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BACHELOR ASSIGNMENT

OPTIMIZING TOOL MANAGEMENT PROCESSES AT HANKAMP GEARS

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HANKAMP GEARS

Al meer dan 100 jaar in beweging

UNIVERSITY OF TWENTE.

Acknowledgment

Dear reader,

You are about to read my bachelor's thesis "Optimizing tool management processes at Hankamp Gears" This thesis is written to conclude my study program in Industrial Engineering and Management at the University of Twente. The assignment was conducted at Hankamp Gears, a company located in Enschede. The aim of this thesis is to improve the tool management processes at Hankamp and ultimately reduce tool expenses relative to turnover.

First, I would like to thank Hankamp Gears for giving me this opportunity. I have gained a lot of knowledge from all the employees and would like to thank them for their willingness to answer all my questions and help me during my research. Additionally, I have learned a lot about the production of gears, which was very interesting. I want to thank Pim in particular, my company supervisor, for the great guidance. He was always able to answer my questions and give feedback on my progress.

I would like to thank my university supervisor, Renata, for always being available to address my research-related questions and for offering valuable research suggestions. Despite her busy schedule, she always made herself available to provide guidance and feedback. Her feedback greatly contributed to the development of the thesis and helped in the search for optimal solutions.

I hope you enjoy reading this thesis!

Kind regards,

Sieta Bon

Enschede, July 2023

Management summary

Hankamp Gears is a production company specialized in the production of gears with very high tolerances. They produce gears in all shapes and sizes, requiring the use of several different tools. The company faces problems regarding the high tool expenses relative to the turnover. Over the past four years, this percentage has remained around 7.63%. The objective of this research is to optimize the purchasing processes for tools, with the objective of minimizing tool expenses. This problem is translated into the following main research question:

What are the optimal business processes that impact tool management for Hankamp Gears?

First, a literature review that provides an overview of process optimization techniques is conducted. The methodologies of Business Process Management, Lean Management, and Six Sigma are further elaborated upon. Additionally, inventory management strategies are explained, along with techniques for implementing solutions. These findings form the theoretical framework for this research.

Next, the current situation at Hankamp Gears is assessed. The purchasing processes and inventory management are examined, leading to the identification of several bottlenecks. These bottlenecks include problems related to internal orders, lack of structure, absence of an inventory management policy, many different suppliers, no contractual agreements, and a lack of organization in tool storage.

Once the bottlenecks are identified, the solution design phase begins, focusing on finding solutions to these problems. Research is conducted on employees, information systems, and suppliers to improve the purchasing processes. Regarding inventory management, research is done on storage locations, inventory management systems, and specific article numbers. This solution design phase results in a list of potential solutions, which are ranked based on their importance in terms of improvement and required effort. This information is gathered through interviews with the management of Hankamp. The desired solutions are those that offer the greatest improvement with the least amount of effort. The ranked solutions are as follows:

1. Specify roles and responsibilities.
2. Establish contractual agreements with suppliers.
3. Digitize internal orders.
4. Ensure clear storage locations and traceability of tools.
5. Enhance employees' tool knowledge.
6. Implement a combined automatic ordering system.
7. Implement an inventory management system.

In the solution results phase, the expected changes in performance indicators after implementing the solutions are predicted. Additionally, a goal model is created to determine the changes necessary to achieve specific goals. This provides a comprehensive overview of how the solutions will impact the current performance.

To implement the solutions smoothly, several steps need to be taken, including defining goals, conducting research, mapping out risks, scheduling milestones, assigning tasks, and allocating resources. Change management is also important during this transition, involving planning, implementation, and monitoring of changes to minimize disruptions. The ADKAR model is used to implement these changes smoothly.

Based on the research findings, the following recommendations are suggested for Hankamp:

- Hold a meeting to specify roles and responsibilities among employees.
- Discuss contractual agreements with suppliers.
- Digitize internal orders.
- Organize storage locations and implement traceability for tools, ensuring that tools are not left lying around and ensure that for shared tools, the latest user is recorded.
- Provide internal or external training on tool selection for employees.
- Investigate suppliers and tools that can be ordered together, and automate these orders.
- Explore the possibility of implementing an inventory management system.

