Optimization of the picking process at the warehouse

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Abstract:

This thesis studies the optimization solution for the picking process at the warehouse. Research question which is answered in this thesis: How to optimize and restructure the picking process at the warehouse to reach high productivity and reliability of it?

The data for the research was obtained from both primary and secondary sources. Primary data was collected thought the collection of the key indicators which are used to calculate the productivity of the warehouse.

The results suggest that the optimization and improvement of the routing system at the warehouse is the best solution for optimization of the picking process. Furthermore, the findings revealed that subsequent to the implementation of the aforementioned modifications, there was a marginal increment observed in the key performance indicators of the warehouse. This incremental improvement already demonstrated a beneficial impact on the overall efficiency and functioning of the warehouse operations.

Keywords:

Warehousing, picking process, delivery reliability, delivery performance, optimization, routing system.

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1 INTRODUCTION

Competitiveness is one of the most important components in any business. Companies are looking for new ideas for the products, new ways of advertising or just compete in the price range. Besides, are the any options for companies to be competitive from the logistical point of view? The answer is a delivery service. This case study is revealing the importance of one small part of the warehousing which has huge impact on the overall output – picking process.

Picking process is closely related to principle of 7Rs in Logistics. Definition of this principle is the following: "The process of planning, implementing, and controlling the efficient and effective forward and reverse flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of meeting customer requirements." (Council of Logistics Management 1991)
This is the list of all 7R is logistics (Trichai et al., 2021): 1. The right product, 2. The right quantity, 3. The right time, 4. The right quality, 5. The right place, 6. The right cost, 7. The right consumer.

Among these 7 principles two of them have a direct connection with picking process. End consumer must always receive exactly what has been ordered and this brings us to the two principles of 7R: right quantity and right product. This is the most important part of the warehousing activity – to satisfy customer wants by delivering ordered goods. In addition, these 2 principles have a direct impact on the customer loyalty level and number of claims. For instance, customer who received 2 products instead of 3 will be definitely not happy and is going to conduct a claim. In most of the times, this customer will not order from this company again due to the negative experience.
These 2 factors have to be considered during the optimization and conducting of the picking process.

My thesis is a case study for the one warehousing company. I have some understanding in this field since I work at the warehouse with dispatching customer orders by picking goods and packaging them according to given picking lists for each customer order. One of the most discussed problems in the warehousing business is how to optimize and bring to the perfection the picking process – crucial part of the delivery service. After working

at the warehouse for 3 months, I understand that picking process is not perfect and it is the main reason for most of the problems and profit losses. It was decided that the topic of picking can be research and new solutions has to be implemented into the process. It was also discussed that it is required to know opinions of the staff about the problem. With the help of it, it is possible to deeply understand the issue and find a right way what has to be investigated.

1.1 Problem statement

What challenges and problems can disorganized picking bring to the company? The list of these problems can be huge; however, the most obvious issues are connected with additional unwanted costs and claims from unsatisfied customers. As it was stated earlier, picking reliability has a direct impact on the number of claims from the customers. Furthermore, in most of the cases claims are followed by order returns.

Returns of the products results in additional costs for the warehouse (delivery to the warehouse, opportunity costs). Based on this information problem statement can be set. Disorganized picking process leads to increasing of the claims and brings additional undesirable costs for the warehouse.

1.2 Aim of the study

The aim of this case study is to find new optimization solutions to increase productivity and reliability of the picking process at the warehouse.

The research question of this study is how to optimize and restructure the picking process at the warehouse to reach high productivity and reliability of it.

1.3 Demarcation

At the warehouse of the case company only manual picking is used as a tool to collect and conduct orders from the customers. In logistics, there is also so called “autonomous picking” which is do not include human interaction in the process. This particular case

study has an aim to find solutions for optimization in the field of manual picking. Autonomous picking is not considered as a part of this study.

1.4 Definitions

Delivery reliability - accuracy of the delivery time which can be measured by the number of deliveries out of total orders, or the value of orders delivered out of the total value orders. (Nils G. Storhagen, 2018)

Delivery performance - the correctness of collected orders. (Nils G. Storhagen, 2018)

Picking system design - processes designed to increase the efficiency, speed and accuracy of picking activities. (Bottani et al., 2019)

Zone picking - a design where each picker is assigned to the specific region of the storage area and is responsible to pick items only from that particular region. (Parikh & Meller, 2008)

Batch picking – picking design where orders are batched (grouped) together and picker should pick all orders at a time. (Tompkins et al., 2003)

LSQ – the model that focuses on providing customer-oriented logistics services over a period of time. (Wu & Dong, 2023)

Warehouse design layout – the strategic plan for arranging storage space in an efficient and cost-effective manner. (Rakesh & Adil, 2015)

Action research – an approach in which the researcher and a client collaborate in the identification of the problem and in the development of the solution based on the problem. (Alan Bryman, 2011)

Validity of the data – the integrity of the conclusions that are generated from the research. (Alan Bryman, 2011)

Reliability of the data – Repeatability and accuracy of the conducted research. (Alan Bryman, 2011)

1.5 Presentation of the company

This case study is done for a warehousing company. Its primary activity is to provide warehousing solutions to another companies. Current client of the warehouse (the company chose not to disclose its name) outsourced full responsibility for the warehousing management to a case company.

There are some boundaries which warehousing management is obliged to perform for its client. Conduct of inbound and outbound logistics is considered to be one of the main and important routine for the warehouse. In addition, the list of boundaries is also complemented by picking and sending out orders, both B2C and B2B; claims and returns handling and everything what is connected with inventory management (control of the stock levels, inventory refills, EOQ etc.).

All cases that are going to be discussed in this study, will be taken from the company's working experience.

2 THEORY

This chapter is discussing related theory for this case study. In this chapter main topic of discussion is a Delivery service which is connecting all main aspects of the warehousing. In addition, definitions of Zone and Batch picking are explained and compared for further identification of the more appropriate way of picking. Zone and batch picking is done according to the pre-planned route. These pre-planned routes are correspond to the theory of the picking alternatives which are compared to each other in this chapter.

To sum up this part of the thesis, all indicated theory and models have a direct impact on Customer Service. It is shown to what extend and how Customer Service is influenced by these theories and models.

2.1 Delivery Service

Delivery service can be defined as a measurement of the logistical performance of the supplier during the delivery. (Nils G. Storhagen, 2018) What is the purpose of the delivery service for the companies nowadays? One of the main advantages of the delivery service is to add more value and due to that increase company's competitive advantage. Delivery service is a good follow up factor for the supplier as well as for the buyer. A supplier needs this information to improve their business and customer service while a buyer needs this kind of information to rate supplier's performance. There are nine elements of the delivery service with the help of which companies can improve its competitiveness. (Nils G. Storhagen, 2018)

1. Stock availability
2. Delivery time/lead time
3. Delivery Reliability (on-time delivery)
4. Delivery performance (error-free)
5. Information flow
6. Customized solutions
7. Choices regarding the environmental impact
8. Flexibility
9. Other service elements (packaging method, return policy, claim handling etc.)

All these elements have a direct and valuable impact on the customer service and overall performance of the company. However, only two of these elements relate to the topic of the case study and to the warehousing, in particular to the picking process. Elements number three and four which are Delivery Reliability and Delivery Performance are entirely depends on the quality of picking.

2.1.1 Delivery Reliability

There are many different definitions of the delivery reliability among researchers.
According to Hils Storhagen, delivery reliability represents accuracy of the delivery time which can be measured by the number of deliveries out of total orders, or the value of orders delivered out of the total value orders. (Nils G. Storhagen, 2018)

Moh'd Anwer Al- Shboul indicates that delivery reliability defined as a range to which the firm is eligible and able to provide customer orders without delay with different kinds and sizes of products (Anwer AL-Shboul, 2022). As we can see from these definitions, main idea of the delivery reliability is to deliver ordered goods to the customer on-time stated in the delivery/lead time.

