Ganzeboom

Inventory discrepancies at Ganzeboom

Identifying the frequency of inventory discrepancies at an SME with combined warehouse usage & recommending change

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26-11-2024
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Preface

Dear reader,

This thesis about “Inventory Discrepancies at Ganzeboom”, has led me to new experiences in my educational career. The company of Ganzeboom focuses on gearbox revision and gearbox parts and have had problems with inventory discrepancies for a while. This thesis addresses literature and case data to analyse and reduce the causing problems. The thesis at Ganzeboom has been the final step towards my Bachelor of Industrial Engineering & Management at the University of Twente.

The journey learned me to handle data, to communicate properly towards the company, to feel responsible for the work, and many more things. This all was possible due to the help received from the supervisors. I therefore want to thank my first supervisor, Lucas Meertens, who has guided this thesis into an addition to the academical world, by giving feedback on the different chapters and advising on academic value. The guidance in critical thinking has also helped to improve the quality and usefulness of the thesis. Next, I also want to thank my second supervisor, Renata Guizzardi-Silva Souza, for helping out with overall improvements, but mostly validation improvements.

In the company I was guided by Sergio Ganzeboom, who made time to help me whenever needed. It was due to this guidance that I was able to get the required knowledge to execute this thesis. For that, I hope the thesis will give insight into the problem at hand and hope that the suggestions made can improve the company its inventory record performance.

Last of all, I want to thank my family and friends for the support during the different stages of the thesis. Although motivation was sometimes lacking, with their support I managed to push through and are now able to take the next step: obtaining my Master of Industrial Engineering & Management.

Merijn van der Voort

Management summary

This case study researches a business that needs to overcome a complex challenge. The business focuses on the complex world of gearboxes, in both revision and parts. The company called Ganzeboom develops this business to great extent. Hiccups in some of the processes are however visible to the management. Inventory discrepancies is one of the things that lead to bad performances. This thesis has its goal to uncover the reason behind this discrepancy and makes it clear which improvements are needed. To improve its processes to reduce its average amount of stock corrections by at least 50%, the company of Ganzeboom has to implement the 5S methodology to the problems of not booking items, kit-picking, and communication. The company can then focus more on future growth, rather than looking back at this bottleneck.

Reason behind research

The company of Ganzeboom is rapidly expanding in their sector of business. However, a reoccurring problem is affecting their operational performance. The problem consists of a discrepancy between the physical and data stock levels. The discrepancy results in extra work hours in the form of counting stock, noting down, communication, correcting, and more. If this problem can be resolved, a drastic productivity improvement can be accomplished. Is it possible to find the underlying causes of this problem?

Approach

How can Ganzeboom improve its processes to reduce its average amount of stock corrections by at least 50%?

This main research question will be answered using MPSM, BPMN, Lean, and data analysis. In the visits to the company and unstructured interviews with management, it became apparent that the stock discrepancies were due to human errors. It also became evident that processes in place facilitated human errors to a large extent. Using BPMN and Lean was opted out as a possible way of tackling this problem. In different data gathering methods, both interviews, and numerical data, the processes in place could be changed in such a way that human errors are facilitated less so, in fact, to an extent of a 50% decrease in corrections.

Added value

The research will show to other researchers, businesses, and readers, whether the methodology of MPSM, BPMN, and Lean, is a suitable methodology to use in SMEs where the combined warehouse usage is the case. No literature on two entities in the same warehouse and its impact on inventory discrepancies has been published yet. In this research, the influence of this case is assessed, together with other causes for inventory discrepancies that have already been researched. The case would be even more interesting for companies that also are dealing with inventory discrepancies and both have separate entities, while also not being able or willing to invest in expensive digitalization options.

Recommendations

In the processes of Ganzeboom, the following recommendations were determined using the methodology of BPMN and Lean:

Kit-picking: As a growing sector of the company and with great impact on inventory discrepancies, it is important to focus on realizing more accurate kit-picking processes. Current kit-picking processes could be the cause of more than a quarter of current manual corrections. With the future where kits have an even bigger impact on manual corrections, it is advised to use a standardized process.

Separation of entities: Based on interviews with employees in the warehouse, one of the biggest problems of inventory discrepancies was said to be not booking in items. The separation between the two entities of Ganzeboom, Parts, and Revisie, should be obtained to reduce the impact of not booking items.

Communicating: To make sure that the mentioned recommendations of kit-picking and separation of entities run smoothly, communication between teams is key. Not only those recommendations are adapted well to communication, also further grip on the inventory discrepancies capable of being tackled if communication is improved. Therefore a system of periodical interactions between employees is recommended.

Conclusion

SME's with combined warehouse usage and inventory discrepancies can learn from this thesis. Conducting the research by combining multiple data sources has led to the believe that the reliability of the research is strong. BPM was chosen as tool to understand where inefficiencies might occur, which then was expanded on with the combined data. The usage of lean, and in particular 5S, has been discussed as key solution. This 5S methodology is in this case in need of additional methodologies such as separating entities and communication. The thesis can form the basis for the implementation of these discussed solutions. For other research, this case study can form the basis for how to asses underlying inventory discrepancy problems.

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Glossary

Terms to be defined:

- MPSM:
  - Managerial Problem Solving Method. A systematic approach to use for solving management problems
- Delivery note:
  - List that the supplier put on the package that is delivered at the warehouse
- Receiving:
  - Processes connected to accepting the package till stored in the warehouse properly
- Inslaglijst:
  - The Dutch term used by employees of the company for the physical paper that contains contents of the package arrived, such as amount and place to store
- Put away:
  - Processes connected to the moving of items of a package from the “inslaglijst” location to the physical location.
- BPM(N):
  - Short for Business Process Modelling (Notation), BPMN is similar to a flowchart. It visualizes processes in a company or other settings where a start event sets out different activities until the end of a process is reached.
- Lean (& 5S):
  - Lean is the term used in the field of IEM to reduce certain wastes from processes in a company or chain. It is used to describe multiple methodologies to reduce these wastes. One of the methodologies that is named in this research is 5S.
- WMS:
  - Short for Warehouse Management Systems. Often technological advanced systems for process improvement and decision-making.
- Gearbox:
  - Component of a car that has the goal to deliver the right amount of torque to the wheels to drive. Transmission of automatic and manual are both used in cars nowadays.
- (Ganzeboom) Revisie:
  - In this context the remanufacturing of gearboxes
- (Ganzeboom) Parts:
  - Ganzeboom Parts its main goal is supplying gearbox parts throughout the Netherlands and Europe.

1. Introduction

1.1. Ganzeboom

The company at which I will perform my bachelor thesis is Ganzeboom. Ganzeboom can be divided into two distinct parts, gearbox remanufacturing and gearbox parts. Both are in the same building at location Almelo. While those entities are working together, each entity has its own goals.

The process of remanufacturing gearboxes needs a helping hand from the Ganzeboom Parts business, while the Ganzeboom Parts business is supplemented with the remanufacturing process of leftover parts. Next to this inbound of parts, also new parts are ordered for reselling purposes. These processes accumulate into inbound parts. Inbound from sources other than remanufacturing are coming in throughout the day and need to be administrated. This happens at multiple stages including counting parts, noting down supplier comments, destined place in the warehouse, etc.

As said, outgoing parts sometimes go through the remanufacturing side of the Ganzeboom business, while parts are also ordered by customers. The gearbox parts at Ganzeboom are being ordered by both regular and new customers, which is making the company grow. The incoming orders need to be picked and placed with their dedicated delivery company. Those delivery companies come to pick up a pallet at their own set time. The administration is done to show clients that their package is picked up by the delivery company, as well as other administrative duties such as invoice, counting of stock amount, checklist, etc.

The processes mentioned in these enumerations are carried out both on paper and digitally. The digital administrative tasks are managed through their IT system within a third-party digital environment. For example, stock amounts, prices, invoices, status of packages, etc are in this IT system. Both automatically, e.g. when ordered through the website, and manually the data is entered. Manual entry of data is used a lot for mistakes in data. These manual entries are considered manual corrections in this research.

1.2. Core problem identification

The identification of the core problem started with the worries of the company about its physical stock amount not matching with its data stock amount too often. Currently, this is fixed by counting the products every time when an added item is disposed of in the warehouse and reporting the actual stock amount to the employees in the logistics sector, who change this using manual entry. Addressing this issue is crucial, as it can directly impact tax compliance and cause delays in order processing. There are multiple causes for this problem, which I have summarized in the problem

cluster down below.

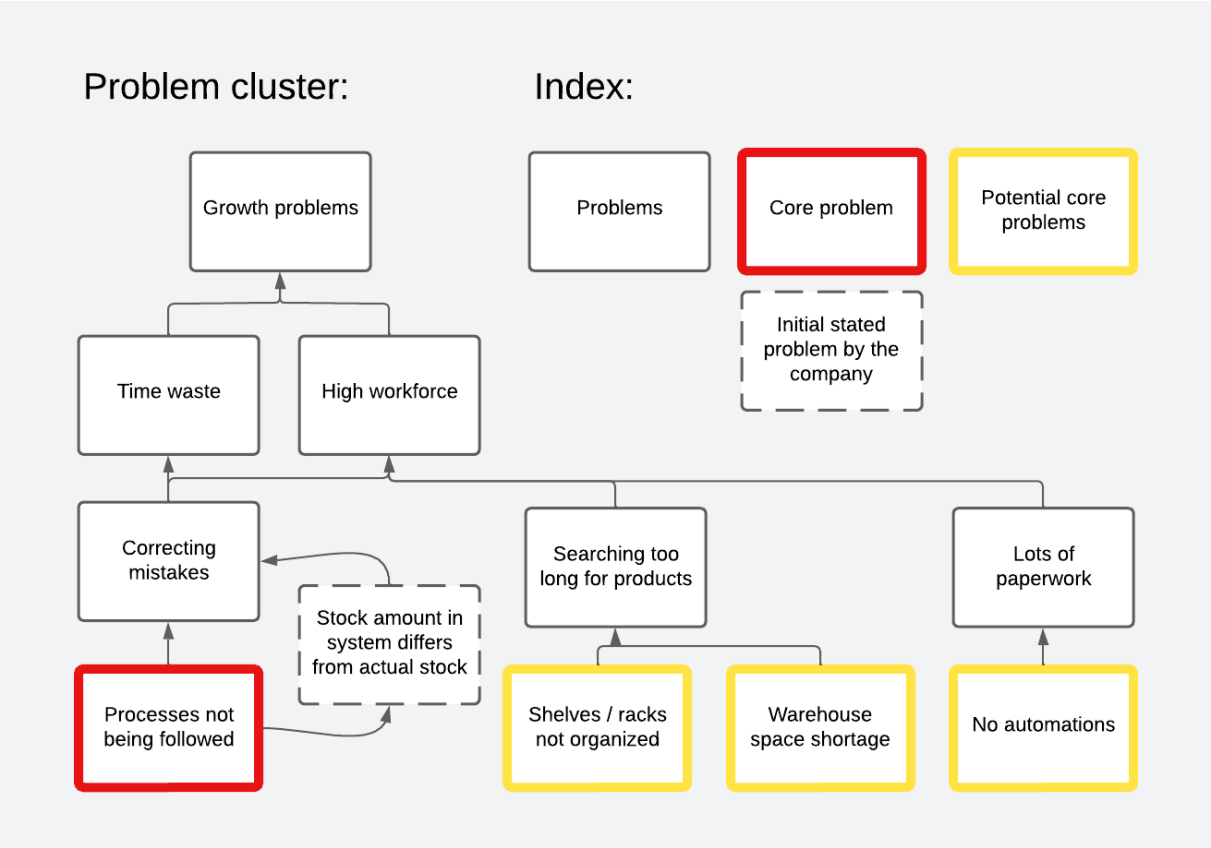


Figure 1 Problem cluster (LucidChart)

The company's problems at hand were deducted through both joining in with every part of the process at Ganzeboom Parts from arrival to departure and speaking with the company management. This led to the insight that there were currently two causes for growth problems at the location of Almelo: time waste and high workload. Both are caused by correcting mistakes, which on its own is directly influenced by processes not being followed. Logistic management of the company reflected on the problems that were identified, and pressed the most urgent problem at hand being the processes not being followed. Choosing other potential core problems that caused growth problems such as warehouse space is something not in my hand to tackle, and other root problems were not picked as they did not influence the stock amount difference, which is something the management wanted the most from me to solve. Cost-benefit of the potential core problems is also something that is looked at. Warehouse space is an example of where an unconscious border between costs and potential benefits has been crossed. This border is set according to intuition from the company. While this border is not defined, expansion of the warehouse would mean buying a new space, as the current building does not own any space surrounding the current warehouse. No automations as core problem also crossed the border of cost benefit ratio. In the case of automations, not only the cost can get high, but also knowledge required is high (Vecna Robotics, 2024). The benefits of automations are in potential high but are not measurable, as different types of companies require other automations. So there is a factor of uncertainty in the benefits of automations. Shelves / racks not organized was not chosen as core problem as this problem is being tackled by the company. Agreeance on processes being not followed as core problem was the eventual outcome of the identification. The relevance of the core problem chosen to the objective is clear and has the component of being the best cost-benefit ratios as discussed, which is a component stated by Heerkens and Van Winden (2021). The benefit to solving this core problem will be that the workload

of correcting mistakes in administration is reduced, enabling to have time for realizing the desired growth.

At the company, there was already once research about the company processes conducted. This research resulted in a plan of processes for inbound deliveries, however, this research only covers the beginning of inbound. The processes further down the line cause the most correcting work nowadays at the company. When speaking to employees of the company and while observing the work done, it can be said that in most cases, the inbound to the system is correctly followed. But for example, the supplier delivering only part of their delivery causes the process to be not sufficient and in need of extra steps to make sure the stock amount is correct, customers are content, and the finance is correct.