Contents

List of abbreviations

- ADKAR = awareness desire knowledge ability reinforcement
- BPM = business process management
- BPMN = business process model notation
- CNC = computer numerical control
- DMAIC = define measure analyze improve control
- EDI = electronic data interchange
- EOQ = economic order quantity
- ERP = enterprise resource planning
- FMEA = failure mode effect analysis
- IM = inventory management
- IS = information system
- ISO = international organization of standardization
- JIT = just in time
- MPSM = managerial problem-solving method
- RACI responsible accountable consulted informed
- ROL = re-order level
- ROP = re-order point
- SIPOC = supplier input process output customer
- SLR = systematic literature review
- VSM = value stream mapping

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1 Introduction

This chapter provides an introduction to the research topic and outlines how the research will be conducted. Section 1.1 describes the company, Hankamp Gears. Following that, section 1.2 presents the problem description, which includes an action problem and a core problem. Section 1.3 explains the aim of this research. The problem-solving approach is detailed in section 1.4. The scope of the research is outlined in section 1.5, and section 1.6 presents the deliverables of the research. Section 1.7 introduces the research design, including the research questions and sub-questions. In section 1.8, the reliability and validity of the research are discussed. Lastly, in section 1.9 a summary of this chapter.

1.1 Company description

Hankamp Gears started in 1909 as a gear production company for watches and has now grown to one of the specialists in the field of gears with very high tolerances. Gears with tolerances up to 0.0001 mm are produced by a modern CNC machine park. CNC stands for Computer Numerical Control. Hankamp is an organization consisting of 60 employees, of which 10 comprise the management and 50 are involved in the production process. Hankamp produces gears for all types of sectors. They mainly produce for the aircraft, energy, robotics, print, and pumping industries. Gears could be ordered in small to medium batch sizes, from 1 to 1500 pieces. The gears are made in all shapes and sizes, either with straight or helical teeth, screw threads (inside and outside), worms, fuel injection systems, and match grinding.

Hankamp Gears is EN-ISO 9001:2015 and AS 9100D certified. This standard means that they use quality management systems that are standardized, measurable, and controllable. Internal and external audits are performed to keep the quality of the supplied deliverables high. Hankamp incorporates failure mode effect analysis (FMEA) as part of their work preparation phase to mitigate risks. This results in reducing the failure rate and the supply time also the price of their components will be reduced. Hankamp aims to perform at the highest level, these measurements help to keep the performance high.

The production process of Hankamp Gears varies depending on the type of gear that needs to be manufactured. Some gears are produced in only 6 steps but others are undergoing a 23 steps process and could be outsourced a few times. The production process of an average gear from Hankamp goes through several steps. These steps are in Figure 1.

Hankamp is doing most of the production process in-house. Long round metal bars are usually used as raw materials, but sometimes metal discs are used. Metal discs could go straight to the turning or milling process. Metal bars could be first sawn into discs before being processed or the bars could immediately be processed by a bar stock feeder machine.

The hardening and surface treatments are complicated processes that are outsourced to specialists in this field. This is done to guarantee high quality and tight tolerances. In some cases, the turning process is outsourced as well.

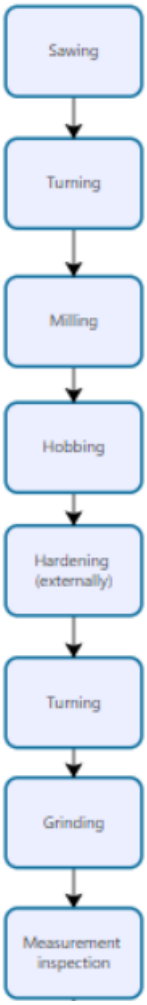

Figure 1: Production process of Hankamp Gears (Willems, 2022)

The responsibility for outsourcing these processes lies with the purchaser, including the task of purchasing raw materials and tools. Many different tools are used, like drilling tools, milling tools, and cutting plates. The tools used vary depending on the type of gear being produced. Some gears require complicated and expensive tools. Before the purchaser orders the materials, a long process containing different steps takes place. First, a job traveler is made. The job traveler contains all the steps that have to be taken in the production process to produce the correct gear. After that, the activities will be scheduled on the machines. Once the process is scheduled on the machines, the purchaser can proceed to order the materials.