2.1.2 Delivery Performance

Delivery Performance indicates the correctness of collected orders. In other words, order from customer has to contain the right product in the right quantity, delivery must include exactly what has been ordered. This element can be considered more important than Delivery reliability. Poor delivery performance can cause claims from the customers which are going to be followed by additional and unwanted costs for the warehouse. These costs can be transportation cost for the return, opportunity cost, cost for the next picking and packaging of this product.

Besides, if the delivery error was made, it is vital to always control and follow up the reasons of the error and the way of how these situations had been solved. This provides company with the experience and helps to prevent further errors that can be done. Vital part of the warehousing is to send right quantity and right products to the customer (error-free delivery). (Nils G. Storhagen, 2018)
Delivery performance measurement is a crucial aspect that warrants attention. Notably, Johan Hedin, Martin Jonsson, and Johan Ljunggren have conducted scientific research on this topic, proposing a method for measuring delivery performance as a percentage of customer orders delivered "on time and in-full" (OTIF) (Hedin et al., 2006). This approach entails comparing the total number of successfully delivered orders with those containing inaccuracies, such as incorrect item delivery or quantity discrepancies. By utilizing this method, an order accuracy rate can be derived, providing a more comprehensible understanding of delivery performance.

Order accuracy rate = (Total orders – Error orders) / Total orders * 100

Figure 1 - Order accuracy rate

2.1.3 Effect on Customer Satisfaction (LSQ)

All kind of improvements in every company have their own specific goal. Some of them are done to decrease and cut unnecessary costs, some of them are done to improve productivity and profitability of the company. However, there is one big general goal for every company that is working with customers. This goal is to gain customer satisfaction. In the field of logistics, Logistics service quality (LSQ) is responsible for that.

What is Logistics Service Quality (LSQ)?

LSQ model focuses on providing customer-oriented logistics services over a period of time. (Wu & Dong, 2023). This model includes 9 main elements: personnel contact quality, order release quantities, information quality, ordering procedure, order accuracy, order quality, order discrepancy and timeliness (Mentzer et al., 2001). There is another definition to that concept. Yang et al. (2010) has defined LSQ to be a set of performance factors, measured be the ability to distribute products in accordance with customer requirements.

How LSQ influence customer satisfaction?

As it was defined earlier, one of the main goal of the company is to gain and increase customer satisfaction. In the field of warehousing, it can be reached via logistics service quality. However, is there any relation between customer satisfaction and LSQ?

Studies indicated that there are 3 main elements of the LSQ that has a positive impact on the customer satisfaction: quality of the service personnel, the quality of information and quality of the orders. In addition, customer satisfaction significantly depends on the punctuality of the logistical service (Saura et al., 2008).

Nevertheless, in the study about the influence of IT tools on the relationship between LSQ and customer satisfaction, it was found that IT tools has no direct impact on the customer satisfaction, but rather on the LSQ, which is, it turn, influenced customer satisfaction (Bienstock and Royne, 2010).

2.2 Picking system design. Zone and Batch picking

Picking system design is an important factor to consider in the warehousing. Speed and reliability that were discussed in the previous chapter depends on the choice of the picking design. In the warehousing management and design there are several commonly used order picking terms: batch, discrete, zone, bucket brigade and wave picking. Zone and batch picking are the main priority to discuss in this chapter.

2.2.1 Zone picking

One of the commonly used picking designs is a zone picking. According to the paper of Pratik J. Parikh and Russel D. Meller, zone picking is a design where each picker is assigned to the specific region of the storage area and is responsible to pick items only from that particular region. (Parikh & Meller, 2008)

In the picture below the principle between zone picking is illustrated. There are 3 zones with different types of products. Each picker is assigned to one of them and their task is to collect order in their "zone" and bring it to the delivery conveyor which is illustrated at the bottom of the picture.

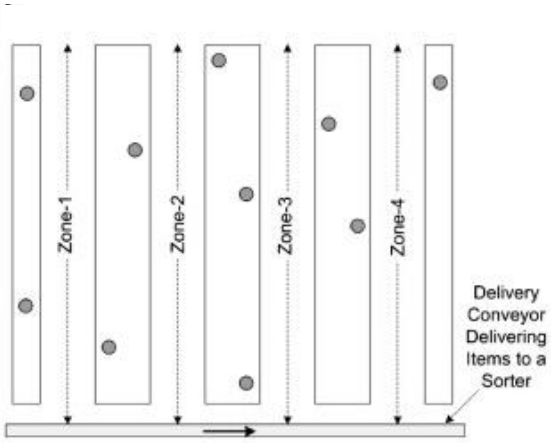

Figure 2 - Zone picking.

Zone picking can be divided into 2 types: *sequential* and *simultaneous* (Tompkins et al., 2003). Main idea behind the *sequential picking* is that only one order processed at a time in one particular zone. *Simultaneous picking* differs from sequential picking by the fact that all orders from the batch are picked at the same time from various zones and then sent to the sorting system for further order conduction.

To compare these two types of zone picking, two factors should be considered: pick-rate and additional processing. Due to the fact that during the sequential zone picking only one order is picked at a time, this is dramatically reduce pick-rate, which is influencing delivery reliability, however, it eliminates usage of the downstream sorter. Besides, simultaneous zone picking increase pick rate in several time because all order from the batch is collected at the same time, but this type of picking requires additional processing with the downstream sorter.

2.2.2 Batch picking

Batch picking is another alternative of the picking design. How batch picking works? Basically, orders are batched (grouped) together and picker should pick all orders at a time.

At the picture above batch picking process is illustrated. It is shown that the picker has a route (pick-tour) which should be followed, and orders have to be collected from specific pick locations.

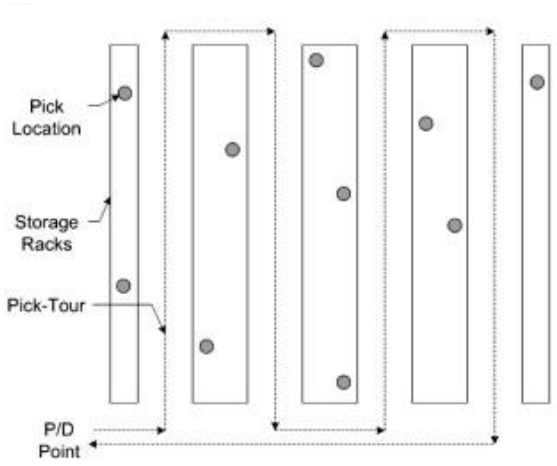

Figure 3 - Batch picking

There are two types of batch picking: *pick-and-sort* and *sort-while pick* (Tompkins et al., 2003). Pick-and-sort type implied that picker *do not* sort orders while picking, sorting is done afterwards though manual or autonomous sorting system. In contract, sort-while-pick type means that orders are sorted into customer orders during the picking process.

To compare these two batch picking types, same factors as in zone picking have to be considered: pick-rate and additional processing. Pick-and-sort type increase pick-rate because picker do not spend time to sort orders while picking, but in the end, it required sorting afterwards. Sort-and-pick type has a lower pick-rate, however, it does not involve additional sorting after the picking.

Nevertheless, there are two factors which have an impact on the comparison of zone and batch picking: *blocking* and *workload-imbalance* (Parikh & Meller, 2008). Blocking can occur in the batch picking due to the fact that pickers move freely around the warehouse. Blocking result in waiting-time which reduces the productivity of pickers and affects delivery reliability. Workload-imbalance means that there is a possibility that orders are batched and distributed unequally between pickers. Unequal workload can result in some orders not being picked at the stated time schedule which is again affect delivery reliability. (Parikh & Meller, 2008)
Zone and batch picking have their own benefits and drawbacks. For a better understanding here is a table which is illustrate all pros and cons of them.