The core problem selected needs to be written in a research question that contains a norm-reality gap and a problem owner. To go from the core problem of 'processes not being followed', a measurable variable is firstly needed, this can be the variable that was discussed with the management, namely the times the data stock amount is needed to be corrected manually. This data can be obtained in their IT system. The variable came up in conversation with the management because it was said that standard processes not being followed were believed to be one of the only ways the manual stock corrections were influenced by. In theory, the variable would show a very strong correlation with the processes not being followed by employees. The management has observed that correlation over multiple years and besides that got a report by an intern.

How can Ganzeboom improve its processes to reduce its average amount of stock corrections by at least 50%?

This research question variable is easily measurable because of the data from the IT system. Management of Ganzeboom expects a reduction of 50% minimum due to their reasoning that most mistakes come from easily fixable situations. But still expecting to remain a couple of manual corrections as there are cases that cannot be fixated in a straightforward process.

1.3. Knowledge questions

Answering the main research question cannot be done in one instance, it is too complex to solve without getting to know the following sub-research questions. Those sub-research questions will be extensively answered in the chapters following this introduction.

1. *What are the current processes in place for the inbound and outbound of packages at Ganzeboom?*

This sub-research question is divided into a couple of parts that all need to be answered to eventually help answer the main research question.

   a. What are the 'normal' inbound and outbound processes at Ganzeboom?

Under the term 'normal' we take the case of a complete process, with no supplier comments or miscalculations, including no extra administrative work needed. The way of working on a day-to-day basis. To answer this question, interviews with employees are taken, while also the way of working is observed by walking along without interference. The result can be summarized in a BPM, business process model.

   b. What are the 'special cases' at inbound and outbound processes at Ganzeboom?

With special cases, it is meant that whenever something in the normal process, see the above explanation of normal in this sentence, goes wrong or requires extra work, what steps are taken in those cases? The answer being formed in the same way the normal processes are identified, also resulting in a BPM. Both of the above questions produce qualitative data by collecting primary data from observations and interviews.

2. *Which processes contain inefficiencies blockades or bottlenecks at Ganzeboom?*

This sub-research question helps recognize processes that cause problems. The way of answering this question will be by using quantitative data as well as qualitative data. The current manual entries can give insights into which kinds of products give problems. Next, interviews with employees and management and observation will give qualitative data on the inefficiencies blockades, or bottlenecks. Interviews and observing is a form of primary data (Saunders et al., 2019). Sub-research question one forms the basis of this sub-research question.

   a. What manual corrections are applied the most in the data system at Ganzeboom?

This part contains secondary data, using the IT system at the company. And the question has a quantitative output as statistical analysis can be used to find extreme values. Search for extreme values will be done on the relation between the number of times manually corrected and attributes such as location and article type.

   b. What problems are recognized by employees and management at Ganzeboom? And what problems can I observe?

The result of this research question is a qualitative analysis of inefficiencies blockades or bottlenecks. This will be primary data. The qualitative data is only used if numerical data is insufficient. Qualitative data can be assessed with numerical data from other research, while qualitative data that can't be assessed with any numerical data is assessed with assumptions.

3. *What interventions in inventory discrepancies have been suggested in research and implemented in practice?*

This question will be answered using secondary data, having a qualitative result in the form of known interventions in similar situations. A systematic literature review will be conducted on this research question. It will be answered by a careful assessment of relevance for the situation at Ganzeboom, the question will form the basis of the sub-research question that is followed here.

4. *What interventions in inventory discrepancies will decrease the manual entries needed at Ganzeboom?*

This sub-research question finds its basis formed at sub-research question three. It will be answered by using both sub-research questions two, which itself is based on the first, and three. Evaluative research is conducted and will result in a recommendation for Ganzeboom that answers the main research question and with that the action problem at Ganzeboom.

1.4. Research design: elaboration on knowledge questions

The type of research that will be conducted is a case research. This means that the knowledge acquisition is a single case study. With single case studies, there are certain conditions of practice, unignorable real-world factors (Wieringa, 2014). The knowledge questions answered in this research

do not have the key to every company or academic, but rather are answered for this case only. The research can be useful to other cases due to generalization of knowledge.

The first sub-research question needs primary data. The interviews of the employees for each step in the company process are to fill in gaps that are left behind after observing their handling. The question will be answered by a BPM. Determining what tasks will be in the BPM and which tasks are too small to put in the BPM is done by looking at the functionality of this BPM. The reason that this BPM is made in the first place is because the BPM will provide research in general a clear overview for readers (Recker, 2012). The company might want to have this BPM to look at it themselves, however, as these are the current processes this won't be the case. So defining the level of detail of the BPM can be done firstly by using more detail, and later on, zooming out to create a good overview (Lopes & Guerreiro, 2023). This can also be done in this case study.

The second research question can be partly executed during the interviews and observation from the first research question. Notes on current processes and problems are being made while observing and interviewing. Some problems can turn out to be not as much of an impact on the company processes. To determine the problems that will be enclosed, and which problems will be left out, an interview with the company supervisor will be useful. Just like the selection of the core problem chosen, it is an estimated guess. This guess is based on determining the costs roughly, and can be seen as a valid indication while the benefits of solving the problem cannot be known yet (Heerkens & Van Winden, 2021). The company supervisor has enough knowledge of the scale of the problems to point out which are relevant and which are not. This can be said as the company supervisor often discusses problems with management. Again stressing that this research is a case research which defines the steps taken more like a general blueprint, also called artifact oriented research (Bergen, 2024). In this case, no better solution can be seen than seeing the company supervisor its knowledge as a trustworthy source. A tree map can be made to guide the next knowledge question. This, combined with extreme values found in the quantitative research, will contain most problems.

The third sub-research question is where literature comes in. The selection of which literature is relevant for the project can be determined by inclusion and exclusion criteria that are elaborated on in the systematic literature review, and also the result of the sub-questions one and two. The answer of this knowledge question will be the understanding of relevant topics in a summary.

The last sub-research question combines the knowledge obtained from questions one to three. The result of this question can be made in order to show which solutions are suitable for which problem and why the solutions fit.The solution should be selected based on the best cost-benefit ratio (Cost-Benefit Analysis: What It Is & How To Do It, 2019).. After this is determined, the answer to the main research question can be determined by simply summarizing the last sub-research question.

1.5. Validity, reliability, and limitations

The knowledge questions are all about the location of the company in Almelo, the other location of the company is considered to have different ways of working and processes. The other location does not have combined warehouse usage like the location Almelo and is considered to be out of this research its scope. By answering the knowledge question of where the bottlenecks in the processes of the company are, the results will only include found inefficiencies, not whole processes that will be restructured. Academic proof that whole process restructurings are valid and reliable would cost relatively more time than only academically proving only parts of the process that need to be improved on (Business Process Improvement Vs Business Process Reengineering, z.d.).

Data gathering for the knowledge questions which are necessary to answer the main research question, need a validity and reliability reflection for both qualitative and quantitative data (Saunders et al., 2019). Current manual data entries can result in a validity problem, as there are some products in the warehouse that have a faster turnover rate than others which results in a more error-prone status. In that situation, the error-prone status of manual entries does not measure their relative error-prone status but rather produces their absolute error-prone status. This can be countered by controlling the data of the turnover rate next to the manual entry data (Sürücü & Maşlakçı, 2020).

In reliability, there is a problem that can occur during the interviewing of employees and management, as well as observing the processes. It may occur that whenever the employees know that they are being watched, their behaviour changes. This can be the case whenever the observer choses to reveal their identity to identify negative behaviours (Saunders et al., 2019). This possibility of unreliable circumstances can result in a wrong impression of the problems.

Getting to know the processes that are in operation at the company, the management found the most efficient way to get to know what goes on actually, is to work on some tasks in the company. Working on tasks is an efficient way to know what happens, as you get to understand the tasks at hand to fulfil those tasks. With this in mind, as well as confirmation from employees after making the BPMN, a researcher is capable of making BPMN like in 3.2 of this research. If the tasks at hand are not suitable for performing, interviews and observations helped with identifying the steps that are needed in the processes. The procurement process, as seen in 3.2.1, is not suitable due to a knowledge gap between the functional area and the researcher.

2. Literature review: interventions in process improvement in warehouse operations

The main research question requires to be divided in multiple sub research questions to answer this main research question. The sub research questions vary in ways to come up with the answer. Some of those sub research questions are in need to be researched at the company itself, as those are company specific questions and cannot be find using secondary data (Saunders et al., 2019). Other sub research questions can be answered by secondary data, which will save time in comparison to creating own theories and testing those. It also helps to put research in context and show the debate in the field of working (McCombes, 2023). The knowledge problem chosen to answer using systematic literature review is stated as follows: *What interventions in inventory discrepancies have been suggested in research and implemented in practice?*

This sub research question is chosen because there is a high chance that there is useful knowledge to be gained by looking at research around this topic. To produce the main research question answer, it is needed to have an overview as to how the company can improve certain processes that are playing within the company. The sub research question stated can help with solution generation, as this literature review will result in academic proven concepts and helps in time saving due to the fact it is not needed to create own theory here.

To conduct a systematic literature review, it is however needed to produce a slightly adjusted question, as the current question will have a too narrow result in the search due to the combination of both inventory discrepancies, and in research suggested and in practice implemented. A more specific question would result in this question, with the final search query iteration: *What interventions in process improvement have been suggested in warehouse operations?*

(process W/4 improvement* OR business W/4 process*) AND (warehous* W/4 operation* OR warehous* W/4 manage*)*

This query did not include a lot of synonyms, which does not verify that every useful literature was found in this literature. Usually the step to broaden the search is taken at this point, by accessing the references of the already found papers (McGregor, 2018). With that step, around 90% of relevant literature should be found (Randolph, 2009).

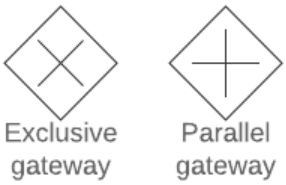
The results of the search query were however sufficient for me to continue with screening of the hits. According to Wiersma and Jurs (2009), the literature review has enough sources based on intuitive aspect. The results of the search showed mostly the same subjects at this point. The screening was based on difference between case studies, considered as important here are factors like company size and product type. Lean, 5S, WMS, are all discussed as viable options. BPM is firstly discussed, as this method is chosen to bring attention to the business processes in the warehouse that are in need of solutions.

2.1. BPM

BPM, short for Business Process Modelling, is about visualizing processes in a certain business. There are multiple types of techniques to visualize a business process. BPMN, flowcharts, UML, are all examples of different business process models that can be used. BPMN is most commonly used in the study of IEM bachelor at the University of Twente, therefore this will be used in this case study as well. According to Recker, 2012, BPM can provide a clear overview for readers of a study. With BPMN, an overview of the processes is indeed given to the readers (Luo & Zhao, 2018).

BPMN has developed in the last few years from BPMN to BPMN 2.0. This BPMN 2.0 includes more choices in detail, such as specific gateways, and specific activity types. From now on in this research, BPMN 2.0 will be regarded as BPMN, or Business Process Modelling Notation. In Business Process Modelling Notation, the following key characteristics can be identified and are depicted in table 1.

Table 1 symbols and characteristics in BPMN

Symbol	Characteristics
	The activity object forms the core of most BPMs and can be activities such as checking, printing, delivering.
	Every BPM starts with a starting event. This starting event can also be checking or printing, but also the arrival of a delivery. An intermediate event can be used in multiple ways, either something that needs to be followed up onto, or an ignorable event that can trigger other processes. The end event indicates whether a certain process has finished and does not need to be followed up onto, or is followed up onto by a different set of employees or different company. Every BPM should have an end event.
	Exclusive gateways are designed to indicate that there are multiple ways to follow up onto the activity. Only one path is chosen in exclusive gateways and often are in the form of a question noted down. For example: 'enough space?' is a question that can lead to the two paths 'yes' and 'no'. The paths can lead to different ends but also often end up together before the end event. Parallel gateways are indicating that multiple activities are happening at the same time. The parallel gateway paths often meet up again.
	Activities are sometimes in need of additional information. This information, or data, can be anything from software to written numbers by a colleague. Datastore object in BPMN is used to indicate that the data is stored and can be used in further applications.

	he structure of the BPM is determined by the pool and lanes. The pool indicates at which larger picture the reader is looking at. This can be a whole company process, however for the use in this case study, which is the most common use, the pool indicates the process. The lanes indicate the employees, functions, in the process. More often than not, more than one function is used, thus more than one lane is used.

The activities, events, gateways, and data object & datastores are connected using arrows. Following the flow from the starting event through the activities is made easy by these arrows. Data objects and datastores can be linked to activities with a dotted line, an association, instead of the sequence flow arrows.

The symbols on the activities are used to indicate specific types of activities, this can be either receiving something, mail something, etc. There are also ways in which the activity should be conducted, this can be either a loop, sequential, etc. The level of detail can be as big as one would like, based on the goal of the BPM.

2.2. 5S

5S is a lean management tool often used by business to improve processes. Improvement by reducing wastes, and increasing productivity are the key factors in lean management. Lean management exist for multiple decades now and has had growing literature publications since then (Sinha & Matharu, 2019). One of the methodologies often associated with lean management is 5S. In this literature review, 5S came up in process improvement in warehouse operations more than other lean methodologies.

5S stems from Japanese philosophy and has been used evidentially in businesses since after the second world war (De Mente, 1987). Since then, 5S has been used for total productive maintenance optimizations, incorporated Kaizen, which is a continuously improvement philosophy, and used for total quality management systems (Kobayashi et al., 2008). 5S is standing for the Japanese terms: *seiri, seiton, seiso, seiketsu* and *shitsuke*. These terms are now referred to as 5S and is commonly used in businesses.