1.2 Problem description

The overall purchasing process at Hankamp Gears is currently not optimal, as the purchaser has a high workload and is not working efficiently. The process lacks a structured approach and involves several different methods. As a result of the high workload and missing structure, other employees in the organization are involved in purchasing supplies as well.

Another issue in the process is not making optimal use of the information systems. Hankamp uses an ERP system and an EDI system. The ERP system Hankamp uses is called, Epicor. Epicor has many capabilities, but not all functions are actually understood and used. This results in a significant amount of manual input during the purchasing process. The current purchasing process entails a lot of paperwork and involves several employees. The two large suppliers of tools for Hankamp, supplier A and supplier B, have an EDI system in place. The EDI system works with a scanner and bar codes. After the barcode is scanned, all the product details will be seen on the computer and you can select how many of that specific tool you want to purchase. The EDI system sends the order directly to the supplier.

Currently, there is no inventory policy for tool purchases. The lead time for most tools is only a few days, but there are some exceptions. When a tool breaks and needs to be replaced. The technical specialist first checks if the tool is available in inventory. If the tool is not in inventory, he makes an order. Tools from different suppliers have different approaches to order. The tools are ordered either through a note from the technical specialist to the purchaser or through the EDI system that depends on the type of tool. Hankamp is not making use of inventory management. The tools that are in inventory are ordered randomly. The employees who work with the tools decide when to order a new tool. This has resulted in a large inventory of different tools at different places.

The process of making work orders and scheduling the job on the machines takes time. After these processes, the materials can be ordered. For some materials with long lead times, this is not a good way of purchasing because they will arrive too late.

The tool management processes lack a standardized approach, partly due to the large number of suppliers and the various methods of ordering they employ. This also makes it difficult to form contractual agreements, such as those regarding the price. While working with an EDI system is convenient, it can be challenging to implement it with all suppliers.

In summary, the problems with the process are attributed to the absence of structure and underutilization of the systems. The absence of an inventory policy leads as well to problems and the sometimes late ordering of tools and materials is also not optimal.

1.2.1 Action problem

The problem is formulated into an action problem. An action problem is a discrepancy between the norm and the reality, as perceived by the problem owner (Heerkens & van Winden, 2017, p. 22). The action problem is stated:

The tool purchasing expenses of Hankamp Gears are relatively high compared to its turnover.

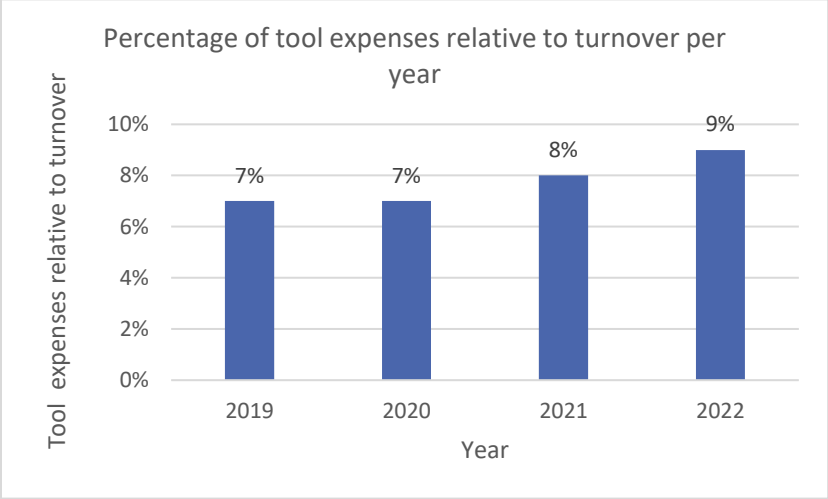

Figure 2: Percentage of tool expenses relative to turnover (n= 11185; data from 2019-2022; source: Hankamp)

In Figure 2, the percentage of tool expenses relative to the turnover per year is displayed. These percentages are high. In the last four years, around €680.000 per year was spent on tools. The high costs were the main reason to start researching the tool purchasing costs. The tools are necessary for production and must be purchased. However, the company wants to reduce the tool cost at the same time. In order to reduce costs, it is essential to focus on inventory management and the purchasing processes.