Table 1 - Zone and batch picking. Advantages and disadvantages (Parikh & Meller, 2008)

Strategy	**Type**	**Advantages**	**Disadvantages**
Batch Picking	Pick-and-sort	• Increases pick-rate because sorting is not part of the picking. • Reduce chances of workload-imbalance.	• Sorting system required. • Increased probability of blocking. • Pick-rate decrease because pick-tour is long
	Sort-and-pick	• Reduce chances of workload-imbalance. • Sorting system is not required.	• Decrease pick-rate because sorting is a part of picking.

			• Decrease pick-rate as pick-tour is long. • Increase probability of blocking
Zone Picking	Sequential	• Increased pick-rate as pick-tour is short. • Sorting system is not required. • Eliminates blocking.	• Increase chances of workload imbalance.
	Simultaneous	• Increased pick-rate as pick-tour is short. • Eliminates blocking.	• Requires sorting system. • Workload imbalance.

2.3 Warehouse design layouts.

In addition to various picking system designs, warehouse design layouts are also a crucial factor in the overall picking process. These layouts refer to the strategic plan for arranging storage space in an efficient and cost-effective manner. According to a paper by Venkitasubramony Rakesh and Gajendra K. Adi, decisions about warehouse layout, such as height, width, lane depth, aisle width, cross-aisle location, and location of input/output points, have a significant impact on both capital investment (construction of the facility) and operational costs (space costs, handling costs, etc.) (Rakesh & Adil, 2015).

In this chapter, three of the most popular warehouse layouts are presented: the I-shaped layout, L-shaped layout, and U-shaped layout. These layouts are compared to demonstrate their respective benefits and drawbacks for better understanding.

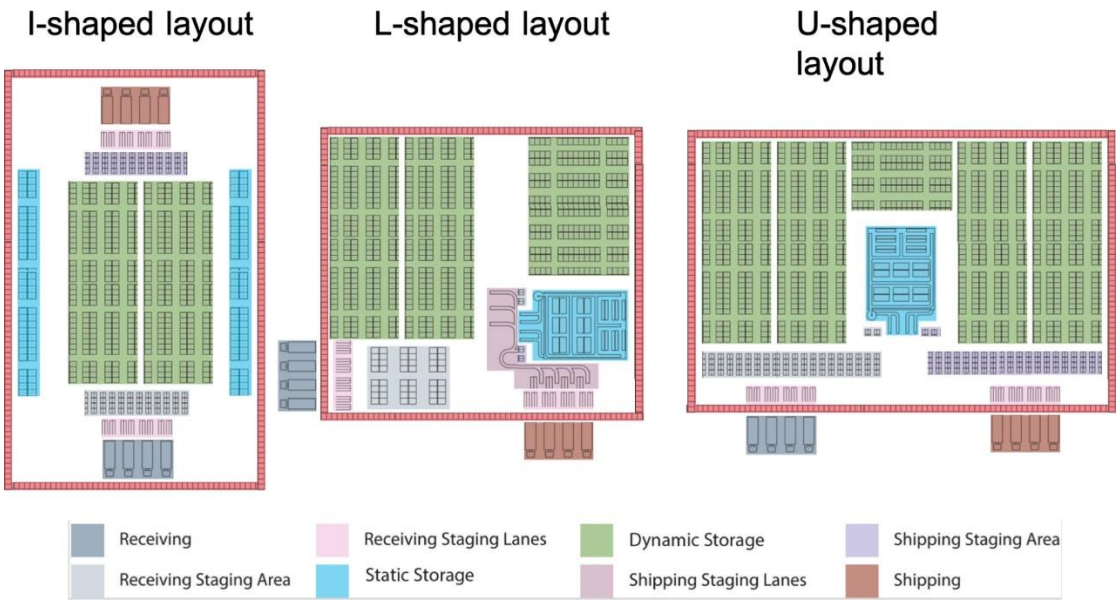

Figure 4 - Common shapes of warehouse layouts (Rakesh & Adil, 2015)

2.3.1 L-shaped model

One of the most commonly used warehouse layouts is the L-shape layout, which is characterized by the configuration of two rectangles. The loading/shipping area (marked in brown on the picture above) and the collection area (marked in dark grey) are positioned in opposite directions.

There are several advantages of using an L-shaped warehouse layout. For instance, separating the inbound and outbound areas allows for larger processing and storage areas. Additionally, it is easier to independently control these areas, providing added protection for the "in" and "out" zones.

The L-shaped warehouse layout is a good choice for businesses that receive products on one side of the warehouse and ship them on the opposite side, which is 90 degrees away. This layout is particularly useful for organizations that receive items in large trucks and then send orders in smaller vehicles (Sarkar et al., 2022).

The I-shaped warehouse layout can also be suitable for such businesses. In general, the decision to use an L-shaped or I-shaped layout depends on the specific needs and requirements of the business, such as the size of the warehouse, the types of products being stored, and the volume of incoming and outgoing shipments.

2.3.2 I-shaped model

The I-shaped warehouse layout is similar to the L-shaped layout in that the inbound and outbound areas are situated on opposite sides of the warehouse. As shown in the picture above, the I-shaped warehouse has a through structure where products move "through" the warehouse until they are prepared for shipping.

The benefits of the I-shaped warehouse are comparable to those of the L-shaped warehouse, such as the ability to have larger processing and storage areas, independent control of the areas, and added protection for the inbound and outbound zones.

2.3.3 U-shaped model

U-shaped model is structured differently from two other layouts. Main idea behind the structure of the U-shaped warehouse is that it is constructed in the form of two rectangles that are comparably longer than the third middle rectangle (Figure 3- Common shapes of the warehouse layouts) (Sarkar et al., 2022). The inbound and outbound areas are located in the way that they are adjusted to each other. This gives a possibility for implementing joint dock facilities like a material handling equipment. In addition, it eliminates stock management and allows implementing extensive cross-docking.

Warehouses with a U-shaped layout (as depicted in Figure 5) are designed to have both receiving and shipping operations on the same side. Such layouts are commonly referred to as U-shape layouts and are used in the majority of distribution facilities. This is because they offer the most efficient utilization of building-to-land ratio and require the least amount of hardstand for handling and shipping vehicle movements (Sarkar et al., 2022).

When choosing a warehouse layout, several factors need to be considered, including the type of products being stored, the flow of goods, the size and shape of the warehouse, and the budget.

Ultimately, the choice of warehouse layout will depend on the specific needs of the business and the products being stored. It is essential to evaluate the pros and cons of each layout and consider the long-term implications of the decision. By carefully assessing the

unique requirements of the warehouse and choosing the appropriate layout, businesses can maximize their storage space, increase efficiency, and improve overall productivity.

2.4 Conclusion

The chapter highlights the numerous factors that influence the picking process and, in turn, impact the delivery service. The delivery service is a critical factor as it directly affects customer satisfaction. Delivery performance and reliability are directly linked to the speed and accuracy of the picking process.

However, there are strategies that can be implemented to improve the picking process. Companies can choose between zone and batch picking, depending on their specific needs and the products they sell. Additionally, the warehouse layout is another important factor that can optimize product movements around the warehouse and improve inbound and outbound logistics.

All of these factors can be grouped under the definition of logistics service quality, which has a direct impact on customer satisfaction - the most important feedback that a company can receive. Therefore, companies must prioritize the optimization of their picking process and logistics service quality to meet customer needs and remain competitive in the market.

