B	Muscat	10/5/2023	2023
5	IQF002	YAZINAHA1	YAZINAHA	TC-K07-D	all shipmer	10/5/2023	2023
6	IQF002	WATERPRC	WATERPR(	TC-K07-D	all shipmer	10/5/2023	2023
7	IQF002	ASWAQKH/	ASWAQKH	TC-K09-A	all shipmer	10/5/2023	2023
8	IQF002	MATJRE-EX	MATJRE-E)	TC-K09-A	Muscat	10/5/2023	2023
9	IQF002	KHALEEJBA	KHALEEJB/	TC-K09-B	Muscat	10/5/2023	2023
10	IQF002	ASWA9ON/	ASWA9ON	TC-K09-B	Muscat	10/5/2023	2023
11	IQF002	IBOURK-SL/	IBOURK-SL	TC-K09-C	Muscat	10/5/2023	2023
12	IQF002	MISSBELT	MISSBELT	TC-K09-C	all shipmer	10/5/2023	2023
13	IQF002	MATJARPR	MATJARPF	TC-K09-C	all shipmer	10/5/2023	2023
14	IQF002	BBCCODBR	BBCCODBF	TC-K09-C	Muscat	10/5/2023	2023
15	IQF002	ANASIAACH	ANASIAAC	TC-K09-D	Muscat	10/5/2023	2023
16	IQF002	JOUHRI-SH.	JOUHRI-SH	TC-K10-A	Muscat	10/5/2023	2023
17	IQF002	TASAWOKN	TASAWOK	TC-K10-B	Muscat	10/5/2023	2023
18	IQF002	ANESATY1S	ANESATY1	TC-K10-C	Muscat	10/5/2023	2023
19	IQF002	SHOVALUX	SHOVALU)	TC-K10-D	Muscat	10/5/2023	2023
20	IQF002	MEDABOR-	MEDABOR	TC-K10-D	all shipmer	10/5/2023	2023

Date	Consignee Number	Client Id	Self location	SKU	Quantity	packge	Count	L/S	Picker name	LM Handover time
1/10/2023	F223609395	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F280611777	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F882064078	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F558152487	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F590073769	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F695162083	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F430989193	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F098729481	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F383636848	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F848834611	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F321558167	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F363696459	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F326272947	OMEGA1	TC-F12-A	MARAL-001	1	AEXPM	1	NO		4:50:00 PM
1/10/2023	F056698545	OMEGA1	TC-F12-A	MARAL-001	2	AEXPM	1	NO		4:50:00 PM
1/10/2023	F815201163	OMEGA1	TC-F12-A	MARAL-001	2	AEXPM	1	NO		4:50:00 PM
1/10/2023	F336179434	OMEGA1	TC-F12-A	MARAL-001	2	AEXPM	1	NO		4:50:00 PM
1/10/2023	F588237890	OMEGA1	TC-F12-A	MARAL-001	2	AEXPM	1	NO		4:50:00 PM
1/10/2023	F431508376	OMEGA1	TC-F12-A	MARAL-001	2	AEXPM	1	NO		4:50:00 PM
1/10/2023	F659244300	OMEGA1	TC-F12-A	MARAL-001	2	AEXPM	1	NO		4:50:00 PM
1/10/2023	F544656944	OMEGA1	TC-F12-A	MARAL-001	2	AEXPM	1	NO		4:50:00 PM
1/10/2023	F452758923	OMEGA1	TC-F12-A	MARAL-001	3	AEXPM	1	NO		4:50:00 PM
1/10/2023	F106058393	OMEGA1	TC-F12-A	MARAL-001	4	AEXPM	1	NO		4:50:00 PM
1/10/2023	F117243029	OMEGA1	TC-F12-A	MARAL-001	3	AEXPM	1	NO		4:50:00 PM

Figure 20. Database screenshots

Appendix 2: Honeywell device

Figure 21. Honeywell Device

Appendix 3: Midpoint policy

This illustrates the midpoint policy, the warehouse is divided into two areas by half, each picker will cover one half area.