A case example of this 5S methodology is used in combination with value stream mapping. Value stream mapping helps visualize a business process. In this research, not value stream mapping, but business process mapping, data, interviews, and observations were used. With these methods, an analysis of where wastes are located is conducted. Wastes are usual business when it comes to lean management, 5S is also a lean management methodology. 5S incorporates the 5 concepts into a business. Those 5 in English are *sort, set in order, shine, standardize, and sustain* (Singh et al., 2014). The method aims to minimize process times, minimize errors and avoid waste by tackling the lack of order, which is believed to be a great problem (Espino-Sanchez et al., 2022).

5S is commonly used with other methods. In case studies that include warehouse as attribute, it has been combined with other lean methods, communication improvement techniques such as kanban, WMS, ABC, slotting, and others, figure 2 depicts. The 5 concepts of 5S can each be guided by these techniques. For example, *sort*, or *Seiri*, can be done by using the ABC method. The ABC method sorts items into different categories based on their importance. This usage of the ABC method is used in

the case study of Alvarez-Calleja et al. (2023). The other concepts also have their own unique way to help reducing waste and improving productivity. *Set in order*, reorganizations such as location changes are often considered. While *shine* reduces wastes in ways that are cleaning of a workplace. *Standardizing* can often be found on its own as a solution to inefficiencies, like in the cases of Vasquez-Quispe et al. (2023) and Espino-Sanchez et al. (2022). *Sustaining* improvements can be achieved by using other techniques such as communication. Figure 2 depicts supporting methodologies for 5S.

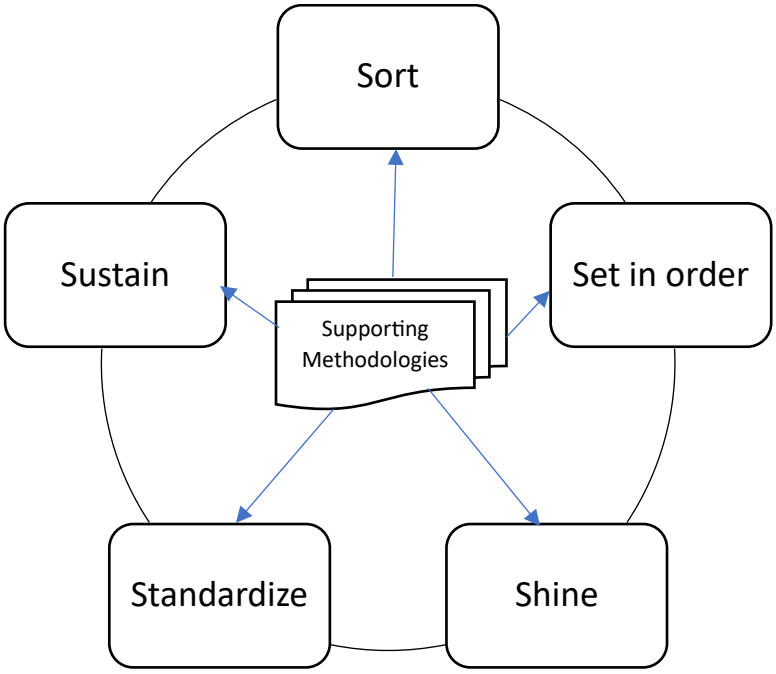


Figure 2 5S often combined with other methodologies

The way 5s helps organizations is by using the 5 concepts step by step. Study results show that 5s is effective in improving health and safety standards, environmental performance, and housekeeping (Singh et al., 2014). The method also minimizes stress, a common factor to making more errors (Espino-Sanchez et al., 2022). The effectiveness of 5s however, can depend on the company size and company structure. The way the 5s can be implemented correctly according to a study by Ho, 1998, is by having training and case sessions.

2.3. WMS

Warehouse management system, or WMS, is the term used for software that helps with inbound till outbound of a warehouse or any other distribution centre. WMS in most cases are in need of a high degree of technical expertise according to Rana (2023). The software that is used to improve efficiency in warehouse activities is all done through new technologies that are continuously changing the way warehouses can be managed. There are also challenges in data security. With those new technologies, a lot of new data is produced and can be of value to cyber theft. Investing in the new technologies that come to play with warehouse management systems, can all in all become a very big project and can already be outdated once implemented correctly. Also according to Rana, 2023, the implementation phase can include third parties that are necessary to keep running the data. If this is the case, the company itself won't hold onto independency and would lose some value to the company that obtains data from the company.

Early WMS adaptations focused on the use of data. Database operations including the coding in SQL or programming languages such as Java have been used for decades now and are still common in

WMS and other management functions. The use of technology to increase efficiency and improve businesses has been focused on since the rise of the technologies. Key aspects for management to adapt WMS are the data driven approach (Chen et al., 2020). Nowadays, more and more WMS adaptations are mentioned in literature, table 2 showcases.

Table 2 WMS adaptations found in this literature review

WMS adaptation	Number of hits during literature review*
RFID	14
Data mining	14
Business Intelligence	11
Data warehousing	9
Internet of Things	7
Industry 4.0	4
Scheduling	4

*according to keywords: can overlap

WMS focuses on the analysis and optimization of five processes: stock planning, receiving and put away, location management, order picking and packing, and transport & tracking (Zunic et al., 2018). For this case study of Ganzeboom, the inventory discrepancies are central and each process its influence on this will be discussed in later chapters. In the case of Zunic et al. (2018), the WMS system that helps in the process of stock planning is algorithms for forecasting. Receiving and location management is assisted by SQL procedures that also form an algorithm for better waking routes and other improvements based on data. Order picking in the case study is assisted by a smart module to aim for better walking routes.

One of the technologies that is mentioned the most in WMS is RFID, or radio frequency identification. RFID "is a communication technology that can identify specific targets and read and write related data through radio signals without establishing mechanical or optical contact between the identification system and specific targets" (Xu et al., 2024, *Basic Principles of RFID Technology*). A reason that this is mentioned relatively more than other options is because of its relatively long presence and one of the easier usages of technology with sufficient results. The RFID technology in warehouse management brings improvement in efficiency, reduction in costs, and improvement in operation effect of the entire supply chain (Xu et al., 2024).

Warehouse management systems can include IoT, Internet of Things. The technology of IoT is mostly concerned with the workflow process transforming to data points (Li, 2022). The implications can vary a lot and can even be used to solve complex problems such as stock count being different from data stock amount. This could be done by sensors, as most of the other IoT solutions are also done with sensors. The IoT warehousing can be complex in solutions, as the technology often is made by only a few select manufacturers. The technology is thus also expensive.

2.4. Conclusion

To answer the research question about interventions in process improvement in warehouse operations, the literature gives us multiple options. Most often, some sort of BPM is used to first identify the processes that are in need of improvement. In this case, the literature on BPMN is used to identify the processes. Then, the literature review concludes that 5S is suitable for SME, as 5S is often used in case studies that are considered similar enough. 5S is an original Japanese method for improving and has existed for many decades now. Often 5S is considered together with other methodologies such as communication improvements. In the case of Ganzeboom, 5S is interesting to look at, as it meets the demand of a low investment with fast effectiveness. WMS is the following

topic discussed in the literature review and has many forms that are varying in feasibility and effectiveness. RFID is mentioned relatively much in the literature. This technology is considered to be quite time consuming to fit in and often needs a third party to help. For this reason mentioned, this method will not be chosen to continue with. The other technologies mentioned in WMS also fall outside the feasibility. Chapter 3 continues with the BPM to identify mistakes that can happen in the processes of Ganzeboom.

3. Current situation

3.1. Manual entries

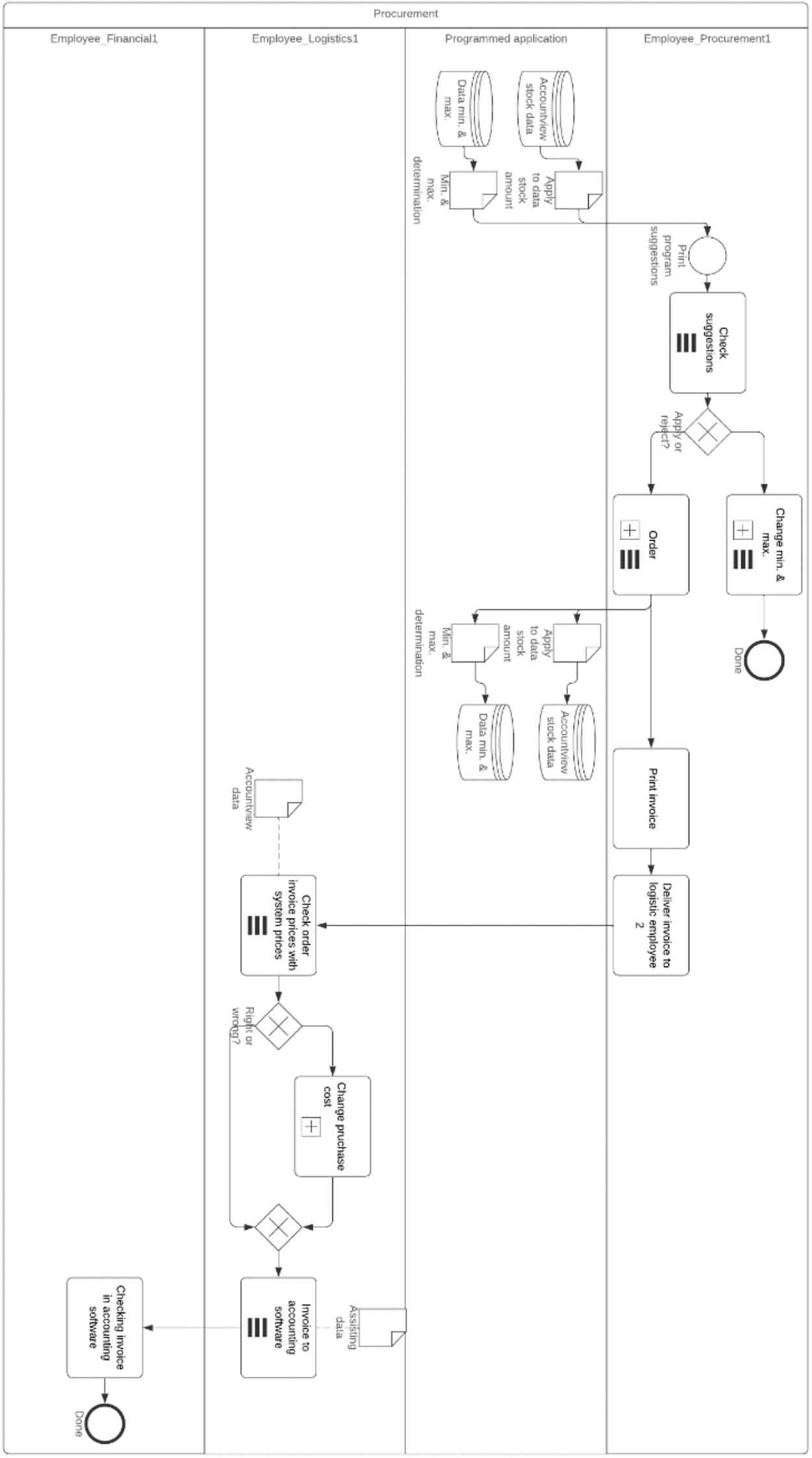
To understand where manual entries come from in a small medium-sized enterprise, the processes in the company should be determined by the research. The manual entries data from January till April are obtained through the financial business software used at Ganzeboom. The dates of manual entries in the data set obtained are not on their actual day of change but are scheduled on 'journal' days. This information is used for statistical analysis in chapter 4 of this research.

3.2. Processes

From the following subprocesses, a BPMN model can be made. This BPMN is a visualization tool of processes as they are now and can be used to bring awareness to employees, but most importantly in this case, provides this research a basis to continue with Chapter 4. The different processes at Ganzeboom are procurement, receiving, sales, and picking. These processes together form the company and are interconnected to deliver gearbox(parts) to customers. A webshop, physical sales, and calls, are used to get customers to buy at Ganzeboom. The involvement of activities in these three things are together called sales. Without sales, there would be no business. In order to fulfil a customer demand, they require it at their warehouse. The procurement process makes sure that items are in the warehouse, how many of what sort of item is one of the activities in the procurement process. Receiving of items are needed in a secure way, monitoring everything that comes in is a key activity in the receiving of items. This receiving of items can only be done if there are items coming in the warehouse through procurement. Picking items is the process after items are received in the warehouse, and the sales process has given a task to get the customer demand.