3 METHOD

In empirical studies, the selection of a research method is a critical determinant of the research outcome. The research method selected should be aligned with the research question to facilitate its adequate resolution. Specifically, the research method should provide clear objectives, define the sources of information to be collected, and outline how the data will be collected and analysed. (Mark N.K. Saunders, 2019)

Two principal categories of research methods are available to researchers: qualitative and quantitative research methods. Quantitative methods employ numerical data to derive insights, while qualitative methods rely on non-numerical data, such as images, words, and audio recordings. (Mark N.K. Saunders, 2019)

Furthermore, the procedures for data interpretation differ between these two methods. Qualitative research methods, for instance, use interviews for data collection and categorize data for analysis. In contrast, quantitative methods utilize questionnaires for data collection and rely on graphs and statistical techniques for analysis. (Mark N.K. Saunders, 2019)

3.1 Choice of method

For this particular research it was decided that qualitative method should be used. There are several different types of qualitative research that can be performed for the information evaluation; however, action research method seems to be the most suitable for this paper.

Action research cannot be identified as a single type of research method, however, broadly speaking action research can be identified as an approach in which the researcher and a client collaborate in the identification of the problem and in the development of the solution based on the problem. The most important factor of this method is that research output results from the "involvement with members of an organization" over a matter of "genuine concern about them". (Alan Bryman, 2011)

Now there is a question: «Why action research is chosen as a research method for this thesis? ». There is a list of factors with the help of which action research can be defined. 1. Experiments are on real problems within an organization and are designed to assist the solution. 2. This involves an iterative process of problem identification, planning, action, and evaluation. 3. Action research leads eventually to re-education, changing patterns of thinking, and action. 4. It is intended to contribute both to academic theory and practical action. (Argyris, Pautnam, and Smith, 1985)

There is a connection between this paper and the list of action research factors, provided by Argyris and others. This thesis is aimed to find an optimization solution for the picking process at the warehouse which is corresponds to the 3rd point of the action research factors. In addition, at the warehouse we have a real problem which related to picking and

myself is involved in the processes there (I am the picker). According to these factors, action research is the best and the most suitable choice for that project.

3.2 Action research cycle

The process of action research, similar to other research methods, is expected to be both emergent and iterative. The action research approach involves a cyclical process known as the "action research cycle", which comprises the various stages of the research project.

The research process encompasses four primary phases: problem diagnosis or construction, action planning, implementation, and evaluation. These stages are conducted within the research cycle. For instance, to illustrate how the process works, let us consider the steps involved in conducting a study using an action research method.(Mark N.K. Saunders, 2019)

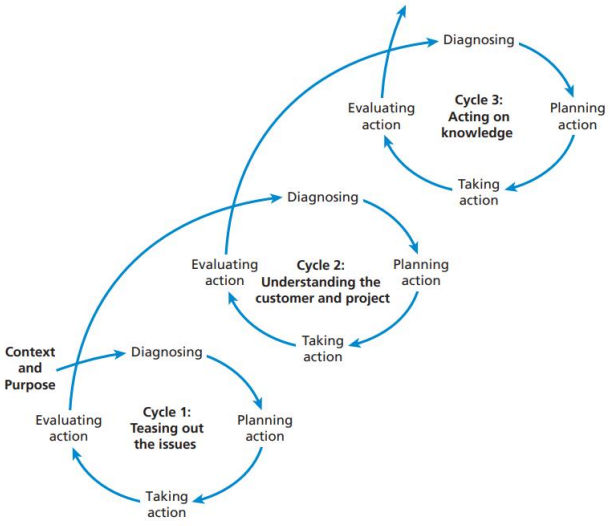

Figure 5 - Three cycles of the Action research spiral

The initial stage is concerned with identifying the problem. This involves implementing the four primary steps of action research. Initially, the problem is diagnosed, which typically involves gathering and analysing data to identify the issue. The collected data are then used to plan and decide on the appropriate action to take. At this point, the first cycle of action research is complete (refer to Figure 4). The assessment of the actions taken provides guidance for the next stage of problem diagnosis, action planning, and implementation, underscoring the iterative nature of the process (cycle 2). Subsequent cycles (cycle 3 and beyond) also involve problem diagnosis, action planning,

implementation, and evaluation, with consideration given to all data gathered during previous cycles.(Mark N.K. Saunders, 2019)

3.3 Research approach

As it was mentioned earlier, the research method for this paper is an action research.
The main idea of the research is a comparison of main factors in the picking process – delivery reliability, delivery performance and total amount of orders picked per day. Comparison is done on the basis of action research cycles. In addition, comparison of the variables (delivery performance, delivery reliability and total amount of picked orders) are compared before and after implementation of the theory that has been presented in the previous chapter.

Research has been done at the warehouse of the company which is the main field for conduct of my thesis. Implementation of new approach and ideas for the picking are introduced gradually into the working process since it is impossible to fully restructure the picking in the shortest period of time without affecting productivity of the process. Besides, management of the warehouse is also involved in the research process, and we are together deciding what solution is more appropriate to the current situation at the warehouse.

Restructuring process has started now and will be held until picking process variables will be improved. In addition, since validity of the research has to be proved, there will be some tests after the research has been done to see whether the result of the research is long-term.

Data for this particular research have been mainly collected from the management of the warehouse. As it was mentioned earlier in this chapter, for the comparison of the variables it is required to have information about delivery reliability, delivery performance and total amount of orders picked per day. Data is basically collected from previous average statistics of the warehouse performance.

3.4 Analysis of the data

Analysis of the data is crucial part of the research project. Main idea of it is to interpret your findings and explain them in more understandable way for everyone. There are many different ways to make analysis, however, there are two main approaches for the qualitative data: analytic induction and grounded theory. (Alan Bryman, 2011)

3.4.1 Analytic induction

Analytic induction works this way: it begins with a rough definition of a research question, followed by a hypothetical explanation of the question, and then continues onto the collection of data. The approach of analytic induction involves analyzing data to search for universal explanations of phenomena, by gathering data until no cases that contradict a hypothetical explanation (deviant or negative cases) of the phenomenon are detected by the researcher. (Alan Bryman, 2011) Here is an illustrated scheme of how analytic induction works.

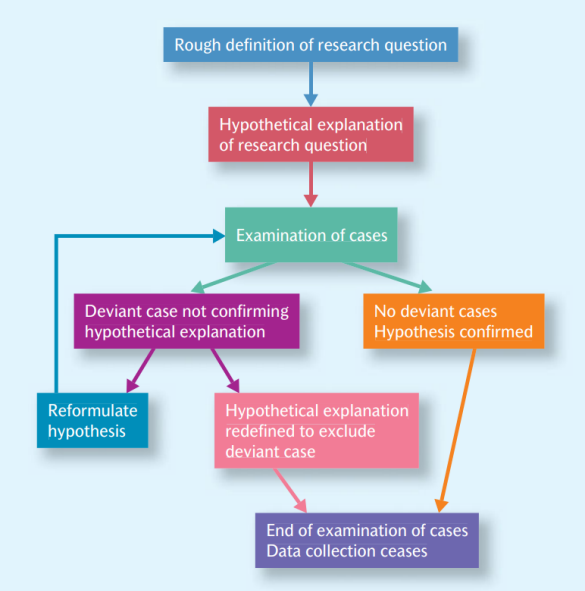

Figure 6 - The process of analytic induction (Alan Bryman, 2011)

3.4.2 Grounded theory

Another way to analyze qualitative data is grounded theory. According to Bryman, grounded theory can be defined as “theory that was derived from data, systematically

gathered and analyzed through the research process" (Alan Bryman, 2007). In the method of grounded theory, data collection, analysis and theory stand in close relationship to one another (Strauss and Corbin, 1998).

There are several tools which could be used when working with grounded theory.