Hankamp currently has a large inventory of tools, but they want to reduce the number of tools it keeps. Having too many tools takes up space and wastes money that could be used for other purposes. However, it is also important to have some extra tools as a backup in case a tool breaks. The company needs to find the right balance between having enough extra tools and not wasting money and space on tools that are rarely used. Some tools are cheap, while others are expensive. The lead time per tool can also be different, so this is important to keep in mind when deciding how many of each tool to keep in inventory. Additionally, some tools are used more often than others, so it's important to ensure enough of those are available. By analyzing which tools are used the most and how long it takes to get each one, the company can make a plan to keep the right number of tools and use its resources efficiently. This will help to save money and make the most of the inventory space.

Improving the purchasing processes could also lead to less tool purchasing expenses. The process could be made more efficient so it will be easier to order the tools and will take less time. Researching the number of steps and the number of employees involved in the process could reduce the costs as well. The company can make more informed decisions about when and how to purchase tools. This will lead to lower tool costs without compromising production efficiency.

1.2.2 Problem cluster

Figure 3 shows the problem cluster of Hankamp Gears regarding the tool management processes. The problems are denoted as the action problem, the (potential) core problem, and as the general problems. A problem cluster is made to create more insights into the relations of the problems and to find the core problem. The action problem, the tool purchasing expenses are too high, and the consequences are shown.

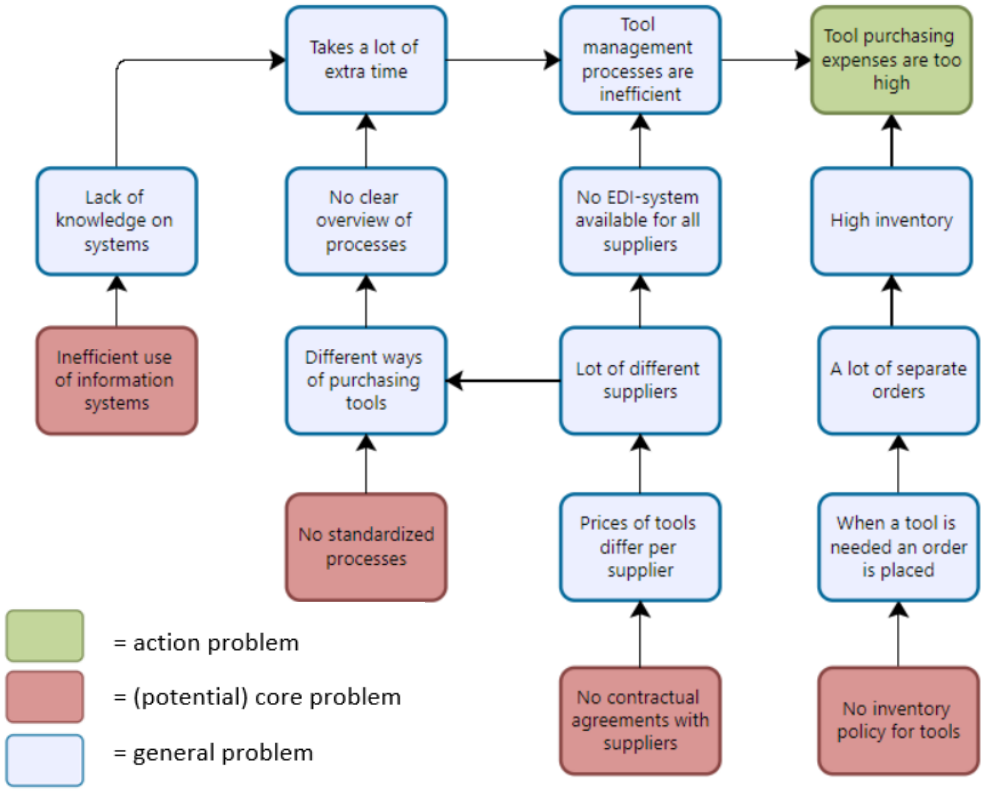

Figure 3: Problem cluster (source: Bizagi Modeler)

Four potential core problems have been identified from the problem cluster:

- Inefficient use of information systems
- No standardized processes
- No contractual agreements with suppliers
- No inventory policy for tools

1.2.3 Core problem

Potential core problems are seen in the problem cluster. To select the main core problem, four rules of thumb should be used (Heerkens & van Winden, 2017, p. 44).

