Improving the outbound ability and efficiency at Jingdong Logistics (Netherlands) B.V.

Su Tong (s2338041)

Bachelor: Industrial Engineering and Management

University of Twente, Enschede, the Netherlands

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Author:

Su Tong (s2338041)

s.tong@student.utwente.nl

Study program:

Industrial Engineering and Management

University of Twente

PO Box 217, 7500 AE Enschede

+31 (0)53-4899111

Company:

Jingdong Logistics (Netherlands) B.V.

Nieuwhuisweg 20, 5804 AN Venray

https://www.jdworldwide.com/

Supervisors (university):

First supervisor (University): dr. Peter Schuur

Second supervisor (University): dr. I. Seyran Topan (Ipek)

Supervisors (company):

Supervisor (JD.COM): TianRun Wang

Head of the outbound department & warehouse supervisor

Foreword

Dear reader,

The report in front of you is my bachelor's thesis assignment "improving the outbound ability and efficiency at Jingdong Logistics (Netherlands) B.V." and is written to conduct the Bachelor of Industrial Engineering and Management at the University of Twente. This article and the research were conducted at Jingdong Logistics (Netherlands) B.V., found in Venray, Limburg, the Netherlands.

First, I would like to thank Dr. Peter Schuur, who is my first university supervisor. I have received a lot of help during the past few months. I always find him enthusiastic when I meet difficulties but also strict with the quality of my paper and wording. I will not be able to finish this paper without his help.

Secondly, I would like to thank Dr. I. Seyran Topan (Ipek), who is my second university supervisor. She has given me useful feedback on my paper, so I can enhance the quality further. Besides that, she was also our earlier module coordinator, and she gave us a lot of help during module 11, which I appreciate.

Lastly, I would like to thank TianRun Wang, who is my company supervisor. He has helped me a lot during my six-month internship at JD.com. I have learned many things about the process of warehouse running and supply chain knowledge. I have met employees from various countries in that warehouse. For example, our warehouse's Polish team leader and Dutch warehouse manager also taught and helped me in that period. In general, it was a wonderful time for me.

Hope you can enjoy my thesis!

Su Tong (*Sam*)
Venlo, Limburg
August 2022

Management summary

Jingdong Logistics (Netherlands) B.V. is a subsidiary of JD.COM, which opened in the Netherlands in August of 2021, supplies warehouse service, and runs in at least five different countries in Europe. This number is still growing rapidly. Within the past few months, the Jingdong logistic warehouse's outbound capability has been put to the test. The warehouse has hosted the Christmas sale (online) and its first Black Friday sale (online) for the client *Hunkemöller* in the Netherlands since it was officially put into operation in 2021. According to its past performance, neither the warehouse itself nor its client are fully satisfied with the outbound ability. Therefore, the research goal and aim of this article is to help the JD improve its outbound ability and efficiency while limiting the extra cost during implementation.

Central research question (CRQ)

As mentioned, both the warehouse (JD) and the client would like to enhance the outbound ability. For the warehouse, they can introduce new clients if the outbound ability and efficiency are improved, since the higher efficiency means the product's moving speed in the warehouse will be faster and part of the storage space can be earmarked for a new client. For the client (*Hunkemöller*), their customers will receive a better online shopping experience since the waiting time will be reduced if the warehouse can process the products faster. But that does not mean we can use unlimited resources and money for this goal. Based on these facts, this paper defines the central research question as "***How can the outbound processing capacity in JingDong logistics be improved while not incurring too many extra costs***?"

Methodology

To develop the answer to the central research question, specific methodologies are needed to make it happen. First, this paper will collect data to build the cognition for the CRQ. Quantitative research will be chosen in this case because this type of data collection can help the paper deliver a convincing numerical result. Second, a pilot and analysis need observation during their process. Observation is used to see the control group and the test subjects in this study. Furthermore, qualitative research is also used to understand literature, ideas, and knowledge.

Results

We propose the following three improvements:

1. **Redesign the layout**
   "Redesign the layout" in this study means changing the layout in a warehouse between the used picking stations and function areas to reduce the walking distance for workers to improve the outbound process flow efficiency. The walking distance between the picking stations and the auxiliary function area has been reduced after the redesign.

2. **Improving labor arrangement efficiency**
   "Improving labor arrangement efficiency" in this study means staggered working hours for different working positions with various job natures. Due to the nature of different outbound process positions, their efficiency is different from other positions. This study staggered the working time slots for different outbound process positions to coordinate and balance the workload at various positions to enhance the total outbound process flow efficiency.

3. **Improving the picking station's capacity by adding one more cabinet**

"*Improving the picking station's capacity by adding one more cabinet*" in this study means increasing the actionable space for pickers at the picking station. This paper adds one more cabinet for picking stations. Those workers have more workable space compared to others, and the system can assign more tasks to those stations to reduce the idle time, eventually improving the working efficiency in unit time.

Table 1, Improvement percentage

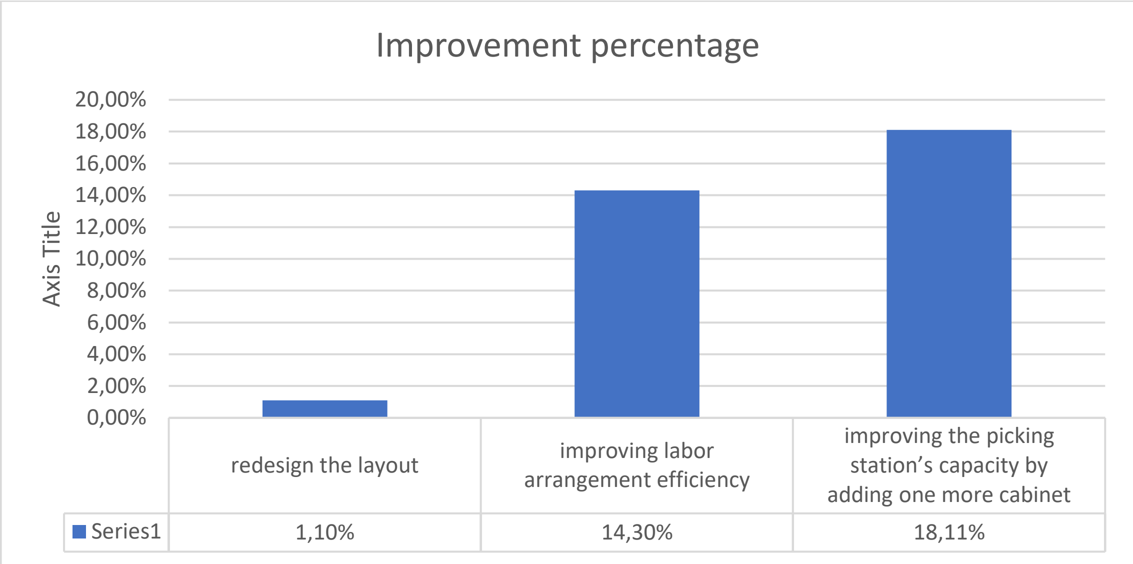

Table 1 writes down the improvement percentages for different methods in numbers, which the reader may check above.

Except for the improvement percentage, this study also estimates the cost for each method, which we have listed below:

1. *Redesign the layout*, 150 euros.
2. *Improving labor arrangement efficiency*, 125 euros.
3. *Improving the picking station's capacity by adding one more cabinet*, 975 euros.

Based on the improvement percentage and costs of each method, plus our grading system, the "Redesign the layout" solution has received the highest score.

Recommendations

The suggested solution "*redesign the layout*" can help the warehouse save operation time and improve its outbound efficiency in units of time, as can the other two solutions (*improving labor arrangement efficiency* and *improving the picking station's capacity by adding one more cabinet*). Besides that, this study also suggested long-term solutions for the warehouse, for example, the "*dynamic routine plan*" technology for its used AGVs in the warehouse. The short-term solution ("*redesign the layout*") will ease the organization's current dilemma, while the long-term suggestion will focus on further improvements.

In conclusion, the contribution of this paper is threefold:

1. Do not only increase the number of workers or extend working time because the cost of labor in the Netherlands is not cheap.

2. All three potential solutions enhance the outbound process efficiency, but the "*redesign the layout*" has received the highest score (readers can check the detailed reasons in section 7.3). It can be applied to daily operations.
3. The warehouse should focus on AGV technology updates. It will help the warehouse eventually.

Except for the text explanation above, this paper also presents an improvement roadmap for the warehouse as follows.

Table 2, Improvement roadmap

Priority	***Action***	***Actor***
1	redesign the layout	warehouse supervisor
2	improving labor arrangement efficiency	warehouse supervisor and labor agency
3	improving the picking station's capacity by adding one more cabinet	warehouse supervisor and warehouse manager
4	study and apply advanced innovative technologies in the AGV field	warehouse software engineer and Jingdong headquarters in Beijing

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1 Introduction

This chapter presents an introduction to Jingdong Logistics (NETHERLANDS) B.V. about the type of business they are doing and how they meet difficulties during outbound process operations. We also present the corporation flow chart, problem identification, and problem-solving approach in this chapter. At the end of this chapter, the reader can find out what the problem is and how we designed the research.

1.1 Company description

Jingdong Logistics (NETHERLANDS) B.V. is a subsidiary of JD.COM (JD). JD has become the world's second-largest online store and China's largest retailing company on the Fortune 500 in terms of revenue (Ma, 2021). With the ambition of expanding its business map to European countries, JD has the ambition of providing a premium supply chain experience to its European Union clients and making a profit through it. As can be seen from Figure 1 below, by the end of 2020, JD has established its global fulfilment center in the United States, Germany, Poland, the United Kingdom, the Netherlands, the United Arab Emirates, Australia, Thailand, Indonesia, Malaysia, Vietnam, and other places (JD International Logistics, n.d.).

Figure 1, The distribution of JDWorldwide's global fulfilment center, exclude mainland China (Image retrieved from JD official website)

Based on such a blueprint, the JD logistic warehouse (Netherlands) was set up in August of 2021, found at Nieuwhuisweg 20, 5804 AN Venray, Limburg. This warehouse's function is to satisfy customers from European countries that are near the Netherlands by supplying excellent logistical service.

Hunkemöller (HKM) is one of the biggest clients of the warehouse now. Hunkemöller is Europe's fastest-growing lingerie brand with over nineteen countries (Hunkemöller Corporate Information, n.d.). Orders cannot be fulfilled by themselves if the client does not have their own warehouse and operating team. Therefore, companies like HKM require warehouses and labor to process their growing orders. Building a warehouse from zero demands a massive investment and considerable time, especially for companies who do not have experience of running warehouses. Cooperation with companies that have their own warehouses and knowledge of warehouse management may be a better option than beginning from nothing. JD's warehouse in Venray can be seen as a connection between the end customers in various countries and the client (HKM), JD receives both orders (synchronized by HKM's system) and stocks from HKM and ships out orders to end customers on time and with efficiency.

The warehouse itself can be divided into three major function modules, which are outbound, inbound, and in-warehouse. First, the outbound operation is focusing on fulfilling received orders and shipping them out in the shortest time possible to enhance the online shopping experience in the region of Europe. Second, the inbound action responds to the receiving stock movement from the end customers (return) and put-away action. The inbound team must make sure the received quantity is fully correct, not more or less. Lastly, the in-warehouse module responds to controlling the stock level at a reasonable level by balancing the in and out operations.

In general, the warehouse found in Venray was built less than one year ago in the Netherlands. However, the organization can expand its business by relying on the resources of the parent company in Beijing, China. The warehouse's business type can be seen as a bridge between the big client (e.g., HKM) and the end-customers. With the support of JD headquarters in Beijing, our client can serve all the European customers without building a warehouse all by themselves. Besides that, JD can make a profit and gain market share during this process. It is a choice where everyone benefits.

1.2 Problem identification & motivation

The author's position in the company is that of an operations intern. He manages the outbound department's operations and helps his supervisor, who manages the whole outbound department. The warehouse is facing a serious challenge with its non-sufficient outbound capability, which has heavily influenced the profit aspect since the client is paying for successfully shipped outbound quantities. In other words, the warehouse's profit will increase if we can improve the outbound quantity. The estimated unit price for each successfully completed outbound order is 2 euros per parcel, with a daily net profit increase of 4,000 euros if JD can increase its outbound ability from 5000 (in orders) to 7000 (in orders). However, the reality is that the outbound capacity is still in the interval of 3,000 to 5,000 orders per day in low seasons and is approaching 10,000 orders in peak seasons. Sum it up, the problem is the low outbound ability (efficiency), which cannot satisfy the client and the warehouse. However, because JD is a Chinese company with its headquarters in Beijing, the warehouse cannot simply replicate the "Chinese model[1]" in the Netherlands because labor costs in the Netherlands are significantly higher than in China. The minimum wage standard in China (using Guangdong province as an example) is 22.2 RMB per person per hour (Minimum Wages in China 2022: A Complete Guide, n.d.), which is equal to 3.15[2] euros per hour. It is another story in the Netherlands, where the hourly minimum wage standard is 9.96[3] euros per hour (Amount of the hourly minimum wage | Minimum wage | Government.nl, n.d.). As the reader can see from the differences in legal minimum wages between the two countries, the cost of labor in the Netherlands is significantly higher than in China. The warehouse cannot just simply increase the number of

[1] Increase efficiency and output quantity by using more manpower per unit time.
[2] The exchange rate conversion time is May 13, 2022, and this may change over time.
[3] 40 hours per week, 21 years of age or older on January 1, 2022.

workers under such a reality, which is another problem the warehouse is facing in saving costs, so the goal and aim of this paper is to improve outbound ability without introducing extra costs.

JD's business is still in its beginning period and is trying to expand its marketing maps not only in the Netherlands but also on the entire continent of Europe with positive profits. We would like to enhance the outbound capability by changing the outbound process and improving the outbound flow process. Therefore, our motivation in this paper is to solve or improve a realistic problem for a logistics company and help the company achieve a new level of outbound ability by enhancing the outbound process without introducing extra costs. The learning goal can be divided into both internal and external aspects, which represent how the author should learn and improve his academic skills in logical thinking, academic writing, and self-driven learning; and how the author should develop the overall outbound process in JD by learning and practicing each link in the outbound process.

1.2.1 Action problem

As described in earlier sections, the distribution center (JD warehouse) in the Netherlands (Venray, Limburg) is facing low outbound process ability and cannot meet clients' requirements. The main client, HKM, is asking JD to improve its outbound ability to meet their increasing orders from various newly developed EU countries. Not only is the client asking for a higher outbound ability than JD itself, but also JD itself. Once JD can improve its outbound ability, the warehouse can have better efficiency and lower stocking levels to introduce new clients. In this case, both internal (JD) and external (client) require improvements. The current situation needs improvements.

Therefore, we define the action problems in this research as "***how to improve the outbound process capacity of the JD warehouse production line."*** The action problem is not only related to HKM but also to other potential clients and stakeholders. Currently, the warehouse's stock level is high because of low outbound ability, which means the warehouse does not have enough free slots for new stock. Such a high stock level also means the warehouse cannot accept new clients since most of the storage spaces are already occupied.

1.2.2 Problem cluster

The author could have an overview of the outbound procedure based on the daily operation in the warehouse for the past six months. Figure 2 in the following presents a general sketch of the organization's problem to the reader. The main picture itself can be divided into three major parts, which are the "general problem," the "action problem," and the "core problem" by color. The connection between specific problems points out the potential hook-ups. As for the details, the reader can investigate them from Figure 2.

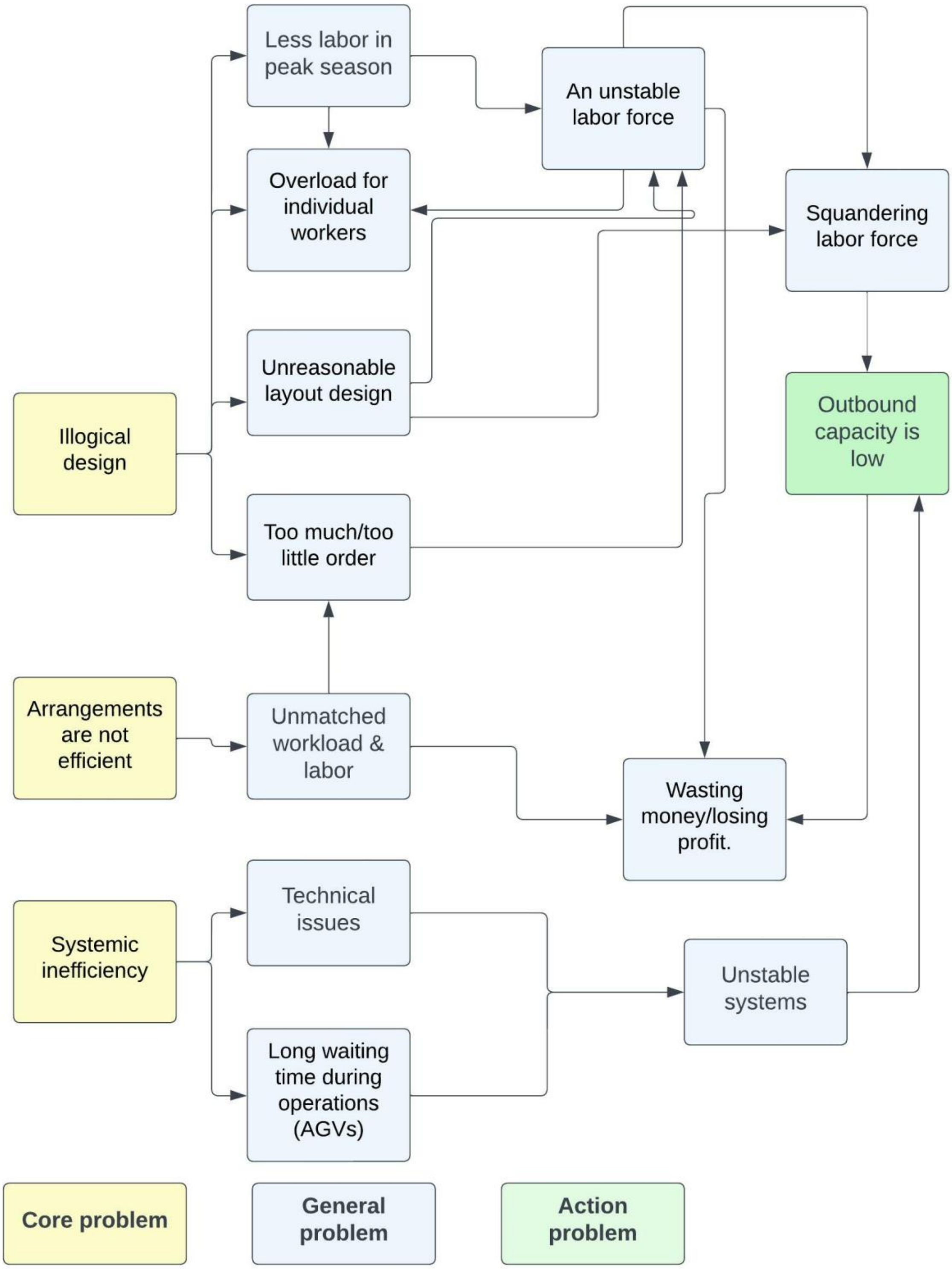

Figure 2, Problem cluster

1.2.3 Core Problems

According to the experience of the author's internship in JD in the past six months and the organized problem cluster in Figure 2 above, we defined three core problems as follows:

1. Illogical design.

2. Arrangements are not efficient.
3. Systemic inefficiency.

The question is, why were these core problems chosen for this study? The answer would be that these three core problems are the beginning of other problems. The outbound ability will be improved once the core problems can be solved. The author's motivation would be to solve these core problems, and other problems would be solved synchronously since general problems and action problems are caused by core problems. Focusing on core problems is the most efficient way to solve the problem itself.

But what are those problems exactly meant to mean in this study once the reasons for choosing these three core problems have been clarified?

The first core problem is " illogical design". The term "design" here means many things. First, the design means labor arrangement design, where sometimes the warehouse arranges more labor when the order amount is low, but sometimes less labor when the order is too much. Therefore, for individual workers, they may feel overloaded with tasks at hand while sometimes feeling there is nothing to do at work. Second, the term "design" in this paper means warehouse layout design, which means the planning in a warehouse is sometimes not reasonable. Workers may walk a longer distance to get their task finished, wasting time. The "arrangements" in this study mean the working period arrangement. The received orders by hours and the working efficiency in units of time by various job natures are different. The output cannot be perfected if the arrangement for the worker's working period does not match with the workload. The "systemic" in the last core problem means both the hardware and software that are used in the warehouse, since the warehouse itself was set up less than one year ago in the Netherlands, and cooperation between various software and hardware is not fluent, bugs and breakdowns happen during production. The picking process is the bottleneck during the outbound operation. The picking process handles picking goods from the shelves brought by the AGVs. Each AGV carries multiple SKUs. It can be seen as a 'mini warehouse'. It drives to an employee at a picking station, who puts requested items from the AGV into grey totes that will be processed manually subsequentially. The following steps cannot be executed if the picking is too slow. That is why this paper chooses the picking stage as the main stage to implement.

1.2.4 Norm and reality

We shall define our norm and reality in a straightforward manner to produce a measurable and clear standard. The author already knows where he wants to go with this paper, but still, the norm and reality need clarification at the beginning.

The first norm and reality are warehouse design (arrangement design and layout design). As explained in section 1.2.3, there are still spaces for the warehouse to make improvements in design. Based on this, warehouse design should be logical, with no waste, no shortage, and friendly to the operators. However, the reality is that deviation still exists, which means more workers are sometimes present while the company has received fewer orders and the operator walks a longer distance in the warehouse due to the unreasonable design. Correspondingly, fewer workers can be used when unexpected orders pour in. The first norm and reality can be measured by the reduction in time and transferred into percentages to get an improvement level.

The second norm and reality are the communication between the Fulfillment Orchestration Platform (FOP) system and the Warehouse Management Systems (WMS) system. The WMS system is designed and used within the warehouse to distribute orders to AGVs, and the FOP system is used to communicate between the JD and our client, HKM. The norm is that communication between various systems should be unhindered with zero resistance. Data transfer between systems should be correct and on time. The reality is that communication delays do exist between the FOP and WMS, which can cause the defective WMS system and eventually influence the outbound ability. The measurement can be shown by the failure times during operation; such a frequency points out the reliability of the systems.

The third norm and reality are the picking process during operations. The picking process is a key point among outbound actions that oversee picking order pieces from the AGV location as well as a packing preparation stage. The norm is to pick actions that are fluent without mistakes to make sure the next stage has enough buffer to process them. However, the reality is that the picking process has various unsmooth links in the time of procedure. In fact, the picking process is the bottleneck of all outbound processes, which has the lowest ability and affects the operation. This norm and reality can be figured out by comparing the picking efficiency and the other link's efficiency in numbers.

In general, both the norm and reality in this case can be shown by correct results in numbers to avoid being fuzzy and uncertain. However, since the second norm and reality are focusing on the IT-related field, we will not spend energy on it and will instead focus more on others.

1.3 Problem solving approach

1.3.1 Managerial Problem-Solving Method (MPSM)

The problem-solving approach needs to be defined clearly before we can implement the research questions into action. The managerial problem-solving method (MPSM) will be applied in this paper, the MPSM was introduced by (Heerkens & Winden, 2016) and has seven major phases:

1. Problem identification
2. Solution planning
3. Problem analysis
4. Solution generation
5. Solution choice
6. Solution implementation
7. Solution evaluation

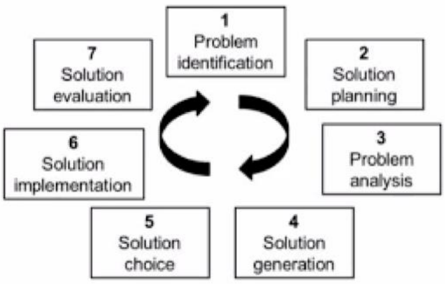

Figure 3, Managerial problem-solving method (Image retrieved from book-Systematisch Management Problemen Oplossen)

The first three steps can be defined as the beginning stages of the MPSM. We shall clearly name the problem with a detailed background, then plan the solutions and analyze the problems. The fourth and fifth steps can be considered together. At this stage, we will generate solutions and choose some of the solutions for the following phase. The sixth step in Figure 3 is about implementing the chosen solutions by evaluating those solutions in real cases to see the outcomes. The last step is to evaluate the solutions and present your suggestions based on the implementation phase's results. We will follow the basic principles of the MPSM and apply the preceptive to this study.

1.3.2 Intended deliverables

We shall deliver various achievements by following the MPSM approach method, as for the detailed items, the reader may check the following:

1. Analyzed data and rating to each potential solution.
2. Detailed reasons.
3. Furter suggestions.
4. Detailed description of the evidence.
5. Detailed reports.
6. Final presentation.