1. **Coding**

The process in grounded theory when gathered data are broken down into component parts which are given names. Coding helps to analyze and prioritize data during the time of working with it. (Alan Bryman, 2011)

2. **Theoretical saturation**

According to Strauss and Corbin (1998), the essential concept is to continue sampling theoretically until a category has been saturated with data, which implies that there is no new or relevant data emerging, the category has well-defined properties and dimensions demonstrating variation, and the relationships among categories are well-established and validated. (Strauss and Corbin, 1998)

3. **Constant comparison**

Constant comparison is an aspect of grounded theory which refers to a process of maintaining a close connection between data and conceptualization, so not to lose the correspondence between concepts and categories with their indicators. The procedure of constant comparison requires the researcher to compare continuously the phenomena that are being coded under a particular category, enabling a theoretical elaboration of that category to emerge in a more precise manner. (Alan Bryman, 2011)

For this particular research grounded theory analysis method has been chosen since data about picking process requires instant analysis during the collection process to be able to implement new ideas and approaches.

3.5 Validity and reliability

Validity and reliability of the data in the research method considered to be one of the most important parts of conducting a methodology research. Let us take a look at each concept separately. Validity is concerned with the integrity of the conclusions that are generated from the research (Alan Bryman, 2011). There are different types of validity that have to be distinguished: measurement validity, internal validity, external validity and ecological

validity. This chapter is more focused on the internal validity since it related mostly to this study. Internal validity is concerned with the question of whether a conclusion that incorporates a causal relationship between two or more variable holds water. (Alan Bryman, 2011)

Reliability of the conducted research is concerned with the question of whether the results of the research are repeatable and accurate (Alan Bryman, 2007). There are also three main concepts that has to be mentioned when talking about reliability. Stability of the research represents whether result gathered from the study are stable over the time and we can be confident that the result will not fluctuated in the future. Internal reliability is responsible for consistency of the indicators that make up scales or indexes in the research. Inter-observer reliability is concerned with the question of when there are more than two observers are involved in the activity. We have to be sure that their conclusions and decision are mutual and consistent. (Alan Bryman, 2011)

How to prove validity and reliability of the research? To begin with, validity and reliability do not have to be proved separately. These terms are related because validity presumes reliability. In other words, if measure is not reliable, it can not be valid. For instance, if the measure is not valid over time, it simply cannot be providing a valid measure. (Alan Bryman, 2011)

Alan Bryman mentioned that inter-observer consistency is one of the best way to prove validity and reliability of conducted research. The concept of inter-observation is that there are external people who are checking the results of the research over some periods of time. (Alan Bryman, 2011)

For this thesis inter-observations are taken as a method of proving validity and reliability. Over some periods of time (each month), there will be an inspection of results which are connected with the performance of the picking process (delivery reliability index, delivery performance index, time spend for pick the order). In that way it will be possible to check reliability and validity of conducted research.

3.6 Ethics

The question of research ethics arises when there is a need to plan a research, seek access to the organisations or individuals, collect and manage your research data. Mark N. K. Saunders indicates that ethics refer to the standards of behaviour that guide the conduction in relation to the rights of those who become the subject of your work or are affected by it. (Mark N.K. Saunders, 2019)

There is a set of principles which are collects all ethics "rules" for any research.

1. **Integrity, fairness, and open-mindedness of the research.**

This means that research is done in an open, truthful and accurate way. Researchers have to avoid deception, dishonesty, and misrepresentations.

2. **Respect for others**

People who are participating in the research have to be treated with respect and all their rights have to be recognized.

3. **Avoidance of harm (non-maleficence)**

Any type of harm must be avoided. Harm may occur through the risk to emotional well-being, mental and physical health, social or group cohesion, embarrassment stress and discomfort.

4. **Privacy of participants**

Privacy is the main principle which links and underpins several other very important principles. Data of all participants and everything what is connected with that should treated in the private manner.

5. **Voluntary nature of participation**

The right not to participate in a research project is unchallengeable. In addition to that, it is supported with the right not to be harassed to participate. Participants have rights not to answer any question, set of questions or provide data which they think is sensitive for them.

6. **Informed consent of those taking part**

Researchers must provide sufficient information and assurances about taking part to allow individuals to understand details of participation.

7. **Ensuring confidentiality of data and anonymity**

Individuals and organizations should remain anonymous, and data should be processed to make it non-attributable unless it was discussed.

8. **Responsibility in the data and reporting**

Assurances about privacy, anonymity and confidentiality must be upheld when analyzing and reporting data. Primary data should be based on the research, it cannot be made up or altered. Secondary data requires the sources to be clearly acknowledged.

9. **Compliance in the management of data**

All personal data must be treated according to the legislation that regulates the processing, security and possible sharing of personal data.

Since I am doing action research, not all principles will be applicable to the thesis. However, it can be assured that research is done with integrity, fairness and open-mindedness. The research is done with respect to all rights of participants and responsibility for the data provided.

4 RESULTS

This chapter presents the results of the research which has been carried out to enhance the picking process at the warehouse. The aim of this research was to compare 3 main KPI's (key performance indicator): delivery reliability, delivery performance and number of orders picked per day, depending on the strategies which have been introduced to the picking process to find the best variant for the most productive and valuable optimization alternative.

To achieve the research objectives, a comprehensive analysis was conducted, utilizing qualitative methodology strategies. The research encompassed the collection of relevant data related to item locations, travel distances, and other key variables that impact the picking process. The dataset used for analysis was collected over a three-month period, ensuring a representative sample of the warehouse's operations.

The optimization techniques employed in this research encompassed a combination of some operational improvements. These techniques included mainly warehouse layout optimization, item sorting optimization and routing optimization. Each technique was implemented with specific objectives in mind, targeting various aspects of the picking process to achieve optimal results.

Furthermore, it is important to note that this research primarily focused on assessing the outcomes of implemented changes. Other variables such as variations in the number of days per month, discrepancies in the volume of incoming orders, variations in the number of orders or order lines, variations in the number of pickers, and variations in their level of experience were also examined within the scope of this study. Nevertheless, it was observed that these factors did not exert as significant an influence as the changes that were implemented.

Throughout the research period, the number of working days remained relatively consistent, with February and March both having 20 working days and May having 21 working days. This indicates that the number of working days did not exert a significant influence on the research outcomes. Additionally, the demand for orders during the February to May period remained stable, as there were no sales campaigns during this time, resulting in minimal variations in the number of incoming orders.

The warehouse maintained a fixed workforce of 18 employees. Newly hired pickers underwent a training period, often referred to as an "internship," which lasted for approximately 1.5 to 2 weeks. During this period, they were supervised by management while fulfilling test orders.

The ratio of orders to order lines consistently remained at a level of 12 orders for every 30 order lines. This is attributed to the utilization of a batch picking system within the warehouse, where, on average, 30 order lines are handled for every 12 orders.

4.1 Warehouse operations

To enhance comprehension of the warehouse under investigation in this research, it is advisable to provide an elucidation of its internal day-to-day operations. These operations encompass three primary activities: inbound logistics, outbound logistics, and in-house operations.

Inbound logistics encompasses several essential functions. Firstly, it involves the receipt of products intended to replenish the warehouse's inventory. This process is imperative for maintaining product availability and preventing inventory obsolescence. Another

critical facet addressed within inbound logistics is the management of reverse logistics. Reverse logistics is a recurring aspect of warehouse operations, as it deals with instances of product returns stemming from various reasons, including picker errors, unsuitable product selections, or instances where packages have not been collected from designated pick-up points.

In contrast, outbound logistics at the warehouse is relatively straightforward. The warehouse designates four distinct areas for outbound operations, each catering to a specific delivery company: Posti, Matkahuolto, Budbee, and Fetch. Pallets containing packaged orders are organized in accordance with the respective delivery company and are subsequently collected by trucks dispatched to the warehouse.

To facilitate the operations of delivery companies, certain regulations are enforced at the warehouse. Firstly, the height of pallets must not exceed 160 centimetres. Secondly, the boxes stacked on pallets should not extend beyond the pallet edges, as this could lead to pallet failure during transportation. Additionally, each pallet must be securely wrapped and labelled with appropriate documentation corresponding to the designated delivery company.