- To include a problem in your problem cluster, you should be confident that the issue exists and is related to other problems. Any problems that do not meet these criteria should be excluded from the problem cluster.

- Follow the chain of problems back to their root cause because initial problems often result from other problems.
- If you have no control over something, it cannot be considered a core problem.
- If there are multiple problems in the problem cluster, prioritize fixing the most important one. The main core problem is the problem whose solution would have the greatest impact on lowering the costs.

After considering the four rules of thumb the main core problem is determined*:*

The lack of standardized processes

This problem is linked to other potential core problems. As stated in rule two, this is the root cause of the other problems. When standardizing the processes attention is also paid to the other problems. For example, in order to standardize the purchasing processes research could be done on the information systems. Ways to optimize the use of the systems could result in a more standardized process. The same goes for contractual agreements, when the process is more standardized and the number of suppliers is reduced the company enables better negotiation of contractual terms with suppliers. Part of standardizing the purchasing processes is related to the inventory policy. Currently, the inventory is determined randomly, creating a policy will result in more structure in the process. A more streamlined and effective way of purchasing will be the outcome and will lead to lower tool purchasing costs.

To solve the action problem, and lower the purchasing expenses of tools, the company needs to make its purchasing processes more efficient. This can be done by standardizing the approach of the purchasing department and focusing on inventory management. The company can create a more organized process that requires fewer steps and less involvement from multiple employees. This will result in reduced costs and a more streamlined process. As stated in rule number four, this has the most impact on lowering the costs. Therefore, the lack of standardization is the main core problem.

In summary, the high costs of tools are an issue for the company. Making the purchasing process more standardized, by focusing on inventory management, reducing the number of suppliers, and optimizing the utilization of the systems. The company can reduce its tool expenses and improve its overall operations.

1.2.4 Norm and Reality

The reality is the current tool management processes. The reality is that the company's opinion is that the tool purchasing expenses are too high. There are several reasons why the costs of these processes are too high, for example, the not optimal use of systems. The tools are supplied by many suppliers, leading to different ordering methods. Currently, there is no inventory policy regarding tools. When a tool is needed it is ordered immediately. These are all reasons why the tool purchasing costs are high. Looking at these problems and finding solutions will result in lower costs and a more standardized purchasing process. This is the desired situation for the company.

The desired norm is lower tool purchasing expenses. The wish of the company is to optimize these processes so they will cost less and fewer tools will be in inventory. The wish is to have as less suppliers as possible to make the purchasing processes more standardized. Some products can be delivered the next day but others have a longer lead time. The company also wants to optimally use the systems to be able to order tools very easily and quickly.

The norm and reality could be measured with the following KPIs:

- Tool expenses relative to turnover
- Total order frequency
- Number of suppliers
- Number of people involved in the purchasing process
- Number of automated tasks in the purchasing process

1.3 Aim of this research

The aim of conducting this research is to optimize the purchasing processes for tools with the objective of minimizing tool expenses, as well as making the processes more clear and simplified for everyone. A lower workload for the purchaser and fewer tools in inventory want to be achieved.

1.4 Problem-solving approach

In this research, the Managerial Problem-Solving Method is used to solve the research question. The MPSM consists of 7 phases, seen in Figure 4. The MPSM is a more general method, applicable to various problems encountered in various situations in all areas of expertise (Heerkens & van Winden, 2017, p. 36-37). Phase 1 of defining the problem has already been conducted. This is done through various interviews with different employees to get a better understanding of the problem. The action problem is discussed in the previous sections. The problem cluster and the core problem are determined.

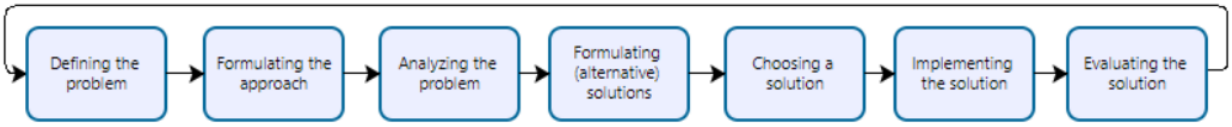

Figure 4: MPSM

This section covers phase 2, which involves formulating the approach for solving the research question. Here, the necessary steps to move from the core problem to the solution are determined. As said earlier the MPSM method will be used.