1.3.3 Research questions

The problem is clear in this study, with a straightforward expected outcome for JD. JD would like to improve its outbound capability/efficiency to meet the growing demand from customers in various nations and the growing total number of orders. Based on the real question and the current situation in the warehouse, one research question becomes obvious to us. "***How can the outbound processing capacity in JingDong logistics be improved while not incurring too many extra costs?***" This research question is proposed to discover actions and solutions that will eventually improve the outbound capacity/efficiency of the Jingdong organization. However, the research question can be too broad and may need refinement to make it more reachable and attainable. Therefore, we have divided the main research question into sub-research questions to make it easier to approach.

SQ1: What methods have been proven not effective for improving outbound ability in warehouse?
The first sub-research question is designed to figure out what kinds of solutions have been proposed and implemented in our warehouse but found to be ineffective. Such activities can become guidance in further studies to avoid meaningless research and implementation.

Failure knowledge can be applied to improve performance (Schroeder & Gibson, 2010). Before the proposed solutions can be implemented, it is critical to understand what types of methods were previously applied to the warehouse but were found to be ineffective. Therefore, we would like to organize some used, non-efficient methods that have been applied in a warehouse and discover potential reasons why those methods are not working.

SQ2: (short term) What effective method(s) or strategies can be used to improve the outbound process in JD organization?
Once the first research question has been answered correctly, the next step would be to find a suitable method or solution to solve the current outbound capacity dilemma. This research question focuses on the current situation and what methods can be applied to improve the capacity, while the first research question is more likely to find out the "past."

SQ3: (long term) What recent technology for AGVs in warehouse is available?
Unlike the earlier research question that focused on current circumstances, this research question pays attention to the future possibilities of improvement in AGV's technology that can help the warehouse to upgrade.

In general, these three sub-research questions are separate from our main research question, but these three research questions focus on various directions (the first research question tries to study the past, the second research question is about solving the current dilemma, and the last research question takes care of the future) with the same final goal.

2 Context analysis

2.1 Process description

2.1.1 General process

As introduced in section 1.1 above, the warehouse itself can be divided into three major function modules, which are inbound, outbound, and in-warehouse. However, the minimal introduction has limitations on constructing a clear impression in the reader's mind. Because of the diminished introduction, the reader may still feel disorganized from the limited introduction.

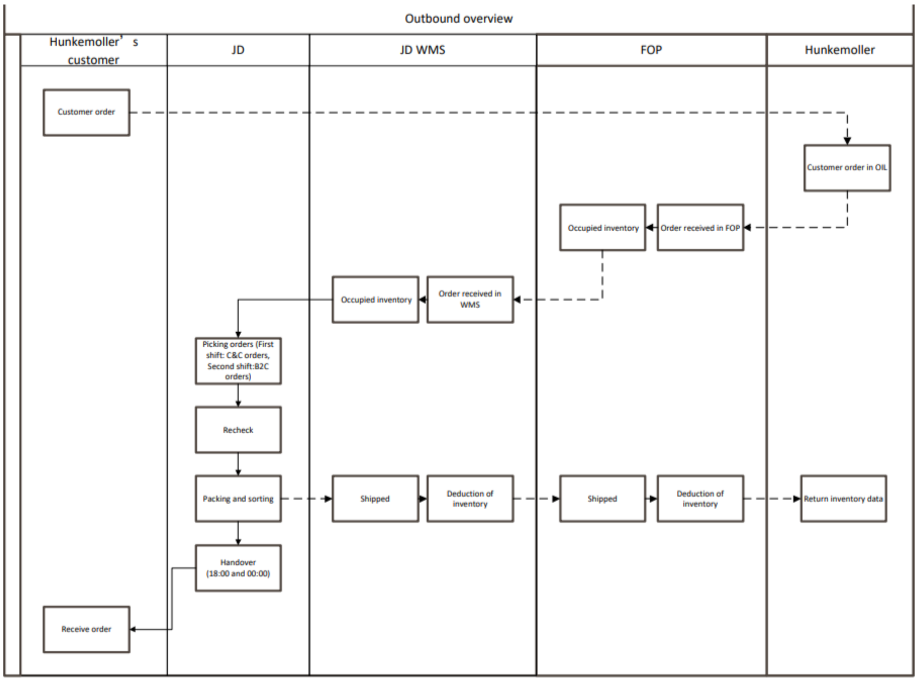

Figure 4, Outbound process overview (Image retrieved from company internal file)

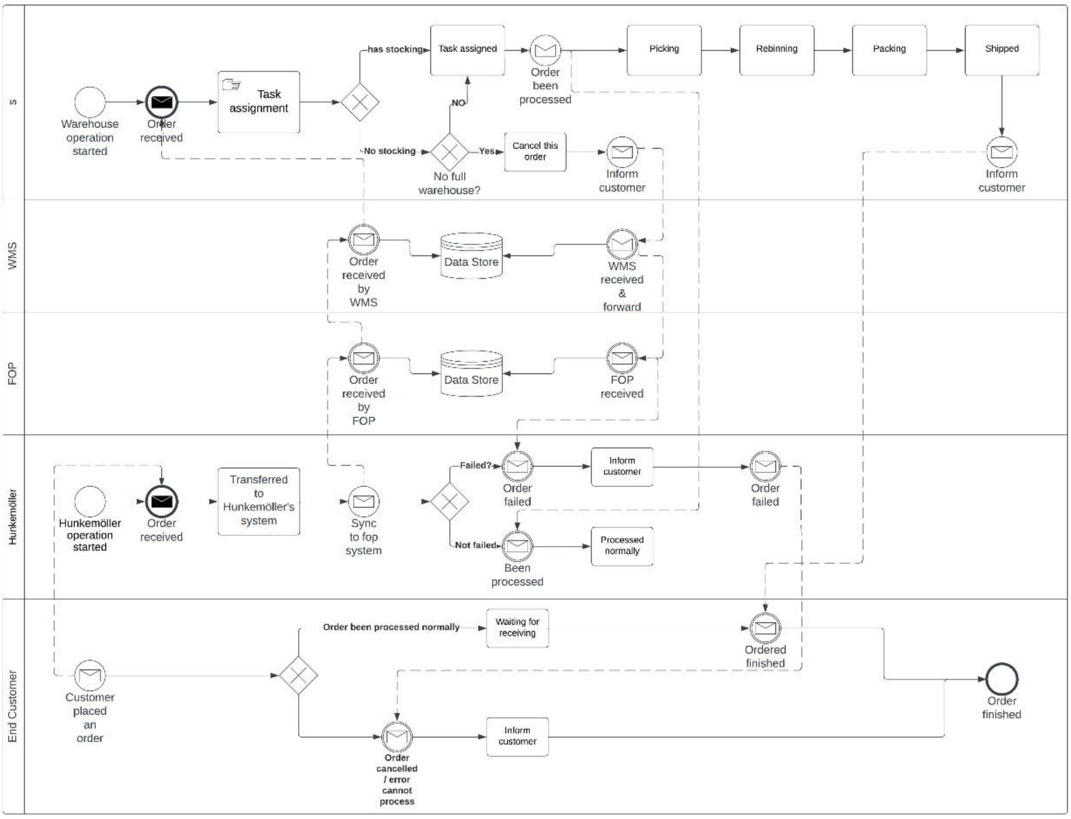

Figure 5, BPMN process

To deliver an intuitively strong impression to the reader, we have used Figure 4 (Outbound process overview) and Figure 5 (BPMN process) above. Figure 5 shows the order and message flowing between various organizations and systems, and Figure 4 expresses the basic overview of outbound processing in the warehouse. However, we would like to explain (see Table 3) several specific vocabulary words that have been used in both figures and context before the detailed explanation.

Table 3, Vocabulary explanation

HKM	An abbreviation of "Hunkemöller"
JD	JINGDONG LOGISTICS (NETHERLANDS) B.V.
Warehouse Management-system (WMS)	JD WMS is a system which is designed for JD itself, an internal company system. This system is designed for order management, task assignment, historical data storage, etc.
Fulfillment Orchestration Platform (FOP)	Based on the consideration of data security and privacy, the systems between HKM and JD cannot communicate directly. FOP is designed for communication between two different companies.
AGV	AGV stands for an automated guided vehicle, which is used in the picking stage.

Specifically, Figure 4 presents a big picture of the flows between various companies and systems. In general, information will be updated between our warehouse and HKM when customers place orders on HKM's website via the *Fulfillment Orchestration Platform* (FOP), then synchronized to the *Warehouse Management System* (WMS). The warehouse will take over the placed orders and start the internal process for further operations. Such an action will need cooperation between three major function modules in the warehouse to make the order successful.

First, the in-warehouse department is a foundation for other processes since the inventory should be sufficient for shipping orders. The in-warehouse department has the following tasks and duties:

1. **Receiving goods from HKM & recalls**. The in-warehouse department stays connected with HKM by updating stock levels constantly. HKM will arrange replenishment if some specific clothing category is selling well, and its safety stock level is dropping fast. In contrast, recall action will be taken if some category is overstocked because of unmarketable products.
2. **Inventory checking.** The inventory check frequency is every three months, four times per year as required by HKM. The leader, who oversees the in-warehouse department, will start the inventory checking event by arranging a specific date and labor. HKM shall be notified and receive a copy of the inventory check report.
3. **Consumable management.** The in-warehouse leader is also responsible for the consumables, the mentioned tasks (i.e., packing) above will use consumables daily. The consumables are provided by HKM, for example, plastic bags, paper boxes, and so on. The head of the in-warehouse department shall count the stock level of consumables and report it to HKM to keep the stock level at a reasonable point.

Overall, the in-warehouse administration's responsibility is to keep the stock (SKU and consumables) level inside the warehouse at a safe level for order fulfilment while not increasing stocking costs too much. Orders can only be assigned when available inventory is greater than zero. Otherwise, the orders will be at a "pending" stage if usable quantities cannot be met.

Second, the inbound department is the key element for the warehouse along with our client (HKM) to keep the after-sale service quality. The inbound department has the following tasks and duties:

1. **Return.** The inbound team manages the return of orders from the end-customers. Sometimes, customers place an order from the website and receive their order on time. However, they are not satisfied with the quality of products or the quantity of goods and start the return procedure. The return process should be finished in the shortest time possible, so the customer can receive the refund sooner.
2. **Inbound & put-away.** Receiving stocks from HKM by the in-warehouse department does not mean the end of the process; physical inbound is different from system inbound. The warehouse must register all received goods with the system, which means transferring the physical inventory into systematic stocking. As for the put-away process, it is the process that puts goods into specific storage cells and makes them ready for selling.

The inbound team responds to receiving materials that are returned by the end-customers and makes sure the received products are transferred to specific cells and are waiting for outbound procedures. The order will be transferred to the outbound department if the usable storage is greater than zero for placing the order. The orders will be assigned to automated guided vehicles in storage areas. The AGVs will be activated and carry the storage shelves to the picking stations once orders have been assigned to the AGVs. Lastly, the orders will be packed and shipped out if the picking stage is completed correctly.

Lastly, the outbound process is another key part of satisfying customers' orders since availability (the product usable when needed) is one of the four quality dimensions for E-service (Juran & Gryna, 1992). The outbound department has the following tasks and duties:

1. **Outbound process flow control.** On-time delivery is a key factor in the e-commerce shopping experience, and the outbound process flow control is positively correlated with it. The process flow control is about balancing available labor and orders waiting to be processed in the system. To avoid human resource waste, the outbound team must ensure that the outbound process is fluent and runs at an average flow speed.
2. **Technical support.** As introduced, the outbound process is an important link during the warehouse's daily operation. Many printers, computers, etc., have been used in the process. Unavoidably, technical issues happen. Therefore, the outbound team should support it.
3. **Resolving order issues.** Unexpected conditions happen during the outbound process; sometimes orders cannot be packed correctly for no reason. In such a situation, the outbound team should contact the IT departments from both sides (JD and HKM) looking for help and eventually ship out the order.

In conclusion, each department/link has its own responsibilities and focus. Overall, all contribute to the warehouse operation. We were trying to prepare an introduction video that was filmed inside the warehouse. However, such a demo cannot be found on the Internet, and we used another warehouse animation made by JD to give the reader a rough impression of the warehouse in Venray. Despite the intuitional of the animation, the video is still different from the actual scene inside the warehouse, and that is why we presents Figure 6 to the readers.

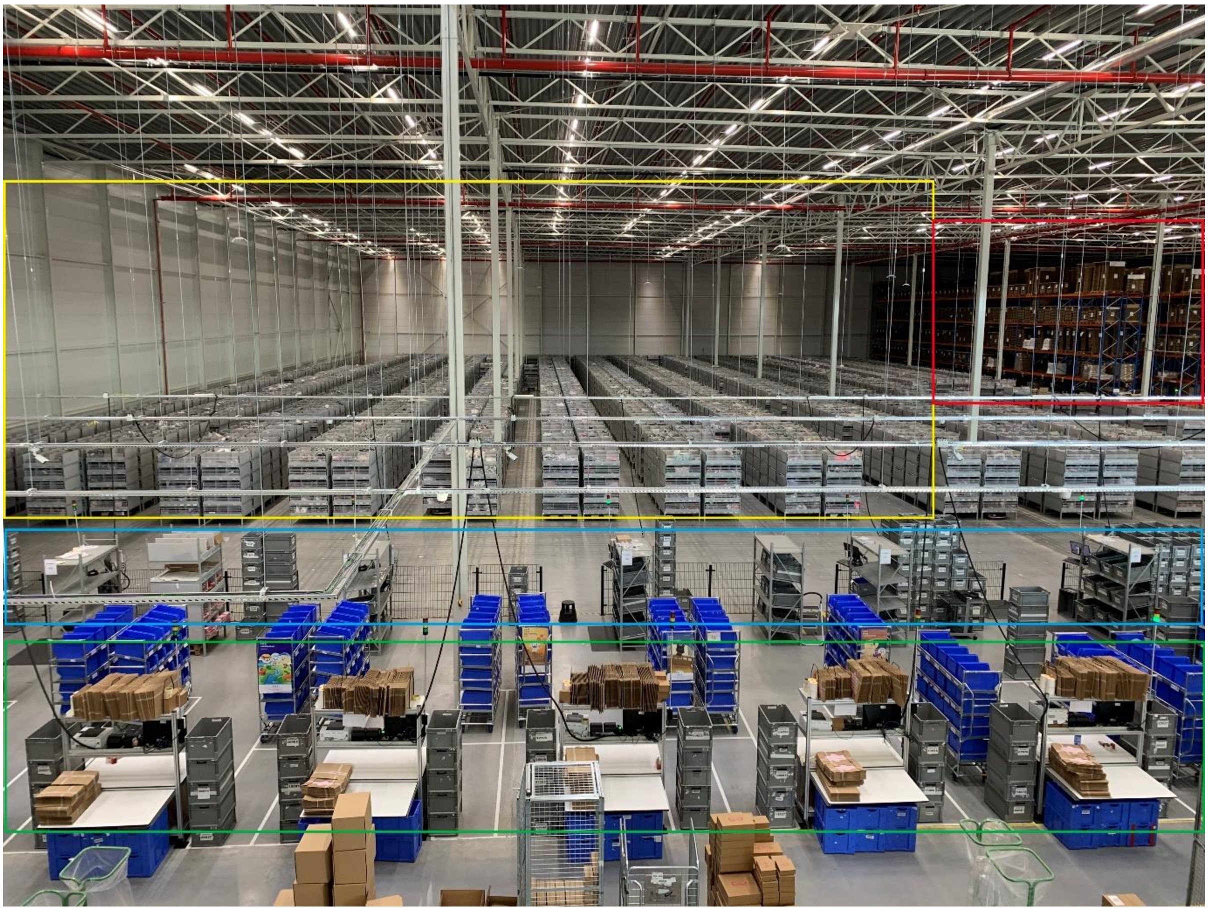

Figure 6, Function areas inside the warehouse by colors

Figure 6 was taken inside the warehouse and can fully show the overview of each functional area by colors. First, the area marked in yellow is the AGV area, with the function of storage and AGV picking. Workers will transfer goods to this location when the warehouse receives new inbound from our client. The AGVs shall carry the shelves to the picking station once orders have been distributed to the AGV. To give the readers a better understanding, the link (remark: the owner of this video is Alibaba instead of JD, but it is quite similar to our warehouse and can be used as a presentation) indicates how the AGVs operate. Second, the area in red is the high-rack location, which is used to store consumables and bulk goods. Lastly, the blue and green areas below are the picking stations and packing stations where the workers pick and pack orders for shipping out.

2.1.2 Outbound process

We have made our basic introductions above, and the reader is able to get the necessary structures for the operations inside the warehouse. However, the author's position in the company is "operation intern," and he oversees the outbound process, which is the focus of this paper. We will use Figure 5 as a foundation to dive into the outbound process running.

As can be seen from Figure 5 in Section 2.1.1, the outbound process starts with the order placed by customers and ends with received orders (or cancelled), with various message flows existing within this process. If we focus on the outbound process alone, straight messages can be found: the order will be processed by following the "picking," "rebinning," and "packing" steps once the stock is sufficient. These three sub-actions are the key elements of the outbound process, but what are these sub-processes and what do the specific operational steps look like? The answers can be seen as follows:

1. **Picking** (semi-automatic). The picking process is a series of actions that manage the choice of the correct Stock Keeping Unit (SKU) with the right quantities from storage areas. This process is semi-automatic since the first half-stage is executed by robots (AGVs) and the next stage is managed by humans.
2. **Rebinning** (manual). The rebinning process can be defined as "sorting" in the warehouse. Customers' orders are mixed at the end of the picking stage and cannot be packed directly. The rebinning is the stage where the products that belong to the same customer's order are sorted. Packing action can be implemented once this stage is finished.
3. **Packing** (manual). The packing is processed manually by scanning all products that belong to the same customer and packing them correctly.

Once the definition of these sub-processes has been explained clearly in the section, the next move would be to explain what the specific operational steps look like in a real operation. The reader can learn more about the "picking," "rebinning," and "packing" processes by consulting appendices A, B, and C, where detailed step-by-step operations have been listed.

2.2 Current situation analysis

In the beginning paragraphs of this paper, we introduced basic information and dilemmas that currently exist in this company's outbound process. However, the reader may feel incomprehensible without the support of data and detailed elucidations. Such a task will be explained in this paragraph.

The outbound process is made up of three other sub-actions, which are picking, rebinning, and packing. During daily operations, these three sub-actions in the outbound process are non-parallel but tandem. The outbound starts with picking where the picker picks from the AGVs and putting the collected pieces into a specific container. Then the next step would be rebinning, which is a sorting process to split goods in containers into various packing areas and wait for packing. As for the packing movement, it was designed to pack all orders that were prepared by the rebinning stage within a reasonable time. The current efficiency for each stage is as follows:

1. Picking, 180 pieces/per hour/per person.

2. Rebining, 90 pieces/per hour/per person.
3. Packing, 40 pieces/per hour/per person.

As for the layout of the warehouse, we have eight picking stations in total and fifteen packing stations, plus seven rebining stations. However, such efficiency and capability are insufficient to satisfy the client.

2.3 Potential solutions

Till now, this paper has introduced some basic information and background with current situation analysis. The author has worked in the warehouse for six months and has experienced both the peak and low seasons. During this time, the warehouse has experimented with some methods and hopes to change the fact of low outbound ability. However, not all those ideas helped the warehouse. Based on the author's understanding of the company's processes and his responsibilities to the warehouse, we proposed the following solutions, which may solve the outbound ability dilemma:

1. Redesign the layout.
2. Improving labor arrangement efficiency.
3. Improving the picking station's capacity by adding one more cabinet.

The reader may feel the sudden appearance of these ideas. The author has explained in detail how and why he chose these methods in Section 5.5. The reader may check for details there. The proposed three potential solutions will be implemented by us into the warehouse and observed for the outcomes to see whether improvements do exist. It is worth noting that the proposed potential solutions do not mean the final solutions; fresh solutions may arise during the MPSM cycles.

3 Theoretical perspective

Lean management is an approach to managing companies for continual improvement; it is a long-term search for changes to improve efficiency and quality (McLaughlin, 2019). Lean management is a widely used management method in various companies and organizations with several key links, as shown in Figure 7 below.

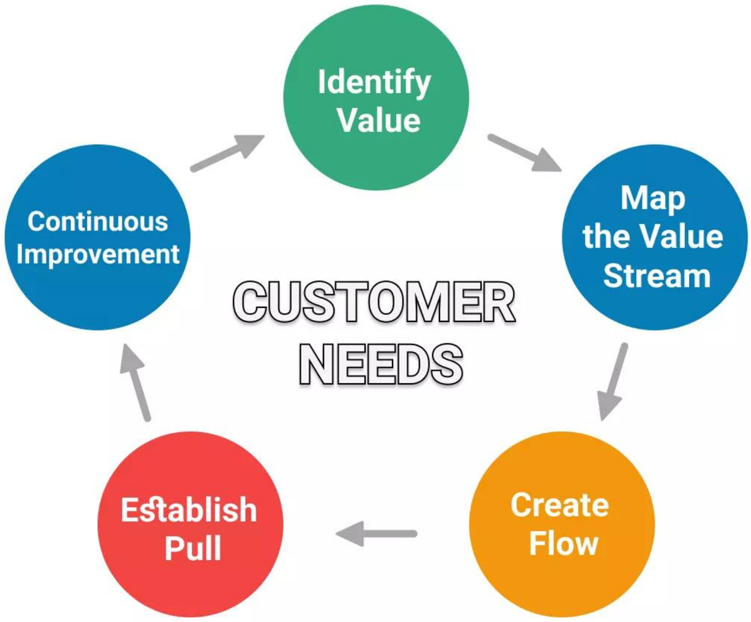

Figure 7, Lean management (Image retrieved from online LEAN management introduction)

The center of lean management is customer needs and is surrounded by five different key factors, which are: "identify value," "map value stream," "create flow," "establish pull," and "continuous improvement." The reason we chose this theoretical perspective is that the goal of this paper is to improve the outbound ability of the company/client, who is a customer focus and a long-term improvement, and make it suitable for this paper.

4 Literature review

4.1 Definition of key constructs and variables

The main research question in this paper is "***How can the outbound processing capacity in JingDong logistics be improved while not incurring too many extra costs?***" A precise definition should be given at the beginning of such a research question. However, the definition should not only focus on the main research question but also sub-research questions. Based on that, we defined "outbound processing," "capacity," and "improve" as the key constructs for the main research question in this paper.

Since the author’s position is an operation intern in a logistic company, the definition of "outbound processing" shall be defined and focused on the warehouse side. From the perspective of operating in a warehouse, the outbound process can be grouped into three sections: methods of goods placement in picking locations; order collection paths; and distribution of workers and operations (Herzog, 2021). Capacity can be defined in a variety of dimensions, and warehouse problems can be divided into three major categories based on their complexity: throughput capacity, storage capacity, and warehouse design (Cormier & Gunn, 1991). However, the ability in this paper will be more focused on throughput ability than others. As for the "improve" variable, it can be defined as " to enhance in value or quality: make better" (Definition of improve, n.d.).

To answer the first sub-research question (**What methods have been proven not effective for improving outbound ability in warehouse?**), two concepts need to be defined in advance, which are "effective" and "outbound ability". What kinds of situations can be defined as effective and non-effective? What is the outbound ability of the warehouse? Such questions require a clear declaration. Effective can be defined as: organizing the overall requirements of the warehouse, incorporating equipment and methods that match all those requirements the most closely in a warehouse (Zhang & Syed, 2019). And the outbound ability can be replaced by the definition of ability in the earlier paragraph.

The second research question is "**What effective method(s) or strategies can be used to improve the outbound process in JD organization**", and the chosen key concepts are 'effective' and 'improve' which have been defined in the main research question. The third research question is "**What recent technology for AGVs in warehouse is available?**", we chose the 'AGV' and 'warehouse' as key concepts for further searching.

We have defined several key concepts in the main research question and sub-research questions; however, the variables also need to be defined to make the concepts measurable and perceivable. The first question would be, how can we calculate and measure the outbound process? To answer this question, this paper will use the variables "order placement," "collection path," and "distribution" as variables to show the outbound process. Secondly, this study would like to decide the ability concept in the main research question. This paper will use output efficiency as an evaluator to make the ability quantitatively calculable. The last one would be how the "improved" concept can be evaluated. To answer it, this assignment will use the ratio between two stages (before implementation and after implementation) to specify the improved level.

4.2 Systematic literature review protocol

A systematic literature review protocol will be applied in this paragraph to find the ideal theoretical perspective. Several variables have been defined in the above, therefore, a combination of variables can be used for systematic search on various search engines.

Table 4, Keywords for systematic search

Variables	Derived/related keywords for searching
Order placement	Warehouse, order placement, collection path, distribute, output efficiency, improve, ratio, outbound, ability
Collection path	
Distribution	
Output efficiency	
Improved ratio	

Several derived and related keywords have been listed, as the reader may see from Table 4 above. The following systematic search action will be choosing the right search engine. The implementation of the search activity would be the next step. We chose ***Google Scholar*** and the ***Web of Science*** as the main search engines. The reason we chose these two search engines is because Google Scholar has a broader collection of resources, and the Web of Science has more journal articles on academic.