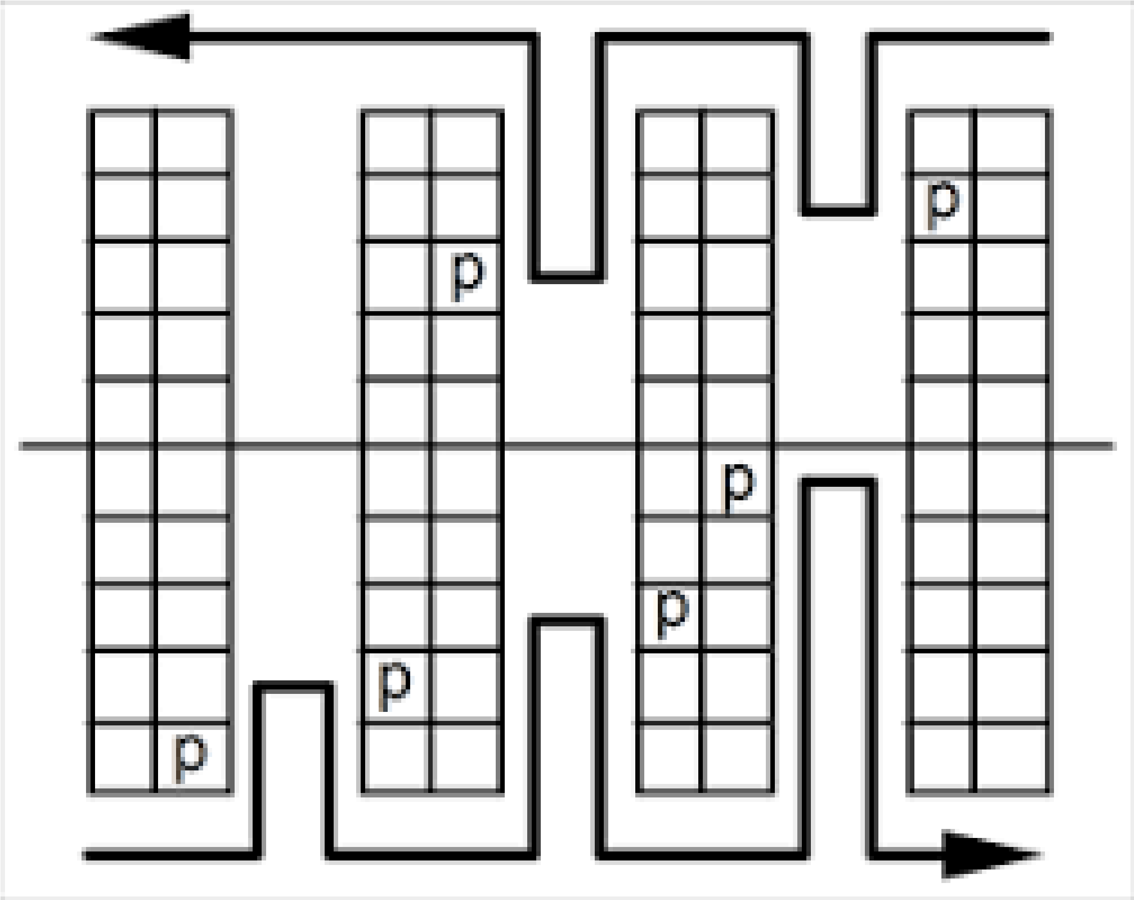


Figure 22. Midpoint routes

Appendix 4: Gantt chart

This is only an overview of the whole Gantt chart to see how it looks like, on next page will be a more zoomed and detailed Gantt chart.