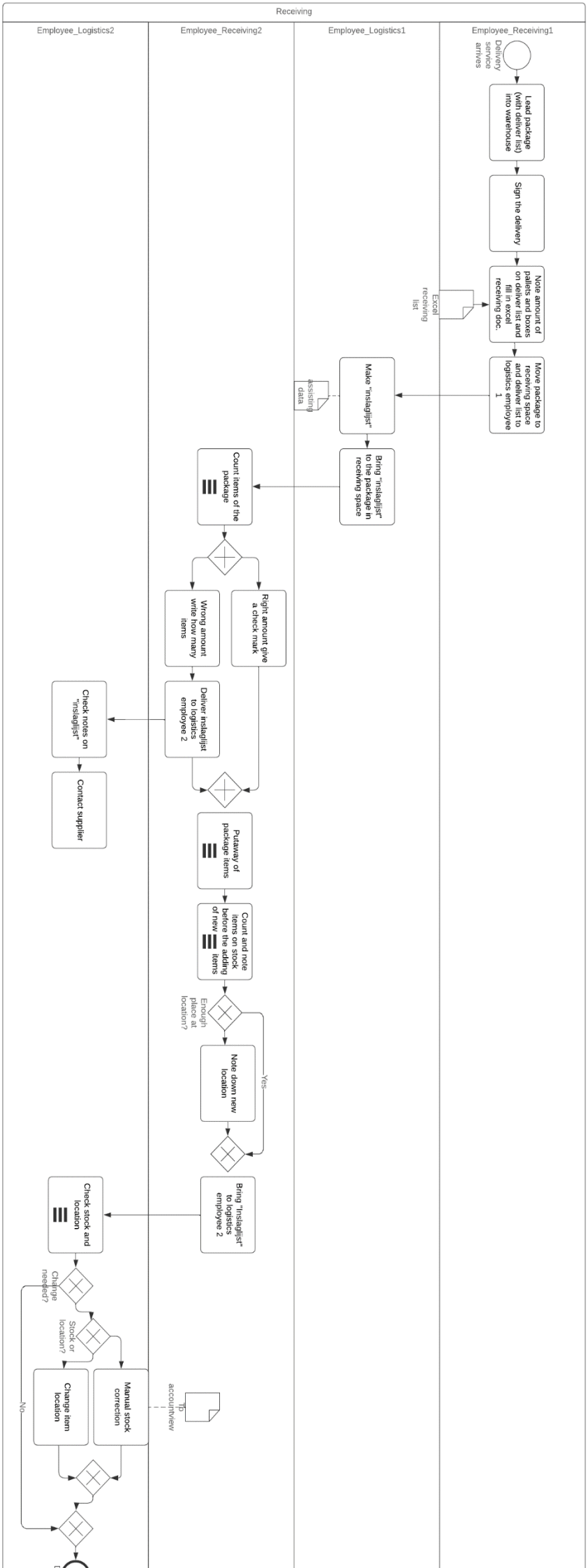
3.2.1. Procurement

The procurement process can be described in the following way, also see appendix. Procurement has one alternative route that is taken whenever the suggestions made by a program are not suitable according to the procurement employee. The procurement process has no direct influence on the manual entries. For further research in the company, it could be interesting to look at automatization within this process. No further research on the effect of procurement on manual corrections can be done in this case.


Procurement
Employee_Financial1
Employee_Logistics1
Programmed application
Employee_Procurement1
Data min. & max.
Accountview stock data
Min. & max. determination
Apply to data stock amount
Print program suggestions
Check suggestions
Apply or reject?
Order
Change min. & max.
Done
Print invoice
Deliver invoice to logistic employee 2
Accountview data
Check order invoice prices with system prices
Right or wrong?
Change pruchase cost
Invoice to accounting software
Assisting data
Checking invoice in accounting software
Done

3.2.2. Receiving

The receiving process contains two alternative routes. In the counting of items by the second receiving employee it can be the case that the number of items does not match the number of items on the delivery list. The second logistics employee normally checks the stock and location without changing anything, however, when this does not match the data in the system, this needs to be adapted. The receiving process currently signs the delivery in all cases. For further research on the effectiveness of operations, this can be tackled. Manual stock corrections are at the end of this process, the influence on the need for manual stock corrections in this process can come from multiple activities: the counting of items of the delivery incorrectly by the employee receiving 2, the communication with employee logistics 2 incorrectly due to incorrect writing or speaking, put away of items incorrectly by the employee receiving 2, counting of items on stock incorrectly by employee receiving 2, noting down new location incorrectly by employee receiving 2, and again the communication with employee logistics 2 incorrectly by employee receiving 2 due to incorrect writing or speaking. All those possible causes for manual corrections are assessed in Chapter 4.


Receiving
Employee_Logistics2
Employee_Receiving2
Employee_Logistics1
Employee_Receiving1
Delivery service arrives
Lead package (with deliver list) into warehouse
Sign the delivery
Note amount of pallets and boxes on deliver list and fill in excel receiving doc.
Excel receiving list
Move package to receiving space and deliver list to logistics employee 1
Make "insiagljist"
assisting data
Bring "insiagljist" to the package in receiving space
Count items of the package
Wrong amount write how many items
Right amount give a check mark
Deliver insiagljist to logistics employee 2
Check notes on "insiagljist"
Contact supplier
Putaway of package items
Count and note items on stock before the adding of new items
Enough place at location?
Yes
Note down new location
Bring "insiagljist" to logistics employee 2
Check stock and location
Change needed?
Stock or location?
Change item location
Manual stock correction
To accountview
No

3.2.3. Sales

In the sales process, the number of manual stock corrections can be influenced by physical sales. Most often the company makes sales via the web shop of Ganzeboom, whereafter the picking process is conducted. Visits by customers are the other sales. The not sold parts of those physical sales are often left behind in all sorts of places. When those parts are not returned soon, or the cycle time of a part is high, an error in the count of the items in the warehouse is obvious. This influence on manual stock corrections is assessed in Chapter 4.

3.2.4. Picking

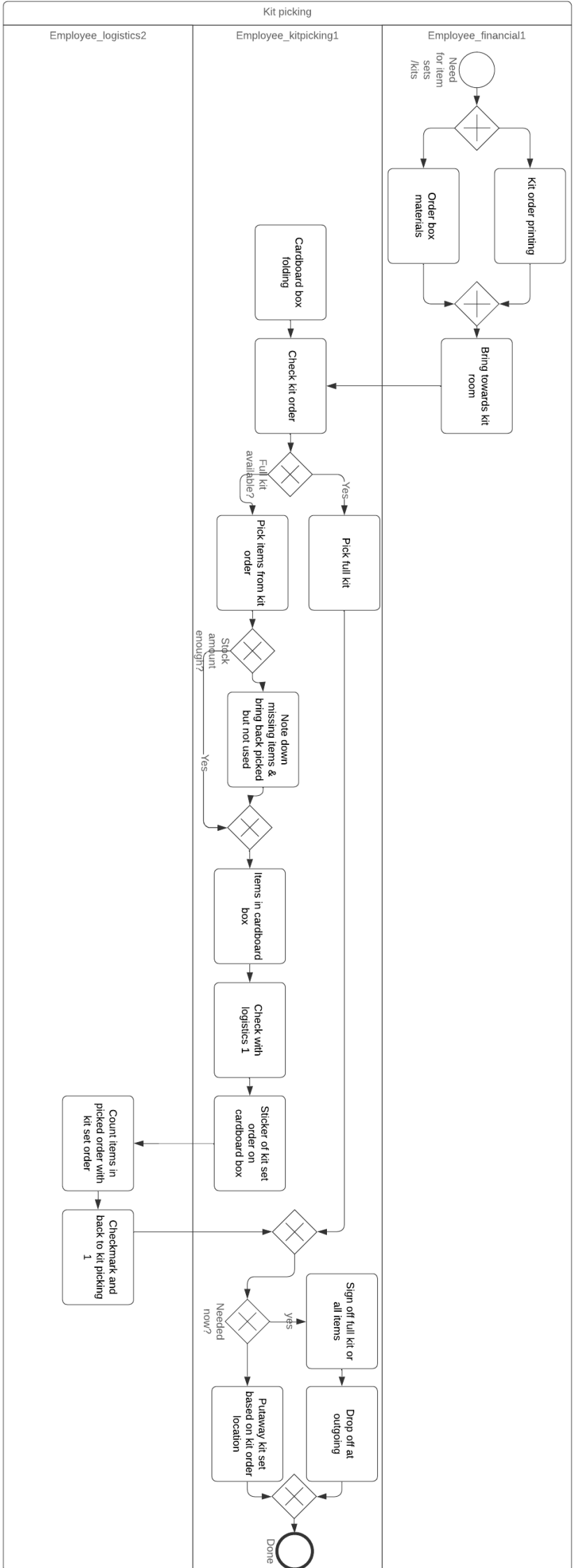
Picking can be divided into kit sets and normal orders. Kit sets are an assembly of parts that are often bought together. Kit orders can come from customers, but also from the procurement employee, who sees the necessity to produce a certain amount of kits. Normal orders are considered whenever no kit is involved and the order comes from customers.

'Normal'

Normal picking orders do not influence manual stock corrections. The exception to this is that it can be the case that the same item is handled in different operations or by different employees. E.g. the moving of item a due to a picking order while the counting of receiving process of item a is taking place. The error occurs when item A is not yet processed in the system and the counting is communicated earlier to logistics employee 2 then the communicating of completion of picking order to logistics employee 2. The impact of this influence is discussed in Chapter 4.

Kit sets

Kit sets are a growing sector within the company and can contain 1 different pathway. This pathway occurs when items are picked by the kit-picking employee and are not present in the warehouse. Normally the kits are picked based on the items that should be available in the warehouse. Due to the discrepancy researched in this thesis, this may not always be the case. The influence of the manual stock corrections in this process is by kit orders from customers. Employee kit-picking 1 can fulfil the order from customers by choosing to pick the items necessary for the kit completion or to fulfil the order from customers by choosing to pick an already completed kit that was made during an order from procurement to make kits. The influence comes from the employee kit-picking 1 giving the system the wrong fulfilment. The employee may have gotten an already-made kit while saying to the system that the items were picked for kit completion. This situation, or the opposite, is assessed on impact in Chapter 4.


Kit picking
Employee_logistics2
Employee_kitpicking1
Employee_financial1
Need for item sets /kits
Order box materials
Kit order printing
Bring towards kit room
Cardboard box folding
Check kit order
Full kit available?
Yes
Pick items from kit order
Pick full kit
Stock amount enough?
Note down missing items & bring back picked but not used
Yes
Items in cardboard box
Check with logistics 1
Sticker of kit set order on cardboard box
Count items in picked order with kit set order
Checkmark and back to kit picking 1
Needed now?
yes
Sign off full kit or all items
Drop off at outgoing
Putaway kit set based on kit order location
Done

3.3. Conclusion

The manual stock corrections are either made at the end of the processes of receiving or the picking of items is not possible. The influences on these manual stock corrections are not found in the procurement process and not in picking normal orders. The influence comes from the receiving process, as well as the kit-picking process. The impact of these influences is discussed in the next chapter. Furthermore, in the discussion, the possibility of researching other inefficiencies found in the mapping out of processes is discussed.

4. Blockades, inefficiencies, and bottlenecks

4.1. Manual entries data analysis

Ganzeboom works with a third party financial business software. Procurement and sales data are all in that system. This data creates new data, such as stock level. The stock level data can contain errors that are discovered when counting stock levels during the put-away process discussed in the previous chapter. Data gathered is from the calendar year 2024 January till begin April. The data is straight from the business software extracted to the application of Excel. The usability of this data is limited by the length of the period tracking the data.

Manual corrections, of the errors discovered, sections 3.2.2 and 3.2.4, are done in the financial business software. These manual entries are done in a separate list in the system and can be extracted to use for data analysis. The data set contains the attributes article, article description, amount added or detracted, invoice number, location, and date of input. The data is, after getting obtained, screened on the attributes. The screening consists of looking at extreme values within the data set. For example, the attribute of the date of input is set against the number of corrections and is then used for calculating corrections per period. The results of this attribute are shown down below.

4.1.1. Date of input

Figure 3 represents the number of corrections made on each journaling day. To utilize this data effectively, it is necessary to consider the intervals between journaling days, thereby enabling the calculation of relative values rather than absolute values, for which a visualisation is given in figure 4.

Rijlabels	Aantal van Artikel
⊟ jan	584
⊞ 2-jan	222
⊞ 12-jan	95
⊞ 15-jan	267
⊟ feb	372
⊞ 5-feb	214
⊞ 19-feb	158
⊟ mrt	561
⊞ 1-mrt	81
⊞ 4-mrt	332
⊞ 25-mrt	148
⊟ apr	277
⊞ 2-apr	277
Eindtotaal	1794

Figure 3 Date of Input and Number of Corrections

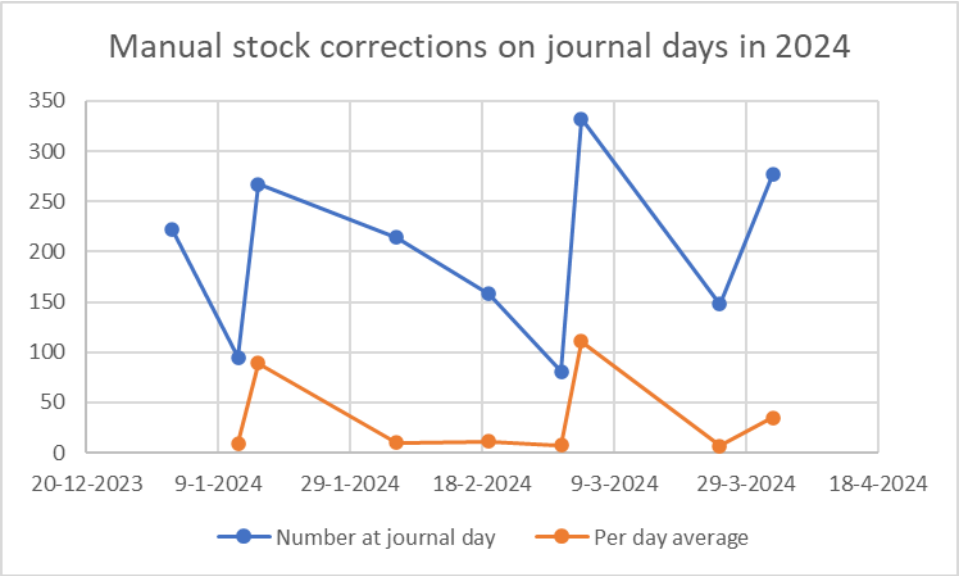


Figure 4 Visualisation of Input and Number of Corrections

By normalizing the data to a per-day average, visual analysis suggests a negative correlation between the number of days between journaling and the number of corrections made, shows figure 5.