The following phase will be to fulfil the searching activity once the search engine and keywords have been settled. The following Table 5 lays out the search results[4] from two chosen engines.

[4] Implementation data by the author is 12-04-2022, the outcome number may change by date.

Table 5, Results by type of search engine without constraints

Search terms and strategies	Results (Google scholars)	Results (Web of Science)
Warehouse, order placement	67700	41039
Warehouse, collection path	127000	30157
Warehouse, distribute	94400	1266
Output, efficiency	5510000	123415
Warehouse, improved	354000	3584
Warehouse, improve ratio	110000	105
Outbound, ability	77000	1448450

The number of outcomes is shown in Table 5 above, but the results are too numerous to go over one by one. The rough results can be refined by introducing constraints to each search engine. As for the filtered results, the reader may check table 7 below.

Table 6, Constraints by type of search engine

Google scholars	Web of Science
• Articles • Custom range: after 2000 • Review articles	• Publication year: after 2000 • Document type: articles • Open access: gold • Language: English

Table 7,Results by type of search engine with constraints

Search terms and strategies	Results (Google scholars)	Results (Web of Science)
Warehouse “AND” order placement	2670	5
Warehouse “AND” collection path	2980	2
Warehouse “AND” distribute	1650	37
Output “AND” efficiency	159000	5189
Warehouse “AND” improved	9250	178
Warehouse “AND” improve ratio	4020	6
Outbound “AND” ability	2780	9

The output[5] from table 7 is way less than the original table by introducing constraints. However, it is still too much to read in a limited time, which means the result from table 7 needs further limitation factors.

The outcomes from Table 7 are still too much to refer to in a limited time, especially considering the number of outcomes in Google Scholar. To make sure the project plan can be finished on time, we will read the first two pages of the results on search engines if the number is greater than ten, since the ordering of the results is of relevance. In the report by (Herrero & Xu, 2022), they mentioned the cost factor, where the labor cost is much higher in the Netherlands compared to other countries (for example, China). The warehouse has tried asking for more workers to meet the growing demand from the client. However, the labor costs in that month increased too much and eventually forced the company to abandon this method.

[5] Implementation data by the author is 14-04-2022, the outcome number may change by date.

4.3 Queuing theory

The outbound process can be simplified to a mathematical study of orders waiting in lines. The essence of the often mentioned "increased outbound ability" in this paper is to reduce the queuing time of each product in the system of a warehouse. According to the literature, queuing theory is often used in business decision-making (Jaroslav, Juraj, & Nedeliakova, 2015). The queuing theory shows the possibility of simplifying a complicated warehouse outbound process into a queuing model to find the bottleneck of the operation. There are several types of queuing theories, such as FIFO (first-in, first-out) and LIFO (last-in, first-out). For a warehouse, LIFO seems like a bad choice since timeliness is a crucial factor for the customer's online shopping experience. Therefore, FIFO will be applied to the warehouse's daily operation fulfillment. The "first-in" will be showed by the receiving time of orders, and the "first-out" will be decided by the package completion time in the warehouse.

Little's law is a useful formula related to queuing theory, and it is written as follows:

Equation 1, Little's law

$$L = \lambda W$$

This formula is simple with three variables in the equation with the meanings of: L is the average number of customers in the system, λ is the average arrival rate into the system, and the W is the average amount of time spent in the system. Applying Little's law to this study, L will be the average number of orders in the system at specific time, λ presents the receiving rates of orders per unit time, W shows the average time in the system (from received to packed) per order. Queuing theory and Little's law are excellent tools for calculating the efficiency of various outbound process links.

4.4 Warehouse layout design

The warehouse layout design is another key factor to improving the ability to work. According to the literature, the layout is a facility design, analysis, conceptual and manufacture of systems for a good service (Wibowo, Nurcahyo, & Khairunnisa, 2016). The design of the layout is even more crucial for the warehouse itself since the layout can affect many aspects (i.e., the walking distance, picking efficiency). The warehouse design has several preconditions before the calculation in the literature (title: Warehouse layout design using shared storage method) which are:

1. Classify the products by the flow of goods (Fast, slow, idle).
2. Needs for pallets.
3. Figure out the storage ability.
4. Design the layout based on storage ability and rack needs storage.
5. Calculate total mileage.
6. Make the product placement using shared storage method.

There is a point worth noting here is that this literature itself focuses on the storage area, about how to achieve the storage efficiency approved for a warehouse. It is true that the idea in the literature is different from the author's focus in this paper, but the literature inspired the author to improve the layout design in the warehouse to improve the outbound ability. Two (see Figure 8 and Figure 9) different layout designs have been introduced in the literature. The upper part within the two figures shows different dock designs. Individual in and out docks have been introduced in Figure 8. However, both docks were designed as in/out. The lower part shows various storage locations (e.g., A1, B1, etc.) classified by their (products) flowing speed in the system.

Although the starting point is different between the literature and this study since the layout design is more focused on storage efficiency than outbound ability. Back to our warehouse in this study, despite the different angles between the two studies (literature and this paper), the idea can be applied here. In our warehouse, the main storage area is the AGV area, where the storage operations and AGV picking activity happen. If the storage area can be rearranged by the flow rate of various SKUs and put the fast-moving SKUs close (e.g., like locations A1, B1, etc. in Figure 8 and Figure 9) to the picking stations, then the AGV can travel a shorter distance and shorten the process time.

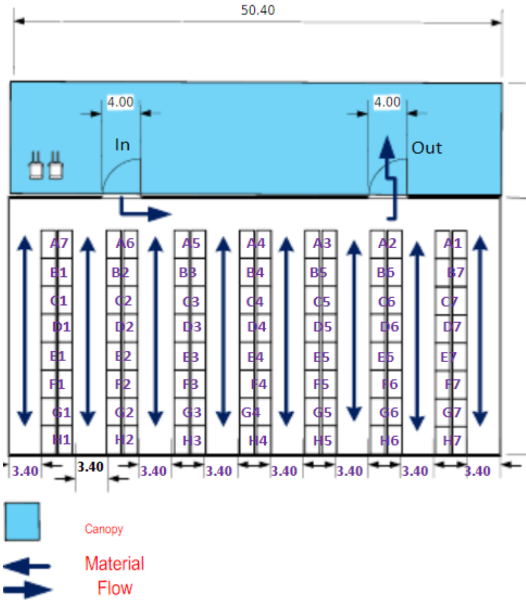

Figure 8, First alternative layout (Image retrieved from literature- Warehouse layout design using shared storage method)

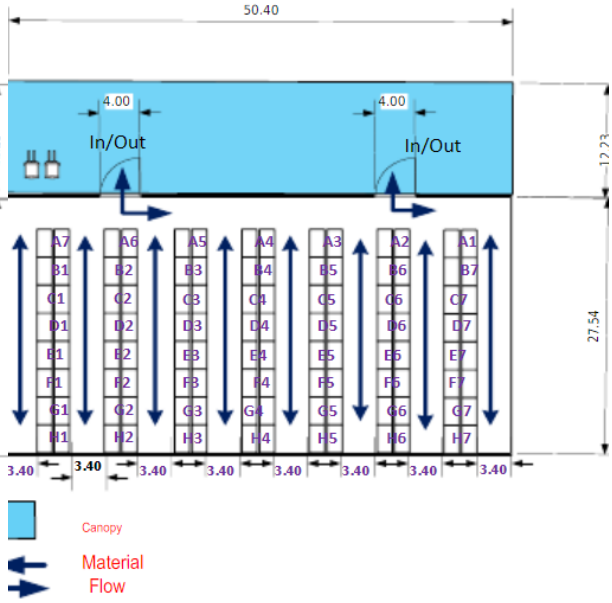

Figure 9, Second alternative layout (Image retrieved from literature- Warehouse layout design using shared storage method)

Besides the mentioned re-designing of the storage method for products, the layout of different function areas can be adjusted to make the outbound process more fluent and require less walking for employees who are working inside the warehouse. The idea of re-designing the layout may reduce the robot's path routing if fast-sold products are closer to the picking stations and the total walking distances. Further discussion will be argued based on such a scheme later in this paper. This theory will be applied to classifying the flow of products, then making those products closer to the picking operation area. But this study will not focus too much on how to design the storage layout itself since the author is not responsible for the storage department.

4.5 Fuzzy Obstacle Avoidance (dynamic routine plan)

Currently, the AGVs that are used in the warehouse are not smart enough. Sometimes AGVs collide[6] with other AGVs during operation (see Figure 10), and sometimes AGVs do not respond[7] to the system (see Figure 11). Such errors happen during daily operations and heavily influence the production activities since each time it takes time to recover the AGVs back to normal. Besides that, the logic behind the AGV control in the company is centralized, which means all orders come from one single system and there is zero communication between robots. Therefore, traffic jams also happen in the warehouse.

[6] Normally, AGVs keep a safe distance from other robots. However, AGVs are meeting a traffic accident in Figure 10.
[7] If AGV is under operation, the vertical green light must be ON and the lights in Figure 11 are OFF.

Figure 10, AGVs collide with each other (Image retrieved from warehouse operations)

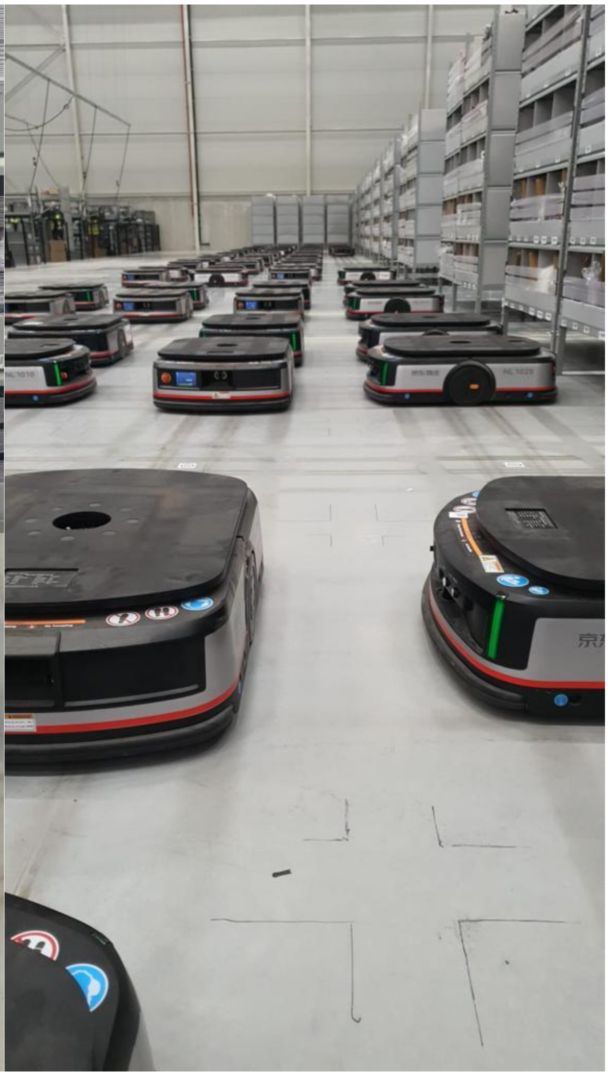

Figure 11, AGV not responding (Image retrieved from warehouse operations)

According to the literature (*Trajectory Planning in Dynamic Environments for an Industrial AGV, Integrated with Fuzzy Obstacle Avoidance*), fuzzy obstacle avoidance can assist the AGV in avoiding unknown or mobile obstacles in its path (Ferreira, Marcal, Fabro, & De Oliveira, 2016). In their theory, fuzzy obstacle avoidance is not a statistic algorithm but a dynamic algorithm. The AGV system has a predetermined knowledge base. The system can guide the AGV to avoid obstacles in its path based on the actual operations of various AGVs and the knowledgebase, which can enhance the AGV's operational efficiency. However, the specific logic and algorithms behind the literature and theory are complicated. This paper will not dive into the logic and algorithms. This would be a long-term idea and will be introduced as a further suggestion to the warehouse in this study rather than as the main direction of research.

4.6 Literature summary

This section is to give the readers an overview of what reviewed literature is and how we are going to use it in the following paragraphs. We can see more details from Table 8 below.

Table 8, Literature summary

NO	Title	Findings	Intend to use

1	Application the Queuing Theory in the Warehouse Optimization	Several queueing theories exist	Potential breakpoint for the AGV's technology
2	Warehouse layout design using shared storage method	Concept for warehouse design to improve storage efficiency	The idea of redesigning a warehouse can improve efficiency
3	Trajectory Planning in Dynamic Environments for an Industrial AGV, Integrated with Fuzzy Obstacle Avoidance	Dynamic routine plan possibilities for AGVs in warehouse	Further possibilities for AGV improvements

5 Solution design

Chapter 5 explains how we arrived at alternative solutions, what those solutions are, and how we implemented and analyzed them, which method this paper chose and why we chose such an idea. In the end, this study evaluates our choices.

This study has chosen the *Managerial Problem-Solving Method* (MPSM) as the problem-solving approach method in section 1.3.1. Hence, the main body structure of this chapter will follow the design of MPSM, which is "*problem identification (section 5.2)*," "*solution planning (section 5.3)*," "*problem analysis (section 5.4)*," "*solution generation (section 5.5),"* "*solution choice (5.6)*," "*solution implementation (section 5.7)*," and "*solution evaluation (section 5.9)*." This paper will answer the listed research questions in this part. Besides that, we will choose one or a few suitable solutions for the warehouse based on the results as well.

5.1 Aims and research

As introduced in the introduction section, JD is in trouble with low outbound ability and efficiency. Furthermore, JD wants to get rid of it. Both the client and the JD organization itself want to improve the production capability. For the client, they can sell more products and reduce the waiting time for end-customers if the working efficiency in the warehouse can be enhanced. For the JD enterprise, they can introduce new clients to the warehouse once the commodity circulation speed is faster, at which point free storage can be spared. Therefore, the aim of this study is to solve or improve the low outbound process ability problem for the JD organization without incurring too many extra costs and try to reduce the process time and enhance the outbound capabilities. A certain design is needed to achieve such a target since we focus more on the quantity aspect for measuring the outbound process ability enhancement.

To recap the reader's memory on the research questions in the section 1.3.3, we have listed the research questions and a few potential solutions as follows in Table 9 below.

Table 9, Research questions & potential solutions

SQ1: What method (s) has been proven non-effective for improving outbound ability in a warehouse? **SQ2: What effective method(s) or strategies can be used to improve the outbound process in JD organization?** 1. *Redesign the layout.* 2. *Improving labor arrangement efficiency.*

3. Improving the picking station's capacity by adding one more cabinet.

SQ3: What recent technology for AGVs in warehouse is available?

There are multiple ways to go about solving and answering these research questions. Nevertheless, we shall figure out what kind of research is needed here before going one step further. Quantitative research has been chosen as the main research method which was driven by the aim. Quantitative research has various sub-types, which are "*experimental*," "*quasi-experimental*," "*correlational*," and "*descriptive*" (McCombes, 2021). Each sub-type and sub-research question will be discussed in the following section.

Three sub-research questions exist in this study and need to be considered separately. For the first research question, we do not have to execute experiments but study previously used methods and look for reasons why those methods did not work. Therefore, descriptive quantitative research will be used for the first research question due to its characteristics. The second research question is about finding a suitable method (or several) for the warehouse to enhance the outbound ability. Such an action may need to be implemented by experiments, so experimental quantitative research will be used. Therefore, experimental quantitative research will be applied to this research question to investigate the most effective method (*s*) for improving the outbound process. As for the last research question, it is about looking for existing literature and finding out what the most recent technologies for the AGVs that are can be applied to enhance their operational efficiency. Therefore, descriptive quantitative research will be applied to this research question.

5.2 Problem identification

Section 5.2 is the beginning stage of the Managerial Problem-Solving Method (MPSM), this step defines the problem in this study. The dilemma that the JD organization is facing has been explained in section 1.2 along with its sub-sections, and the problem cluster is designed in section 1.2.2. The action problems (see section 1.2.1) and core problems (see section 1.2.3) that have been found give the direction of study about how this paper can continue its research.

The action problem has been proposed as "***How to improve the outbound process capacity of the JD warehouse production line."*** To make this action problem reachable, research questions have been suggested as shown in Table 9 above.

5.3 Solution planning

Section 5.3 is about how we can approach the alternative methods and steps to arrive at solutions. Once the problem has been shown and discussed clearly, the following action should be analyzed: the planning of solutions. According to the explosion of the managerial problem-solving method by the university (*University of Twente*), solution planning can be divided into three major steps, which are "Do," "Know," and "Choose" (Heerkens & Winden, 2016).

First, the "Do" action. The "do" step here means all the first preparation work. We shall see what the problems are; what problem-solving approach will be applied in the article; what efforts have been made by earlier predecessors in a specific area; etc. Back to this paper, action problems and research questions have been exploded in section 1. 2, MPSM has been chosen as the main problem-approaching method here, and the literature review has been present in chapter 4 of this paper.

Once the preparation work has been completed, the implementation phase will begin to evaluate the results.

Second, the "Know" action. The "know" step here means knowing and seeing the outcomes from the "Do" step. Detailed data and experimental/analysis processes must be recorded correctly. Referring to this paper, we must know what this study can learn from the outcome of the first research question about what direction has been assessed and should not waste time on that direction. We shall know about the implementation results from the second research question, which method can be applied to solve the current dilemma. Lastly, we should know what further suggestions this paper can make to the warehouse to enhance its ability.

Lastly, the "Choose" action. The "choose" step involves selecting the best warehouse solution(s) based on predefined judgment standards and outcome results. Before deciding which warehouse solution(s) to use, we must first supply a set of rules describing why this study chose such a solution or solutions. The choice step is far more than a randomly selected solution from implemented solutions. Instead, it should have detailed rules as support.

5.4 Problem analysis

Section 5.4 dissects the first research problem of why two applied methods are not suitable for the warehouse and briefly discusses the second and third research questions. Detailed argumentation about the second and third research questions will be discussed later.

The problem is that the warehouse is meeting low outbound process ability, which means the warehouse cannot satisfy the client with its current production capability. The nature of the problem is the warehouse's inefficient process, which dragged down the outbound operation's output. As introduced, the research questions have been considered and listed (see Table 9) above. The first research question is, *"**What method (s) has been proven non-effective for improving outbound ability in a warehouse?"*** The motivation behind this research question is to avoid doing useless research if any idea has been applied to the warehouse but proved not to work. We have noticed a few methods have been used in the warehouse to enhance the outbound ability, which are "*increasing number of workers" and "night shift*." But in the end, the results from these ideas are not satisfied with the warehouse for assorted reasons.

First, the warehouse manager tried to increase the number of workers to improve the process ability. As can be seen from Figure 12 below, the data in various columns stands for the forecast, warehouse capability, and human resource arrangement. The warehouse supervisor and warehouse manager have the responsibility to update the forecast file based on the feedback from HKM (e.g., promotion date, selling plans) and other aspects (e.g., national holidays, weekends) to make sure labor can be arranged in advance, avoiding temporary labor requirements since temporary arrangements for workers ask for higher salaries to make it happen. As the reader can notice from the figure, a few rows have been highlighted in yellow, which means no production on that day. The warehouse will be closed each Sunday and only run for six days per week instead of seven. But sometimes the manager will also choose to close the warehouse on Saturday if there are not too many orders in the backlog, or just simply transfer the workload from weekends to Monday and Tuesday since the salary on weekends is higher (the company must pay extra allowances to workers who are working on weekends) than on normal working days.

	I	J	K	L	P	Q	X	Y	Z	AA	AB
267			Forecast		Capacity(in orders)		Labor arrangement (in person)				
268			Outbound Order (in orders)	Pieces	Outbound (in orders)	Backlog (in orders)	Outbound	Inbound	Return	IVC	Total
338	Friday	17-Dec	5,220	15,369	4,500	-63	47	6	20	3	76
339	Saturday	18-Dec	4,726	16,985	4,100	-83	43	0	13	2	58
340	Sunday	19-Dec	5,089	18,291	3,080	1,246	32	0	13	0	46
341	Monday	20-Dec	4,362	15,678	5,000	-46	53	5	20	3	80
342	Tuesday	21-Dec	7,138	15,678	8,000	5,000	84	8	20	3	115
343	Wednesday	22-Dec	7,138	14,372	8,000	-1,933	84	8	20	3	115
344	Thursday	23-Dec	14,276	14,372	9,000	3,135	95	8	14	3	120
345	Friday	24-Dec	9,517	35,276	4,000	7,225	42	8	14	3	67
346	Saturday	25-Dec	10,806	19,359	0	16,410	0	0	0	0	0
347	Sunday	26-Dec	10,237	17,321	0	25,112	0	0	0	0	0
348	Monday	27-Dec	8,247	14,265	9,000	23,121	95	2	17	3	116
349	Tuesday	28-Dec	6,825	9,170	9,000	19,923	95	8	17	3	122
350	Wednesday	29-Dec	6,825	11,208	9,000	16,724	95	8	17	3	122
351	Thursday	30-Dec	6,825	14,265	9,000	13,525	95	8	17	3	122
352	Friday	31-Dec	7,109	15,284	4,000	15,568	42	4	7	2	55
353	Saturday	1-Jan	9,128	18,396	0	23,326	0	0	0	0	0
354	Sunday	2-Jan	7,987	16,097	7,500	22,615	79	0	7	0	86
355	Monday	3-Jan	7,987	16,097	9,000	20,404	95	5	17	3	120
356	Tuesday	4-Jan	7,416	14,947	9,000	17,708	95	8	17	3	122
357	Wednesday	5-Jan	7,987	16,097	9,000	15,496	95	8	17	3	122
358	Thursday	6-Jan	8,557	17,247	9,000	13,770	95	8	17	3	122

Forecast per day + promotio (2) | Sheet1

Accessibility: Investigate

Figure 12, Daily forecast and labor arrangement (Image retrieved from warehouse forecasts)

We may look at the figure first, and we will explain them first to make the readers easily understand. This paper will start from the I^{th} column to the AB^{th} column. The I^{th} column denotes different data on a weekly basis, while the J^{th} denotes a specific date in a specific month. The K^{th} and L^{th} columns share the same title "forecast", the number in column K means orders while the number in column L means pieces, they have different units (orders and pieces). As for the P^{th} column and Q^{th} column standing for the warehouse's production capability, the column P means the maximum ability in a specific data set with the unit of orders, while the column Q means the backlog from the previous day. If some day's capability is greater than the sum of received orders that day and the backlog from the previous day, then the backlog outcome will be negative. In corresponding, the number will be positive with a red highlight as shown in Figure 12 if the capability is lower than the sum of the previously dated backlog and new received orders. From the X^{th} column to the end, these numbers mean labor arrangements in different departments and positions, for example, outbound, inbound, etc., and the unit is in person.

The X^{th} (i.e., the labor arrangement for the outbound department) column in Figure 12 with the title "Outbound" is highly related to the outbound orders in K^{th} column. As mentioned in the beginning of this section (section 5.4), the company has tried to simply increase its workforce to cover the increased order number. We will use Figure 12 as a source of data to explain why this method is not working in the warehouse.

The dates of December 24, 2021, and December 27, 2021, will be chosen to conduct the calculations. On December 24, 2021, the expected received order number is 9517 (see K^{th} column), outbound capacity is 4000 (see P^{th} column), by the end of the day, 7225 ($9517 * 0.85$[8] $- 4000 +$ 3135[9] $= 7225$) backlog will be produced. On December 27, 2021, the expected received order number is 8247 (see K^{th} column), outbound capacity is 9000 (see P^{th} column), by the end of the

[8] 0.85 is the correction coefficient, outbound order 9517 is provided by the client, which is not fully correct. Backlog = (correction coefficient) * forecast order number – ability + previous day's backlog.
[9] 3135 denotes the backlog as of December 23, 2021, with orders as the unit (see 344th row and Q^{th} column).

day, a 23121 ($8247 * 0.85 - 9000 + 25112^{10} = 23121$)[11] backlog will be produced. Specifically, the pressure on December 27, 2021, is way much higher than on December 24, 2021, since the backlog amount is growing. In the past two days (Saturday and Sunday), the backlog has needed to be cleaned. The labor arrangement for these two days is 42 (December 24, 2021) people for outbound and 95 (December 27, 2021) people for outbound.

The warehouse gets paid 2[12] euros for each packed parcel from the client (HKM), while the salary paid to the labor agency (JD does not sign contracts with labor directly but with labor agencies) is 23[13] euros per person per hour (regular working days, excluding holidays, weekends, and over-time, etc.). Regular working hours per day are 8 hours (9 hours in total for one shift, with one-hour break time) per person. Therefore, the warehouse must pay $23 * 8 = 184$ euros per person per day. According to the labor arrangement from Figure 12, 42 people have been organized on December 24, 2021, while 95 people have been organized on December 27, 2021. A detailed calculation of incomes and costs between December 24, 2021, and December 27, 2021, has been listed in Table 10 below.