Phase 3 is an important step that involves analyzing the problem thoroughly. To effectively solve the problem, a good understanding of the current situation is necessary. This includes analyzing and documenting the current tool management processes. This is done through interviews with all the employees involved in these processes. A systematic literature review is conducted to gain more insight into the methods and theories related to the optimization of the processes.

Phase 4 is dedicated to formulating potential solutions for the problem based on the research and theory gathered in the previous phases. These solutions include solutions to improve the processes.

In Phase 5, the optimal solution is chosen in consultation with the company's management and employees. This solution should align with the strategy of the company and offer the most effective solution to the problem.

Phase 6 involves the development of an implementation plan for the chosen solution. The plan should describe how the solution will solve the core problem and how it can be implemented.

Finally, Phase 7 is focused on evaluating the implemented solution and reflecting on its effectiveness. Additional research topics may be recommended based on the results. After this step, the MPSM cycle starts again. The problem is most of the time not solved after the first round of the cycle. This method follows several iterations until the solution is complete.

1.5 Scope

The time horizon of this research is ten weeks. The research will focus on the purchasing department of Hankamp Gears, and more specifically the tool management processes. The purchaser also purchases materials and manages the outsourcing. However, the priority of the company is improving the tool management processes, so this topic has been chosen for research in this thesis.

1.6 Deliverables

These deliverables should be delivered to the problem owner:

- Analysis of the current tool management processes.
- Methods and theories to standardize and optimize the tool management processes.
- Business Processes Models of the standardized tool management processes.
- A list with potential solution to optimize the tool management processes.
- An advisory report about the implementation of the improved processes and recommendations for further research.

1.7 Research design

The core problem is translated into the following research question:

What are the optimal business processes affecting tool management for Hankamp Gears?

Several knowledge questions are needed to answer the main research question, such as:

1. What are the current processes applied by the purchasing department at Hankamp Gears?
    - *What are the bottlenecks in the current processes?*
    - *What is the desired situation for the processes?*
2. What are relevant techniques for process optimization in the purchasing department?
    - *What are the best methodologies for implementing process optimization in the purchasing department?*
    - *How can technology support process optimization in the purchasing department?*
    - *What is the most suitable modeling language for improving the processes in the purchasing department?*
    - *What kinds of inventory policies can be applied to improve the tool purchasing processes?*
3. What are the best solutions to optimize the purchasing department processes at Hankamp Gears?
    - *What activities can be added/removed/changed to optimize the processes?*
    - *How can the available Information Systems be applied to optimize the processes?*
    - *What kinds of inventory policies can be applied to improve the tool purchasing processes?*
4. What is the expected impact of the chosen solutions?

- *What is the effect on the performance indicators?*
- What actions need to be taken to achieve the desired outcome?

5. How to implement and evaluate the chosen solutions for the purchasing department processes at Hankamp Gears?

    - *What factors should be taken into account when implementing the solutions?*
    - *How can the chosen solution be effectively monitored?*

A more elaborated overview of the research design can be found in Appendix A.

1.8 Assessment of reliability and validity:

Reliability and validity are both about how well a method measures something. Reliability refers to replication and consistency. If a researcher can replicate an earlier research design and achieve the same findings, then that research would be seen as being reliable. Validity refers to the appropriateness of the measures used, the accuracy of the analysis of the results the and generalizability of the findings. (Saunders et al., 2019, p. 820)

The reliability of this research will be assessed by performing a complete literature study. Different databases will be used to get the most complete sample of literature. Also, interviews will be held with multiple employees to be able to compare the outcomes to get the most complete overview of the tool management processes.

The validity of this research will be assessed by being careful with the obtained data. The data should be cleaned before analysis is performed to make sure appropriate conclusions are drawn. This research can be generalized and implemented in another production company. The research design is formulated in a way that can optimize processes in general.