The scope of in-house operations within the warehouse encompasses a multifaceted array of tasks. Principally, these operations entail the packing and packaging of customer orders. The process of picking, wherein items are selected for inclusion in orders, is facilitated through the utilization of specialized trolleys, each capable of accommodating up to 12 individual orders. A distinctive feature of this operational approach is the adoption of batch picking, wherein a picker aggregates all 12 orders during a single traversal or "lap" through the warehouse. To facilitate this process, each picker is equipped with a handheld scanner device equipped with specialized software. This software not only assists in the efficient execution of batch picking but also delineates the optimal routes that pickers should traverse to assemble the requisite items for all orders.

Following the completion of the picking process, the subsequent step involves the packaging of the selected items. This packaging operation is conducted within designated packaging lanes, ensuring a systematic and organized approach to order

fulfilment Furthermore, the warehouse possesses the capacity to store items necessitating low-temperature storage conditions, facilitated by the presence of a dedicated freezer room within the facility.

4.2 Objects of the research

This chapter investigates several crucial performance factors within the context of the present research, namely delivery reliability, delivery performance, and the number of orders picked per day. The investigation focuses on three specific months: February, March, and May. The rationale behind selecting this time period stems from the implementation of notable changes in warehouse operations during March and May. February serves as the baseline month for comparing the aforementioned performance factors.

The chosen performance factors play a vital role in assessing the efficiency and effectiveness of warehouse operations. Delivery reliability refers to the ability to consistently fulfil customer orders within the specified timeframes and meet the promised delivery dates. It serves as a key indicator of customer satisfaction and the overall success of the supply chain. Delivery performance, on the other hand, encompasses various metrics such as delivery speed, accuracy, and flexibility. This factor is instrumental in evaluating the timeliness and quality of order fulfilment. Lastly, the number of orders picked per day measures the productivity and capacity utilization of the warehouse, highlighting its ability to handle a substantial volume of orders efficiently.

By examining these performance factors across the months of February, March, and May, this study aims to identify any significant changes or improvements resulting from the modifications implemented in warehouse operations. February, as the initial month of analysis, provides a benchmark against which subsequent months can be compared. This approach enables a comprehensive evaluation of the impact of the operational changes on the selected performance factors.

In March 2023, a new routing variant for pickers was implemented in the warehouse. The primary objective of this implementation was to optimize the picking process by introducing a revised sequence for item collection. Under the new initiative, pickers were

instructed to first gather light items, followed by heavier items, and ultimately the heaviest items just prior to the packaging stage. To comprehend the significance of this change, it is essential to consider the previous procedure followed by pickers. Prior to the implementation of the new routing variant, pickers were required to retrieve light items initially, followed by the heaviest items (such as cat sand and dog food), and finally, medium-weight products before the packaging phase.

In May 2023, a notable change took place in the warehouse with regards to item location. Specifically, heavy items, including cat sand, were relocated to a different area within the facility. This new location was positioned slightly further away from the packaging area compared to the previous arrangement. Prior to this change, cat sand was situated near the exit of section 5, which marked the end of the picking route.

The relocation of heavy items, particularly cat sand, necessitated a re-evaluation of its impact on the key performance indicators (KPIs). To ascertain the effects of this modification, comprehensive comparisons were conducted to gauge any discernible alterations in the identified performance factors.

4.3 Orders per day

The chart below represents the dates when particular changes have been implemented and the number of orders picked per day during the month of the implementation.

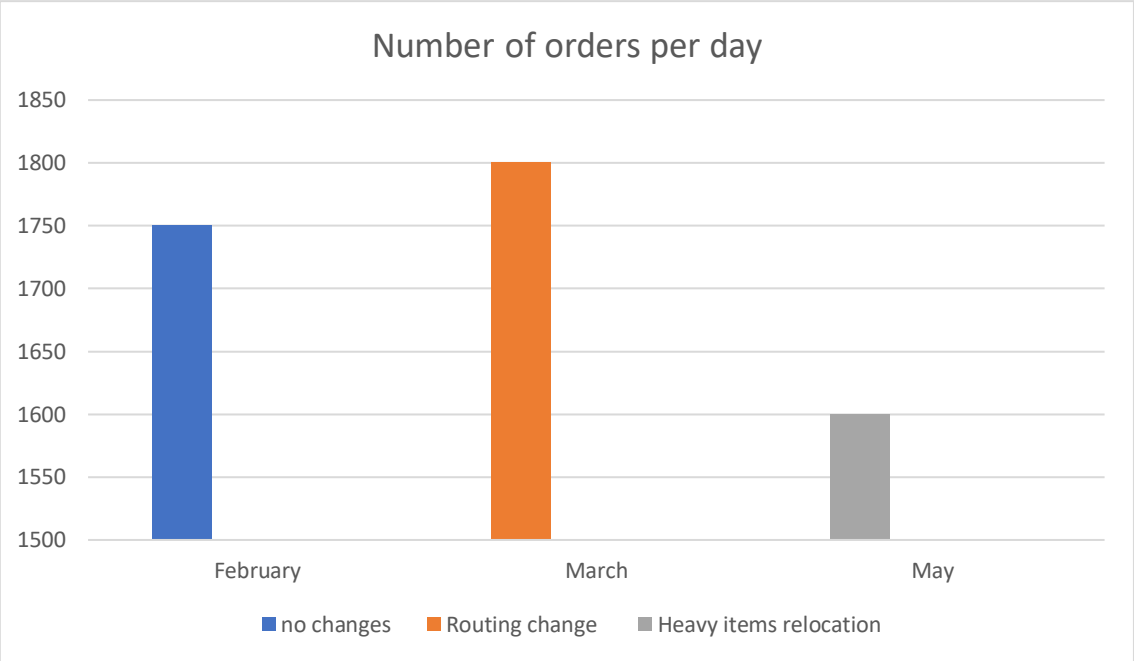

Figure 7 - Number of orders picked per day.

The chart presented illustrates the average daily number of orders picked over a span of three months. These specific months were chosen due to the implementation of changes that impacted the picking process. The data reflects varying strategies and their respective effects on picker performance.

To establish a baseline for comparison, the figures from February were utilized since no changes were introduced during that month. In February, a total of 49213 orders were picked, resulting in an average of approximately 1750 orders per day. Moving on to March 2023, the total number of picked orders reached 55754, leading to an average of 1800 orders picked per day. In May 2023, the total number of orders recorded at the time of analysis stood at 32000. It is important to note that the order count was recorded midway through the month, and the average number of orders per day was calculated based on these figures. In May, the average daily number of orders picked amounted to 1600.

The data from these three months provides insights into the changes in the average number of orders picked per day. The figures reveal the impact of the implemented strategies on picker performance, allowing for a comparative analysis and evaluation of the effectiveness of the changes made during March and May.

Based on the provided data, an analysis can be drawn regarding the impact of the routing changes and the relocation of heavy items on the average number of orders picked per day, in comparison to the baseline month of February. The findings indicate that the routing changes resulted in a 2% increase in the average number of orders picked per day, whereas the relocation of heavy items led to an 11% decrease in the average number of orders picked per day, both in comparison to the baseline month.

Table 2 - Percentage change in average number of picked order per day.

February	March	May
1750 orders per day	1800 orders per day (+2%)	1600 orders per day (-11%)

4.4 Delivery reliability and delivery performance.

Delivery reliability and delivery performance are critical key performance indicators (KPIs) that hold significant importance in modern warehouse operations. The impact of new implementations on these metrics has been examined in the conducted research. In order to establish a baseline for comparison, the month of February has been utilized.
Based on the information provided by the warehouse management, the research findings indicate that the changes implemented in routing and item locations had a relatively minimal effect on delivery reliability and delivery performance, as compared to the impact on the number of orders picked per day.