Table 10, Incomes & labor costs between December 24, 2021, and December 27, 2021.

Date	Labor cost	Income
December 24, 2021	$42 * 8 * 23 = 7728$ (€)	$4000 * 2 = 8000$ (€)
December 27, 2021	$95 * 8 * 23 = 17480$ (€)	$9000 * 2 = 18000$ (€)

There are a few things that we can discover from Table 10:

1. When simply increasing the number of workers to cover the workload, the income has increased by 10,000 euros.
2. From December 24 to December 27, labor costs increased by 9,752 ($17480 - 7728 = 9752$)euros.
3. The labor cost increase rate[14] is $(17480 - 7728)/_{7728} * 100\% = 126.24\%$
4. The income increase rate is $(18000 - 8000)/_{8000} * 100\% = 125\%$

As can be seen from the earlier calculation, two days of data were used as an example to show how the costs and income changed from December 24, 2021, to December 27, 2021. From the calculation, the income has increased 125% (from December 24 to December 27) while the costs have increased 126.24% (from December 24 to December 27), which means the income for the warehouse has been increased but the costs have increased even higher compared to the income. The reader may notice that both days' profits[15] are positive because the revenue exceeds the labor cost. However, which is not fully correct in a real situation, the warehouse does not have other income but the payment from our client, but the cost is more than just labor cost. This defined the profit in the footnote as a simplification. The warehouse must pay for various bills (e.g., water, gas, electric, etc.) and pay for the rental fee monthly. Besides that, the equipment's cost is another major investment that needs to be considered. The increase rate of labor costs is higher than the increase rate of income when JD wants to increase the number of workers to cover the gross number of

[10] 25112 denotes the backlog as of December 26, 2021, with orders as the unit (see 348th row and Q^{th} column).
[11] Backlog = (correction coefficient) * forecast order number – ability + previous days' backlog.
[12] which is an estimated number after a comprehensive calculation based on various conditions (e.g., income from storage, label printing, etc., costs from consumables, equipment depreciation, etc.).
[13] The total amount that the warehouse needs to pay to the labor agencies.
[14] Increase rate = [(increased number – previously number) / previously number] *100%.
[15] Profit= income – labor cost.

orders, which means simply increasing the number of workers in the Netherlands for a warehouse is not an excellent choice since labor costs in the Netherlands are not cheap. The outbound ability is increased in this case, but the cost is higher than income. Even though the profit is positive for both days in this section, many other factors have not been considered, for example, equipment investment, different bills, etc., so the net profit is still negative. In general, the method of "*increasing number of workers"* indeed enhanced the outbound process ability (in Figure 12, the capacity increased from 4000 orders to 9000 orders) but was too expensive to conduct. The warehouse cannot simply increase the number of workers, which is too expensive to cover in the Netherlands.

The earlier part discussed the first applied method in the warehouse, which is the "*increasing number of workers*." Now, we will discuss the "*night shift*" solution in this section. Like the first idea, the "*night shift*" solution was proposed to cover the increasing number of orders since current capacity is insufficient. Normally, only two shifts exist in the JD organization, which are from 6 am to 3 pm and from 3 pm until 12 pm. These two shifts can cover most of the day. However, sometimes the warehouse is still facing serious challenges if the order volume is greater than 10,000[16] orders per day. The second idea, "*night shift,*" has been proposed under this premise.

Still, this paper will use the data from Figure 12 as an example. The date ranges from December 27, 2021, to December 30, 2021, in P^{th} column (capacity) have a substantial number of orders, there are 9,000 (this number is greater than the forecast because of backlogs) orders to do each day, which is close to 10,000 orders per day. The warehouse has opened night shifts for these few days considering the backlog and upcoming orders. The reader can see from the X^{th} column that the labor arrangement for the outbound process is 95 people, excluding other departments. As introduced, daily shifts are from 6 am to 3 pm and from 3 pm until 12 pm. The extra night shift is from 12pm until 6am, six hours in total for this night shift. If we use 95 people as the cardinal number, then the labor arrangement for the night shift is that around 24($95 * ({}^{6}/_{24}$ [17]$) = 23.75$), therefore around 24 people(outbound) will work overnight. If you work in night shifts, you get a 50% salary increase (Minimum wage – NLwork – Jobs in The Netherlands and Germany, n.d.). The warehouse pays a salary of 23 euros per hour per person (excluding team leaders) normally, which means the warehouse must pay 50% extra for individual night shift workers, which is $23 * 1.5 = 34.5$ euros/person/hour. By following the calculation below, we can see that the warehouse pays 4968 euros for one night shift and 6532 euros for one normal shift.

1. Night shift cost. $24 * 6 * 34.5 = 4968$ euros.
2. Normal shift cost. ${}^{(95-24)}/_{2} * 23 * 8 = 6532$ euros.

By comparing these two numbers, the workload and labor of one night shift equals to $\left[{}^{24}/_{(95-24) * 0.5}\right]$ [18] $* 100\% = 67.6\%$ of one normal day shift. Since most of the worker's working efficiency is like each other, we will ignore individual differences here. However, the payment of one night shift equals to $\left[{}^{4968}/_{6532}\right] * 100\% = 76.1\%$ of one normal day shift. In general, the night shift does improve the outbound ability amount, but only extends the working

[16] Estimated number.
[17] This formula decides the proportion.
[18] Two normal shifts for one day.

hours and increases the total output numbers, the cost is even larger than the improvement. So, this method is not a desirable choice.

Until now, we have discussed two methods applied in the warehouse and have explained why these two solutions give deficient performance. Although these methods indeed enhance the outbound ability, but the cost is even higher than the output.

Now, let us look at the second research question in this paper. Under the condition of knowing some methods that have been used in the warehouse but found out to not be efficient because the cost is too high, we can avoid falling into the trap of studying in the wrong direction. The second research question is key to finding some useable methods for the warehouse to relieve the current dilemma. The second research question (***What effective method(s) or strategies can be used to improve the outbound process in JD organization?***) is an effort to find one or a few solutions that may help the JD organization get out of the woods at its current stage. Three potential solutions have been proposed (the study will discuss the reasons for choosing these solutions later) for the second research question, and we are trying to find out which one (or several) of these solutions is suitable for the company. We will analyze these solutions later, and the second research question will be answered after the implementation stage.

The last research question (***What recent technology for AGVs in warehouse is available?***) wants to develop some new discoveries in the field of AGVs that can be used in the warehouse to improve the outbound ability. This is a long-term solution and suggestion for the warehouse, and this research question will not become the main direction of this paper. Instead, this research question is more focused on further possibilities.

5.5 Solution generation

Section 5.5 explains how this study arrived at those solutions, which means processing focus. The detailed solution analysis will be covered in chapter 6. In section 5.5.1, we discuss some pre-conditions for generating our alternative solutions. Next, section 5.5.2 explains the alternative solutions. More specifically, 5.5.2.1 is the origin of our ideas, which is about how we produced these ideas, and 5.5.2.2 to 5.5.2.4 is about globally introducing our alternative solutions. Sections from 5.5.2.4 to 5.5.2.9 have extra discussions.

The solution generation step requires a clear understanding of the outbound operation process and a big, sharp picture of the problem cluster where the core problems are found precisely. Two failed methods (JD organization simply increasing the number of people to cover the growing number of orders and introducing a night shift to extend working time) have been discussed in Section 5.4. Because of cost considerations, these two methods do not meet the goal of increasing production ability at a low cost. We will discuss the second research question in this part, which is the main topic of this paper, to find a suitable method (s) to help the warehouse improve outbound capacity without incurring too many extra costs.

Except for the verified methods "increasing number of people" and "night shift," which were recommended and implemented by the warehouse supervisor before, where did the other proposed solutions (see Table 9) come from? In fact, the author pre-set various requirements (section 5.5.1) for the process of generating potential solutions. The author and his colleagues had some brainstorms in daily life under those restrictions. As part of a collaborative effort to answer the research question (***What effective method(s) or strategies can be used to improve the outbound process in JD organization?***), the author proposed these alternative solutions (see Table 9). More specifically, we can look for where each alternative solution came from in section 5.5.2 below.

5.5.1 Setting requirements

The goal and aim of this paper are to improve the outbound ability of the JD organization. Of course, sufficient paths may exist for solving or improving the capability, but that does not mean every method is suitable for the warehouse. The real situation is different from the phantasy in mind. Dozens of conditions need to be met before brainstorming and proposal, the following circumstances must be designed in advance.

1. Measurable.
2. Combined with the actual situation in the Netherlands.
3. Executable.
4. Focus on the roots of problems (core problems).
5. No (or less) other cost.

We have suggested these circumstances as constraints for potential solutions, but what are these circumstances?

First, measurable means the outcome can be calculated or estimated in numbers when a specific solution is implemented. The improved ability by adopting methods must be represented by a specific number or percentage. A descriptive outcome without numerical results cannot be adopted in this paper. Therefore, the first requirement for proposing a solution is to make sure this solution is measurable.

Second, a valuable solution should be based on the real situation in the Netherlands rather than making a car behind closed doors. According to the calculation in section 5.4 and the declared message about labor costs between China and the Netherlands in section 1.2, labor costs in the Netherlands are approximately three times higher than in China, implying that the warehouse manager cannot increase labor costs arbitrarily.

The third characteristic is executable. One idea can be highly imaginative but cannot be executed for assorted reasons; for example, it is too complicated to conduct within a few months or ask for a large investment, etc. Considering the author only has six months to spend in this warehouse, making it too complicated is not a wise choice since the time is limited. Therefore, executable is a meaningful characteristic that needs to be considered.

The fourth characteristic is focusing on the root of problems. As written down, plenty of workable solutions may exist to improve the outbound process capability in real life. However, because of differences based on cases, the chosen methods must focus on the root cause of problems in the problem cluster (see section 1.2.2). Many derived issues can be solved once the root of problems can be explored at the same time.

The last but not the least is the cost aspect. It is true that this study is trying to fix and improve the outbound process ability for the JD organization. However, it does not mean we can ignore the cost factor in this piece of literature. The warehouse and the author are compelled to discuss the cost factor because labor costs are much higher in the Netherlands (around three times higher than in

China; see introduction in section 1.2) than in China. As a Chinese company that wants to survive in the European business environment, JD must consider the local laws and costs.

We have explained several pre-considered requirements for potential solutions. All the potential solutions must meet these preconditions in the brainstorming process. We suggested and proposed that these requirements be used for generating alternative solutions. These prerequisites need to be met during brainstorming and analysis. Please keep in mind the distinction between the grading system in section 5.6 and the requirements in this section. There are also some circumstances in section 5.6 where it is used for grading alternative solutions instead of generating solutions, these two need to be distinguished.

5.5.2 Alternative solutions introduction

This part is designed to generate alternative solutions based on the inspiration of literature and the result of brainstorming. The reader may already notice that this paper has listed three potential solutions to the second research question in earlier sections and paragraphs. However, since we did not explain in detail how these ideas came up and based on what basis they came up, we will do it in this part.

5.5.2.1 Origin of our ideas

As mentioned earlier, three workable solutions have been proposed and are hoping to improve the outbound process ability. And those three workable solutions are: *redesigning the layout*, *improving labor arrangement efficiency*, and *improving the picking station's capacity by adding one more cabinet*. "Redesigning *the layout*" is not originally from the author. Instead, this idea was introduced by a literature review (see sections 4.4 and 4.3) about redesigning the layout of a warehouse to improve its storage efficiency. The difference is that this paper's focus point is not storage optimization but the layout design of working stations.

"Improving labor arrangement efficiency" is not all the work of one person (the author); instead, it was the outcome of the brainstorming of several warehouse officers. In the opening paragraphs, we introduce the labor arrangement as not efficient enough. Sometimes the warehouse asks for an increased labor force. In response, sometimes the warehouse wants to cut the number of workers since there is a reducing number of orders. Such an uncertainty drives the warehouse and the author to improve labor arrangement efficiency. This idea has been proposed after brainstorming.

"Improving the picking station's capacity by adding one more cabinet" is also the outcome of brainstorming by the author and warehouse officer. The idea originally came from the observation of daily life. During the observation, idle time (we will explain this in detail in this method's section) exists during the operators' working process. Based on this finding, we suggested this idea here.

5.5.2.2 Redesign the layout introduction

We have defined several basic requirements (see section 5.5.1) for alternative solutions, which are the foundations for all workable solutions for the JD organization. In the literature review section, Wibowo, Nurcahyo, & Khairunnisa have introduced a layout design within their literature to improve the storage efficiency in a certain warehouse. In corresponding, the layout design in JD Warehouse still has the potential for improvement. Figure 16 in section 6.1 shows the detailed top view of the current layout (outbound process focused) design inside the warehouse, and the author has explained each function area in Table 13 below (section 6.1 in chapter 6). The reader may check for details there, but for the convenience of readers, we have cut off part of Figure 16, which is Figure 13 below.

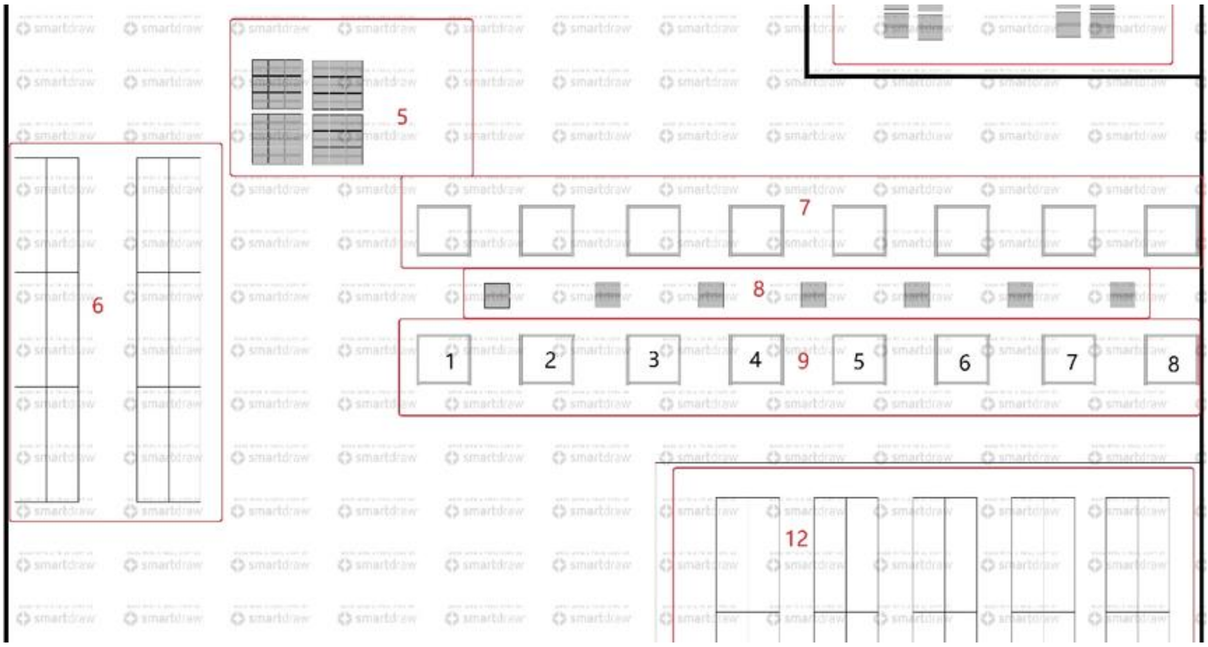

Figure 13, Cut out from Figure 16

In the warehouse, the outbound process can be simplified as follows: picking →buffer →rebin →pack, pick operations and packing processes are not continuous. In general, forty[19] percent of received orders are confluence in the warehouse. Confluence here means one order asking for two individual picking processes, which are picking from the AGV area (code 12 area in Figure 13) and the human pick area (code 6 area in Figure 13), and that is because some orders' SKU cannot be fulfilled in the AGV storage location, reservoir 6 (Figure 13) as a supplement. Based on such a fact, a specific worker (nicknamed "*water spider*") must move the gray containers (see Figure 14, gray container with blank bubble sign) between the pick station (area with code 9 in Figure 13), the confluence area (area with code 5 in Figure 13), and the human pick area (area with code 6 in Figure 13). The reason why we need a "*water spider*" is that the rebin and pack steps can only be processed in specific areas (i.e., rebin & buffer area-code 8 area in Figure 13, pack area-code 7 area in Figure 13), but the finished picking containers cannot move to a certain area by themselves, all finished confluence orders are in the gray containers, and those containers need workers to move them to the rebin and pack workstation areas.

Figure 14, Gray container

As mentioned above, a specific worker will move the finished gray container to the buffer area (area with code 8 in Figure 13) once the AGV picking process and human pick is done. Considering the walking distance between exits for employees, since workers must move the gray containers between the buffer area (area with code 8 in Figure 13), the human pick area (area with code 6 in Figure 13) and picking stations (area with code 9 in Figure 13), distances exist between various function areas. We would like to redesign the arrangement of working stations to reduce the walking distance. To

[19] Empirically derived estimates.

give readers a more intuitive understanding, we are presenting the changes to this design as follows:

1. Before (currently stage): There are eight pick stations in total (see Figure 13, code 9), but not all pick stations are used since the number of orders is changing. The current design/arrangement tries to space a free workbench between workers (e.g., use pick station 1, 3, 5, 7 instead of 1, 2, 3, 4). If we arrange pick stations close to each other, for example, using pick stations 1, 2, 3 and 4 to cover the workload, workers in various picking stations will chat with neighbors, which is non-related to normal work content through our daily inspections. Based on such a finding, we noticed some efficiency loss during the picking process.
2. After (after design): Considering the walking distance for workers between pick stations (area with code 9 in Figure 13), confluence area (area with code 5 in Figure 13), and human pick area (area with code 6 in Figure 13), the design here is to try to use pick stations that are close (pick stations 1, 2, 3, 4, and 5 that are close to the confluence area, and try to avoid using stations 5, 6, 7, and 8 that are far from the confluence area) to the human pick area and confluence area to reduce walking distance.

This idea formed the first alternative solution (*redesigning the layout*), and this idea worked out. As for the detailed application and analysis, the reader may check out chapter 6 later.

5.5.2.3 Improving labor arrangement efficiency introduction

Currently, the warehouse has two shifts (special arrangements like night shift will not be discussed here), which are 6 a.m. to 3 p.m. and 3 p.m. to 12 p.m., and individual workers for each shift follow this arrangement. However, the problem is that labor does not have the same job nature as the inbound, outbound, and in-warehouse species. This paper will not discuss the inbound and in-warehouse departments since the focus is outbound. Individual workers who belong to the outbound department may have the following specializations: pick, rebin, pack, and mobile personnel[20]. The reader may find detailed descriptions of their foci in section 2.1.2.

This paper has mentioned working efficiency (see section 2.2), where the efficiency is different from several types of work. The result is that some types of workers are always faster than other specific types because of job nature, while unbalanced conditions can lead to wasting time since some types of work have to wait. Therefore, this method tries to re-arrange the working time slots for outbound labor and find a balance to make sure the workflow is constant and continuous. Similarly, we are presenting the changes to this design as follows for an intuitive overview:

1. Before (current stage): All individual workers follow the same time slot arrangement, which is 6 a.m. to 3 p.m. or 3 p.m. to 12 p.m. The warehouse generally must use one hour to pick buffer to process the following steps (e.g., rebin, pack). Because the outbound process is tandem, which means picking first, followed by rebinning, and finally packing, in the morning, we barely have any buffer left to process since all the buffer was used up the day before. Therefore, we must use one hour to pick up buffers, which is a waste of time for other outbound process positions (e.g., rebin, pack).
2. After (after design): We will arrange the pickers' work one hour in advance, and their working periods will be 5 a.m. to 2 p.m. or 2 p.m. to 11 p.m. We should note that this

[20] On-call backup personnel who work on a case-by-case basis.

arrangement is not mandatory, and we only arrange workers[21] who agree to do so. Now, we make sure when other workers arrive in the warehouse, they already have buffer to process instead of waiting for buffer.

Readers can more intuitively see from the overview what the current situation is in the warehouse and what we are going to change, so that would be the introduction of the "improving labor arrangement efficiency," and this idea worked out. As for the detailed application and analysis, the reader may check out chapter 6 later.

5.5.2.4 Improving the picking station's capacity by adding one more cabinet introduction

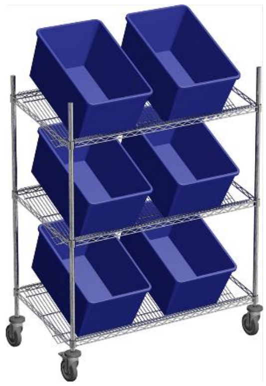

Figure 15, Picking station's shelf (retrieved via the Internet)

Figure 15 shows what the picking station's cabinet looks like in a warehouse, where the cabinet means the rack in front of the worker (picker in the picking station) with some big gray containers (see Figure 14). Figure 15 is just a schematic; the actual picking cabinet in our warehouse's size is 3*3, which means three gray containers' spots in one row and three gray containers' spots in one column (there are only six containers in Figure 15). Currently, each picker in the picking station needs to take care of one cabinet (i.e., nine containers), when robots (AGV) bring some SKUs to the picking station, the computer in the picking station will indicate how many pieces of SKU the picker should pick up from the AGV and where he/she should put them in the cabinet's container position. The computer will show green lights when all nine containers' tasks are finished, then "water spider" will move those finished containers either to rebin stations (code 8 area in Figure 13) or to the confluence area (code 5 area in Figure 13), waiting for human pick. As mentioned, the current design is one cabinet for one picker, and since waiting time exists during pricking (one SKU picked is over, the next SKU is on the way), we think adding one more cabinet might be useful to reduce[22] the idle time. Similarly, we are presenting the changes to this design as follows for an intuitive overview:

1. Before (current stage): One cabinet for one pick station.
2. After (after design): Two cabinets for one pick station.

The above text would be the introduction of the "Improving the picking station's capacity by adding one more cabinet," and this idea worked out. As for the detailed application and analysis, the reader may check out chapter 6 later.

For the second research question, we have proposed three potential solutions based on the inspiration of literature and our own working experience in a warehouse. In the following paragraphs, we will implement these three methods and choose the right one for the warehouse.

5.5.2.5 Research subjects

As introduced in section 5.1 above, the main research type is quantitative research, and the micro research type is different among specific sub-research questions.

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[21] Most of the workers in our warehouse are from Poland, only a small percentage of the Dutch labor force. Most of the Polish workers in our warehouse want to make more money, so they are usually willing to accept time changes. All changes are optional; we only arrange people who can accept such changes, forced adjustment is not allowed.

[22] Two cabinets meant double the assigned tasks for these picking stations because the volume of each cabinet equals the number of tasks. In this case, more AGVs will be assigned to this picking station.

The research goal is to explore how to improve the outbound ability with the support of historical data analysis and proposed solutions. In more specific terms, the research subject of the first research question is existing texts and secondary data from the company. The reason we chose this research subject is that the first research question is trying to develop which activities have been applied but proved not to work. The research subject for the second research question needs to be discussed separately since several potential solutions have been proposed in this paper (see Table 9). To deliver a more intuitive solution to the reader, we have listed the research subjects for each potential solution in Table 11. As for the last research question, it is quite like the first research question. This question tries to look for possibilities of further improvements in the field of AGVs. Therefore, the research subject here is existing literature and advanced technologies in the AGV area.

Table 11, Research subject for potential solutions

Potential solution	Research subject
Redesign the layout	Layout design and arrangement in warehouse
Improving labor arrangement efficiency	Current scheduling method
Improving the picking station's capacity by adding one more cabinet	Current working picking efficiency

5.5.2.6 Operationalization of key variables

The research subjects have been clearly defined above, but still, the key variables need to be described and operationalized. The first research question is about methods implemented in warehouses but proved not effective for improving outbound capacity. The key variable for the first research question is "methods". Based on this, operationalization should be as follows:

1. Find out all the methods currently used in the warehouse for improving outbound ability.
2. Find out all the related secondary data generated to support the theory.
3. Try to explain the failed reasons why such an implementation did not work.

More specifically, the first step would be to gather information that has been applied to the warehouse. This step may need help from the warehouse supervisor. The next action would be an analysis of historical data to find out why those methods did not fit into the warehouse. And since the first research question has already been discussed in section 5.4, readers may check there for detailed information.

The key variable for the second research question must be discussed separately since three potential solutions have been proposed for this research question, but the general operationalization would be as follows:

1. Organize and get familiar with the current strategies.
2. Looking for theories that may help with the strategies.
3. Make suggestions for enhancements.
4. Implementation.

Lastly, the variable for the third research question would be "recent technology," and the operationalization would be as follows:

1. Organize the current technology that is used in the JD warehouse for AGVs.
2. Looking for theories that have recently been published.

3. Make suggestions for improvement based on recent technology.

5.5.2.7 Data gathering & analysis

The main research type in this paper is quantitative research, and the main data gathering method for three sub-research questions will be the observation method, which allows us to see workers in the warehouse when implementing suggestions. As for the analysis part, data analysis is another key element to cleaning raw data that was collected in the data gathering phase. Such an action involves spotting data inconsistencies or errors to improve the data quality (Bhandari, 2021). The quantitative data analysis method will be applied to this paper as a data analysis method. Since secondary data will be used in this paper, quantitative data analysis will help us analyze the data efficiently.