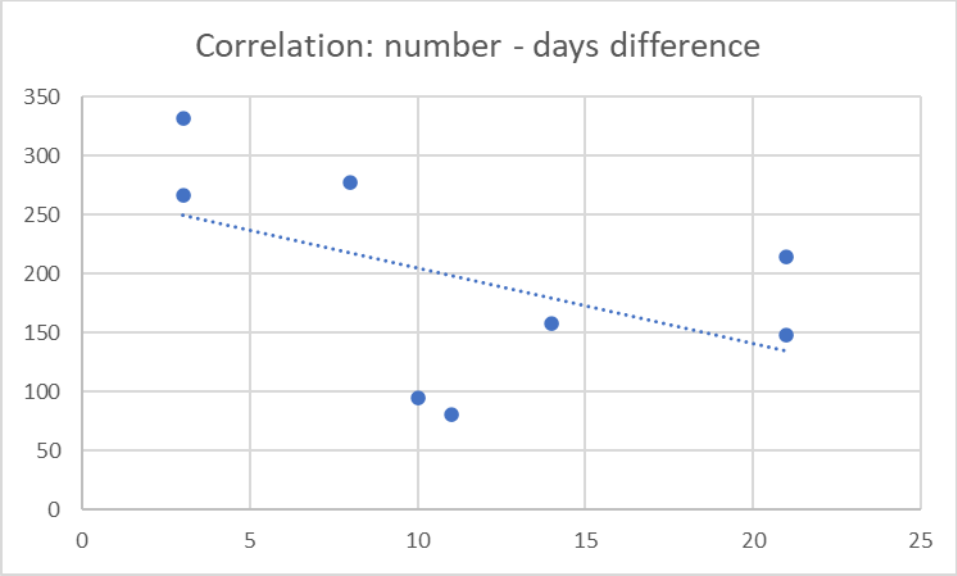


Figure 5 Correlation between Number and Days Difference

The computed correlation coefficient between the interval of days between journaling and the quantity of manual corrections is approximately -0.5, indicating a weak negative correlation. The underlying reasons for this correlation and potential strategies to mitigate it are not immediately clear.

4.1.2. Location

For three other attributes a descriptive analysis is applicable, the location of the item, article, and article description. Those results are shown in the tables 3, 4 and 5.

Table 3 Location attribute statistics from the correction data

Location attribute	
Gemiddelde	1,566812
Standaardfout	0,050686
Mediaan	1
Modus	1
Standaarddeviatie	1,715096
Steekproefvariantie	2,941555
Kurtosis	274,8895
Scheefheid	14,05865
Bereik	39
Minimum	1
Maximum	40
Som	1794
Aantal	1145
Betrouwbaarheidsniveau(95,0%)	0,099447

For manual corrections with regards to the location of articles in the warehouse, the confidence interval for the number of corrections per location would mean that every location that has 2 or more corrections would be considered as an extreme value. There are 10 locations in the data that have more than 5 corrections. Those locations are Hal (40), L-ZK (28), X-VLR (17), ONB (9), RK3 (7), L-ZG (7), RK2 (7), YD-B4 (6), XD-E5 (6), RN1 (6).

The locations named here can almost all be used to help explain possible impacts, such as human error in stock counting, not booking items, etc. Those impacts are discussed in 3.2 & 3.3.

The location of Hal, with its highest amount of manual corrections, indicates the influence of a factor that makes this number high. The number can be explained with the knowledge that Ganzeboom Revisie is mostly in need of articles that are located in location Hal. Also, the fact that this location contains the most space of the locations can influence this number, just as the factor of overloaded space in this location plays a part in this number.

X-VLR is also one of the bigger locations in the warehouse and besides that also chaotic. The location visibility of products is due to this chaos low and not sustainable for accurate stock levels regarding counting items.

Location ONB stands for location unknown, in Dutch *onbekend*. The articles in this location are miscellaneous items and are not used often at the company for sale. It contains items such as hand gel and crates. Locations with similar situations are possibly not influenceable, those locations make up around 7,5% of corrections.

XD-E5 is a location where there are not any direct indicators as to why the number of manual corrections could be that high. The location is one of many other locations that is a rack with the same space. The property of this location is its height, which can influence its impact. But also recent placement changes can influence the impact on corrections.

For each of the locations that stand out due to visibility, near the Ganzeboom Revisie work floor, or unknown places, the manual corrections data can be described using the maximum impact percentage, as seen in 3.2.2.

4.1.3. Article and article descriptive

In the manual corrections, it can be seen that articles are being changed multiple times in a journalling day, often compensating for the previous correction. E.g. the article named 7252720537, has been added 8 times to the data stock and subtracted 8 times as well on the same journalling day. To classify such cases, from now on we use the term CorrectionA. Another form of manual corrections that spring out, is the number of times an article is corrected multiple times with a relatively big number of articles added or subtracted. E.g. article 50260BW, when corrected, this article has values added or subtracted from -10 to 90. This indicates that the article is probably small and not countable for employees due to high time consumption. This can now be considered as CorrectionB.

CorrectionA is conducted with the same journalling date, for good measures, it is also calculated for any return of products, including different journalling days. CorrectionB, the relatively large numbers of a certain article, is evaluated with numbers more than 10. From the articles that are corrected 4 or more times, CorrectionA happens 18,4% of the time. CorrectionB happens 28,9% of the time. From all corrections, CorrectionA happens 2,7% of the time. CorrectionB happens 6,1% of the time, see the overview in table 6.

Table 4 Article attribute statistics from the correction data

Article attribute	
Gemiddelde	1,153698
Standaardfout	0,011476
Mediaan	1
Modus	1
Standaarddeviatie	0,452553
Steekproefvariantie	0,204805
Kurtosis	14,69858
Scheefheid	3,521818
Bereik	4
Minimum	1
Maximum	5
Som	1794
Aantal	1555
Betrouwbaarheidsniveau(95,0%)	0,022511

Table 5 Article description attribute statistics from the correction data

Article desc. Attribute	
Gemiddelde	1,220408
Standaardfout	0,017909
Mediaan	1
Modus	1
Standaarddeviatie	0,686636
Steekproefvariantie	0,471469
Kurtosis	153,4444
Scheefheid	8,819179
Bereik	15
Minimum	1
Maximum	16
Som	1794
Aantal	1470
Betrouwbaarheidsniveau(95,0%)	0,03513

Table 6 CorrectionA & CorrectionB occurrences in ***absolute*** and relative numbers

	CorrectionA (same journal day)	CorrectionA (different journal days included	CorrectionB (<-10,>10)	CorrectionB (<-5,>5)
Amount (>1 corrections))	*48*	*144*	*110*	*223*
Percentage	**2,7**	**8,0**	**6,1**	**12,4**
Amount (>3 corrections)	*7*	*14*	*11*	*13*
Percentage	**18,4**	**36,8**	**28,9**	**34,2**

4.1.4. Kit-picking

With data from which articles have a history in kits, the data from manual corrections can be compared. Articles that have been used in kits make up 25,8% of the articles that are manually corrected. This percentage is the maximum explainability of manual stock corrections, as those articles are also in some cases used as a single product. This differs from each product and cannot be assessed with data from the internal system.

4.1.5. Conclusion

The results indicate a few outliers in the date of input. The manual corrections are weak and negatively correlated with the amount of difference in days. Furthermore, the location of articles in the warehouse is due to the differences in size and reachability & visibility determining how many manual corrections. In section 4.2 this is approached. Article and corrections analysis gives insight into the impact of certain process mistakes. In 4.2 and 4.3 this will be discussed more on.

4.2. Impact according to data

4.2.1. Influence of processes

From the processes described, the procurement process does not contain any influence on manual stock corrections. This was both observed and mentioned by the management. The receiving, picking, and sales processes all have an impact on the manual stock corrections.

4.2.2. Impact of activities

The possibility that counting goes wrong within the receiving process, is soon to be restored by a new count. The CorrectionA, mentioned in 4.1, must be the case if this happens. Either on the same journal day, if the cycle time is fast, and thus is counted again fast, or on other journal days if the cycle time is slower. The statistics show that within all the corrections in the data 8,0% of the time it happens that the same number positive and negative is manually entered in the system. This percentage can be inflated by other factors than only wrong counting, such as the article being handled in other processes than receiving, like physical sales or picking. It is unlikely for an article being handled in other processes due to the consistent delivery times for receiving and consistent outbound times for shipping. The picking and receiving processes are thus not likely to be simultaneously acted upon.

The case of CorrectionB happens 12,4% of the time. These correction cases possibly come from smaller objects. Boxes full of small rubber pieces are not uncommon in the warehouse of Ganzeboom. Those parts are not countable at all by the employees. Whenever there tends to be too much to count, an estimate is usually made. The estimate can differ from the data stock amount, if the difference is big enough according to the logistics employee 2, see Chapter 3, then this leads to this change. Other possibilities for CorrectionB are rare, such as a name change of product.

Now only 20.4% maximal can be described. Adding the location attribute to this discussion, the percentages that explain the manual corrections are a bit higher. Three types of influence that location can have on the manual corrections are Revisie, visibility, and other. The Revisie part of Ganzeboom usually takes items from location Hal. Visibility can be identified as the reason for administrative errors and warehouse errors.

A maximum of 53.3% of the total percentage of corrections can be explained from retrieved data from the IT system, including 25.8% kit-picking. This is shown in the following treemap graph, figure 6.

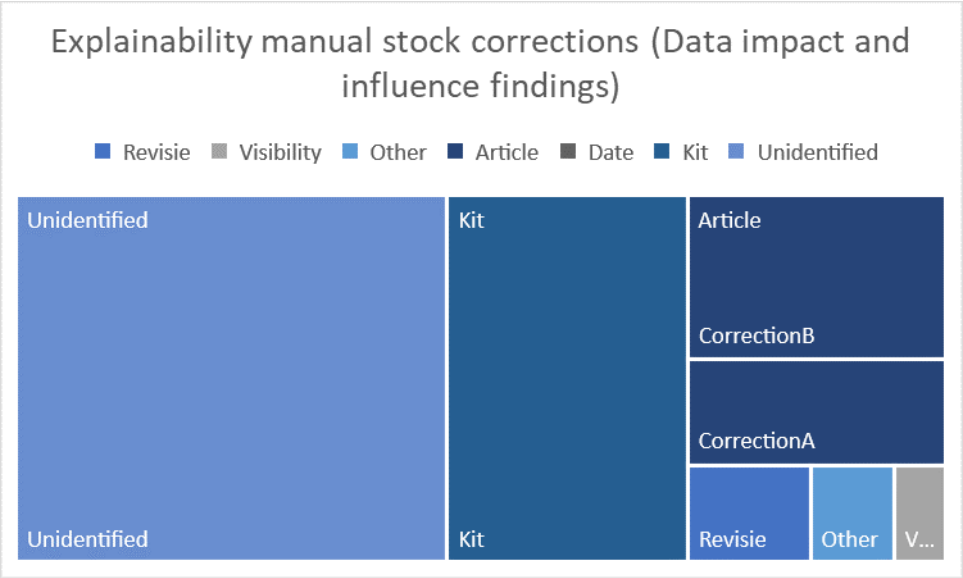


Figure 6 Relative impact on the manual corrections according to the data analysis

4.3. Impact according to literature and interviews/observations

4.3.1. Kit-picking

Problems that cannot be researched easily with the help of the dataset, are for example kit-picking's impact on the corrections. The influence of this factor was given by the management in an interview. The kit-picking process, described in 3.2.4, causes the system to note down the kit items, while a whole kit is taken from the warehouse instead of the items. This happens, according to the interview, more often now than it did in the past. According to Caputo et al. (2015): “preparing a kit involves a number of time consuming and error-prone tasks” and “kit preparation may be a physically stressful work, owing to repetitive movements, and this increases likelihood of errors” (Christmansoon et al., 2002). Ganzeboom has increased the types of kits for customers to choose from and is working to exploit this possibility. The growth has led to an increase in manual stock corrections. Best et al. (2022) mention that there is a positive correlation between the IRI (inventory record inaccuracies) and case packs. Case packs in this study are the equivalent of kits. The study simulated the effect of such case packs on inventory discrepancies. Not only the inventory discrepancies were positively influenced ‘highly significant’ (Best et al., 2022), but also the misplacement with the presence of case packs is more likely to happen than with single items. This leads to the next assessment of problems.

4.3.2. Receiving process: misplacement

In receiving, the location of the article is given on the *inslaglijst*. The racks of the warehouse at Ganzeboom are labelled. The shelves are indicated with a thin bar. As the study of Best et al. (2022) found, the misplacement of items can have a great impact on inventory record inaccuracies. Not only kits but also single articles are prone to misplacement errors that prove to impact discrepancies. In the case of Ganzeboom, this error does seem to be less of a problem than it could be. Misplacement happens in over-stacked shelves mostly, as assumed from observations in the warehouse. Reducing over-stacked shelves would be a logical step to reducing this impact (Bixler & Honhon, 2021).

4.3.3. Receiving process: communication

As discussed in section 3.2.2, the communication between the receiving employee 2 and the logistics employee 2 is of importance. The influence of communication on manual stock corrections is present according to interviews and observation. The influence of communication is not easily determined by research, as no clear number can be given by interviewing. However, by observing the workflows in

the warehouse and the accounting office, communication can be improved. With communication, not only verbal communication is meant to be addressed but also written communication is meant. Verbal and written communication e.g. writing errors, jargon, speaking in a hurry, etc., or lack of communication between employees causes errors (Chan et al., 2017).

4.3.4. Ganzeboom Revisie & Ganzeboom Parts

In interviews with employees of logistics, as well as warehouse employees, the main reason for the manual stock corrections is discussed. In an interview with warehouse employees, the main problem according to these employees is the collaboration between Ganzeboom Revisie and Ganzeboom Parts. The entities have their own separate goals and are operating on their common basis. The problem arises due to having the same workplace and intertwining activities. If the procedures are followed within the company, Ganzeboom Revisie should buy the items needed from Ganzeboom Parts. If Ganzeboom Revisie does not buy the items from Ganzeboom Parts, there is no clear overview on costs and means that customers cannot be given a consistent price for certain practices of Ganzeboom Revisie. Ganzeboom Revisie buying from Ganzeboom Parts does not always happen due to human error. Employees of Ganzeboom Revisie are required to take additional steps when purchasing these items, but a lack of motivation to complete these steps has been observed. This observation has been made as a complete observer and later confirmed by further observations as more participating researcher as suggested by Saunders et al. (2019).