project of applying ABC storage assignmenr and mid point pick-by-scan methods

Asyad Express

Project Start: Sat, 7/1/2023

Display Week: 1

TASK	ASSIGNED TO	START	END
Phase 1: Planning			
Define the objectives and goals of the new picking, routing and storage assignment methods	Manager	7/1/23	7/4/23
Identify the project scope	Manager	7/4/23	7/6/23
Establish project team	Manager	7/6/23	7/7/23
Determine resource requirments	Manager	7/7/23	7/8/23
Create project plan and timeline	Manager	7/8/23	7/15/23
Phase 2: Analysis and preparation			
Gather data on inventory	workers,supervisor	7/9/23	7/18/23
Conduct a thorough analysis of the current picking and routing methods.	Manager	7/18/23	7/23/23
Identify the strengths and weaknesses of the existing policies	manager	7/23/23	7/28/23
Gather data on order volume, inventory layout and historical performance.	workers,supervisor	7/9/23	7/23/23
perform ABC analysis	manager/supervisor	7/23/23	7/25/23
Phase 3: Design and Strategy			
analyze warehouse layout	manager	7/25/23	7/30/23
determine storage zones and assignments	manager	7/30/23	8/1/23
define standard operating procedures	manager/supervisor	8/2/23	8/6/23
Determine the hardware and software requirements for barcode scanning.	manager/ IT department or system controller	8/6/23	8/9/23
Define the scanning process for picking items accurately.	manager	8/9/23	8/13/23
Determine the criteria for selecting midpoints based on order characteristics	manager	8/13/23	8/14/23
identify appropriate the midpoint locations.	manager	8/14/23	8/15/23
Phase 4: ABC storage assignment implementation			
explain for the workers what needs to be done	manager/supervisor	8/15/23	8/17/23
set a designated time each day for implementation on no order picking hours	manager/supervisor	8/17/23	8/17/23
switch items between storage location based on the ABC analysis	workers	8/17/23	10/6/23
Test storage assignment method after implementing	workers/supervisor	10/6/23	11/5/23
Phase 5: Midpoint and pick-by-scan Implementation			
explain to workers the midpoints location	manager/supervisor	8/18/23	8/18/23
Procure Honeywell Barcode Scanning Equipment	manager/procurment department	8/19/23	9/2/23
Install and Configure Scanning System	manager/ IT department or system controller	9/2/23	9/5/23
Develop Scanning Processes and Training	manager	9/5/23	9/12/23
Train employees on the new pick-by-scan method and midpoint routing policy.	training team, manager	9/12/23	9/17/23
Gradually transition to the new system, starting with a pilot area or specific orders.	workers	9/17/23	9/22/23
Monitor the implementation process, addressing any issues or challenges that arise.	workers/supervisor/manager	9/22/23	10/22/23
Ensure effective communication and support during the transition.	manager	9/17/23	10/22/23
Phase 6: Training and Communication			
train the staff on the new strategies and ensure thet do it well	manager, training team if possible	9/5/23	9/17/23
communicate changes to stakeholders	manager	9/22/23	11/5/23
Phase 7: Go-Live and monitor and new methods			
Transition to new methods and aprrove it as the standard policy and procedure	manager	11/6/23	11/7/23
Phase 8: Evaluation and adjustment			
Measure the performance of the new system after implementation.	manager/supervisor	11/7/23	11/14/23
Compare the results with the defined objectives and goals.	manager/supervisor	11/14/23	11/16/23
Collect feedback from employees and stakeholders.	manager/supervisor	11/7/23	11/14/23
identify areas for improvement and make necessary adjustments.	manager/supervisor	11/16/23	11/20/23