5.5.2.8 Research design limitations

This paper has said the research design and implemented how the research design will be executed step by step. But it does not mean the design is perfect. Limitations still exist in the design process. One of the limitations is that the observation method for data collection will take a lot of time and is not comprehensive enough.

5.5.2.9 Assessment of validity and reliability

To ensure the validity and reliability of the assessment, we will behave as bystanders during the research and cannot influence the result of the research.

5.6 Solution choice design

This part is designed to give the basic ideas of the grading system on proposed solutions, as mentioned, detailed solution analysis will be discussed in chapter 6.

We will give a specific grading method for the second research question's proposed solutions in this part. A few workable solutions have been proposed in section 5.5.2, but it does not say all these solutions meet the interests of stakeholders and the author. Therefore, these solutions may meet the requirements and can solve or improve the outbound ability. The stakeholders and the author have determined some standards together to evaluate whether the solutions have relieved the dilemma.

We chose the following standards and gave the solutions weights ranging from 3 (the highest score) to 1 (the lowest score) based on discussions with stakeholders and importance to the warehouse. Each solution to the second research question will be scored after the implementation step. We will choose the most suitable one or few methods as a suggestion to the warehouse.

1. *Improvement percentage*. The improvement percentage here means how the outbound process was enhanced after the implementation. The focus of this paper is to try to improve the outbound process ability. Therefore, this criterion becomes the most important one. If some of the proposed solutions improve the outbound process the most (by number), then this method will receive the highest score, which is three. If some method improved the outbound process the second most (by number), then this method would get a score of 2, and so on. Besides that, the definition of improvement here means a percentage number. The author must give a number after the implementation for each method and show the enhanced percentage. For example, one method may have reduced waiting time for outbound processes. The author should use a percentage to show the improvement level.

2. *Cost*. Although this paper wants to improve the outbound process ability, the cost factor must be taken into consideration since the warehouse has low profit margins and enormous pressure from Beijing (headquarters) about the positive profit requirements. As a result, we must consider the cost factor. If some method costs the least, then it will receive the highest score, which is three. If some method costs the second least, then it will receive a score of 2, and so on.
3. *Resource*. When we want to implement some methods, he needs resources to process them. The resources are more than just tangible materials that are used in the warehouse but also invisible stuff. For example, we may need the help of the warehouse manager or shift team leader to conduct a task or experiment. All of these can be called resources in this paper. If one method requires the least resources during implementation, it will receive the highest score, which is three. If some method requires the second lowest number of resources during implementation, we will give a score of 2, and so on.
4. *Time*. This paper, along with the internship, has a time limitation, which means the author does not have years to process some experimental or certain design. We only have a few months to finish his thesis and internship in JD; therefore, time is another crucial element to take into consideration. If some idea will take months or years to see the outcomes we will give it the lowest score, which is one. If one method takes a shorter time, then it will receive a higher score than the other.
5. *Impact on other parts*. In business, the warehouse is considered as one organization instead of individual departments, which means this paper only focuses on the outbound part. But it does not mean other departments are isolated. We must consider the impact on other departments when he implements the solution. If one method has the lowest influence on another department, we will give the highest score, which is three. If some method has the second lowest influence on other departments, we will give the highest score, which is two, and so on.

Table 12, Score calculation template

	Improvement percentage	Cost	Resource	Time	Impact on other parts
Redesign the layout					
Improving labor arrangement efficiency					
Improving the picking station's capacity by adding one more cabinet					

Table 12 above writes down a template of how we will calculate the scores for individual solutions in the second research question. Based on the grading system and standards in this section, each method can be quantified in scores, and the following equation will be used for the final score for each method:

$$\sum_i (\text{Improvement percentage} + \text{Cost} + Resource + \text{Time} + \text{Impact on other parts})$$

In this equation, i stands for the various proposed solutions, which are "redesigning the layout," "*improving labor arrangement efficiency," and* "*improving the picking station's capacity by adding one more cabinet."* A final score equals the sum of standards (improvement percentage, cost, etc.). By comparing final scores, this study can select the proper method(s). But before we can explain the peak and off-peak seasons, we would like to say one more thing about this template. This template, grading system, and standards (i.e., improvement percentage, cost, and so on) are not imaginary by the author himself but a product of communication with stakeholders. As this study mentioned a few times, the goal is to enhance the outbound process ability and efficiency without adding too many extra costs, so that is why the improvement percentage and cost are explained and listed in the beginning.

5.7 Peak and off-peak seasons

In earlier paragraphs and sections, we have implicitly mentioned that there is a peak season and a low season for the warehouse. We would like to discuss what the peak and off-peak seasons represent for our warehouse in this study and explain the differences before we can move into the next chapter since our proposed solutions correspond to various scenarios.

First, the peak season for our warehouse means outbound received orders reach or exceed 10,000[23] daily. Peak season is usually when:

1. Regular promotional events. For example, Black Friday and Christmas sales.
2. Hunkemöller promotions. Unlike the regular sale seasons, this type of promotion is planned by Hunkemöller itself, and Hunkemöller always informs the warehouse in advance to make sure the warehouse can arrange labor earlier.

At the same time, there will be some inherent principles and situations during the promotion season for us (the warehouse), and we have listed those possible situations as follows:

1. Labor shortage. The warehouse will have to deal with the fact that the labor amount is sometimes not sufficient. Therefore, we will communicate with the labor agency and ask for replenishment during the peak season.
2. Limited ability. The warehouse accepts over-orders in a fleeting period, and the ability to satisfy such a sudden change cannot be matched. There are no free spots in various departments; every place is occupied by workers, and we cannot increase our ability anymore.
3. AGV traffic jams. Every picking station is running at full speed during the peak season since the order receiving rate is greater than the outbound ability. In this case, robots (i.e., AGVs) will expect a traffic jam and the running speed is fixed in this case since the AGV is in a queue and the worker's operating speed is reaching its limit.

The warehouse defines the peak season by its received order numbers, and the peak season is usually triggered either by regular promotions or the company's own behavior. In regular promotion months, Hunkemöller will have a promotion just like many other merchants, and the number of orders will increase during such a period. The warehouse must account for the labor shortage occasionally. Besides that, our outbound ability has reached its maximum and the AGVs are expecting traffic jams during operation.

[23] Warehouse empirical estimation figure.

Second, the off-peak season is a more normal phenomenon compared to the peak season. Similarly, the off-peak season is defined by our warehouse by the number of received orders per working day. The warehouse usually receives 5000[24] orders each day during the off-peak season, sometimes a little bit higher or lower than this number. The off-peak season often happens between after the new year and before the autumn of the following year[25]. There will be some phenomena and situations during the off-peak season as follows:

1. Extra labor forces. Unlike the peak season, the warehouse does not need that much labor forces during the off-peak season.
2. Inefficient AGV utilization. In the off-peak season, the warehouse does not have enough orders to run each workstation at full speed, and that will reduce the AGV use since most of the AGVs are on standby.

Basically, we have introduced the peak and off-peak seasons for our warehouse and listed some possible phenomena and principles in two cases (peak and off-peak seasons). In the following chapter, this study discussed and analyzed some solutions, and each of the solutions either focuses on the peak season or the off-peak season.

In chapter 5, we have clarified our research questions along with its aims; we have analyzed two applied methods in the warehouse, but they are not suitable, and this study explains in detail why those methods are non-perfect choices. Besides that, we discussed the origin of our ideas, along with the global introduction and some requirements. In the end, we introduced data analysis, research limitations, and our grading system for choosing the right solution. Besides that, we also introduced the peak and off-peak seasons for the warehouse, and the solutions in the following chapter correspond to each case (peak and off-peak season). In conclusion, chapter 5 is a linking chapter before we can step into the detailed discussion in chapter 6.

6 Solution analysis

Chapter 6 describes the analysis details of three proposed potential solutions and is about implementing the solutions that we mentioned earlier. This chapter answers the second and third research questions based on the results and data.

6.1 Redesign the layout

As mentioned in earlier sections, the outbound process includes picking, rebinning, and packing as its sub-processes. Figure 16 depicts the current warehouse design[26] (this figure did not include all details of the warehouse design but was more focused on the outbound process layout design), and Table 13 explains the meaning of various areas in Figure 16. Besides that, there are also things to prepare in advance before execution.

1. *Site Planning*. We shall decide on which specific area we are going to use in the warehouse since we are trying to redesign the layout.

[24] Warehouse empirical estimation figure.
[25] It is based on the observations made in our warehouse found in the Netherlands and may be different from other countries and regions.
[26] Schematic diagram.

2. *Communication with the warehouse team leader*. The team leaders are the actual people in charge inside the warehouse. We must discuss with them which day we want to do this test and how many people we need to change some layout.
3. *Labor arrangement* Once the preliminary preparations are completed, we can let the team leaders arrange people to execute the tasks.

Table 13, Explanation of Figure 16

Code in Figure 16	***Meaning***
1	Trucks
2	Loading and unloading area
3	Forklift
4	Office
5	Confluence area (storage area for confluence containers)
6	Human storage/pick area
7	Packing stations
8	Rebin stations and buffer area
9	Picking stations
10	High-value goods area
11	High rack
12	AGV storage/pick area

The reader can see from Table 13 that the warehouse has two storage areas (code 6 and code 12 in Table 13), which are the AGV storage area and the human storage area from Figure 16. We will explain these two storage areas before he can dive into details:

1. AGV storage/pick area. This area is designed for storing products that came from HKM directly, which means new products. Normally, these new products come in larger quantities. SKUs in this area can only be picked by robots, not humans.
2. Human storage/pick area. This area is designed for the purpose of returning products which have decent quality (category A) for re-selling. SKUs in this area can only be picked by humans, not robots.

The warehouse wants to increase the consumption rate of returned goods from customers. One way is to store and pick the returned goods individually and not mix them with new SKUs (mixed SKUs of return and new will slow down the moving speed of returned goods since robots cannot tell whether an item is returned or new), which is why these two storages have distinct functions. But the "*human storage area*" only occupied a small percentage when compared to the AGV storage area. The AGV storage area is still holding the main body of total storage spaces. The "*human storage area*" only plays a supplementary role.

Section 5.5.2.2 already explains the intent of the "redesign the layout" method about the "before" and "after" stages. The layout design is between the picking station (see code 9 from Figure 16) and the confluence area (see code 5 from Figure 16). Next to the "*human storage area*" is the confluence[27] area, where the confluence gray containers are stored. One specific worker with the nickname "water-spider" is responsible for moving the confluence container from the picking station to the confluence area (picking in the AGV area is finished; the next stage is human picking); and moving the confluence container from the confluence area to the packing station (both robot zone

[27] Confluence refers to SKUs from an order that are in both the AGV storage area, and the storage area depicted in Figure 16.

picking, and human picking are finished; the next stage is packing). There are eight picking stations in the warehouse (see code 9 in Figure 16). The picking station closest to the storage area is picking station 1. From left to right are stations 1, 2, and 3 until station 8 (see code 9 in Figure 16). Every day, not all eight picking stations will be open, depending on the number of orders received that day. If someday the warehouse receives a large (around 10,000 orders) number of orders, then the picking station will be running at full speed, which means all eight picking stations will be open for operation. As explained in section 5.5.2.2, the idea of this design is to try to open stations close to the confluence area when the order amount is not much to reduce the walking distance between the picking station and the confluence area.

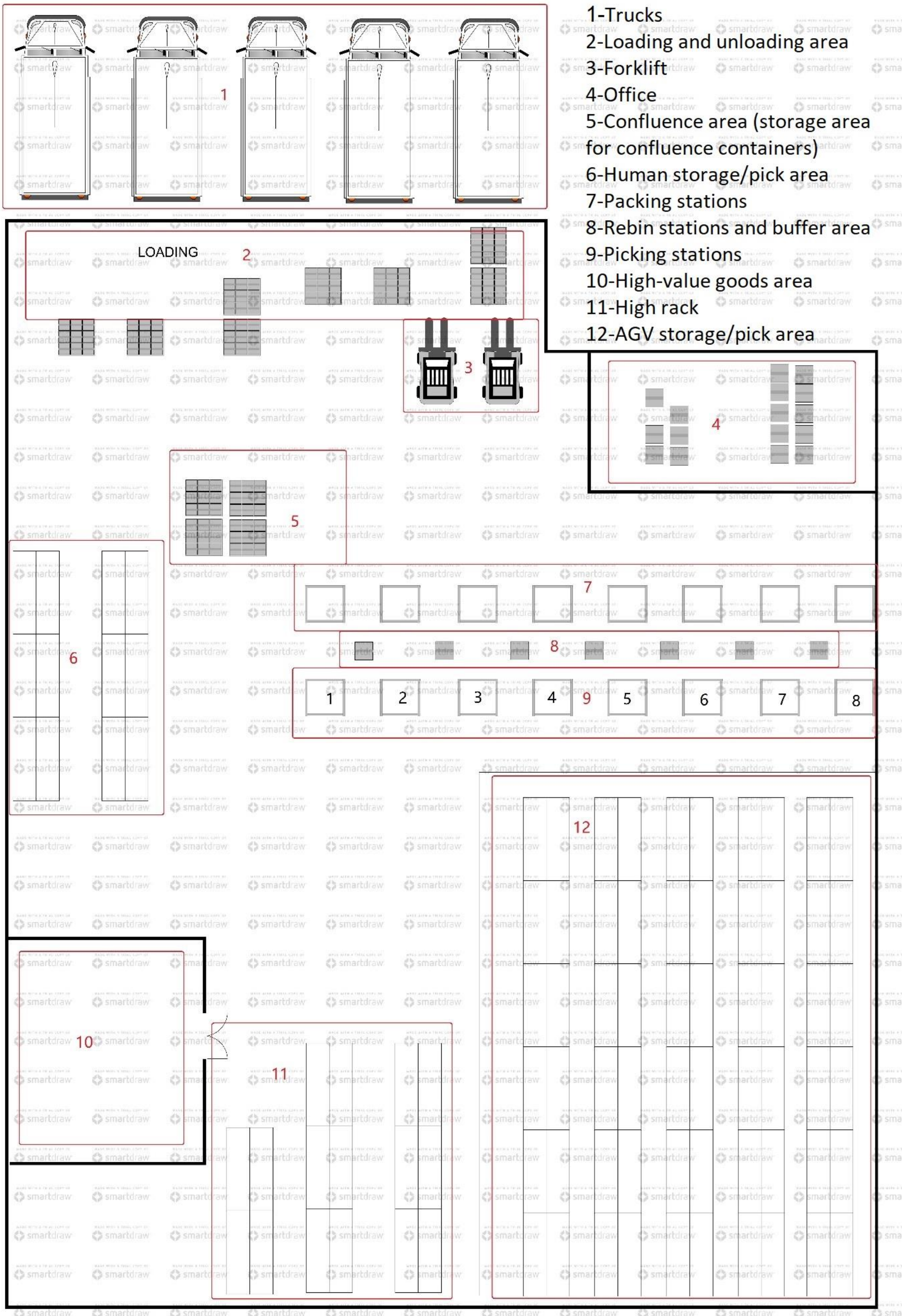

Figure 16, Current warehouse Layout

The distance between picking stations (see code 9 in Figure 16) is around one meter, which means the spacing between station one and station two is around one meter, station two and station three's distance is around one meter, and so on, and the distance from picking station one to the confluence area (see code 5 in Figure 16) is around three meters.

This paper will use February 14, 2022, (*excel file name: "customerOrderIntegratedQuery2022-01-14"*) as an example to calculate this time reduction after redesigning the layout. Table 14 shows the number of orders on February 14, 2022, which is $1258 + 362 + 1500 = 3120$ orders in total. For each order, there are 2.5[28] pieces of goods (SKUs), which means $3120 * 2.5 = 7800$ pieces for operation. From section 2.2, the reader can notice the picking efficiency is 180 pieces/per hour/per person, which means the warehouse must arrange $^{7800}/_{180 * 8} = 5.42$ workers (picking stations) for this workload.

Table 14, KPI on February 14, 2022

Type	Order	KPI unachieved	KPI achieved	Issue excluded	KPI
CC[29]	1258	1	1256	1	99.92%
Bpost B2C[30]	362	0	362	0	100.00%
DHL+UPS B2C[31]	1500	0	1500	0	100.00%

The arrangement at that time was to use pick stations 1, 2, 3, 5, 6and 8, leave pick stations 4 and 7 as free. The supervisor's idea was to try to isolate as much as the workers and prevent small talk between workers. However, this design makes the "*water spider*" travel a longer distance.

Let us look at the reduced time after the redesign of the workstation's layout. First, let us assume that all the picking stations finish their tasks at the same time, so the "*water spider*" will collect those finished gray containers from station 8 and take them to the first picking station once. This assumption is an ideal situation, which barely happens in a warehouse. Normally, the "*water spider*" must travel multiple times since he cannot make sure that he can collect 8 gray containers at one time. We will discuss how much time the "*water spider*" will save in the ideal situation, the real situation, and whether the improved percentage will be greater than the outcomes.

Now, we will compare the "before" and "after" stages that were mentioned in section 5.5.2.2. First, the "before" is the current layout design, which has open pick stations 1, 2, 3, 5, 6, and 8 in the case. If all picking stations are finished at a certain moment, and the "*water spider*" must move the confluence container to the confluence area (see code 5 in Figure 16), the traveling distance is $(7 * 1^{32} + 3^{33}) + (5 * 1 + 3) + (4 * 1 + 3) + (2 * 1 + 3) + (1 + 3) + 3 = 37$ meters for a single trip, the walking speed is 3 to 4 miles per hour (Schimpl, et al., 2011) and equals 1.34 m/s to 1.79 m/s. In conclusion, one single trip will take $^{37}/_{1.34} = 27.6$ seconds for the "*water spider*".

Then, let us discuss the "after" stage, which is the status of redesigning the layout of picking stations. The new designed case uses pick stations that are closer to the confluence area, and that means we

28 Estimated number based on warehouse supervisor's experience.
29 Type of order, which means the parcel will be delivered to the access point (or HKM store) instead of the end customer.
30 Type of order, which means the parcel will be delivered to the end customer directly by a specific carrier (Bpost).
31 Type of order, which means the parcel will be delivered to the end customer directly by a specific carrier (DHL or UPS).
32 1 (meter) means the distance between picking stations.
33 3 (meters) means the distance between picking station one and confluence area.

will use pick stations 1, 2, 3, 4, 5, and 6. We will always use the nearest picking stations to the confluence area, the new moving distance is $3 + (1 + 3) + (2 * 1 + 3) + (3 * 1 + 3) + (4 * 1 + 3) + (5 * 1 + 3) = 33$ meters, which means the new travel time is $33/_{1.34} = 24.6$ seconds. Compared to the current design, $27.6 - 24.6 = 3$ seconds have been saved for a single trip.

Furthermore, we should know how many trips that the "*water spider*" needs to make per day on average. Back to this paper, our example says we have 3120 orders for this day. In general, 40%[34] of those orders are confluence orders, so the "*water spider*" must take care of $3120 * 0.4 = 1248$ orders that are confluence orders. Similarly, we assume all these orders are distributed on average to all the six picking stations. For each picking station, each picker shall manage $1248/_6 = 208$ orders that are confluent. Again, we assume the time usage for one confluence order is equal, therefore, the "*water spider*" at least has 208 trips for a single day, which means $208 * 3$[35]$/_{3600} = 0.173$ hours saved for labor costs on one day. However, we still need to convert the calculated result in hours to a percentage since we need such a percentage to measure improvement level. This layout design has saved 0.173 hours for the "*water spider*" and the whole outbound process. If we use normal daily working hours as our total working period, we may convert this saved number into percentage, and the improvement level would be $0.173/_{(8 * 2}$[36]$_{)} * 100\% = 1.1\%$.

In conclusion, the innovative design of the usage layout of picking stations in this section indeed saves some time for the workers and the outbound process. The improvement level for this method is 1.1%. But we should also notice that we have made some assumptions in this section to simplify our question and make it easier to calculate. The actual result will have a higher percentage than the current result (i.e., 1.1%) due to the simplifications in this study. This solution can be applied to both the peak and off-peak seasons since we have perfected the layout and walking paths. This method can save some walking distance for workers, so this layout design can be applied to both the peak and off-peak seasons.

6.2 Improving labor arrangement efficiency

In section 5.5.2.2, this paper briefly introduces the current labor arrangement, which is based on two major shifts (6am to 3pm and 3pm to 12pm) and requires all individual workers in each shift to follow the same time slot. However, a few truths and dilemmas exist here, which are:

1. Working efficiency (in unit time) is different from various outbound process positions (e.g., pick, rebin, and pack). Some processes are faster to execute than others due to the nature of their sub-processes. For detailed information and efficiency (in numbers), please see section 2.2.
2. The order acceptance rate is not even by hours; some hours receive more orders than others; an unbalanced environment exists.

These two dilemmas cause two consequences, which are the unbalance of working load for distinct positions and an unpredictable hourly order acceptance rate. For example, Figure 17 below shows the number of systems receiving orders by hours (see original raw data Excel attachment

[34] Estimated number obtained from warehouse team leader.
[35] Saved time (in seconds) for a single trip.
[36] Total number of working hours per day.

"customerOrderIntegratedQuery"), and Figure 18 shows the picking results (see original raw data Excel attachment "pickingResultsOfQuery") by hours for picking stations. Similarly, we have these things to be prepared in advance before execution.

1. *Planning*. We shall decide on when and how we will conduct this task in advance.
2. *Communication with the warehouse team leader*. The team leaders are the actual people in charge inside the warehouse. We need to collaborate with the team leaders and let them give us a list of pickers who would like to change their shift.
3. *Communication with the pickers.* The team leaders have provided us with their list of pickers who can change their shift (i.e., one hour earlier), but we still need to verify and make sure everyone is willing to do so instead of being forced.

We shall discuss and prepare the steps to perform once the first preparation work has settled down. Based on the discussion with team leaders and the warehouse office, we analyzed our solution by following the steps below.

1. Choose the date. To make our solution happen, we must choose one or a few suitable dates for implementation. We shall understand one important rule, which is that the implementation cannot influence normal production. Therefore, we shall choose one day in the off-peak season to implement our solution to minimize the influence.
2. Choose workers. A solution cannot be implemented by itself; it needs workers to execute it. Correspondingly, the warehouse cannot arrange and force someone to change their working schedule against their will. So, we only arrange and choose workers who can accept such an adjustment.
3. Observation. If everything is settled and prepared, we must see the outcomes and record the data correctly.
4. Data analysis. The last step is analyzing the data once we collect it.

First, we would like to discuss these two figures individually to supply more details for the reader to make it easier to understand. As explained, Figure 17 shows the number of a system's received orders from customers at various hours, where the reader can see that the graph starts at 6 a.m. instead of 0 hour, which is because the warehouse operating starts at 6 a.m. From 0 a.m. to 6 a.m., a few customers are still ordering from the HKM website. Additionally, there are orders that were not completed the previous day; the system will collect and hold those orders and present them to the warehouse together at 6 a.m. by updating the systems. Therefore, the order number at 6 a.m. is high, and before 6 a.m. there are zero orders from the graph. As for the left-side table inside Figure 17, the first column means hours, from 6 a.m. to 23 p.m., and the right-hand side with the title "count of receiving time" means how many orders were received in each hour with the unit of orders/hour, we may see from the figure that 8216 orders were received on that day. The abscissa of Figure 17 shows the hours, and the ordinate says received orders in each hour. At the beginning of the day (6 a.m.), there are a lot of orders in the system. Between 6 a.m. and 7 a.m., the received orders go down because fewer orders are placed during that period. At 8 a.m., 3028 orders had been received, as shown below. After that, there is a small wave in the afternoon, and then the graph goes stable.

Second, we would like to talk about Figure 18. Figure 18 displays the picking efficiency in picking stations. The abscissa means hours in one day, and the ordinate shows picked orders in that hour. As can be seen, the first hour (6am to 7am) was slightly growing where a lot of pending orders existed. From 7am to 9am, the picking efficiency and amount are higher than in the afternoon. The reader can see more clearly from Figure 18 that the mismatch between order receiving, and order picking occurs.