The warehouse employees estimate that the two entities their inseparability affects up to 75 percent of the manual corrections. As the employees of the interviews that have been conducted are those who only work for the Ganzeboom Parts business, response bias can be present. This can happen with semi-structured interviews when the topics get sensible (Saunders et al., 2019). The bias concerning the logistics employees should be less because of their higher position in which they need to address these sensible topics, but they confirm that the biggest problem is the fact that items are not always booked in the system. In addition, the logistics employees emphasised that the issue is not just that these items aren't being booked by the Ganzeboom Revisie team, but that other departments in Ganzeboom Revisie, like physical sales, also play a role in the problem.

A separation between the two entities, Ganzeboom Revisie and Parts, would resolve what is believed by employees to be the biggest problem in manual stock corrections. The Revisie part of the company does not currently care enough to resolve this problem by mentioning it. Making it easier for the Ganzeboom Revisie company to buy the products from the Parts company, will likely result in fewer manual stock corrections due to these human involvements. Enabling a system where Ganzeboom Revisie and Parts are more seperated can significantly reduce the amount of errors on the situation.

4.3.5. Impact of activity types

With the knowledge from interviews and observations, a new estimate of frequencies of manual corrections can be made. The estimate assumes that the employees of the warehouse have a response bias of the situation. The generizability of these interviews can thus be questioned, however in this case the interviews are used to interpreter and add to the observations and literature (Saunders et al., 2019). Furthermore, the employees saying the problem not being due to their faults and errors is logical, but to what extent are the observed frequencies correct?

Rekik et al. (2019) identify 5 types of inventory record inaccuracies after analysing two companies. For both companies, an estimated 8% of the corrections are due to reception errors. These errors can be fitted in Ganzeboom to the first steps in the receiving process, 3.2.2. The study also shows that in both cases around 5% of the corrections are due to damage. The chart of figure 3 can be made according to these impacts. The chart includes the impact of not booking items as most important

factor of explainability. This was based on the interviews with the warehouse employees of Ganzeboom Revisie. It is important here to stress that the percentage of cases where the not booking of items is the reason for manual stock corrections, is based on the interview data. This means that there is evidential proof for this to be true. The interview data was combined with case studies to "compensate for the weaknesses of each individual mode" (De Leeuw, 2005). Figure 7 depicts the literature findings.

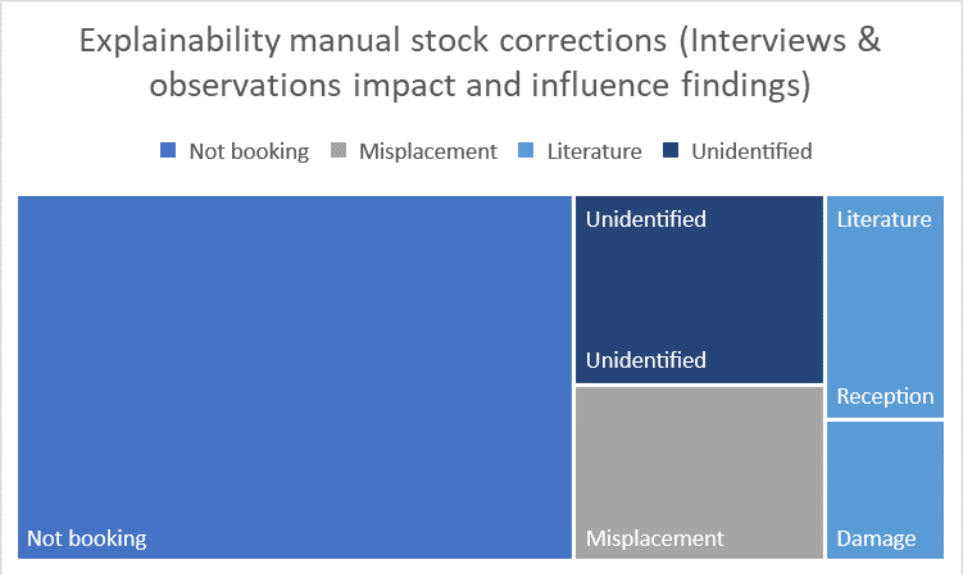


Figure 7 Relative impact on the manual corrections according to the interviews/observations and literature

4.4. Combined impact analysis

Based on the data and the literature & interviews we can create a new assumed impact on manual corrections. This combined distribution forms the basis for Chapter 5. Assumptions on these numbers are discussed with the management of Ganzeboom and are assumed to be accurate estimates according to what was discussed about validity in chapter 1.5. The validity can be questioned as this step shows unacademical measures, but as discussed in chapter 1.5, the approach of this case study cannot give more accurate numbers (Wieringa, 2014).

In 4.3 the impact of damage is assumed correctly. The case study of the two companies are showing the same percentage of occurrence for damage. The case study of Ganzeboom might be different, however a better guess than this cannot be found. From 4.2, the correctionB is assumed to be accurate. In no other ways than large quantities and small items, does it happen that the amount of inventory is corrected, therefore correctionB from the data set has to be assumed to be correct. Furthermore, it is estimated that 2,5% of the manual corrections are caused by items not for sale that are stored at locations that are mainly used for other purposes. Table 7 showcases the above mentioned percentages. The percentages that are assumed accurate, are combined 19,5%.

Table 7 manual corrections relative frequency assumed correct from 4.2 & 4.3

Manual correction type (assumed correct from 4.2 & 4.3)	**Percentage (%)**
Damage	5
CorrectionB	12
Locations Other	2,5

While kit-picking is in this case study chosen to be slightly less than the maximum impact from 3.2 Now instead of the maximum of 25,8%, the estimated impact is set to be 20%. The reason to pick a

lower number for kit-picking is that the 25,8% is the maximum frequency of causing manual corrections. Some of the other reasons, such as the not booking of items, can also be potential kit items but should not be treated as one, as the kit-picking was not the problem at first. To set the impact to 20 and not any higher or lower is in this case based on the factors of literature, the interviews, and management thoughts. This determining of the percentages is used for each of the named impacts in this case study. Not booking items is based on 46,5% not identified in the data, while 60% has been estimated in the other part of the estimation. Reception errors named in literature to be good for around 8% of the manual corrections, should have been reduced by previous actions suggested at Ganzeboom. Assumed here is now 4% of manual corrections still from reception. Table 8 summarises the percentages that are mentioned in this paragraph.

In addition to the enumerated causes for manual corrections, location changes are considered to be present, which are needed. These were estimated at the remaining 10% of the cases. Either too little space, or the need for change due to for example simplicity, is executed once in a while. This is based on misplacement outcomes from the interviews and observations part. The visualization of the assessed impact by combining data from literature and primary data, is shown in figure 8.

Table 8 Re-assessed impact (assumed inaccurate at 4.2 & 4.3), percentage of manual corrections

Re-assessed impact (assumed inaccurate at 4.2 & 4.3)	Percentage (%)
Kit-picking	20
Not booking items	46,5
Reception errors	4
Location change	10

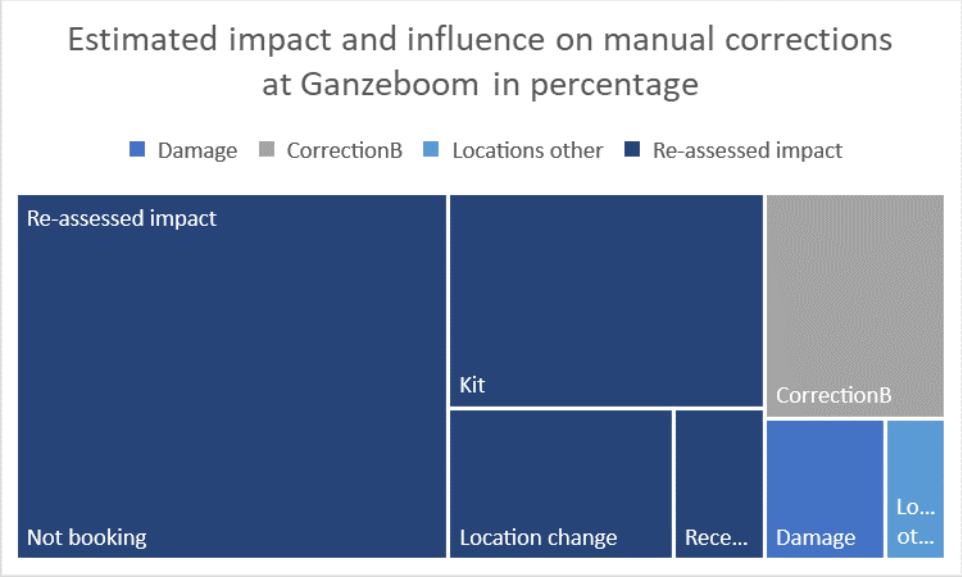


Figure 8 Relative impact on the manual corrections after combining primary and secondary data

4.5. Conclusion

To continue to tackle the main research question, we need to find ways to reduce the number of corrections by a minimum of 50%. As the efficiency of interventions will probably be less than 100%, due to warehouse operations with human errors always being discussed as improving the situation, instead of getting rid of it complete (Dewa et al., 2017). Thus we need to find options that tackle every evident cause that is stated in this chapter to achieve the goal. Evident causes for manual corrections can be regarded as not booking items, the kit-picking process, correction, reception

errors, location change, and damage. From these causes, the correctionB, reception, and damage, are not considered further in this research due to determining a threshold of cost-effectiveness. The discarding of correctionB has been decided upon due to the items being both not expensive, as well as too small and too many to count in an already full work schedule for employees. Reception errors are managed with suppliers and are not chosen for this research to delph deeper into, as it also takes up a small part. Damage was not chosen to look further into due to the smaller percentage And would not be possible to influence if a third party caused the damage.

5. Solutions

5.1. Kit-picking

Currently, 20% of the occurrences are considered to be kit-picking issues. The impact is big as highlighted in the simulation study from Best et al, 2022a, And as a growing sector, it is important to set a good basis for this growth. Accomplishing this basis can be done by starting to taking a look at the kit-picking process defined in the earlier section of 3.2.3.

When looking at the process, the possible cause of manual corrections is expanding the pack list to single items and taking a full kit. In this case, the single items are booked, but the kit is not, while this should have been the other way around. It also happens that the kit is selected, and this kit is not in inventory, so items have to be picked.

To find a proper solution to this problem, it is important to note that this problem is, just like many other cases of inventory inaccuracies, due to human error that is facilitated by improper tools/surroundings (Yamazaki, 2017). The extent to which the current tools/surroundings facilitates human error should be tackled.

Reducing human errors in the kit-picking process can be achieved by implementing a standardized procedure. Employees that are competent and working full-time at a company are most of the times aware of their standard procedure and are needed to reduce discrepancies (Chuang & Oliva, 2016). The current process gives the chance for employees to make human errors by allowing the sales to customers to choose kits or single items. With making the standard option a kit, and the employee needing to check whether there is a kit, the probability of making the error of choosing the single items drops. IT employees by the external party Ganzeboom works with can carry out the intervention of an IT system change. Cost of this IT system would depend on if the IT system can easily allow this change or not. In both cases, at least the expenses of the external party are paid. The results of this change can be seen by comparing figure 9, the current process, with figure 10.

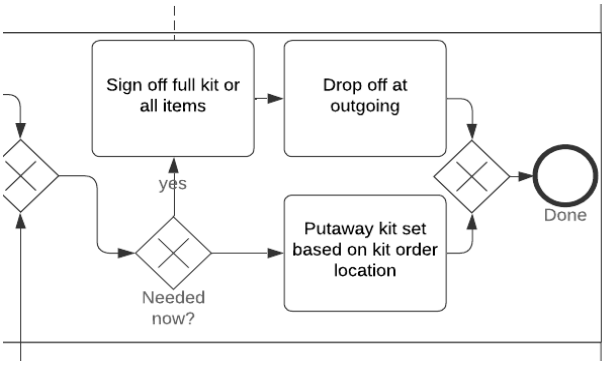


Figure 9 Current situation in the kit-picking process

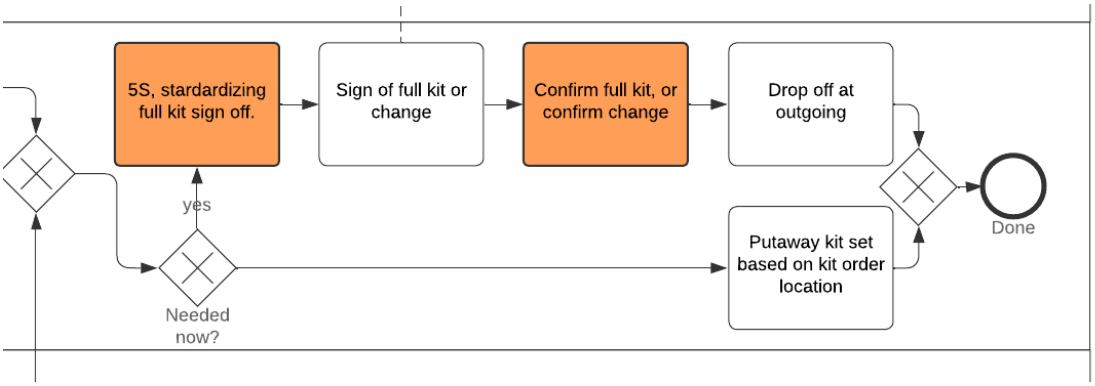


Figure 10 Suggested situation in the kit-picking process with standardizing full kit sign off

A double check on these situations currently does not help, as the single items are checked after the kit has been assembled. Then, there is no difference visible for the checking by the colleague. Having the check before there is no visible difference would be ideal, this would require a dedicated space for kit orders from customers. There is currently a location for kit orders from Ganzeboom itself, however not yet a specific location for assembly for customer orders. The lack of space in the warehouse makes it difficult to reserve a room. A reorganization of the order floor is also an option. The space in the kit-picking area for Ganzeboom is further away from the outbound than the picking area for 'normal items'. To still have the kit-picking for customers close to the outbound area, for time saving reasons, the kit-picking for customers can have its 'own block' inside the normal items picking area. A space dedicated to kit-picking for customers with kit boxes already prepared and extra room to check the items can facilitate easier work for employees and improves kitting time as well as space efficiency in the case study of Ahmed et al. (2023). This change in workfloor outlay can be cheap as only 'normal items' picking should be moved over into a smaller space. This can be done by keeping it organized and have no unnecessary materials/tools around. Also the space for kit boxes can be made with little to no expenses if the use of a cheap bin is realised.