1.9 Summary

This chapter explains the problem being addressed in this research, as well as the problem-solving approach. The main issue at hand is the high tool purchasing expenses relative to the turnover, which results from inefficient use of information systems, lack of standardized processes, absence of contractual agreements with suppliers, and no established inventory policy for tools. The core problem identified is the lack of standardized processes.

To address this problem, the current situation will be analyzed, followed by the exploration of process optimization techniques. After that, the solutions will be determined through research, and the necessary activities will be identified. The expected impact of the proposed solutions will be shown, and an implementation plan will be provided to guide the implementation process.

2 Literature review

This chapter presents the theoretical framework for the research. The aim is to investigate relevant techniques for process optimization in the purchasing department, which will be accomplished through a literature review. The following research question will be addressed: *What are the relevant process optimization techniques for the purchasing department?*

Section 2.1 provides information about process optimization techniques, including their benefits and methodologies. The methodologies Business Process Management, Lean Management, and Six Sigma will be further addressed in the corresponding sections 2.1.1, 2.1.2, and 2.1.3. Section 2.2 explains and provides inventory management strategies and section 2.3 explains method to implement changes. Lastly, section 2.4 give a summary of this chapter.

2.1 Process optimization techniques

Process optimization techniques can be useful when a process is not working efficiently. Process optimization involves implementing structured methods, tactics, or strategies to improve processes. One benefit of process optimization is that it creates more consistency. Activities that do not add value are removed from the process, which results in more streamlined activities without repeating steps or unnecessary activities. Another benefit of process optimization is the improvement of the quality of processes. Less attention and money need to be invested in any additional fixes or patchwork corrective measures when processes have high-quality outcomes. The processes become more standardized, making it easier for all involved parties to perform in a unified and collective manner. Furthermore, process optimization improves resource management, saves money, increases productivity, and reduces problems (Indeed Editorial Team, 2022).

There are numerous methodologies available, that contain various steps and measures to optimize processes. The methodologies help to increase productivity, optimize workflows, and make better use of the available resources. This theoretical framework elaborates more on Business Process Management, Lean Management, and Six Sigma, which are all process optimization techniques with different approaches.

2.1.1 Business Process Management

Business Process Management is a process optimization technique that involves analyzing and improving business processes. It oversees how tasks are performed in an organization to ensure consistent outcomes and to take advantage of improvement opportunities (Dumas et al., 2018, p. 1). A business process refers to a sequence of tasks or activities performed to achieve a specific goal. BPM is a methodology that identifies business processes, analyzes them, and redesigns them to create optimal processes. The implementation of BPM could result, for example in reducing bottlenecks, automating manual work, optimizing and streamlining inefficient processes, or reorienting project goals to achieve specific business outcomes (Martins, 2023).

The BPM lifecycle consists of six phases (Dumas et al., 2018, p. 21):

- Process identification
- Process discovery
- Process analysis
- Process redesign

- Process implementation
- Process monitoring and controlling

The first phase is the process identification phase, where all the processes related to the problem are identified, delimited, and related to each other. This gives an overview of the processes in the organization and the relationships between them. Once the processes are identified, the process discovery phase can begin. In this phase, the current situation of the processes is visually modeled. When the as-is model is done, the process analysis phase can start. Issues related to the current situation are identified and made quantifiable by using performance indicators. The output of this phase is a collection of issues, which are often prioritized based on the estimated effort and impact of solving the problem. In the redesign phase, changes will be made to solve the previously identified problems. Multiple change options are analyzed, and the pre-determined performance indicators are evaluated. The changes that have the most positive impact on the performance indicators are combined, resulting in the redesigned process. After this, the changes required to shift from the current state to the desired state are prepared and implemented. Once the new processes are in place, relevant data is collected and the performances are analyzed. New issues could occur, requiring the cycle to be repeated continuously.