Row Labels	Count of Receiving Time
6	1393
7	29
8	3028
9	40
10	40
11	22
13	248
14	1172
15	311
16	337
17	376
18	233
19	195
20	203
21	162
22	248
23	179
(blank)	
Grand Total	**8216**

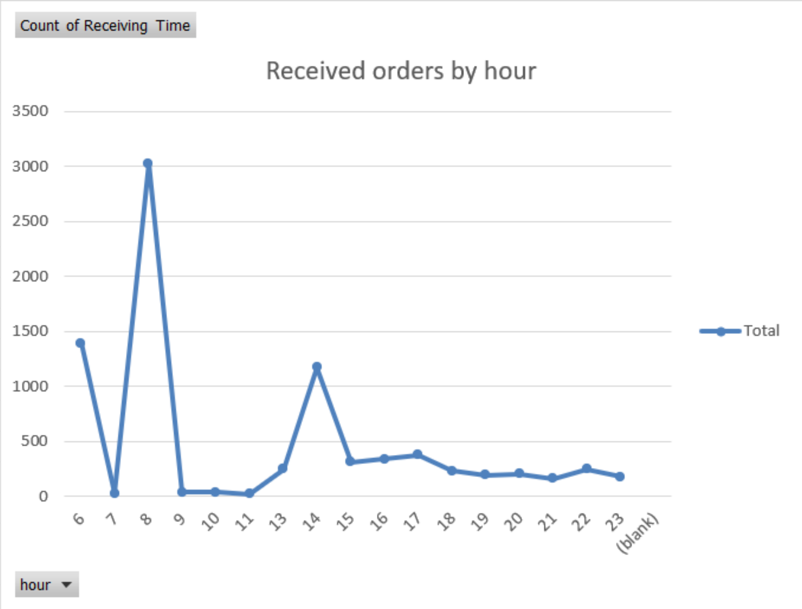

Figure 17, Order received by hours

Row Labels	Count of Picking Completion Time
6	54
7	917
8	341
9	990
10	442
11	409
12	448
13	304
14	413
15	196
16	385
17	261
18	477
19	411
20	407
21	458
22	401
23	333
(blank)	
Grand Total	**7647**

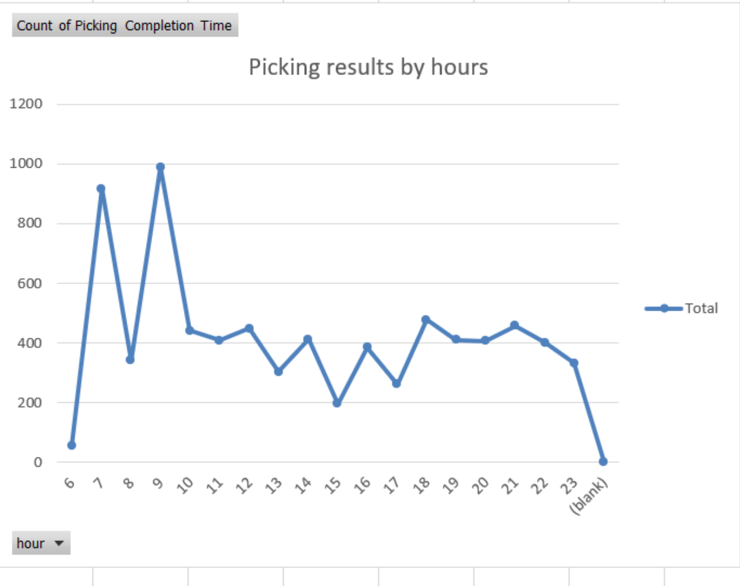

Figure 18, Picking result by hours

Row Labels	Count of Picking Completion Time	Count of Receiving Time
6	54	1393
7	917	29
8	341	3028
9	990	40
10	442	40
11	409	22
12	448	
13	304	248
14	413	1172
15	196	311
16	385	337
17	261	376
18	477	233
19	411	195
20	407	203
21	458	162
22	401	248
23	333	179

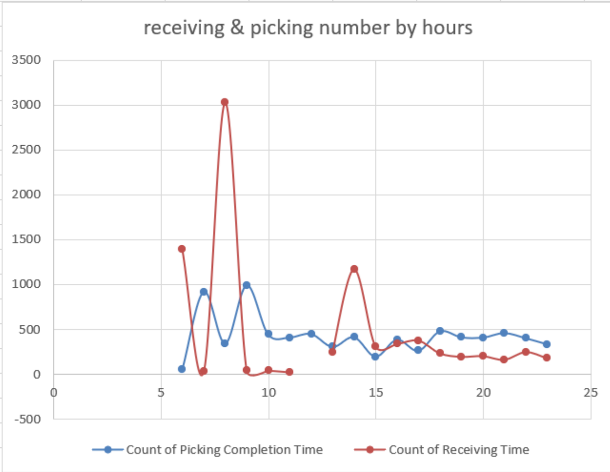

Figure 19, Receiving & picking number by hours

If we can combine these two (Figure 17 and Figure 18) figures' data together, we may receive some new findings. This paper has thought about one arrangement that is "one hour's picking in advance" to improve the picking efficiency. We can see from Figure 18 and Figure 19 that the picking result and amount are growing between 6 am and 7 am, when there is the beginning of the picking action. However, since the picking activity is the foundation of rebinning and packing, the following process cannot be sped up if the picking result is not good enough. We are trying to make the workers who oversee the picking process change their schedules, which is from 6 am to 3 pm to 5 am to 2 pm. The pickers do not have to follow the fixed schedule. In this way, the rebin and packing stations can have enough buffer when they come to work since the pickers have already worked in the warehouse for one hour. They do not have to wait for the buffer to process their work.

Now, we shall put the idea into practice once we have explained what we were trying to do in the earlier section. As the reader can check in the two excel files, day one (excel file name is "customerOrderIntegratedQuery2022-01-13") is the test subject with one hour of picking in advance (5 am to 6 am), while day two (excel file name is "customerOrderIntegratedQuery2022-01-14") is the control subject with normal arrangement (picking starting at 6am instead of 5am). We may discuss these two results one by one as follows:

First, we may look at the test subject (day one, with the Excel file name "customerOrderIntegratedQuery2022-01-13"). There is a lot of information in Figure 20, and the reader may feel lost in this figure. Therefore, have highlighted those used data in Figure 20 with color yellow. $P^{th}$and Q^{th}columns are the pick start time; the difference is that the Q^{th}column only has hour (Excel formula “=hour ()”) numbers without any distractors, such as data, minutes, and seconds. By inserting a pivotable, we may receive a statistic result as shown in Table 15 below. The pivotable shows that the picking begins at 5 a.m.[37], and the total number of picked orders is 6084 (with units in orders, not pieces).

[37] The first two rows (0 and 1am) mean orders were not finished yesterday on time and workers finished a little bit later than usual. We will ignore these two rows.

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	J	K	L	P	Q	R
1	Site Code	Site Name	Positioning Node Status	Picking Start Time	hour	Picking Completion Time
2	site0001	site0001	Positioning completed	2022-01-13 17:44:33	17	2022-01-13 17:46:01
317	site0001	site0001	Positioning completed	2022-01-13 05:50:23	5	2022-01-13 06:57:45
318	site0001	site0001	Positioning completed	2022-01-13 09:27:24	9	2022-01-13 11:00:50
319	site0001	site0001	Positioning completed	2022-01-13 13:17:27	13	2022-01-13 14:12:13
323	site0001	site0001	Positioning completed	2022-01-13 08:17:22	8	2022-01-13 08:48:50
324	site0001	site0001	Positioning completed	2022-01-13 11:31:37	11	2022-01-13 11:32:53
332	site0001	site0001	Positioning completed	2022-01-13 08:09:25	8	2022-01-13 09:40:10
349	site0001	site0001	Positioning completed	2022-01-13 12:55:21	12	2022-01-13 12:56:39
350	site0001	site0001	Positioning completed	2022-01-13 08:27:20	8	2022-01-13 08:56:54
352	site0001	site0001	Positioning completed	2022-01-13 09:31:20	9	2022-01-13 11:28:16
353	site0001	site0001	Positioning completed	2022-01-13 08:41:21	8	2022-01-13 10:58:56
354	site0001	site0001	Positioning completed	2022-01-13 12:19:35	12	2022-01-13 12:21:34
366	site0001	site0001	Positioning completed	2022-01-13 14:35:59	14	2022-01-13 14:40:50
367	site0001	site0001	Positioning completed	2022-01-13 08:39:20	8	2022-01-13 11:11:09
368	site0001	site0001	Positioning completed	2022-01-13 06:56:23	6	2022-01-13 07:43:21
369	site0001	site0001	Positioning completed	2022-01-13 09:25:17	9	2022-01-13 10:23:10
373	site0001	site0001	Positioning completed	2022-01-13 07:54:29	7	2022-01-13 07:56:29
387	site0001	site0001	Positioning completed	2022-01-13 06:58:22	6	2022-01-13 07:58:52
388	site0001	site0001	Positioning completed	2022-01-13 11:29:40	11	2022-01-13 11:32:10
389	site0001	site0001	Positioning completed	2022-01-13 09:36:54	9	2022-01-13 09:38:00
390	site0001	site0001	Positioning completed	2022-01-13 11:24:44	11	2022-01-13 11:25:31
391	site0001	site0001	Positioning completed	2022-01-13 14:35:59	14	2022-01-13 14:40:08
392	site0001	site0001	Positioning completed	2022-01-13 14:16:33	14	2022-01-13 14:17:46
393	site0001	site0001	Positioning completed	2022-01-13 14:09:41	14	2022-01-13 14:12:50
394	site0001	site0001	Positioning completed	2022-01-13 08:13:26	8	2022-01-13 08:43:39
395	site0001	site0001	Positioning completed	2022-01-13 08:44:16	8	2022-01-13 10:48:39
402	site0001	site0001	Positioning completed	2022-01-13 12:59:27	12	2022-01-13 13:32:55
403	site0001	site0001	Positioning completed	2022-01-13 09:23:22	9	2022-01-13 10:13:59
404	site0001	site0001	Positioning completed	2022-01-13 09:35:19	9	2022-01-13 09:46:50
405	site0001	site0001	Positioning completed	2022-01-13 08:59:59	8	2022-01-13 09:01:05
406	site0001	site0001	Positioning completed	2022-01-13 06:48:24	6	2022-01-13 08:05:30
407	site0001	site0001	Positioning completed	2022-01-13 08:37:19	8	2022-01-13 10:54:34
409	site0001	site0001	Positioning completed	2022-01-13 15:42:14	15	2022-01-13 15:44:34
419	site0001	site0001	Positioning completed	2022-01-13 07:17:23	7	2022-01-13 08:12:32
420	site0001	site0001	Positioning completed	2022-01-13 09:56:44	9	2022-01-13 10:00:41
421	site0001	site0001	Positioning completed	2022-01-13 11:02:12	11	2022-01-13 11:04:11

SheetJS | Sheet2 | Sheet1 | cc | b2c bpost | b2c ups+dhl

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Figure 20, Day one, customerOrderIntegratedQuery2022-01-13

Table 15, Statistic result of Day one

Row Labels	Count of Picking Start Time
0	160
1	5
5	186
6	395
7	459
8	727
9	251
10	142
11	384
12	335
13	521
14	246

15	104
16	559
17	416
18	162
19	91
20	214
21	308
22	298
23	121
(blank)	
Grand Total	**6084**

Now let us look at day two (Excel file name "customerOrderIntegratedQuery2022-01-14), similarly with day one, we will use the P^{th} and Q^{th} columns and generate a pivotable (Table 16) based on the results. Similarly, the first row means some orders were left over from the earlier date, and the worker worked longer to finish those orders. We will ignore the first row and start from the second row in Table 16.

Table 16, Statistic result of Day two

Row Labels	Count of Picking Start Time
0	23
6	211
7	449
8	408
9	392
10	330
11	332
12	23
13	335
14	188
15	220
16	310
17	206
18	120
19	153
20	145
21	112
22	296
23	408
(blank)	
Grand Total	**4661**

Currently, we have some data about the hourly picking efficiency for two days along with the total picking order amount for two days (day one and day two). Furthermore, we may need the labor arrangements to calculate the exact number of personal efficiencies. From Figure 21 below, we can see that 64 people have been arranged on Jan. 13 and 56 people have been arranged on Jan. 14. 6084 orders have been processed on Jan. 13 (6084 means picked orders, and once these orders are picked, they must be followed by rebin and packing, so 6084 also represents the finished orders on that day) and 4661 orders have been processed on Jan. 13 (4661 means picked orders, and once these orders are picked, they must be followed by rebin and packing, so 4661 also represents the finished orders on that day). So, the efficiency for these two days is:

1. Jan. 13. $^{6084}/_{64} = 95.1$ orders/person/day
2. Jan. 14. $^{4661}/_{56} = 83.2$ orders/person/day

If we compare these two days' data, we can see that the test day's (day one, Jan. 13) performance is better than the second day (day two, Jan. 14) and the improvement percentage is $^{(95.1 - 83.2)}/_{83.2} * 100\% = 14.3\%$.

	I	J	X	Y	Z	AA	AB
267			Labor arrangement (in person)				
268			Outbound	Inbound	Return	IVC	Total
359	Friday	7-Jan	95	8	17	3	122
360	Saturday	8-Jan	95	0	17	2	113
361	Sunday	9-Jan	79	0	8	0	87
362	Monday	10-Jan	95	2	17	3	116
363	Tuesday	11-Jan	95	10	17	3	124
364	Wednesday	12-Jan	60	6	17	3	86
365	Thursday	13-Jan	64	6	17	3	90
366	Friday	14-Jan	56	6	17	3	81
367	Saturday	15-Jan	59	0	17	2	78
368	Sunday	16-Jan	39	0	8	0	47
369	Monday	17-Jan	64	2	20	3	89
370	Tuesday	18-Jan	52	2	20	3	77
371	Wednesday	19-Jan	56	2	20	3	81
372	Thursday	20-Jan	52	2	20	3	77
373	Friday	21-Jan	44	2	20	3	69
374	Saturday	22-Jan	48	0	20	2	70
375	Sunday	23-Jan	37	0	8	0	45
376	Monday	24-Jan	71	3	20	3	97
377	Tuesday	25-Jan	48	7	20	3	78
378	Wednesday	26-Jan	60	7	20	3	90
379	Thursday	27-Jan	56	7	20	3	85
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Forecast per day + promotio (2) | Sheet1

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Figure 21, Labor arrangement (in person, retrieved from an internal file)

In conclusion, section 5.7.2 has analyzed two days' performance, with one day that does not have the "one hour's picking in advance" for labor's arrangement and one control date with the "one hour's picking in advance" for labor's arrangement. By referring to section 5.5.2.3, the "before" and "after" stages for this method are as follows:

1. Before (currently stage): Two fixed time slot arrangements, which are 6 a.m. to 3 p.m. and 3 p.m. to 12 p.m., are made. Workers in other parts of the outbound process must wait for buffers, resulting in low labor arrangement efficiency.
2. After (after design): We have changed the labor arrangement to *one hour's pick in advance*. We make sure when other workers arrive in the warehouse, they already have buffer to process instead of waiting for buffer. improved labor arrangement efficiency.

As we can see from the compression, the "*improving labor arrangement efficiency*" method did improve the average outbound process efficiency, and the improvement percentage is 14.3% according to the calculation. This method (*improving labor arrangement efficiency*) can apply to both the peak and off-peak seasons, and that is because this design (one hour's picking in advance) will always create an extra buffer for other positions, whether it is low season or peak season. However, for the warehouse, most of the time we apply this method in peak season instead of off-peak season, and that is because the total number of orders is not much, we do not have to use this method since this method needs the cooperation from workers to change their schedules. So, while this method can be used in both peak and off-peak seasons, it is most often used in the peak season.

6.3 Improving the picking station's capacity by adding one more cabinet

According to the introduction in section 5.5.2.4 along with its diagrammatic sketch (Figure 15), we shall understand the current situation in a warehouse is "*one cabinet for one picker in one picking station*". As this paper did in section 6.1 and section 6.2, this method also has some things to be prepared in advance before execution.

1. *Planning*. We shall decide on when and how we will conduct this task in advance.
2. *Communication with the warehouse team leader*. The team leaders are the actual people in charge inside the warehouse. We need to collaborate with the team leaders and let them provide us with labor and available time to make this change (i.e., adding one more cabinet).
3. *Administration support.* Unlike the earlier two solutions, this method causes other cabinet costs, so we will need administrative support to buy it.

There are three rows and three columns in one cabinet, which means nine (3*3) available places for placing gray containers (see Figure 14, a basket for placing collected goods) when the picker processes its picking operations. As introduced in section 5.5.2.4, idle time exists during the picking process since the picker must wait for the next robot (AGV) to bring the specific items from the AGV storage area when the earlier AGV's task is over while the next AGV is on the way. Such a process is a waste of time. To improve such a situation, one way is to enhance the program algorithm for AGVs, which means making those robots smarter and faster to reduce the waiting time in picking stations for pickers by perfecting codes, but that would be a computer science focus, which is not this paper's field. Except for the computer science method, we have produced another idea, which is adding one more cabinet for the picking station, as introduced in section 5.5.2.4. Such a design can increase the probability of AGVs coming to a picking station, and this design can also achieve the purpose of reducing waiting time. Now, let us summarize these two cases:

1. Before (current design). "*One cabinet for one picker in one picking station,*" pickers must wait for the next AGV when the earlier AGV's task is over while the next AGV is on the way.

2. After (innovative design). "*Two* cabinets *for one picker in one picking station,*" the picker still must wait for the next AGV, but the probability of AGVs coming to a picking station has increased since the operating places (there will be eighteen available places for two cabinets) have increased. For example, we now have two stages (stage 1 and stage 2; see Figure 22 and Figure 23). Stage 1 is the stage before design, and Stage 2 is the after design. First, the two picking stations in stage 1 have the same layout, the same picking efficiency for pickers, and both have one cabinet only. The AGV (small boxes colored green) is moving in the direction of 1-2-3-4-5. The closest AGV to the worker is under operation[38] while the other AGVs are in queue. Once the operation is finished, this AGV leaves[39], and the next AGV replaces the spot. In Stage 1, the workable free space is the same (cabinet number is the same, see Figure 22), the system will assign a proximate number of tasks to the stations and the AGV amount[40] is similar (both five AGVs in Figure 22). Second, let us look at Figure 23. We have added one more cabinet for one picking station (left side of Figure 23) and left one cabinet for the control group (right side of Figure 23). The test picking station (left side of Figure 23) has doubled its workable spots because the cabinet has been doubled. The system will assign[41] more tasks to the test picking station, and the number of AGVs (nine AGVs for the test station, see Figure 23) will increase, as shown in Figure 23, when compared to the control group.

In general, there is only one unique variable between Figures 22 and 23, which is the amount of cabinet. Once we have changed the number of cabinets, differences will happen: the probability and total amount of AGV will increase; the idle time will reduce. Here are the reasons:

1. AGVs are not always in line and queuing since the warehouse does not always have that vast number of orders, and that it is something about the peak and off-peak seasons we have mentioned in section 5.7.
2. Two cabinets mean more workable spots, and the system will always assign more priority to specific picking stations that have more free spots.
3. More orders assigned means more AGVs assigned to stations since the AGV is the physical carrier of orders.
4. In off-peak seasons, one specific picking station with two cabinets can receive more orders than other picking stations with only one cabinet. Since the density of AGVs (i.e., the number of orders) assigned to that specific picking station has been increased, the idle time for this specific picking station has been reduced in unit time.

[38] Workers take out SKUs from AGV under the instruction of the system.
[39] Move in the direction of number 5 in Figure 22.
[40] The number of AGVs stands for the number of orders since the AGV handles moving the SKUs.
[41] The action of assigning tasks to picking stations is based on the workable spots in each station, which means if one picking station has more workable spots, then the system will recognize it and assign more tasks.

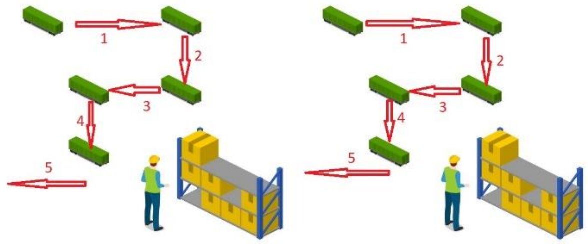

Figure 22, Stage 1 (one cabinet for each picking station)

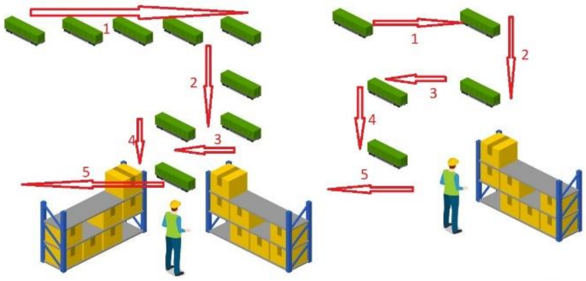

Figure 23, Stage 2 (adding one more cabinet)

Although this method can increase the picking efficiency for pickers, it can only help during the off-peak season instead of the peak season. Every station, pickers, and AGVs are busy during peak season, which means AGVs are always in a queue. The moving speed of AGVs and pickers' efficiency are fixed, so adding one more cabinet will not help. All picking stations have the same layout design in the warehouse at their current stage, which is one cabinet with nine spots for gray containers. As for the experimental subjects, we chose to pick stations one and eight. Picking stations one and eight will have two cabinets each, while the other stations will remain the same with one cabinet as a control group. As explained in section 6.1, the walking distance between picking stations is one meter (e.g., station one and station two, station two and station three, and so on). The reason we did this is that we want to limit the influence factor (AGVs may block each other’s way if these two stations are too close) between these two test stations. Now, let us have a look at the outcome data in the Excel file named “*summary01*”.

There are 9 subpages inside the excel file (named *summary01),* which are "13", "14", "15", "16", "17", "18", "calculation", "5 picking stations", and "8 picking stations." We will explain each of these subpages individually to make it easier for the reader to understand the contents.

First, the numbers "13", "14", "15", "16", "17", and "18" in the excel file represent six different days, which are from Monday to Saturday since Sunday is an off day for the warehouse, so basically, these six days equal one week’s data (see Figure 24).

The A^{th} column means picking station (e.g., 1001, 1002, etc.), and from the B^{th} column to the right means how many pieces did the picker pick in a specific picking station with the unit of pieces per hour per person. There is no working plan from 1 am to 5 am, so those columns are blank. One more thing about the data: as mentioned in section 2.2, the average picking efficiency for the picking process is around 180 pieces per hour per person. However, some data with large errors, like 20 or 80 pieces per hour per person in the raw excel file, is because the team leader may arrange pickers to do other tasks and their picking period is less than an hour, so we have removed such errors and the data in Figure 24 is after correction.

B12 =AVERAGE(B3:B5,B9)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Workstation No	0 o'clock	1 o'clock	2 o'clock	3o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	8 o'clock	9 o'clock	10 O'Clock	11 O'Clock	12 O'Clock	13 O'Clock	14 O'Clock	15 O'Clock
2	1001	130						154	152	197	105				201	184	108
3	1002	100						182	148	181	132			104	214	126	
4	1003	102						146	170	168	102	127	152	101			
5	1004	101						166	201	189	105		225	110			
6	1006							149	155	174	166					220	
7	1007							173	167	201	118					229	
8	1008							139	162	165							
9	1009	125						132	177	203					255	225	
10																	
11	picking station	130						146.5	157	181	105				201	184	108
12	non-picking station1，8	107						158	169.666667	186	124.6	127	188.5	105	234.5	200	
13	Average by hours	111.6	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	155.125	166.5	184.75	121.333333	127	188.5	105	223.3333333	196.8	108
14	count of picking stations	5						8	8	8	6	1	2	3	3	5	1
15																	
16		130	184	257				154	152	197							
17		100	126					182	148	181							
18		102		165				146	170	168							
19		101		192				166	201	189							
20			220	268				149	155	174							
21			229					173	167	201							
22								139	162	165							
23		125	225	175				132	177	203							

13 | 14 | 15 | 16 | 17 | 18 | calculation | 5 picking stations | 8picking stations | summary

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Figure 24, picking station's hourly data (retrieved from warehouse's system)

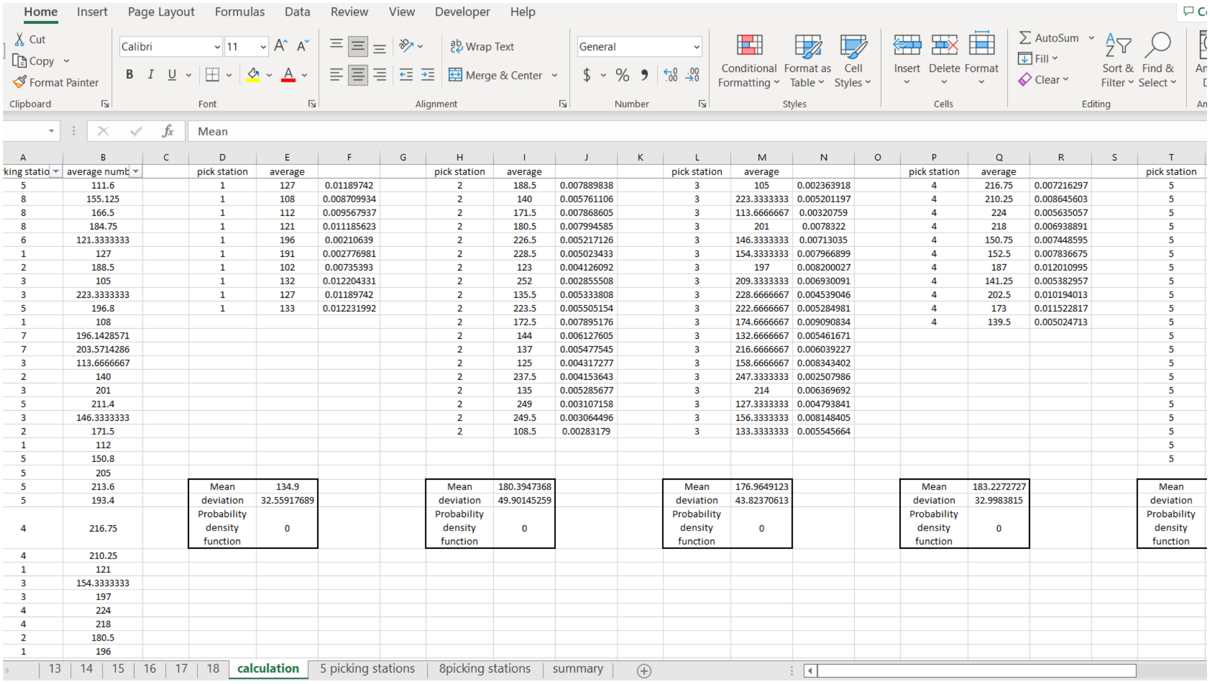
According to the corrected data in Figure 24, we can first calculate the average picking efficiency in picking stations 1 and 8 (test subjects), and then we can calculate the average picking efficiency in other picking stations (excluding stations 1 and 8). These two results can be seen from the 11th and 12th rows in Figure 24, both with the unit of pieces per person per hour. We have two reasons for calculating such an average number for our test subjects (picking stations 1 and 8) and control group (excluding stations 1 and 8). First, let us compare the efficiency. We can see that the average picking efficiency is higher in the test subjects according to the results in the 11th and 12th rows. Second, the calculated number will be used later in other sub-pages. Besides that, we can calculate the total average number from picking station 1 to the last picking station as a comparison, and the result can be seen from the 13th row in Figure 24 with the unit of pieces per person per hour. Lastly, we can count the opening pick-up station by hours, which can be seen from the 14th row in Figure 24. And that is how the four rows came from the raw data below an hour's picking efficiency.