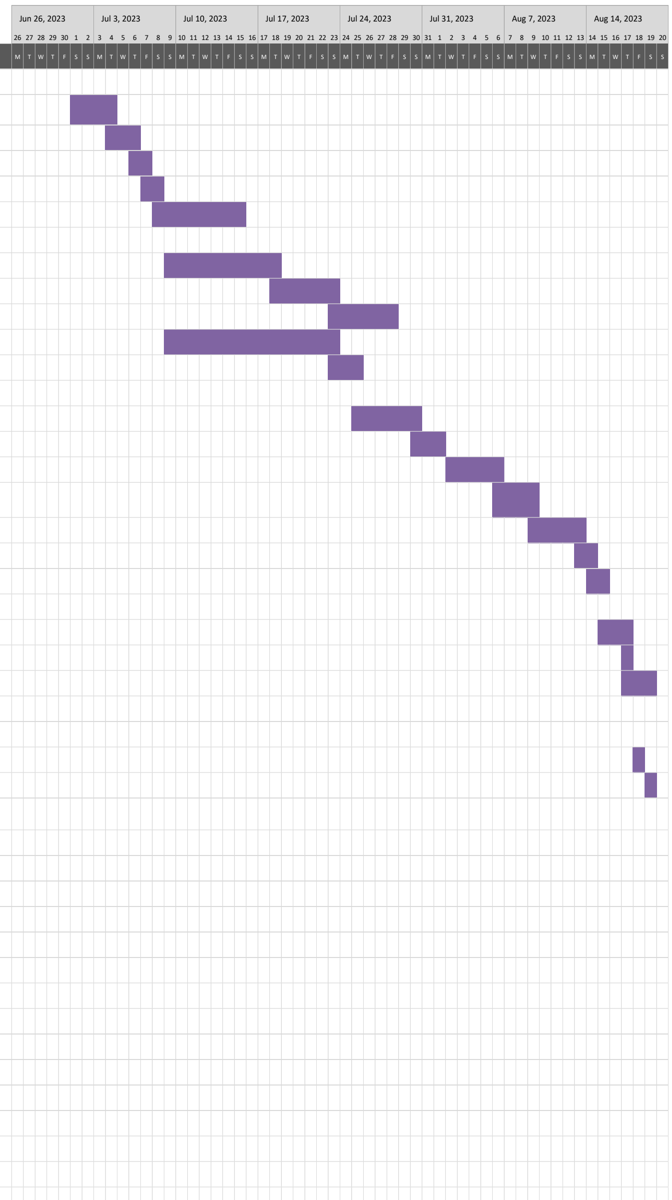


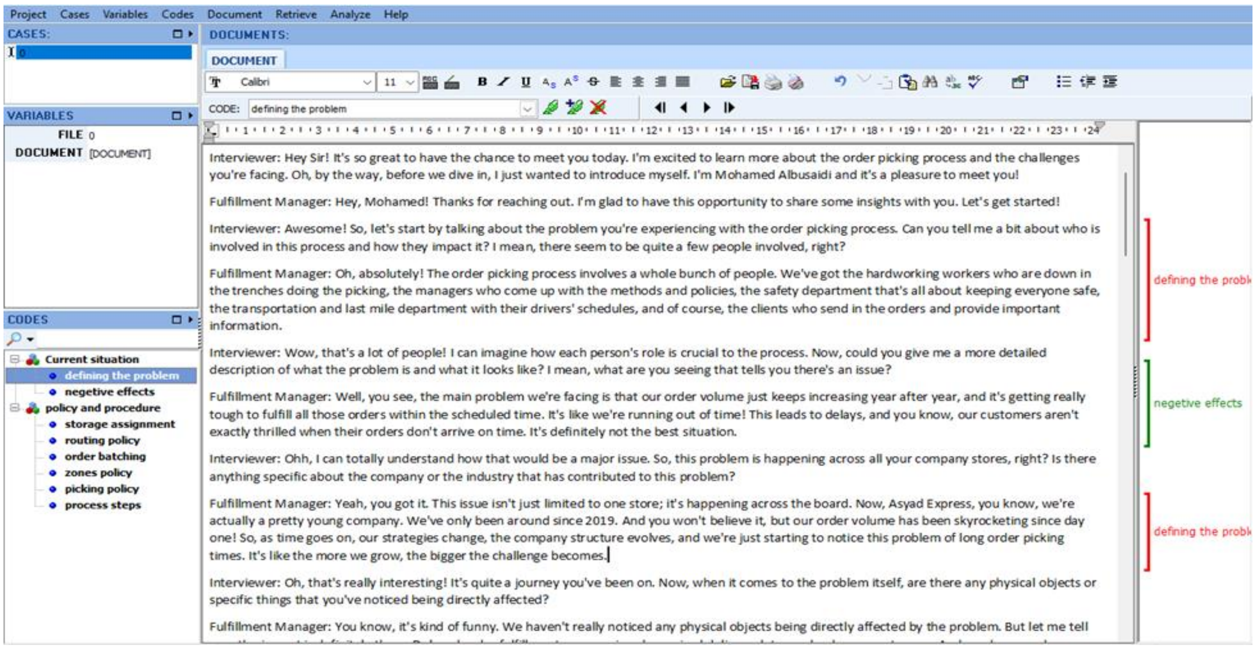
Figure 23. Gantt chart overview

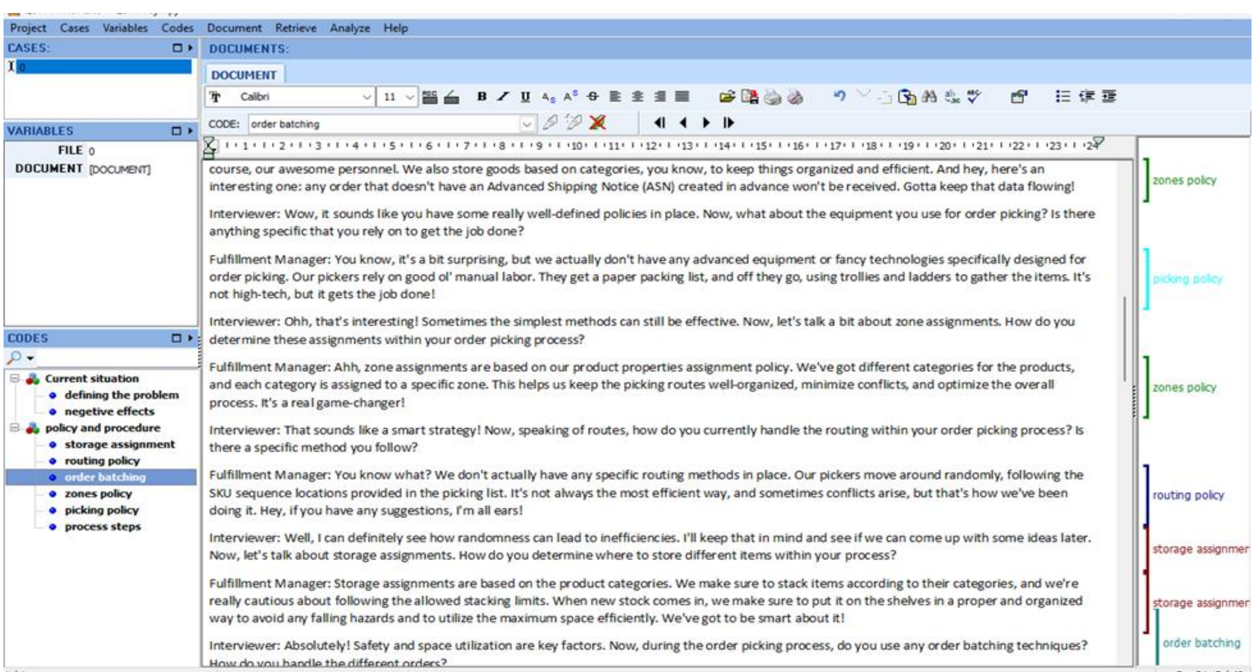
TASK	ASSIGNED TO	START	END
Phase 1: Planning			
Define the objectives and goals of the new picking, routing and storage assignment methods	Manager	7/1/23	7/4/23
Identify the project scope	Manager	7/4/23	7/6/23
Establish project team	Manager	7/6/23	7/7/23
Determine resource requirments	Manager	7/7/23	7/8/23
Create project plan and timeline	Manager	7/8/23	7/15/23
Phase 2: Analysis and preparation			
Gather data on inventory	workers,supervisor	7/9/23	7/18/23
Conduct a thorough analysis of the current picking and routing methods.	Manager	7/18/23	7/23/23
Identify the strengths and weaknesses of the existing policies	manager	7/23/23	7/28/23
Gather data on order volume, inventory layout and historical performance.	workers,supervisor	7/9/23	7/23/23
perform ABC analysis	manager/supervisor	7/23/23	7/25/23
Phase 3: Design and Strategy			
analyze warehouse layout	manager	7/25/23	7/30/23
determine storage zones and assignments	manager	7/30/23	8/1/23
define standard operating procedures	manager/supervisor	8/2/23	8/6/23
Determine the hardware and software requirements for barcode scanning.	manager/ IT department or system controller	8/6/23	8/9/23
Define the scanning process for picking items accurately.	manager	8/9/23	8/13/23
Determine the criteria for selecting midpoints based on order characteristics	manager	8/13/23	8/14/23
identify appropriate the midpoint locations.	manager	8/14/23	8/15/23
Phase 4: ABC storage assignment implementation			
explain for the workers what needs to be done	manager/supervisor	8/15/23	8/17/23
set a designated time each day for implementation on no order picking hours	manager/supervisor	8/17/23	8/17/23
switch items between storage location based on the ABC analysis	workers	8/17/23	10/6/23