5.2. Separation entities

Not booking items mainly stems from the situation in the warehouse where Ganzeboom Revisie and Ganzeboom Parts collaborate. Logically, those entities are working together to optimize both entities. The entities do have their own goals: Ganzeboom Revisie wants to fix gearboxes fast and reliably, while Ganzeboom Parts wants to become a big reliable business for its customers. With employees mostly having their tasks at either one of the two, separation is needed. Currently, the warehouse employees are getting asked questions if Ganzeboom Revisie employees took items from parts. Friction between the two entities is present and no separation in the current situation is also leading to manual corrections.

Improving this separation can be tried in multiple ways, such as formalizing transactions, clear roles and responsibilities, regular meetings, separating inventory locations, and standardization of processes.

This intervention would likely be costing time as well as money to hold trainings by professional third parties. It is needed to make the effort big in order to be efficient and sustaining. A separation between inventory locations would make high costs.

5.3. 5S

5.1 and 5.2 asses the two biggest impacts on the amount of manual corrections. 5S focuses on all of the impacts. For not booking items the separation must be executed in a way that is cost efficient as

well as current processes not completely being reinvented. Using 5S to solve this can work. And for the kit-picking impact, 5S is also suitable.

In the case of Ganzeboom, 5S can be used in both non-booking and kit-picking correction reductions. For not booking items, the 5S can offer the separation of entities by *sorting* items. *Sorting* items that are often used by Ganzeboom Revisie, can be *sorted* to a new place where more view on actions is present. Currently, there is not a clear sight for logistic employees or warehouse employees to check whether the Ganzeboom Revisie employees are taking items without booking. *Sorting* items that are often used by Ganzeboom Revisie employees closer to the place where items are booked in the system, could also decrease errors due to a lower threshold for employees to book items in. After *sorting* those items, also *setting* them *in order* is done. Another more radical idea of *sorting* and *setting in order*, as mentioned in 5.2 is by physical separation of the two entities. Entering or leaving in only one way rather than all over the place can give more insight for the employees that are next to this one way into booking or not booking items. The separation between the entities can also be accomplished by setting out *standardized* processes. Those processes can be fitted to booking items in the system. A possible way of doing this is by visualizing a standard process for Ganzeboom Revisie employees using BPMN. Currently, the employees know what to do and how, but are lacking in applying the steps. The visualization can be simplistic and just a reminder. Besides those steps of 5S, *sustaining* these improvements is important. By stressing the impact of manual corrections this is possible. This would be accomplished by both a briefing about the problem, as well as a poster of important information containing numbers on estimated extra work time for employees.

For kit-picking the 5S can also be used. The *sorting* and *setting in order* are already being applied in the warehouse, where certain racks are specifically containing kit items. This progress is good to *sustain* and keep up to date as the kit sector grows further. *Standardizing* the process of kit-picking is already discussed in 4.1. *Sustaining* the improvements in the kit-picking will take the most work. Mentioning *sustaining* is in this case not enough, due to this already often-mentioned growth of the sector. The kit-picking process needs to be monitored more. This monitoring can also be subject to one of the principles of 5S, namely *standardizing*.

Standardizing the monitoring of the 5S process by using the same steps constantly can save time and indirectly reduce corrections that stem from kit-picking activities. Therefore, a procedure that contains the steps that are also taken in the data analysis of this research is recommended. The procedure would be to periodically, advise every quartile, retrieve the manual correction data, as well as the kit item history data, and count the number of times that an article has been corrected manually that is also used as part of a kit. The count divided by the total amount of corrections indicates the maximal percentage of impact that the kits have on manual corrections over that period. When a sharp increase happens, further information should be gathered regarding the problem of the increase.

5.4. Communication

The above interventions cannot be executed without communication. But next to using communication to help other solutions, good communication can also be regarded as a solution in itself. The small mistakes that occur in the warehouse are usually the result of bad communication and/or no clear workspace (Bock & Fierce, 2011). These are both underlying reasons for the smaller mistakes, that add up in the long run, as assessed in chapter 4. The biggest barrier to implementing 5S is the use of communication, or better to say, the lack of communication (Singh et al., 2014). Another barrier named in this article is the lack of connection between managerial and floor employees. Dealing with these barriers in the best way possible to make a good implementation of

5S, is by continuous training (Singh et al., 2014). To ensure that the interventions, or hoped to be improvements, are making a positive difference, communication internally has to be improved.

To serve as a solution in itself, mostly the part of written communication has to be improved. In many interviews with employees, especially logistic employees, the written communication is said to be of poor quality. E.g. scratching numbers, unclear handwriting, inconsistency in place of information. To solve this problem, either digitalization is needed, or principles of 5S can once again be used. Digitalization requires an extensive switch, which can be looked at but not implemented directly. Discussed in chapter 2, WMS requires a high degree of technical expertise and can cost a lot according to Rana (2024). IoT solutions also require a lot of money as these solutions are in the hands of only a few companies (Li, 2022). 5S can help to standardize places of information for example, what we see in writing down the number of received goods as an example. Figure 11 shows the interventions for each indicated problem.

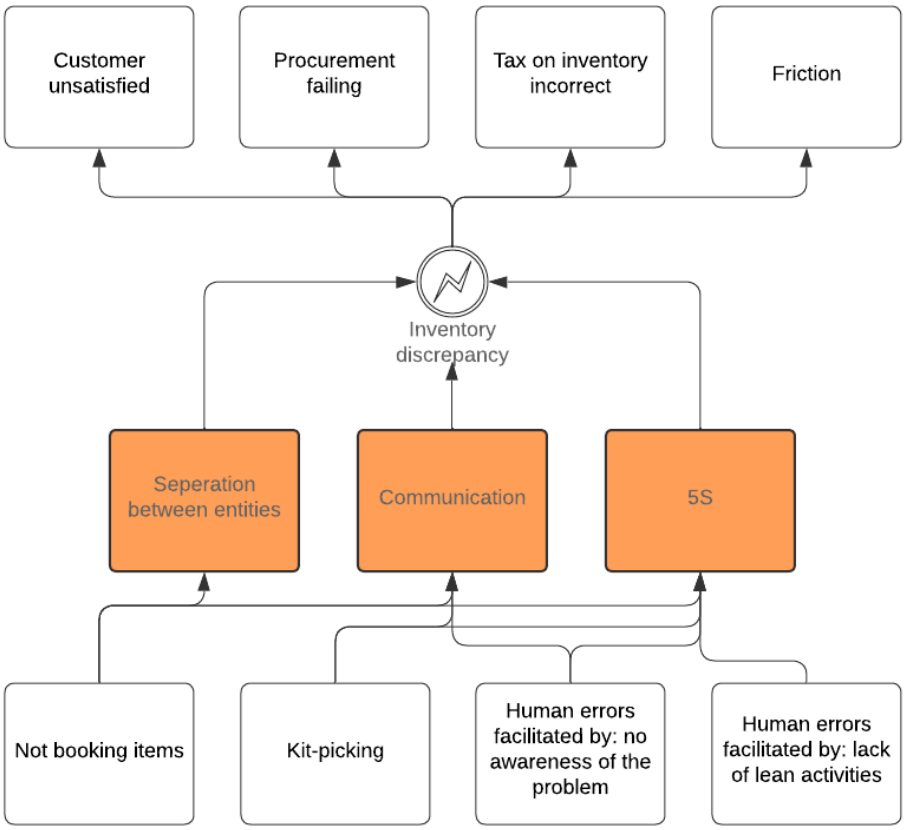


Figure 11 Solutions to the activities in receiving and kit-picking that cause inventory discrepancies at Ganzeboom

Communication improvement to facilitate the solutions mentioned in 5.1 to 5.3 is also possible. In all regards, to sustaining improvement habits, a step in 5S can be obtained by monitoring these habits. Monitoring using communication is a good way to do this. With the right setup in meetings with employees, whether it would be one-on-one, or talking to the whole floor of employees, it can help to sustain improvements. According to Wynn (2021), the trainings are needed to execute the inventory management plans at hand. White and Censlive (2013) mention that lacking knowledge of inventory systems creates mistakes. Having a goal for each communication session, such as the goal to get informed about the influence of standardizing kit-picking activities, should help in sustaining the improvements. Also, communication with the input of employees can help to reduce manual corrections. Getting input from employees can be an easy way to improve the situation, while also

the employees feel heard. To get this input, not only mention things that go wrong but also what can be done against this and why it goes wrong.

5.5. Validation

To improve the quality of this research, the validation through surveys has been used. In the survey, linear scales were used to ask the employees with different functions within the company about both the existence of the problems stated at the bottom of figure 11, and also they were asked to answer questions about the effectiveness of the proposed interventions, the orange blocks in figure 11. Saunders et al., 2019, suggestions to reduce bias by forming the questions both positively and negatively have been implemented. The results of this survey are based on averaging out the linear scales and are depicted in tables 9 and 10.

Table 9 Validation of Problems from Survey Results

Problem questioned:	**Agreeance on problem:**
Kit-picking	0
Not booking items	0
Communication	+0,5

Table 10 Validation of Interventions from Survey Results

Intervention questioned:	**Agreeance on intervention:**
Kit-picking standardizing (5S)	+1,5
Kit-picking location management (5S)	+0
Separation entities	+1
Briefings/trainings/meetings for not booking items (communication & 5S)	+1,5
Non-verbal communication; standardizing (5S)	+1,375
Verbal communication; briefings/../meetings (5S)	+1,5

Observed from these tables, the interventions are estimated to be helpful. The most significant results are standardizing of kit-picking, briefings for not booking items, and in communication improvements. All these scored an average of +1,5 out of the maximum of +2. The open questions in the survey that give room for additional feedback on the interventions give that the current interventions would need to be in more detail, while this current idea can serve as a starting point for the future plan.

Further outcomes of this survey indicate that there are still doubts in different employee and management functions about what is causing the problems at first hand. A difference in the agreeance on problems and the agreeance on interventions can be observed. The way this survey has been conducted, in combining the average of all individuals, can mean that the numbers are cancelled out by each other. This is in fact the case when looking at the individual survey results. The survey is also not significant for statistical analysis. The margins are to thin and there were too little responses due to lack of people with knowledge about all the different sections of the company. For simplicity reasons, the agreeance on interventions is taken positively. There are not any reasons to believe that employees and management would deny that standardizing, separating entities, and briefings would improve the situation. This makes the agreeance on interventions likely.

To draw definitive conclusions out of the survey is not possible due to the lack of statistical proof. Here it serves as a better understanding of what employees think of the problems and solutions at hand. Academically this survey should have received more responses in order to make definitive conclusions.

5.6. Conclusion

5S principles *sort, set in order, shine, standardize, and sustain*, can all be applied to reduce the impact of the biggest factors to manual corrections: not booking, and kit-picking. The 5S principle its main challenge, communication, is in itself a solution to the smaller factors of manual corrections. The kit-picking and separation between entities are focussed on in this chapter. Sorting, setting in order, standardizing, and sustaining, are used in the separation between entities. Kit-picking has already started with sorting and setting in order and needs standardizing and sustaining. Sustaining consists of a suggested procedure with the financial business software data and Excel. Communication as a solution is chosen mainly for written communication, in which the 5S steps are also used. The employees, and management, agree with the fact that the interventions would help in reducing inventory discrepancies. The survey conducted about these interventions has led to believe that standardizing the kit-picking process, separation between entities, and briefings can help the most. But, the linear scale questions did not significantly prove anything. It did however confirm the open question answers, where it is mentioned that these interventions worked out into detail would help.

6. Conclusion, recommendations, and discussion

6.1. Conclusion

How can Ganzeboom improve its processes to reduce its average amount of stock corrections by at least 50%?

The main research question is answered in this research by chapters 1 to 5. To improve its processes to reduce its average amount of stock corrections by at least 50%, the company of Ganzeboom has to implement the 5S methodology to the problems of not booking items, kit-picking, and communication. Not booking items as cause for corrections can be reduced by applying sorting, setting in order, standardizing, and sustaining. Kit-picking as a cause for corrections can be reduced by standardizing and sustaining. Communication as a cause for corrections can be reduced by standardizing written communication. While verbal communication improvements can reduce smaller impacts on manual stock corrections.

6.2. Recommendations

The case study at Ganzeboom was conducted to reduce average number of corrections. This study finds that 5S, in combination with separation of entities, and communication improvements will help Ganzeboom with more than 50% reducement in the average number of corrections. Further research on how the manual corrections can be reduced even more are the next step. Those would be bigger and more time consuming answer then the ones found in this case, including the named digitalizations that are part of WMS. The 5S principles are literature-based solutions to various problems and can be used in the case of Ganzeboom. The company is advised to use the 5S principles for each of the cases. Not-booking items as cause for corrections can be reduced by applying sorting, setting in order, standardizing, and sustaining. Kit-picking as a cause for corrections can be reduced by standardizing and sustaining. Furthermore, communication as the solution can be used by standardizing written communication. While communication verbally will help as a tool with the replacement proposals for both not booking items and kit-picking.