Second, Figure 25 writes down some calculations (see "calculation" page in "*summary01" excel file*) based on the analysis of the previously organized data in earlier texts. The first two columns (column A and column B) mean how many picking stations have been opened in the last six days' different hours and the average picking efficiency (13th row in Figure 24). These two columns are used for statistics and summarization about the past week's status by hours of how many picking stations have been opened and their efficiency. In general, the first two columns in Figure 25 were copied from the earlier sub-pages, which are "13," "14," "15," "16," "17," and "18." For example, the first row with numbers 5 (picking station) and 111.6 (average number) means five picking stations have been opened and the average picking efficiency is 111.6 in a certain hour of a certain day of a certain week. From the D^{th} column in Figure 25, we have separated the raw data by stations, for example, from column D to column F means:

1. Column D means a gathering of a specific week (six working days) with the same number of open picking stations, which is one. This column shows how many times the warehouse opened only one picking station in some hours of one week. No units.

2. Column E means the average (Excel function "=average ()") picking efficiency when only one picking station is open in a week. Unit is pieces per hour per person.
3. Column F means the probability density function. No unit.

As for the rest of the blocks (e.g., column H to column J, column L to column N, and so on), the explanations are the same as above. Underneath, we can see the mean, deviation, and the density function by different picking stations. The reason behind this calculation is that we want to know, when opening a different number of picking stations, what the picking efficiency looks like.



A	B	D	E	F	H	I	J	L	M	N	P	Q	R	T
king statio	average numb	pick station	average		pick station	average		pick station	average		pick station	average		pick station
5	111.6	1	127	0.01189742	2	188.5	0.007889838	3	105	0.002363918	4	216.75	0.007216297	5
8	155.125	1	108	0.008709934	2	140	0.005761106	3	223.3333333	0.005201197	4	210.25	0.008645603	5
8	166.5	1	112	0.009567937	2	171.5	0.007868605	3	113.6666667	0.00320759	4	224	0.005635057	5
8	184.75	1	121	0.011185623	2	180.5	0.007994585	3	201	0.0078322	4	218	0.006938891	5
6	121.3333333	1	196	0.00210639	2	226.5	0.005217126	3	146.3333333	0.00713035	4	150.75	0.007448595	5
1	127	1	191	0.002776981	2	228.5	0.005023433	3	154.3333333	0.007966899	4	152.5	0.007836675	5
2	188.5	1	102	0.00735393	2	123	0.004126092	3	197	0.008200027	4	187	0.012010995	5
3	105	1	132	0.012204331	2	252	0.002855508	3	209.3333333	0.006930091	4	141.25	0.005382957	5
3	223.3333333	1	127	0.01189742	2	135.5	0.005333808	3	228.6666667	0.004539046	4	202.5	0.010194013	5
5	196.8	1	133	0.012231992	2	223.5	0.005505154	3	222.6666667	0.005284981	4	173	0.011522817	5
1	108				2	172.5	0.007895176	3	174.6666667	0.009090834	4	139.5	0.005024713	5
7	196.1428571				2	144	0.006127605	3	132.6666667	0.005461671				5
7	203.5714286				2	137	0.005477545	3	216.6666667	0.006039227				5
3	113.6666667				2	125	0.004317277	3	158.6666667	0.008343402				5
2	140				2	237.5	0.004153643	3	247.3333333	0.002507986				5
3	201				2	135	0.005285677	3	214	0.006369692				5
5	211.4				2	249	0.003107158	3	127.3333333	0.004793841				5
3	146.3333333				2	249.5	0.003064496	3	156.3333333	0.008148405				5
2	171.5				2	108.5	0.00283179	3	133.3333333	0.005545664				5
1	112													5
5	150.8													5
5	205													
5	213.6	Mean	134.9		Mean	180.3947368		Mean	176.9649123		Mean	183.2272727		Mean
5	193.4	deviation	32.55917689		deviation	49.90145259		deviation	43.82370613		deviation	32.9983815		deviation
4	216.75	Probability density function	0		Probability density function	0		Probability density function	0		Probability density function	0		Probability density function
4	210.25													
1	121													
3	154.3333333													
3	197													
4	224													
4	218													
2	180.5													
1	196													

Figure 25, calculation by picking stations

Third, let us look at the next page as Figure 24 is present in the following. The 8th and the 9th subpages in the excel file with the names "5 picking stations" and "8 picking stations" are about analysis and calculating the difference between the open two test (add one more picking cabinet) stations into five (two test stations and three normal stations) and eight (two test stations and six normal stations) picking stations. We want to see whether the different test subjects' (i.e., the picking station) percentages will receive different improvement levels. Now, we will use Figure 24 as an example to explain what the author calculated and the results.

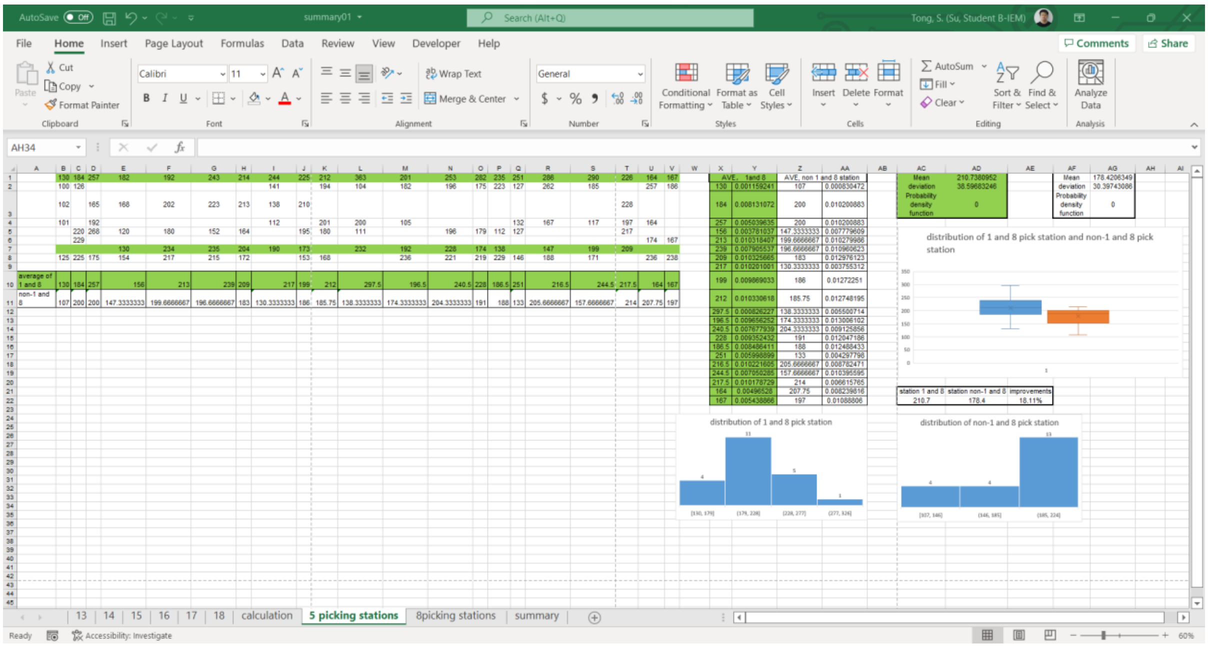


Figure 26, Results of 5 picking stations' sub-table

The explanation is as follows:

1. The upper left area, the data from the 1st row to the 8th row and the B^{th} column to V^{th} column, is copied from the first six pages (i.e., the "13", "14", and up to the "18" subpages in the excel file), but only chooses those hours that opened five picking stations in that hour, which means we choose the picking efficiency results from earlier sub-pages' results that five pick stations were opened at a certain hour of a certain day of a certain week. The unit is pieces per person per hour.
2. The 10th row (the upper left area) means the average number of working efficiencies of picking stations 1 and 8 (test subjects). The unit is pieces per person per hour.
3. The 11th row (the upper left area) means the average number of working efficiencies of non-picking stations 1 and 8 (control group). The unit is pieces per person per hour.
4. The data from X^{th} column to AA^{th} column is just a copy of the 10th and 11th row's results along with their probability density function.
5. The rest of Figure 24 shows all kinds of graphs of distributions. For example, Figure 25 is the picking efficiency distribution of 1 and 8 pick stations and non-1 and 8 pick stations (5 pick stations in total) with their maximum distribution number of 297.5 pieces per person per hour, their minimum distribution number of 130 pieces per person per hour, and the average number of 210.7 pieces per person per hour.
6. As for the detailed exploitation and calculation, please check the attached Excel files.

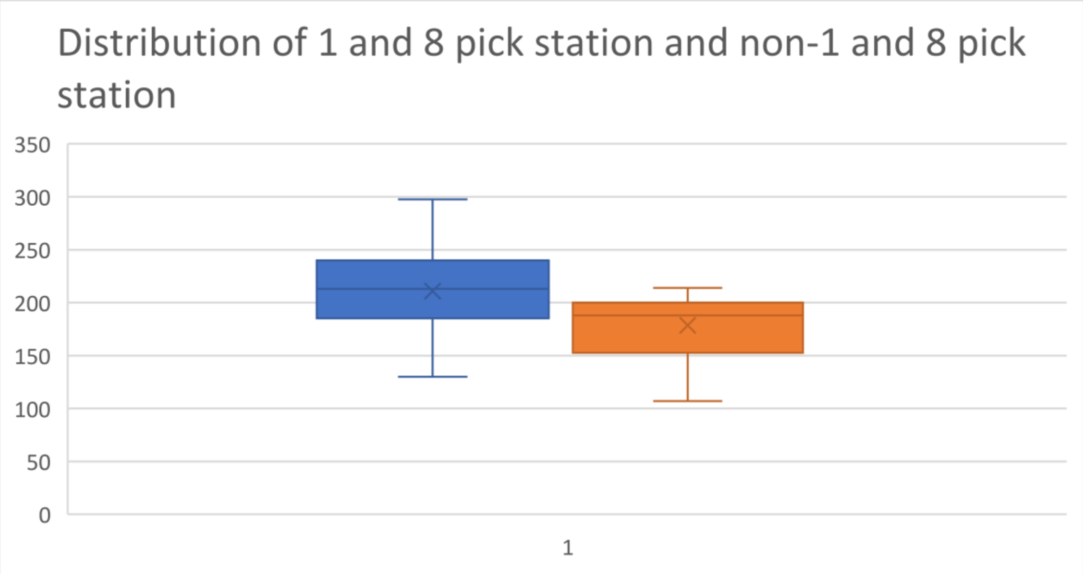


Figure 27, Picking efficiency distribution of test subjects (picking station 1 and picking station 8, color blue) and control groups (non-picking station 1 and non-picking 8, color yellow). Five picking stations in total (two test subjects and three control groups).

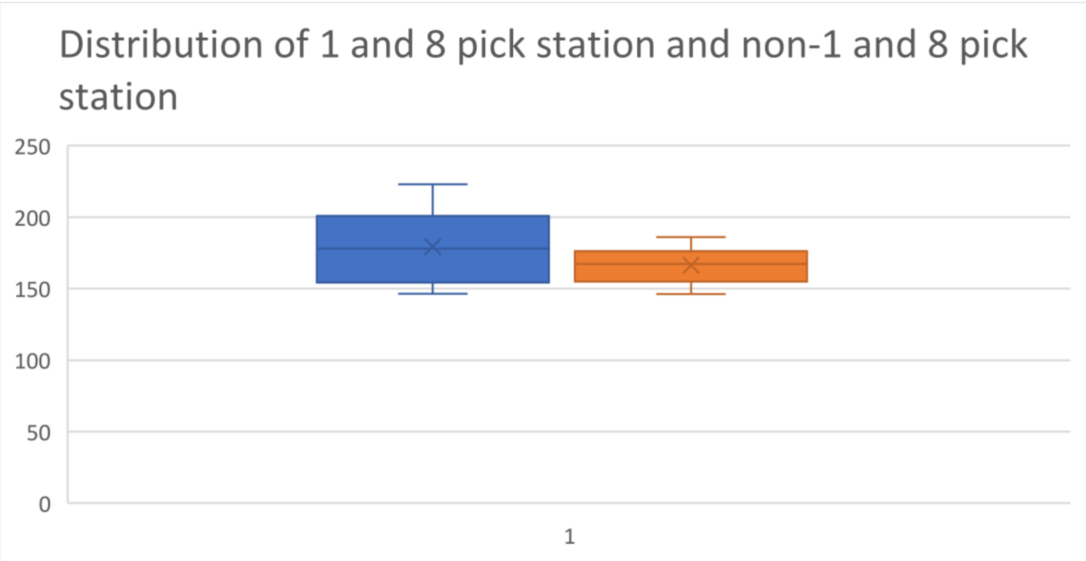


Figure 28, Picking efficiency distribution of test subjects (picking station 1 and picking station 8, color blue) and control groups (non-picking station 1 and non-picking 8, color yellow). Eight picking stations in total (two test subjects and six control groups).

Figure 25 and Figure 26 show the results after testing and implementation. Figure 25 has five (two test stations and three normal stations) pick stations in total, while Figure 26 has eight (two test stations and six normal stations) pick stations in total. As for the result, both two pick stations' efficiency improved (color blue in both figures means test subjects while color yellow stands for the control group), with 18.11% (see Table 17) having been improved in Figure 24 and 7.82% (see Table 18) having been improved in Figure 25. As for the detailed calculation process and results, the reader may check the attachments.

Table 17, Implementation result (5 picking stations, two of them are evaluating stations)

station 1 and 8	station non-1 and 8	improvements
210.7	178.4	18.11%

Table 18, Implementation result (8 picking stations, two of them are evaluating stations)

station 1 and 8	station non-1 and 8	improvements
179.3	166.3	7.82%

In section 6.3, we discussed our third idea, which is "Improving the picking station's capacity by adding one more cabinet." We calculated two situations during the implementation and analysis. First, we calculate the picking efficiency when we open five pick stations, which means two test subjects (two cabinets for one pick station) and three control groups (one cabinet for one pick station) in a certain week (six working days). From the results, we received the following messages:

1. The test subject's picking efficiency is higher than the control group in numbers (results from Figure 24).
2. The improvement level will decrease with the reduction of the test subject's percentage. The improvement percentage when open five (two test subject and three control group) pick stations in total is 18.11%, the improvement percentage when open eight (two test subject and six control group) pick stations in total is 7.82%.

Therefore, we can say that the picking efficiency is indeed enhanced by adding one more cabinet to a pick station. But the results show that the improvement is not endless, and there will be limitations. Since most of the time we do not open eight pick stations, five pick stations is more like the norm, so we will use the result of 18.11% as our improvement percentage for this method (improving the picking station's capacity by adding one more cabinet). However, we must understand that this method will be helpful during the off-peak season, and there are reasons for this conclusion. First, the major difference between the peak and off-peak season is the number of orders, as we introduced in chapter five, all stations are occupied by workers. And the AGVs are running, which means there will always be AGVs in queuing (received orders amount is greater than maximum processing speed), and we cannot perfect this situation by adding more cabinets. Second, we can see one principle from our results: the improvement trend and rate of the picking efficiency is decreasing along with the increase of after designed (two cabinets for one picking station) picking stations. So, this method applies to off-peak seasons.

6.4 Long-term suggestion

Till now, we have discussed and analyzed the second research question, which is designed for short-term relief, which means those solutions may help the warehouse improve its current outbound capability dilemma, but not in the future. We may look at some modern technologies in the AGV area in his section and hope to find a solution for the warehouse, which is focused on the future.

This paper has shown that the system design in the warehouse for now is centralized, which means all the order distribution is conducted by a central planner, all routes for the robots inside the AGV area are fixed, and they (the robots) cannot avoid traffic jams. In section 4.5 (literature review), we have discussed a dynamic routine planning technology that is used in the warehouse. Compared to the current technology that is used in the warehouse, this technology can help the warehouse develop innovative technologies in AGVs in the future. Besides that, we also introduced the queuing theory in the literature review section. The warehouse operation can be simplified as "raw material in and products out". The core idea is that there is a shortage of "in-system" time for the operation. Therefore, this paper would like the warehouse to focus on the decentralization technology and Fuzzy Obstacle Avoidance (dynamic routine planning) technology, study the influence of various queuing methods (e.g., FIFO), and update the AGV's current technology to make sure the AGVs in the warehouse can be smarter than at present.

6.5 Costs

Cost is another key factor along with the enhanced ability or efficiency for each proposed solution in earlier sections and chapters since our research question is about improving outbound ability while controlling costs at a low level. Therefore, we shall further discuss the costs for each solution when we finish the improvement calculation.

6.5.1 Redesign the layout

To refresh the reader's memory, we would like to briefly re-introduce the "redesign the layout" solution in this section first. In this thesis, we have changed the layout of the picking station and other operational areas in the warehouse to make them closer to reduce the walking distance for workers, eventually enhancing the outbound process efficiency. You may check out the detailed description of this idea in section 5.5.2.2 for a better understanding of the "redesign the layout" method.

This solution did not include any new equipment or other labor, but we still need to digitize the cost rather than describe it. We must build our own standards for calculating the "redesign the layout" method's cost since this idea asks for zero investment in equipment. Coordination and arrangement are the main components of the expense during the implementation of this method. Now, we are trying to digitize them. According to the experience and reality in the warehouse, we need to coordinate with both team leaders and workers to make this idea happen and executed. Therefore, this paper uses total hours spent to stand for the cost of this method.

First, the office must consult with the warehouse team leaders, as they oversee the entire front-line production. Generally, this kind of communication will take a few days or even weeks to settle into such an implementation and arrangement, but of course, this process is intermittent instead of continuous. For example, small discussions last for half an hour about this topic (when and how the warehouse should be going to implement the "redesign the layout" method) during a daily meeting or weekly meeting. Based on discussions with the author and his supervisor, we settled on one week as the length of time and half an hour per working day to stand for the time spent in the preparation stage, totaling 0.5[42] $* 5$[43] $= 2.5$ hours.

Second, we now must calculate the amount of time spent in the implementing stage once we find out how many hours were used in the preparing phase. To see the outcome data and the effect of the experiment, we normally need a few days to check whether this new method will work or not. According to the actual process of implementation, the warehouse used another week to discover the result. However, we only changed the layout of some working areas and their positions during this period without influencing the normal producing process, so we cannot use working hours to stand for the used time; instead, we need to check how many hours are being used in inspection action of the come-out results. This is the extra time used. Similarly, as being discussed with the warehouse supervisor, we estimated the inspection hour as one hour per day for a week. So, we spent $1 * 5 = 5$[44] hours inspecting the results.

[42] We use a half hour to discuss the arrangement of this method per day.
[43] There are five working days in a week.
[44] One hour per day, five days a week.

According to the simplification and calculation, we now know that we spent 7.5 extra hours on this method. If we calculate the basic salary given by the warehouse, which is 20 euros per hour, we can notice that the cost for this method is $7.5 * 20 = 150$ euros.

6.5.2 Improving labor arrangement efficiency

We would like to simply re-introduce this method to recall the reader's memory of this idea. "Improving labor arrangement efficiency" is about changing some outbound positions' working periods to increase the starting buffer volume for other positions, eventually increasing the outbound efficiency. As for the detailed introduction, the reader can check section 5.5.2.3 for more information. In conclusion, we have made some of our workers start working one hour earlier than others.

To understand and calculate the cost of this method, we must know which actions related to this method can lead to extra expenses. Just like the deviation in section 6.5.1, at least two parts will exist. First, it is communication before the application of our idea. Second, it is about observation during the process of practice. Besides that, we must understand one more invisible cost exists here, which is the employee's mood in such an arrangement. Now, this study tries to calculate the costs of "improving labor arrangement efficiency" one by one.

First, the commutation and arrangement costs before the implementation can be represented by extra hours used. Unlike the "redesign the layout" solution, this method focuses on choosing a person who can accept such an arrangement without re-designing the layout of the warehouse. Therefore, the used period is shorter than the first method. According to the communication between the author and his supervisor, we decided to give this estimate a specific number, which is half a week and half an hour per day. So, now we may calculate the extra hours used for this method, which is $0.5 * 2.5 = 1.25$[45] hours in total.

Second, we would like to calculate how many extra hours we spent on observation on this method. There is no significant difference between observing these two methods ("improving labor arrangement efficiency" and "redesigning the layout"), so we still use one week as an observation period and one hour per working day. Then the used extra hours would be $1 * 5 = 5$[46] hours in total.

Lastly, we want to estimate the impact on an employee's mood by applying such an arrangement (working one hour in advance). Mental health can affect the way you deal with money (The link between money and mental health - Mind, n.d.). For example, they may not manage their finances well when in a bad mood or make impulsive financial decisions. However, we can never calculate this part correctly or even estimate it since too many variables exist here, so we will not include this cost in this study since it is complex to calculate. We will just remember that this cost should exist.

Based on the simplified calculation above, we could give an estimate cost for the "improving labor arrangement efficiency" method. Similarly, we use a basic paid salary in our warehouse, which is 20 euros per hour. As a result, the cost of this solution is $(1.25 + 5) * 20 = 125$ euros. It is worth noting that the cost of an employee's mental health is not included here since it is too complicated to estimate. It may cost thousands of euros or zero, so we did not include this part.

[45] 0.5 hours per working day and 2.5 working days per week.
[46] One hour per day, five days a week.

6.5.3 Improving the picking station's capacity by adding one more cabinet

Unlike the previous solutions, this method requires an extra investment in equipment, which is an extra cabinet in a warehouse. Therefore, the cost for this method will have three major components: equipment cost, communication cost, and observation cost.

First, the equipment cost for the cabinet. The price of a warehouse used cabinet without rollers is around 213 euros (Middelzware stelling Manutan Rapid 2, Hoogte: 1980 mm, Aantal niveaus: 4, Type legbord: Massief, n.d.). This number is for a single cabinet. We have bought four cabinets for our warehouse, which is because we want to evaluate the limitations for efficiency improvement of using cabinets. We can calculate the cost of equipment at $213 * 4 = 825$ euros.

Second, we decide to use the cost that has been calculated in section 6.5.1 as for the communication and observation costs, which is 150 euros. As for the reason, we both need cooperation with warehouse team leaders and communication with workers during the application of this method and the "redesign the layout". There are no big differences for time used between the two ideas, so this paper uses the come-out number in section 6.5.1 for simplification. We can add the total cost for this method up, which is $825 + 150 = 975$ euros.

6.6 Trade-offs

This study has discussed and calculated the three potential solutions in this chapter. As a result, each solution has enhanced the outbound process efficiency to a different level. However, we must understand that no single solution is perfect. Each method must come up with side effects, and that is something we have not argued the trade-offs yet.