Test storage assignment method after implementing	workers/supervisor	10/6/23	11/5/23
Phase 5: Midpoint and pick-by-scan Implementation			
explain to workers the midpoints location	manager/supervisor	8/18/23	8/18/23
Procure Honeywell Barcode Scanning Equipment	manager/procurment department	8/19/23	9/2/23
Install and Configure Scanning System	manager/ IT department or system controller	9/2/23	9/5/23
Develop Scanning Processes and Training	manager	9/5/23	9/12/23
Train employees on the new pick-by-scan method and midpoint routing policy.	training team, manager	9/12/23	9/17/23
Gradually transition to the new system, starting with a pilot area or specific orders.	workers	9/17/23	9/22/23
Monitor the implementation process, addressing any issues or challenges that arise.	workers/supervisor/manager	9/22/23	10/22/23
Ensure effective communication and support during the transition.	manager	9/17/23	10/22/23
Phase 6: Training and Communication			
train the staff on the new strategies and ensure thet do it well	manager, training team if possible	9/5/23	9/17/23
communicate changes to stakeholders	manager	9/22/23	11/5/23
Phase 7: Go-Live and monitor and new methods			
Transition to new methods and aprrove it as the standard policy and procedure	manager	11/6/23	11/7/23
Phase 8: Evaluation and adjustment			
Measure the performance of the new system after implementation.	manager/supervisor	11/7/23	11/14/23
Compare the results with the defined objectives and goals.	manager/supervisor	11/14/23	11/16/23
Collect feedback from employees and stakeholders.	manager/supervisor	11/7/23	11/14/23
identify areas for improvement and make necessary adjustments.	manager/supervisor	11/16/23	11/20/23

Figure 24. Detailed Gantt chart

Appendix 5: QDA minor screenshots

These screenshots illustrate the use of QDA minor software.