In February 2023, the level of delivery reliability was reported to be 97.5%. This signifies that 97.5% of all processed orders were delivered within the specified timeframes. Following the implementation of the new routing and item location changes, the delivery reliability level increased to 97.7% in March 2023, and further improved to 98% in May 2023.

Conversely, the picture is slightly different when it comes to delivery performance. In February 2023, the delivery performance level was reported to be 91.7%. This indicates

that 91.7% of all processed orders were accurately delivered with the correct products and in the correct quantities. In March 2023, the delivery performance level improved to 92.1%, showcasing a slight enhancement. However, in May 2023, the delivery performance level experienced a slight decline, reaching 91.9%.

The table below represents the changes of delivery reliability and delivery performance during three month of examination.

Table 3 - Percentages changes of delivery reliability and delivery performance.

	Delivery reliability	Delivery performance
February	97.5%	91.7%
March	97.7%	92.1%
May	98%	91.9%

The acquired data allows for the analysis of the optimization solutions, enabling conclusions to be drawn regarding their impact on warehouse key performance indicators (KPIs). With an understanding of how various solutions affect the KPIs, it becomes imperative to conduct a comprehensive analysis in order to identify the most suitable solution for the warehouse.

5 DISCUSSION

This chapter encompasses a comprehensive examination of the findings and methodologies employed in this thesis. The author presents their own perspectives and insights regarding the obtained answers. The primary focus of the discussion lies in the research results, specifically aiming to determine the most effective approach for optimizing the picking process, which serves as the central objective and research question of this thesis.

Furthermore, this chapter critically assesses the research methodology employed, evaluating its appropriateness for the specific case at hand. Additionally, alternative methods that could have been employed in this research are explored and discussed.

5.1 Discussion of results

Following the execution of various data collection procedures, a set of results has been acquired. Subsequently, a decision was made to assess the implemented modifications in warehouse operations based on three key performance indicators (KPIs): orders per day, delivery reliability, and delivery performance. Each of these indicators corresponds to distinct criteria. First, orders per day serve as a measure of productivity and the capacity to handle high order volumes. Second, delivery reliability reflects the ability to fulfil orders within predetermined timeframes. Lastly, delivery performance encompasses aspects such as delivery speed, accuracy, and flexibility.

5.1.1 Orders per day

Throughout the course of the research, two modifications have had an influence on the selected Key Performance Indicators (KPIs). These modifications entail the introduction of the new routing system and the relocation of heavy items, which were implemented in March and May, respectively.

As delineated in the results section, one of the selected metrics for assessing the efficacy of the implemented changes pertains to the number of picker orders per day. Upon scrutinizing the collected data within the research, it was discerned that daily number of picked orders exhibits an inverse relationship with the introduced innovations. It is worth noting that February serves as the reference month against which all evaluations are benchmarked.

The implementation of the new routing system has yielded a favourable outcome on the daily picked order number. Specifically, there is an increment of 2 percent in the number of daily orders fulfilled in March compared to February. Conversely, the relocation of heavy items has had a markedly adverse effect, resulting in an 11 percent reduction in daily picked order rate from February to March.

In the analysis of these results, it can be asserted that such outcomes are readily explicable. The differentiation between the new routing system and its predecessor primarily lies in the sequence of item picking, wherein pickers now first select medium-weight items, followed by heavy items, and, only before the packaging stage, proceed to pick light-weight products. Notably, the repositioning of heavy item selection to the final

stage has resulted in a reduction in the overall weight of the pickers' trolleys on most of the routes, consequently enhancing the average picking speed of the trolley. This observation implies that an increase in the average trolley picking speed correlates proportionally with a rise in the number of orders fulfilled per day. This correlation can be graphically represented for clarity.

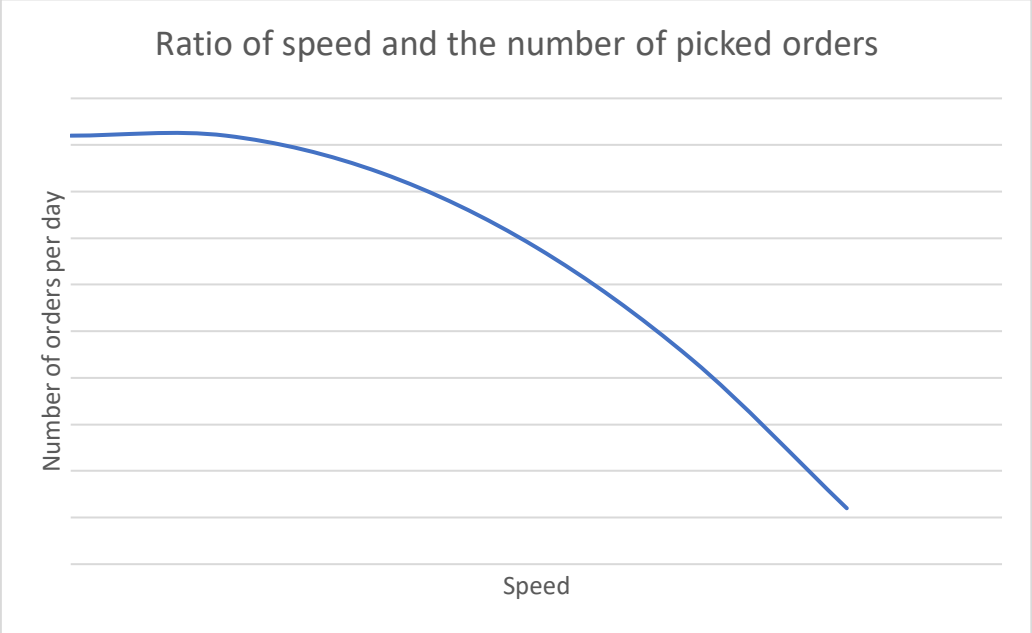

Figure 8 - Ratio of speed and the number of picked orders.

Let us now delve into the implications brought about by the relocation of heavy items. As evident from Chapter 4, primarily derived from the results section, the relocation of heavy items has resulted in a substantial reduction in the daily count of fulfilled orders. To be more precise, the number of completed orders has declined by over 10 percent. In my analysis, this decline can be attributed to the fact that heavy items are now situated farther away from the packaging stage, necessitating pickers to traverse longer distances while handling heavier trolleys. According to my personal experience, it is noteworthy that the average weight of the trolley exerts a negative influence on the picker's walking speed. This implies that a heavier trolley would inevitably decelerate the picker's pace. These insights can be readily comprehended when depicted graphically.

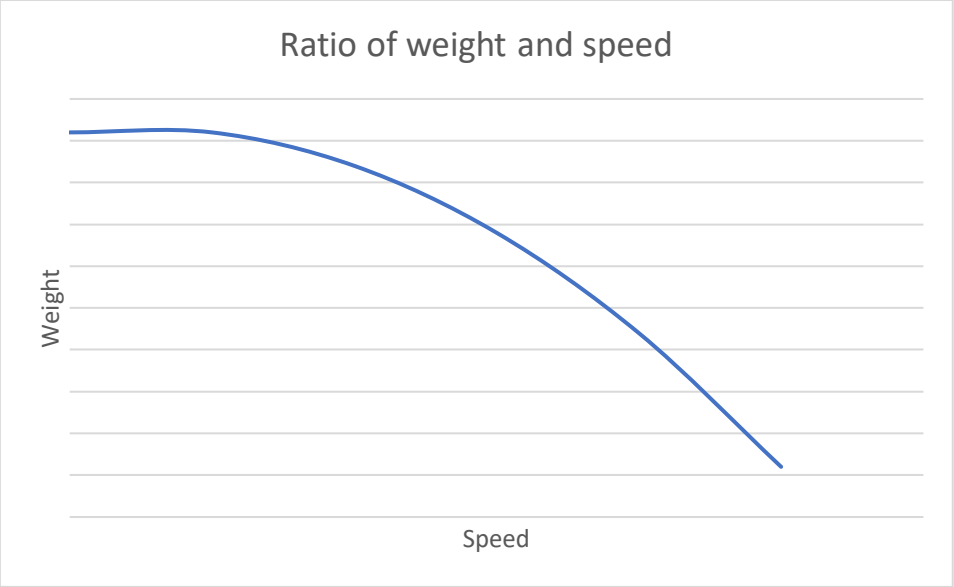

Figure 9 - Speed and weight ratio

5.1.2 Delivery reliability and delivery performance

Another two important variables to consider are delivery performance and delivery reliability. As it was previously mentioned in the research, delivery performance indicates the correctness of collected orders while delivery reliability represents accuracy of the delivery time which can be measured by the number of deliveries out of total orders, or the value of orders delivered out of the total value orders. (Nils G. Storhagen, 2018)

Based on the obtained results, it is evident that the changes implemented in warehouse operations have yielded distinct effects on two key variables. Over the course of a four-month period, the delivery reliability exhibited a positive trend. Specifically, between February 2023 and May 2023, the delivery reliability rate increased from 97.5 percent to 98 percent.