First, the "redesign the layout" method does not require extra equipment and just focuses on changing the layout design in the warehouse to eventually enhance the outbound efficiency. However, changing the layout design in a warehouse needs cooperation between the different departments, for example, the warehouse office and the warehouse operational team. Besides that, changing the layout will cost time. Overall, this method may not need direct investment in equipment but will cost time and vigor. We can call these "*invisible costs.*" According to the warehouse's actual results, we have spent two to three days refining this new layout.

Second, the "improving labor arrangement efficiency" method made some arrangements on labor's working period and made sure the pickers in picking stations could work one hour earlier than other positions to ensure a sufficient buffer level for other labor. Here we need to reiterate that such an arrangement is based on the premise that the worker has agreed to do so; there is no mandatory demand. However, we must realize that the pickers' work and rest rules can be broken by such an arrangement, and those workers may feel frustrated. So, this can be a trade-off for the second solution.

Third, the "improving the picking station's capacity by adding one more cabinet" method is the only solution that asks for an extra investment in equipment. For this method, the first trade-off is extra costs, even though this solution has improved the outbound efficiency. The second trade-off is that this method is not much help during peak seasons, so this idea is not a workable solution for peak months.

6.7 Summary

As said, no methods and solutions are perfect in all directions. Each solution has some trade-offs during implementation. This study has discussed and analyzed some trade-offs for three proposed solutions, as mentioned in section 6.5 of this chapter. All three solutions can enhance outbound efficiency, but they also have trade-offs and cannot be ignored. Besides that, this paper has analyzed the proposed three solutions' applicable scenes to decide whether the method is suitable for peak or off-peak seasons. For the readers' convenience, we have listed the applicable scenes as in Table 19.

Table 19, Applicable scenes summary

No	Solution	Applicable scenes
1	redesign the layout	Peak and off-peak seasons
2	improving labor arrangement efficiency	Peak and off-peak seasons
3	improving the picking station's capacity by adding one more cabinet	Off-peak season

Except for the applicable scenes in Table 19, we also did some calculations in Section 6.5 and this paper listed the overview in Table 20 below.

Table 20, Summary of costs

NO	Solution	Costs
1	redesign the layout	150 euros
2	improving labor arrangement efficiency	125 euros
3	improving the picking station's capacity by adding one more cabinet	975 euros

However, as explained, these calculations are not one hundred percent correct since some of the variables are too abstract to be calculated. Therefore, these calculations are estimated and just used to stand for the cost level of each method.

7 Solution evaluation

Chapter seven discussed our research along with the judgements and the solution choice step. We evaluated the proposed potential solutions in earlier sections and chapters that belong to the second and third research questions. The findings revealed that solutions improved the outbound process at various levels of positive improvement.

7.1 Research

We have proposed three potential solutions to the second research question in earlier chapters and sections. By analyzing and implementing those solutions, we found all solutions did improve the outbound process ability or efficiency at various levels. According to the results, we can see that the outcomes may be different from the numbers, but all three outcomes are positive, which means we have verified that those methods indeed enhanced the outbound ability or efficiency. This study has moved from reality to our norm, which has enhanced the outbound process capability or efficiency without (less) extra cost. The factors influencing success are the ability to propose suitable potential solutions based on earlier experience and careful observation.

7.2 Judgement

Although the end results are good from the three solutions, we also proposed some further possibilities for the warehouse about upgrading its AGV system to make the AGVs smarter than the current stage. From the angle of a student at university, the author believes his study indeed helped the warehouse. However, the warehouse may feel that the improvement level or percentage is not high enough, but it is still better than nothing. Besides that, the warehouse would like the student to design some simulation models that can simulate the entire process and arrange each link by such a model, as explained to the warehouse that the student may not have sufficient time to do so in his bachelor thesis.

In general, we are satisfied with the results. The student has found some temporary alternatives from the results that may help the warehouse relive its dilemma and some further suggestions.

7.3 Choice

This paper has proposed its reasons and foundations for the choice in Table 12. We can now rate these three proposed solutions using those standards.

1. ***Improvement percentage***. The improvement percentage for the first method is 1.1%, 14.3% for the second method, and 18.11% (take the maximum value) for the third method. So, the third method gets three points, the second method gets two points, and the first method gets one point.
2. ***Cost***. The first method (redesigning the layout) in this paper did not cause other costs, and according to the calculation in section 6.5.1, the cost is 150 euros. The cost of the second method (improving labor arrangement efficiency) is 125 euros based on the calculation in section 6.5.2. As for the last idea (improving the picking station's capacity by adding one more cabinet), the cost is 975 euros from the calculation in section 6.5.3. So, the second method has the lowest cost, and it also receives the highest score, which is three. Similarly, the first method receives a score of two, and the last idea (improving the picking station's capacity by adding one more cabinet) has the highest cost, which makes it get the lowest score, which is one.
3. ***Resource***. Both the second and third methods ask for extra resources when doing the implementation, which are cooperation with team leaders and physical material support. Therefore, both the second and third methods can only get one point. While the first method does not have to ask for extra resources but slight changes, it will get three points here.
4. ***Time***. In general, the time spent by these three methods is not significantly different, but the second and third methods require a little more time because the author requires extra cooperation with the warehouse's management team. The first method gets three points, while the second and third methods can only get two points.
5. ***Impact on other parts***. The first idea has the least impact on other parts; the second idea may influence the total labor arrangement; and the third method does not have an impact on other parts. So, three points for both the first and third ideas, and the second method will get two points.

Table 21, Grading on solutions

Score	Improvement percentage	Cost	Resource	Time	Impact on other parts
Redesign the layout	1	2	3	3	3
Improving labor	2	3	2	2	2

arrangement efficiency					
Improving the picking station's capacity by adding one more cabinet	3	1	2	2	3

Then the final scores for these three methods are:

1. Redesign the layout, $(1 + 2 + 3 + 3 + 3) = 12$ points.
2. Improving labor arrangement efficiency, $(2 + 3 + 2 + 2 + 2) = 11$ points.
3. Improving the picking station's capacity by adding one more cabinet, $(3 + 1 + 2 + 2 + 3) = 11$ points.

Finally, we have chosen our method as the first method (redesign the layout) to be the best solution for the warehouse due to its highest score by calculation. Besides the short-term solution, as mentioned in section 5.7.4, we also recommend that the warehouse upgrade its AGVs' systems to make them smarter.

8 Conclusions and recommendations

In chapter 8, we present an overview and elaboration of this thesis for JD organizations, starting with the motivation and our central research question, followed by a summary of the methods used in this paper. Besides that, results, conclusions, limitations, and our final recommendations will be described.

8.1 Motivation & central research question

The author has been hired by the Jingdong (JD) organization and has been serving in the warehouse for six months. During this period, the author has the responsibility for both himself and the organization. Personally, he would like to successfully complete his internship and graduation thesis. Externally, the author must help the company to solve or relieve their dilemma in outbound process operations. Both the personal and external reasons become our motivations in this article.

As mentioned in earlier chapters and sections, the central research question in this paper is "***How can the outbound processing capacity in JingDong logistics be improved while not incurring too many extra costs***?". The central idea of this paper is to help the warehouse improve its outbound processing ability, either by increasing its total outbound ability or by improving its outbound ability efficiency per unit time. Under the guidance of our central research question, we proposed three sub-research questions:

1. What method (s) has been proven non-effective for improving outbound ability in a warehouse?
2. What effective method(s) or strategies can be used to improve the outbound process in JD organization?
    i. *Redesign the layout.*
    ii. *Improving labor arrangement efficiency.*
    iii. *Improving the picking station's capacity by adding one more cabinet.*

3. What recent technology for AGVs in warehouse is available?

By studying and analyzing these three major research questions, we have some data from chapter 6 and can draw some conclusions that are introduced in sections 8.3 and 8.4.

8.2 Methods Used

Chapter 4 conducted a systematic literature review; we have been inspired by the literature based on the findings. Based on inspiration and brainstorming, we proposed our research questions. The Managerial Problem-Solving Method (MPSM) is our contribution to practice. This article has listed and discussed each step of MPSM individually in earlier chapters and paragraphs. By following the MPSM method, we have argued the research problems and received outcome data from the analyzing and implementation process.

8.3 Results & conclusions

As written, the aim of this paper is to try to help the JD organization improve its outbound process ability or efficiency. For the first research question based on our central research question, we have discussed two implemented methods in warehouses, which are "*increasing number of workers" and "night shift*." This paper explains why these two methods are not suitable for the warehouse in section 5.4. This article has three ideas under the second research question, and we have detailed and explained those ideas in Chapter 6. As for the result, the "r*edesign the layout"* has an improvement percentage of 1.1%, the "*improving labor arrangement efficiency"* has an improvement percentage of 14.3%, and the "*improving the picking station's capacity by adding one more cabinet"* has an improvement percentage of 18.11%. The improvement percentage for outbound process efficiency and ability is important, but it is not the only deciding factor. The final score should be decided by the grading system, and we have graded these three solutions in section 7.3. "*Redesign the layout*" received the highest score (13 points), while the other two methods received a lower score than the "*Redesign the layout*" method, and we finally chose this as our choice for the warehouse. Besides that, we also proposed long-term solutions for the warehouse in section 6.4.

In general, we have found two solutions that the warehouse has implemented in the past but eventually found out are not suitable for the warehouse because the cost is higher than the acquisition. Based on such a finding, we may be able to avoid such paths. Furthermore, we have answered the second research question and graded those solutions, eventually presenting our suggestion for the warehouse. We also found useful methods by studying the third research question and developed a long-term solution for the warehouse to help them improve the outbound efficiency eventually.

8.4 Limitations

Although we have received satisfactory results from the research and given out our advice, limitations still exist. First, we implement our ideas within six months, and they may have different results if we change the observation period to years instead of months, so the first limitation is that we do not have enough time to finish all the methods in a longer period. Second, we have made some assumptions when implementing solutions, so our results have come under ideal conditions. Reality can be different and may affect the results and cause a deviation. In general, this paper is far from perfect; limitations and defects exist.

8.5 Recommendations

According to the current work, the first recommendation is to try not to use methods like "adding the amount of labor" and "night shift" since those solutions may increase the outbound ability, but the cost is even higher than the gains. These methods can only be used when the warehouse is facing pressure from our client and time is limited, since customer experience is even more valuable. Otherwise, try not to use these kinds of solutions to improve outbound ability. The second recommendation is to try to change the layout design. This will not cost the warehouse extra money but can bring you some improvements. This method can be applied to both peak and off-peak seasons. This design can improve the outbound process efficiency, does not affect other departments, and virtually no other costs are incurred. Although the other two proposed solutions did not receive the highest grade from our grading system, it does not mean that those ideas are unusable. The warehouse can still be used. Just pay attention to the differences between peak and off-peak seasons. Some solutions are not applicable to all scenarios. Besides the short-term solutions, the warehouse should actively look for modern technologies on AGV and try to enhance the robots' algorithms since the AGV's performance still has potential for improvement. There is still a lot of room for improvements since current AGV technology is not suitable to manage complex situations in a warehouse.

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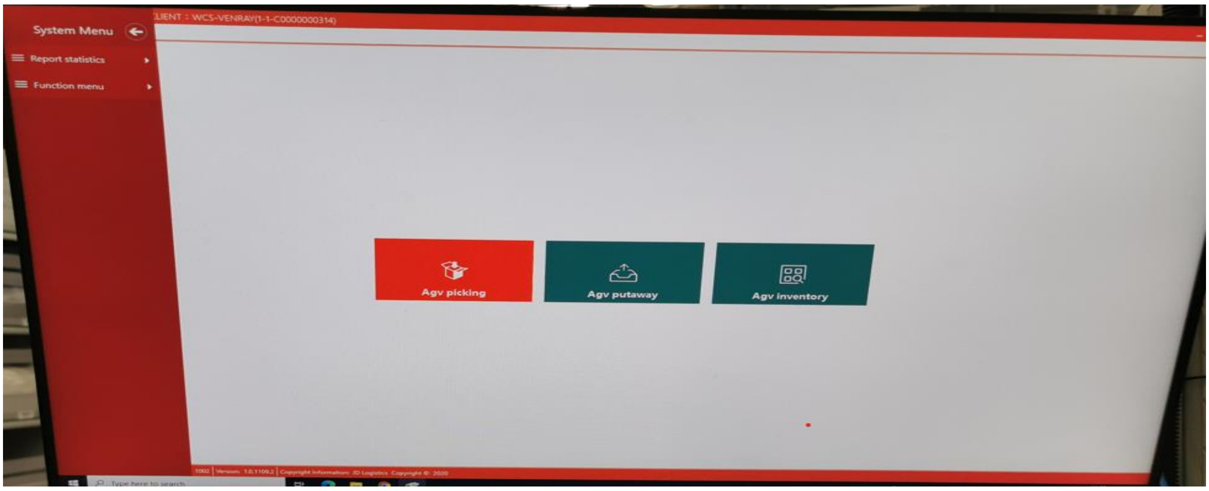
Appendices

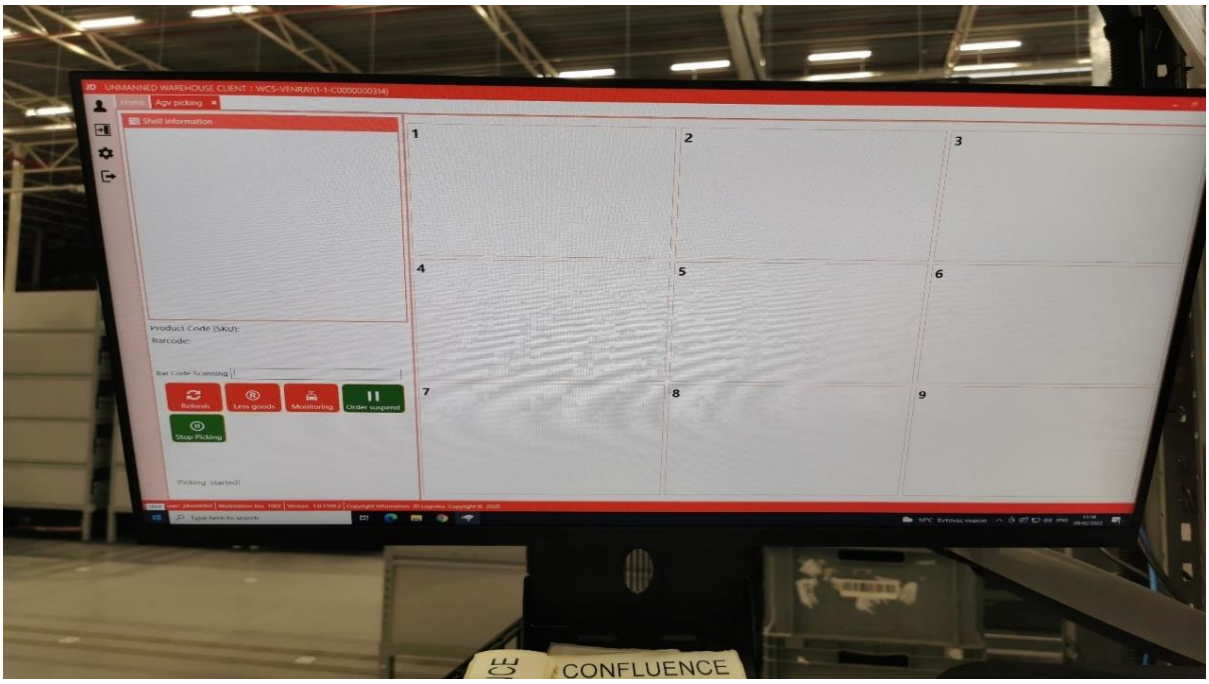
Appendix A: *Picking standard operation process(outbound)*

1. Log in to WCS system by username and password. Use personal account provided by shift leader.

2. Choose “AGV PICKING”.

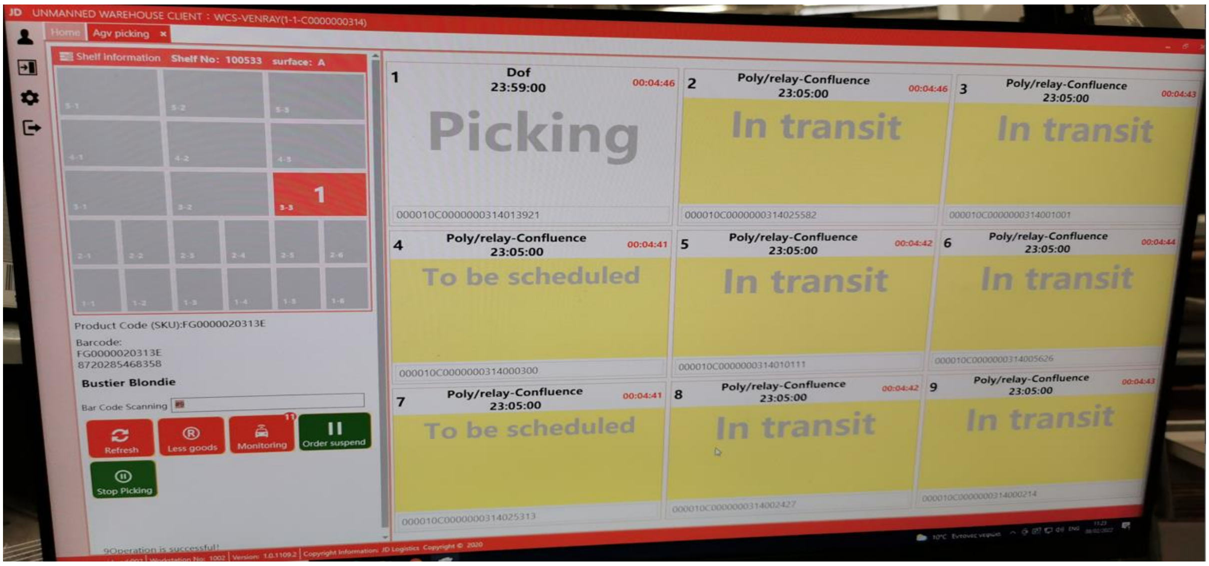


3. Click icons “order continue”, and “keep picking”. Both icons must be green. Then orders will start coming.



4. Put 9 empty grey containers on reck, and scan one by one number on pick reck.
5. After the container are scanned, orders are assigned to them. If the massage “poly/relay-confluence” appears, you need to stick a sticker to the grey container.

6. When AGV arrives, the screen displays the location from which you need to take the product and quantity. Scanning the product barcode, and after this step, on the screen appropriate location on the racking with grey bins is displayed.



7. Take product from location, and scan product barcode.

8. After scanning product, you can correctly scan location on racking, and put product inside the grey bin.

9. You can put the container on the floor and put a new one in its place.

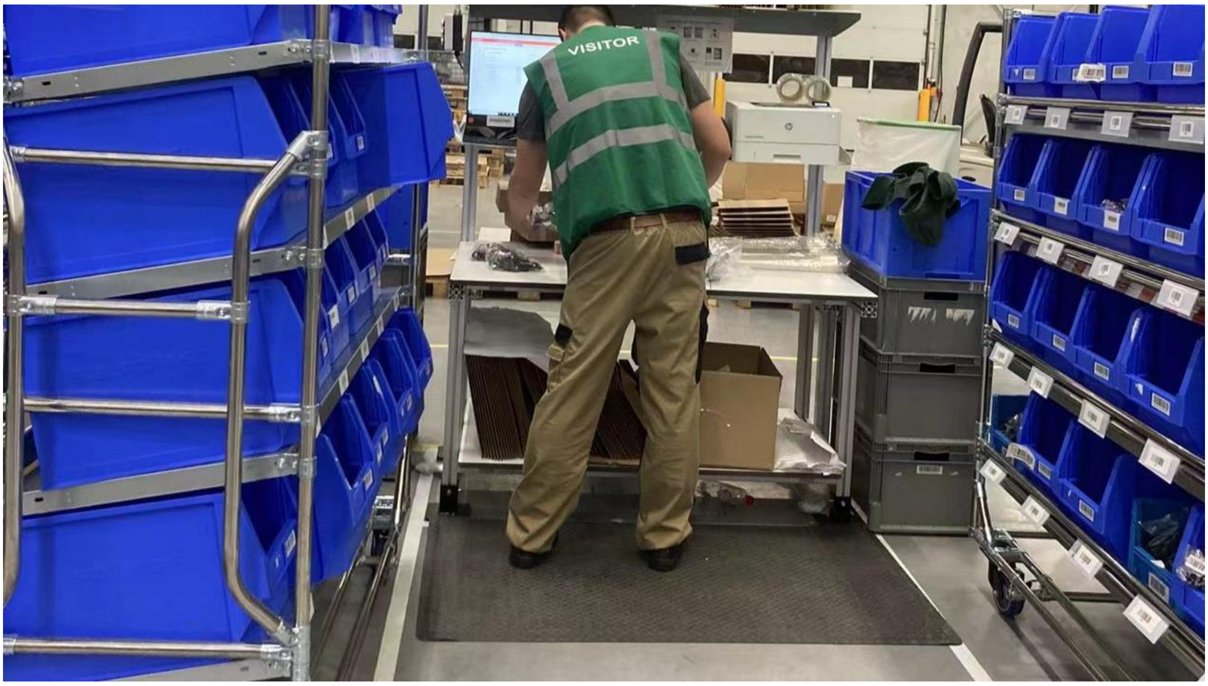
Appendix B: *Rebinning standard operation process(outbound)*

1. Take the finished Collection box from buffer area.

2. Scan the collection box ID to start rechecking task.

3. Bind all rebin boxes on the rebin wall.

4. Pick one item and scan SKU. If any discrepancy, Register as issue order in system.
5. Put item into the Rebin box of system prompts.
6. Scan rebin box ID.
7. Pull the rebin wall to the assigned packing area once one collect container is completed.

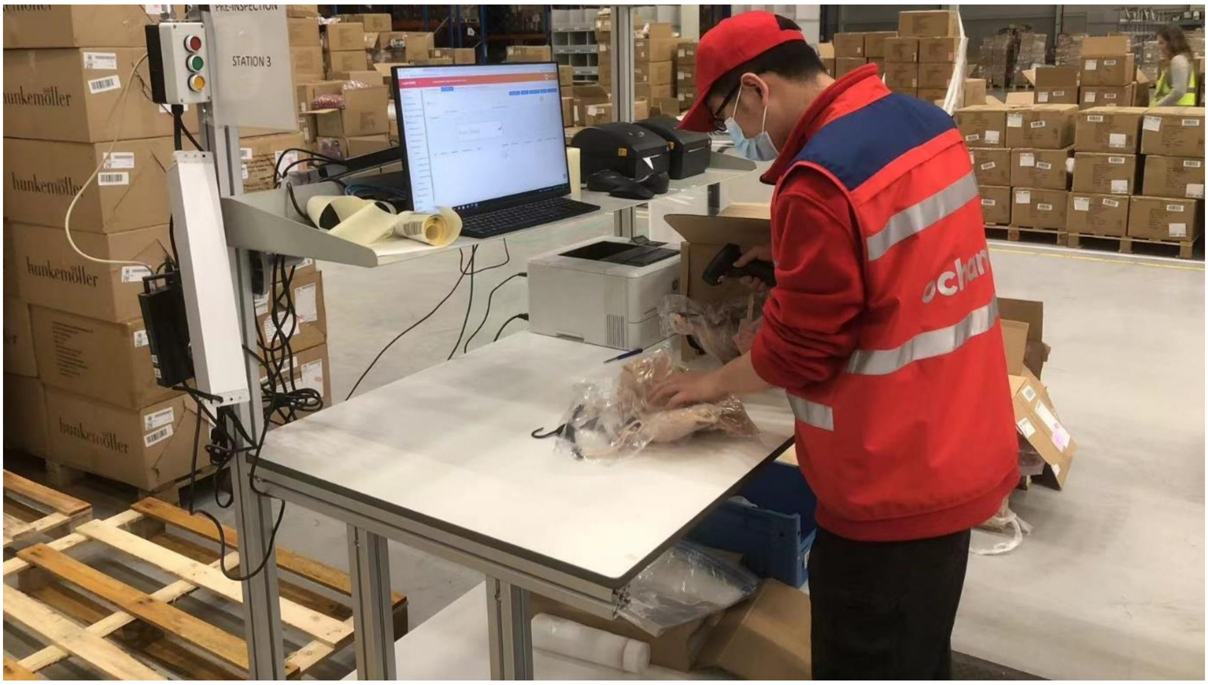


8. Repeat Step 1-7 to continue to work.

Appendix C: *Packing standard operation process(outbound)*

1. Prepare the package material, barcode label, A4 paper.

2. Check the LWMS prompts, if all order for one store is completed, go to flowing rack to pick all blue container to package stations.
3. Judge and select the outbound carton according to the visual package quantity per store.
4. Pick one polybag from blue container.
5. Scan the barcode on parcel label.



6. Load the parcel label to outbound carton.
7. Repeat Step 3-4 till all polybag in all blue container per one store is picked and scanned.
8. Print out the primary carton content list.
9. Insert the primary carton content list to outbound carton.
10. Print out the shipping label for each carton.
11. Paste the shipping label on right corner of carton (need further check with HKM to confirm).