Appendix 6: Interview questions

These are just the main questions that were asked during the interview with the fulfillment manager. There have been some other questions based on the answer to each main question as the LSA technique was followed.

1) Can you tell me about who is involved in the order picking process and how they impact it?
2) Could you give me a more detailed description of what the problem is and what it looks like?
3) Are there any physical objects or specific things that you've noticed being directly affected?
4) Could you tell me about the policies you have in place for the order picking process? What are the guidelines that you follow?
5) What equipment do you use for order picking? Is there anything specific that you rely on to get the job done?
6) How do you determine the zone assignments within your order picking process?
7) How do you currently handle the routing within your order picking process? Is there a specific method you follow?
8) How do you determine where to store different items within your process?
9) during the order picking process, do you use any order batching techniques? How do you handle the different orders?
10) How do you plan and allocate the available resources within your order picking process?
11) How are orders assigned to the pickers?
12) What are the steps that are involved in picking an order?
13) Have you considered any changes to the current policies and procedures? And if not, why? If yes, what? and are they sufficient?
14) Have you conducted any analysis or measurements to assess the development of the problem and evaluate the extent of the damage it has caused?
15) Can you provide some insights into how the problem has developed over time?
16) have you noticed any particular areas or stages within the order picking process where the issue tends to occur more frequently?
17) Can you recall when this problem with long order picking time first started to become noticeable? Was there a specific event or circumstance that triggered it?
18) How would you describe the urgency and importance of finding a solution to this problem?

Appendix 7: Interview transcript

Please note that this interview was done with the fulfilment manager of AEX on Arabic language, the native language in Oman where the company is located. This provides a smoother conversation, and it is much more convincing for the fulfillment manager. The interview was then Translated using a translation software to save time which then the whole transcript is checked to see if it translated correctly to English so some unnecessary phrases or expressions and emotions will not be included to shortening the transcript:

Interviewer: Hey Sir! It is so great to have the chance to meet you today. I am excited to learn more about the order picking process and the challenges you're facing. Oh, by the way, before we dive in, I just wanted to introduce myself. I am Mohamed Albusaidi, and it is a pleasure to meet you!

Fulfillment Manager: Hey, Mohamed! Thanks for reaching out. I am glad to have this opportunity to share some insights with you. Let us get started!

Interviewer: Awesome! So, let us start by talking about the problem you're experiencing with the order picking process. Can you tell me a bit about who is involved in this process and how they impact it? I mean, there seem to be quite a few people involved, right?

Fulfillment Manager: Oh, absolutely! The order picking process involves a whole bunch of people. We've got the hardworking workers who are down in the trenches doing the picking, the managers who come up with the methods and policies, the safety department that's all about keeping everyone safe, the transportation and last mile department with their drivers' schedules, and of course, the clients who send in the orders and provide important information.

Interviewer: Wow, which is a lot of people! I can imagine how each person's role is crucial to the process. Now, could you give me a more detailed description of what the problem is and what it looks like? I mean, what are you seeing that tells you there is an issue?

Fulfillment Manager: Well, you see, the main problem we are facing is that our order volume just keeps increasing year after year, and it's getting tough to fulfill all those orders within the scheduled time. It is like we're running out of time! This leads to delays, and you know, our customers are not exactly thrilled when their orders don't arrive on time. It is not the best situation.

Interviewer: Ohh, I can totally understand how that would be a major issue. So, this problem is happening across all your company stores, right? Is there anything specific about the company or the industry that has contributed to this problem?

Fulfillment Manager: Yeah, you got it. This issue isn't just limited to one store, it's happening across the board. Now, Asyad Express, you know, we're a pretty young company. We've only been around since 2019. And you won't believe it, but our order volume has been skyrocketing since day one! So, as time goes on, our strategies change, the company structure evolves, and we're just starting to notice this problem of long order picking times. It's like the more we grow, the bigger the challenge becomes.

Interviewer: Oh, that's interesting! It's quite a journey you've been on. Now, when it comes to the problem itself, are there any physical objects or specific things that you've noticed being directly affected?

Fulfillment Manager: You know, it's kind of funny. We haven't really noticed any physical objects being directly affected by the problem. But let me tell you, the impact is there. Delayed order fulfillment means missed promised delivery dates and unhappy customers. And you know, unhappy customers can have a big impact on our reputation and overall customer service levels.

Interviewer: Absolutely! Customer satisfaction is key, so it's important to address these issues. Now, let's shift gears a bit and talk about the current situation, policies, and procedures. Could you tell me a bit more about the policies you have in place for the order picking process? Are there any specific guidelines that you follow?