Conversely, the situation concerning delivery performance presented a slightly different trajectory. From February 2023 to March 2023, there was an improvement in delivery performance, with the rate rising from 91.7 percent to 92.1 percent. However, between March 2023 and May 2023, there was a decline in performance, with the rate decreasing from 92.1 percent to 91.9 percent.

These fluctuations in delivery reliability and delivery performance levels can be elucidated through analysis. To begin with, let us examine delivery reliability, which is calculated as the ratio of on-time deliveries to the total number of orders, represented mathematically as:

Delivery reliability = (Number of orders on time/Total number of orders) * 100%

Due to the implementation of the new routing system, there has been a noticeable increase in the total number of orders picked per day. Consequently, this increase in the number of orders picked per day translates into a higher volume of orders being shipped during the day. As a result, the variable "number of orders on time" is positively influenced by the greater number of orders being shipped per day. This means that an augmented volume of orders will reach their intended destinations punctually, thereby improving delivery reliability.

Conversely, the changes observed in delivery performance present a somewhat different pattern. The performance rate exhibited an increase in March followed by a decline in May. In my view, these fluctuations can be attributed to the adjustment period required for pickers to acclimate to the new routing system. Initially, after the implementation of the changes, there was an improvement in delivery performance, indicating the efficacy of the solution. However, in the subsequent months, there appears to have been some refinement as the picking speed increased, which may have led to a potential increase in error rates. In my assessment, it is reasonable to expect that warehouse personnel will require some time to fully adapt to the new system, and as a result, we may anticipate a gradual improvement in delivery performance in the future.

5.2 Discussion of method

As previously detailed in Chapter 3, the selected research methodology for this study is action research. The fundamental premise of this research approach entails collaborative efforts between the researcher and the client to identify a problem and seek solutions. This paper's primary focus has centred on devising solutions for optimizing the picking process. In this chapter, we delve into an elaborate discussion of this research approach to ascertain its applicability and relevance.

At the outset of the research, a plan was devised to collect and interpret data in accordance with the implemented changes. Specifically, data pertaining to the number of orders, delivery performance, and delivery reliability were gathered. As planned, data related to the number of orders and other relevant parameters were extracted from the warehouse database, with the requisite permissions obtained. Subsequently, comparisons and evaluations of the changes were conducted, and the results were duly recorded. In my assessment, the execution proceeded as envisaged, and the resulting data is substantively informative.

Throughout the research, one notable challenge emerged concerning the application of the action research method. Given that action research lacks a predefined set of steps, there were moments when determining the appropriate data collection approach posed difficulties. For instance, the process is straightforward when conducting interviews and structuring the responses into results or when organizing focus groups to obtain raw data for subsequent interpretation. However, in the case of action research, the onus is on the researcher to devise methods for data collection and interpretation. Nonetheless, a resolution was achieved for this paper, and all data have been systematically presented in previous chapters.

In my opinion, the selection of the action research method is highly suitable for this particular research. This choice stems from my direct involvement in warehouse processes and the imperative to observe changes during warehouse operations. However, alternative research methods could also be well-suited to this study. For instance, conducting interviews with warehouse personnel would provide valuable insights by capturing their perspectives on the situation.

The reliability and validity of the collected and interpreted data can be regarded as high. The central objective of the research was to identify one or more solutions to the problem of optimizing the picking process, specifically how to enhance picking efficiency. The research findings underscore the significance of a well-planned routing system in improving picking speed and can thus be considered a potential solution to the research objective. In terms of validity, it can be asserted that the results are clear-cut and consistent. Nonetheless, it is worth noting that the research's focus is confined to a four-

month period (February 2023 to May 2023), whereas the introduced warehouse operations changes are expected to have long-term implications.

In conclusion, the adoption of the action research approach has effectively addressed the research questions and led to the identification of the requisite solutions.

6 CONCLUSIONS

In this chapter whole research is evaluated and final conclusion is made. Taking into consideration everything that has been said and found out, it can be stated that appropriate solution to the research question was found, and warehouse operation will be gradually improving with changes that have been made.

Firstly, it is important to remind what was the aim of the study and the research question of this study. The aim of the study is to find optimization solutions to increase speed and reliability of the picking process. So, the question that has to answered by this study sounds like how to optimize the picking process at the warehouse to increase speed and reliability of it.

According to the results part, the final answer to the research question can be stated. Based on the statistics of the warehouse operations, especially the rate of the picked orders per day, delivery reliability and delivery performance, the best solution for the nowadays situation at the warehouse is putting all the efforts to improve the routing system. Changes that have been made with the routing system at the warehouse indicated that it has the biggest impact on the productivity and reliability of the picking process. During the period of four-month from February until May we saw a significant increase in number of picked orders per day and slight incline movement in the delivery performance and reliability rates.

6.1 Limitations of the study

Like every other study, this particular research had some limitations during the process with is essential. Firstly, the period of the observation was a little bit short. It was enough to notice changes and make some conclusions based on them, however in the ideally, it

is required to observe the impact of the changes over the period of one year to compare the annual results of the warehouse performance. In this case, the research was limited with the amount of time.

Another important factor which has to be included in this chapter is the importance of the market demand. Market demand also plays a significant role in the number of orders picked up during the definite period. The idea here is that some fluctuations in the market demand can directly impact on the performance of the warehouse. In contrast, during the period of the research there were no any market fluctuations recorded but this point worth to be mentioning.

6.2 Suggestions for further studies

As far as current knowledge allows, it is evident that a single research cannot comprehensively address all the issues and inquiries arising in relation to a specific subject matter. Throughout the course of research, various ideas for prospective studies have been formulated, which may be employed to undertake further investigations in the future, with the aim of fully addressing emergent problems.

One pivotal factor that holds significance across all sectors of business, particularly within the domain of warehousing, pertains to the competency of the workforce. Ineffectual work capabilities or a deficiency in experiential knowledge can result in substantial financial losses for a company and, more crucially, the attrition of valuable clientele. Thus, it becomes imperative to consider topics for future research, such as the inquiry: "Is staff training essential for augmenting picking performance?" This line of investigation will predominantly centre on the proficiency of the workforce and the working conditions therein.

Another subject that holds substantial promise for research pertains to autonomous picking. This topic has the potential to explore the necessity of autonomous picking, its associated costs, and its value in relation to monetary expenditure. A central question that arises is whether autonomous picking represents a genuine necessity or constitutes an extravagant expenditure.

In conclusion, the subject of the picking process within warehouse operations is a broad and highly debatable area of discourse within the context of warehousing facilities. In order to optimize operational efficiency within the logistics sector, it is imperative to commence at the foundational level of operations, namely, the picking process. Through the implementation of a well-structured and refined picking process, the logistical sector stands poised to achieve a heightened degree of efficiency.

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