6.3. Discussion

This study focuses more on non-technological interventions compared to other literature findings on reducing manual stock corrections. Most case studies focus on the technology of RFID and WMS. RFID at smaller items in the warehouse was excluded from this case study and WMS as well. This research shows lesser known solutions for manual stock corrections, however the solutions are often used in the IEM field. This can mean that the research may have been influenced by presuppositions. Furthermore the study conducted is on the limits of being too much of a case study, where it may or may not be sufficiently academic proven. This tends to happen in more case studies, however here the basis of other case studies to give this thesis more proof was lacking. Overall, this case study can be used for other cases where digitalization options are not of preference, and the company consists of more than one entity.

6.4. Limitations

The study as it was conducted has its limitations. The manual data corrections could have been taken over a longer period to reduce the variance of the attributes measured. Now, in combination with the use of interviews and observations, literature on the frequency/impact of causes on inventory record inaccuracies is not always verifiable. The influence of two entities such as Ganzeboom Parts and Revisie is rarely discussed in the literature, in regards to inventory even near zero. This research should be an example of how such cases influence manual stock corrections and if it can be

elaborated on in further research. However, in every case, the separation of entities differs, requiring large research containing significant outcomes.

The main research purpose is to identify the influence and impact of manual stock corrections in a company with combined warehouse usage and give recommendations. The given recommendations are based on the research at this company. For external usage, this can be regarded as limited added value to the academic world. However, this case shows that combining two entities in a company on the same location may cause errors and inefficiencies. The recommendations are in line with solutions that apply to not-share warehouse usage.

Concerning other possible solutions, such as digitalization and technology, the scope of this research for the recommendations focused on cost-efficient solutions. Technology such as RFID could be a suitable option for SMEs with shared warehouse usage.

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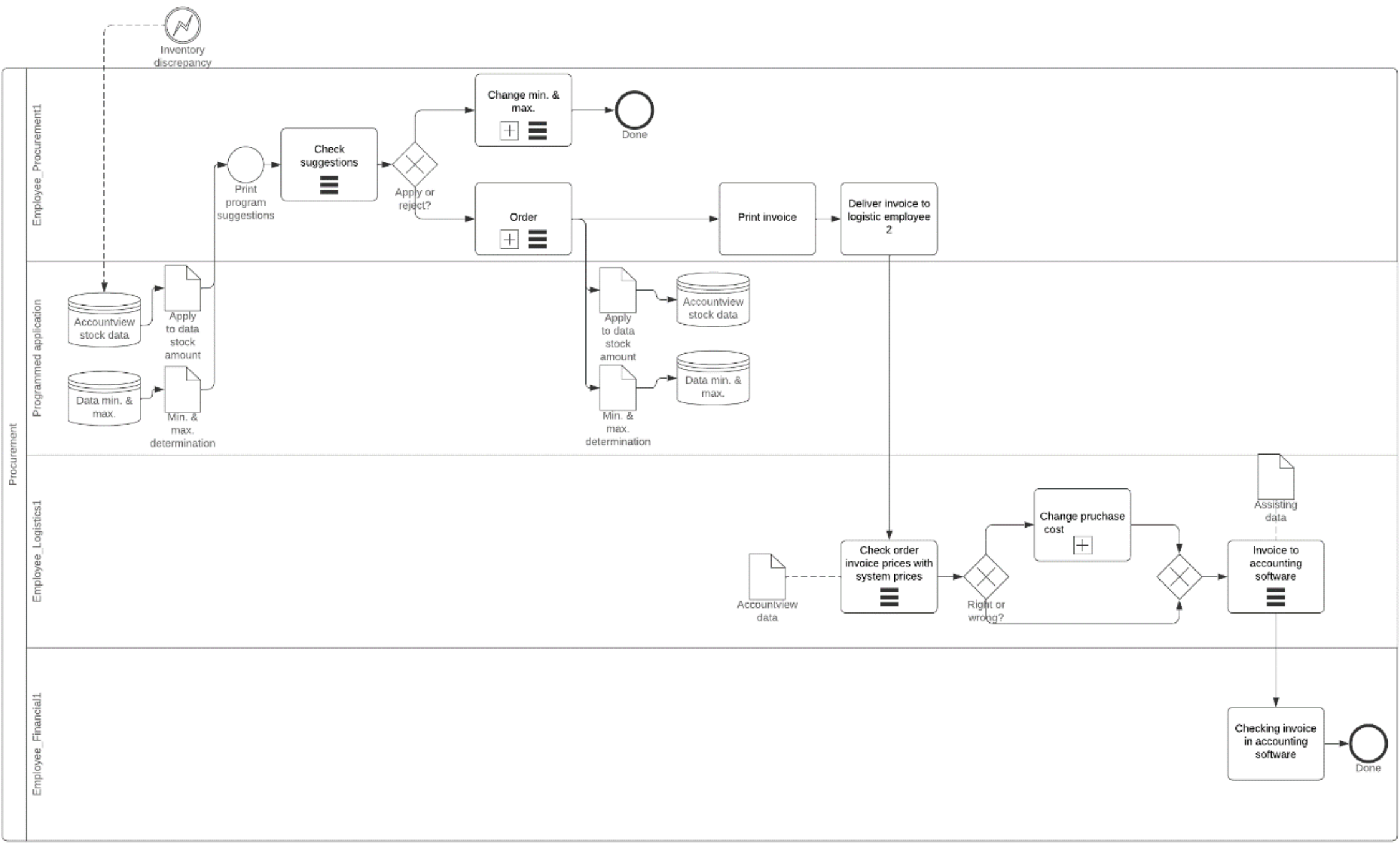
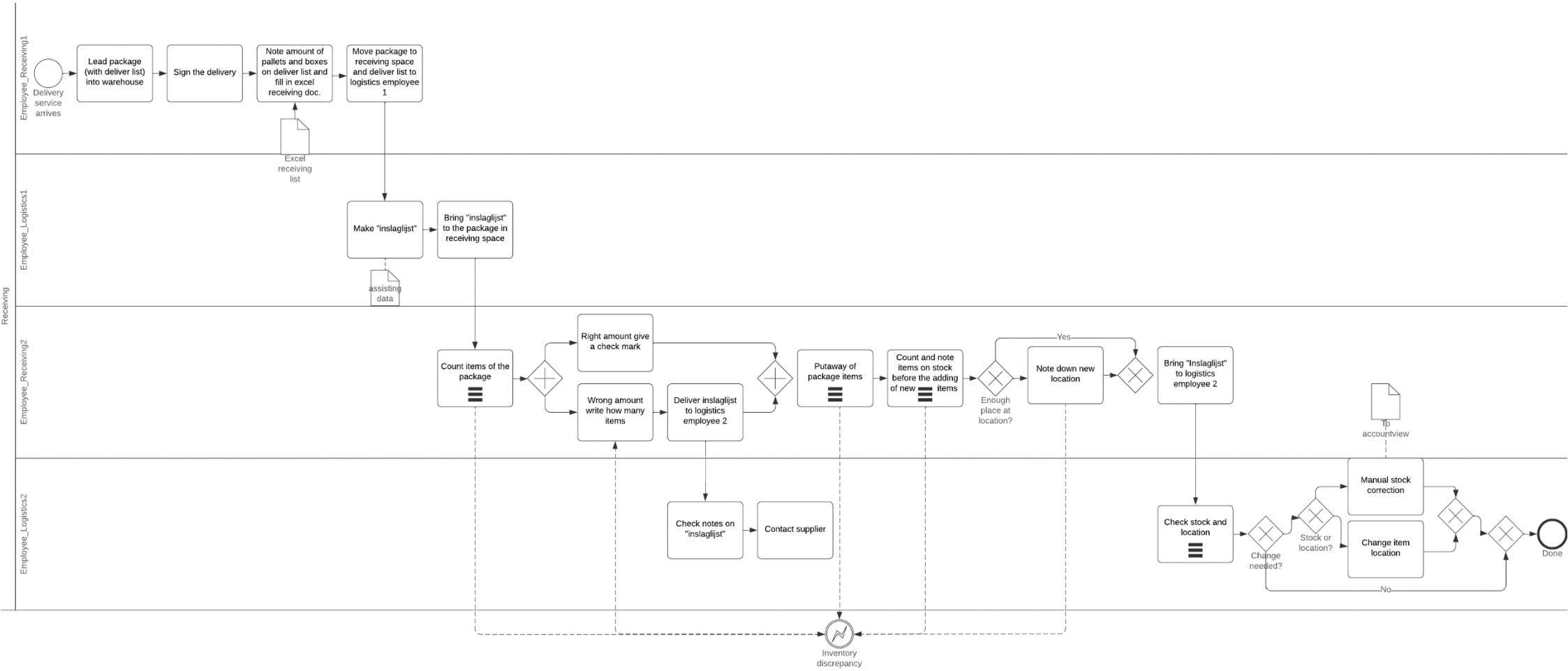
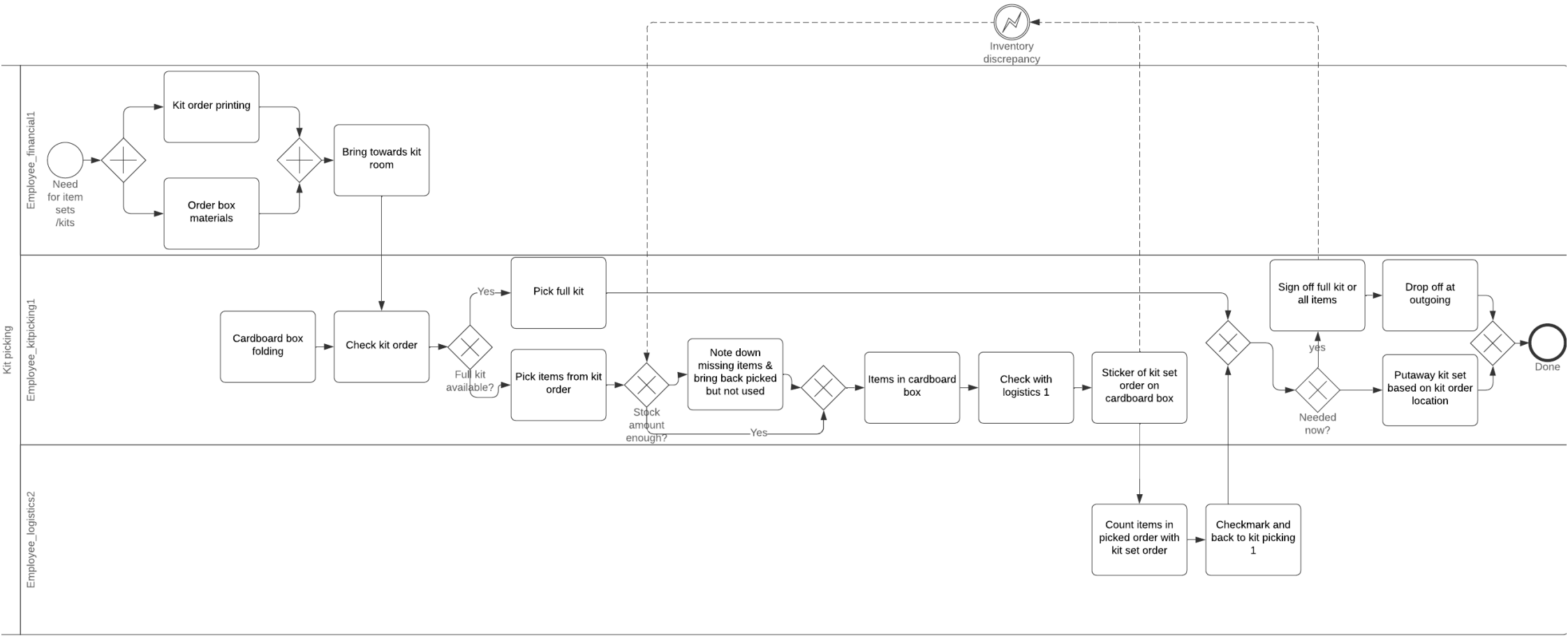
Appendix

Processes


Inventory discrepancy
Procurement
Employee_Procurement1
Change min. & max.
Done
Check suggestions
Print program suggestions
Apply or reject?
Order
Print invoice
Deliver invoice to logistic employee 2
Programmed application
Accountview stock data
Apply to data stock amount
Data min. & max.
Min. & max. determination
Apply to data stock amount
Accountview stock data
Data min. & max.
Min. & max. determination
Employee_Logistics1
Assisting data
Change pruchase cost
Accountview data
Check order invoice prices with system prices
Right or wrong?
Invoice to accounting software
Employee_Financial1
Checking invoice in accounting software
Done


Receiving
Employee_Receiving1
Delivery service arrives
Lead package (with deliver list) into warehouse
Sign the delivery
Note amount of pallets and boxes on deliver list and fill in excel receiving doc.
Move package to receiving space and deliver list to logistics employee 1
Excel receiving list
Employee_Logistics1
Make "inslaglijst"
Bring "inslaglijst" to the package in receiving space
assisting data
Employee_Receiving2
Count items of the package
Right amount give a check mark
Wrong amount write how many items
Deliver inslaglijst to logistics employee 2
Putaway of package items
Count and note items on stock before the adding of new items
Enough place at location?
Yes
Note down new location
Bring "Inslaglijst" to logistics employee 2
Tp accountview
Employee_Logistics2
Check notes on "inslaglijst"
Contact supplier
Check stock and location
Change needed?
Stock or location?
Manual stock correction
Change item location
No
Done
Inventory discrepancy


Kit picking
Employee_financial1
Employee_kitpicking1
Employee_logistics2
Inventory discrepancy
Need for item sets /kits
Kit order printing
Order box materials
Bring towards kit room
Cardboard box folding
Check kit order
Full kit available?
Yes
Pick full kit
Pick items from kit order
Stock amount enough?
Yes
Note down missing items & bring back picked but not used
Items in cardboard box
Check with logistics 1
Sticker of kit set order on cardboard box
Count items in picked order with kit set order
Checkmark and back to kit picking 1
Sign off full kit or all items
yes
Needed now?
Drop off at outgoing
Putaway kit set based on kit order location
Done