Fulfillment Manager: Oh, we've got quite a few policies and procedures in place! When it comes to stock, we make sure it's easily accessible and identified through SKU labels. We're strict about sticking to the allowed stacking limits to avoid any damage or risks to our materials and, of course, our awesome personnel. We also store goods based on categories, you know, to keep things organized and efficient. And hey, here's an interesting one: any order that doesn't have an Advanced Shipping Notice (ASN) created in advance won't be received. Gotta keeps that data flowing!

Interviewer: Wow, it sounds like you have some really well-defined policies in place. Now, what about the equipment you use for order picking? Is there anything specific that you rely on to get the job done?

Fulfillment Manager: You know, it's a bit surprising, but we actually don't have any advanced equipment or fancy technologies specifically designed for order picking. Our pickers rely on good manual labor. They get a paper packing list, and off they go, using trollies and ladders to gather the items. It's not high-tech, but it gets the job done!

Interviewer: Ohh, that's interesting! Sometimes the simplest methods can still be effective. Now, let's talk a bit about zone assignments. How do you determine these assignments within your order picking process?

Fulfillment Manager: Ahh, zone assignments are based on our product properties assignment policy. We've got different categories for the products, and each category is assigned to a specific zone. This helps us keep the picking routes well-organized, minimize conflicts, and optimize the overall process. It's a real game-changer!

Interviewer: That sounds like a smart strategy! Now, speaking of routes, how do you currently handle the routing within your order picking process? Is there a specific method you follow?

Fulfillment Manager: You know what? We don't actually have any specific routing methods in place. Our pickers move around randomly, following the SKU sequence locations provided in the picking list. It's not always the most efficient way, and sometimes conflicts arise, but that's how we've been doing it. Hey, if you have any suggestions, I'm all ears!

Interviewer: Well, I can definitely see how randomness can lead to inefficiencies. I'll keep that in mind and see if we can come up with some ideas later. Now, let's talk about storage assignments. How do you determine where to store different items within your process?

Fulfillment Manager: Storage assignments are based on the product categories. We make sure to stack items according to their categories, and we're really cautious about following the allowed stacking limits. When new stock comes in, we make sure to put it on the shelves in a properly and organized way to avoid any falling hazards and to utilize the maximum space efficiently. We've got to be smart about it!

Interviewer: Absolutely! Safety and space utilization are key factors. Now, during the order picking process, do you use any order batching techniques? How do you handle the different orders?

Fulfillment Manager: Ohh, we do use order batching! Currently, we pick orders in three batches. The first batch is super important because it's specifically for Muscat shipments. We make sure to give it top priority. As for the second and third batches, the timing is a bit more flexible. Orders can be picked throughout the day as the volume keeps increasing. We deliver the orders on the next day after they're picked and packed.

Interviewer: Ahh, I see. That makes sense, especially with the increasing order volume. Now, when it comes to resources, how do you plan and allocate them within your order picking process?

Fulfillment Manager: Well, to be honest, we don't have any dedicated resources or specialized equipment for order picking. It's mostly about the pickers and their trusty trollies and ladders. They manually pick the orders based on the paper packing lists they receive. It's a bit old-school, but it's what we've got at the moment. Do you think we should consider implementing any new resources or equipment?

Interviewer: Hmm, that's an interesting question. I'll definitely explore some possibilities and see if there are any recommendations to optimize your resources. Now, let's talk about how orders are assigned to the pickers. How does that process currently work?

Fulfillment Manager: Job assignment is actually done by distributing the work fairly among the available pickers. We want to make sure everyone has a fair share of the workload, so we try to evenly distribute the orders among them. It's all about teamwork!

Interviewer: Great! Collaboration is key for a smooth workflow. Now, let's dive a bit deeper into the order picking process itself. Could you walk me through the steps involved in picking an order? I'd love to get a better understanding.

Fulfillment Manager: Sure thing! So, the process starts with the pickers receiving the picking instructions based on the WMS (Warehouse Management System) order. They carefully follow the instructions and retrieve the items accordingly. Once they've completed the picks, the orders are placed in the packing stations, where customized packing is done to meet the client's standards. And that's pretty much how we roll!

Interviewer: Oh, that's really insightful! It's great to have a clear picture of the steps involved. Now, based on all the information you've shared, I'm curious about a few things. For example, with the increasing order volume and the growing challenges, have you considered any changes to the current policies and procedures? And if not, why do you think they are sufficient?

Fulfillment Manager: Ahh, well, that's a thought-provoking question. You know, we've been doing things this way for a while now, and it's become sort of a routine. But I can definitely see the need for changes, especially with the increasing volume. Perhaps we've become a bit complacent and haven't explored other possibilities. So, yeah, I think it's high time we reevaluate our current policies and procedures and consider making some adjustments.

Interviewer: That's great to hear! It's always beneficial to reassess and adapt. Now, with the order picking process being a critical part of your operations, have you conducted any analysis or measurements to assess the development of the problem and evaluate the extent of the damage it has caused?

Fulfillment Manager: Well, to be honest, we haven't conducted any formal analysis or measurements specifically related to the order picking process. But we're well aware of the impact the problem has had on delayed order fulfillment and customer satisfaction. It's been a bit of a struggle, but it's definitely something we need to dive deeper into to understand the extent of the damage and find ways to improve.

Interviewer: Absolutely, understanding the impact and finding ways to improve is crucial. Now, let's talk a bit more about the problem itself. You mentioned that the issue of long order picking time has become noticeable only recently. Can you provide some insights into how the problem has developed over time?

Fulfillment Manager: Well, you see, our company, Asyad Express, is relatively new. We were established in 2019, and since then, the order volume has been increasing year by year. As the organization structure and management layers have evolved, strategies have changed as well. It's during this growth period that we started experiencing challenges with the long order picking time. The rising volume, coupled with the changing dynamics of the company, contributed to the problem becoming more apparent in recent times.

Interviewer: That makes sense. As the company grows, it's natural for new challenges to arise. Now, when it comes to the problem itself, are there any physical objects or materials that have been directly affected by the issue of long order picking time?

Fulfillment Manager: Actually, we haven't noticed any specific physical objects or materials being directly affected by the issue. The problem lies more in the delayed order fulfillment, which impacts promised delivery dates and customer service levels. It's more about overall efficiency and customer satisfaction rather than any physical damage or impact.

Interviewer: I see. So, the primary focus is on streamlining the process and reducing delays. Now, considering the impact this problem has had, have you noticed any particular areas or stages within the order picking process where the issue tends to occur more frequently?

Fulfillment Manager: The issue of long order picking time can occur at different stages within the process. It's not limited to a specific area. However, one area where we have observed challenges is in the coordination with other departments, such as the transportation and last mile team. We have fixed departure times for drivers, and if orders are not picked up and ready on time, it can disrupt the entire chain. So, ensuring smooth coordination and timely fulfillment is crucial to avoid any delays.

Interviewer: Ahh, coordination is definitely key, especially when different departments are involved. Now, looking back, can you recall when this problem with long order picking time first started to become noticeable? Was there a specific event or circumstance that triggered it?

Fulfillment Manager: Well, it's difficult to pinpoint an exact moment, but I would say that as the order volume continued to rise, we started to feel the pressure of meeting the increasing demands. It became more evident over time, especially as customer expectations grew, and we faced challenges in fulfilling orders within the scheduled timeframe. So, it was a gradual realization rather than a specific event that triggered our awareness of the problem.

Interviewer: I understand. It's a cumulative effect that gradually became more prominent. Now, considering the impact on customer satisfaction and the challenges you've been facing, how would you describe the urgency and importance of finding a solution to this problem?

Fulfillment Manager: Oh, the urgency and importance are definitely high! Customer satisfaction is our top priority, and any delays or inefficiencies in the order picking process directly affect that. We understand the importance of delivering orders on time and meeting customer expectations. It's not just about improving our internal operations; it's about ensuring that our customers receive their orders promptly and are satisfied with our service. So, finding a solution to this problem is crucial for our overall success and reputation.

Interviewer: Absolutely, customer satisfaction is paramount. Thank you for sharing all these insights and details about the order picking process and the challenges you're facing. It's been really helpful in understanding the scope of the problem and its impact. Is there anything else you would like to add or any other aspects you think we should consider?

Fulfillment Manager: Hmm, let me think... Well, one aspect that might be worth exploring is the impact of product characteristics on the order picking process. Different products may have different requirements or handling considerations, which could potentially affect the time it takes to pick them. It might be interesting to delve deeper into this aspect and see if there are any opportunities to optimize the process based on product characteristics.

Interviewer: That's an excellent point! The product characteristics could indeed play a significant role in the order picking process. Thank you for bringing that up. I'll include that in my analysis. Once again, I really appreciate your time and valuable insights. It has been a pleasure talking with you and learning more about the order picking process and the challenges you're facing.

Fulfillment Manager: It was my pleasure to participate and assist you with your research. If you have any further questions or need additional information, feel free to reach out. Good luck with your research!

Interviewer: Thank you so much for your support and willingness to help. I'll keep that in mind. Have a wonderful day!

Fulfillment Manager: You too! Take care.