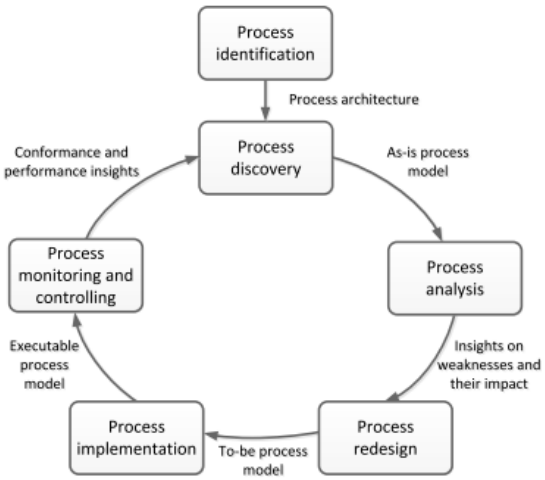

Figure 5: BPM lifecycle (Dumas et al., 2018, p. 21)

2.1.1.1 BPMN

Business processes are modeled in the discovery and redesign phase of the BPM lifecycle. This can be done using Business Process Model Notation. BPMN is a business process method used to model processes from beginning to end. The business processes are visualized in a detailed sequence of activities. Also, the information flows are modeled to get a more complete overview of the business process. The main goal of BPMN is to provide a notation that is understandable for all business users. It creates a standardized bridge for the gap between process design and process implementation (Weske, 2012, p. 206). The BPMN divides the notation elements into four basic categories:

- Flow objects: events, activities, gateways
- Artifacts: data objects, group
- Connecting objects: sequences flow, message flow, association
- Swimlanes: pool, lanes

In this thesis, Bizagi Modeler is used for modeling the business processes. The tables in Appendix B could be used as a legend for the Business Process Model Notation.

Figure 6: Swimlanes (source: Bizagi Modeler)

Figure 6 shows a swimlane, containing a pool, and several lanes. A pool represents the participant in the process, this can be a specific business entity or a more general business role. Lanes lie within the pools and represent the sub-partition within a pool. In this thesis, the pools are represented by the customers, suppliers, and Hankamp Gears. The lanes correspond with the different departments within the organization.

2.1.1.2 iStar 2.0

iStar is a modeling language that is used for goal modeling. It focuses on the intentional, social, and strategic dimensions (Dalpiaz et al., 2016). The iStar language divides the notational elements into five categories:

- Actors: roles, agents
- Actor association links: participates-in, is-a
- Intentional elements: goal, quality, task, resource
- Intentional element links: refinement, needed-by, contribution, qualification

Additionally, there are social dependencies in iStar. Social dependencies represent social relationships between different actors. An example is shown in Figure 7. A depender is an actor that depends on something to be provided. The dependerElmt is the element within the depender's actor boundary. The dependum is an intentional element that is the object of the dependency. The dependee is the actor that should provide the dependum.

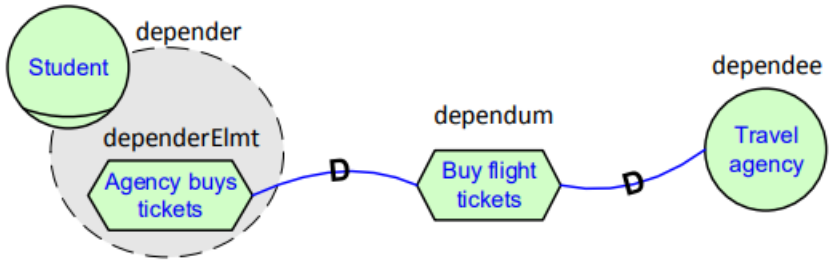

Figure 7: Social dependencies (Dalpiaz et al., 2016)

In this thesis, piStar (Pimentel, n.d.) is used for modeling the goal models. The tables in Appendix C could be used as a legend for iStar models.

2.1.2 Lean Management

Lean Management is a process optimization technique that aims to minimize waste in business processes. The main goals of lean are reducing costs, optimizing the use of resources, and creating a continuous

workflow. These goals may be achieved by eliminating unnecessary tasks or activities. Lean Management focuses on the continuous improvement of processes to increase efficiency and quality over the long term (McLaughlin, 2023). It involves identifying each step in the business process and eliminating any steps that do not add any value. According to Karlinda et al. (2017) and Khairunnisa et al. (2020), there are seven types of waste in Lean management:

1. Waste of overproduction: Producing more products than needed or producing ahead of schedule.
2. Waste of waiting: Idle time due to waiting for the previous process.
3. Waste of transportation: Moving material or work-in-progress between different workstations.
4. Waste of excess processing: Using inefficient or non-standard processes.
5. Waste of inventory: Excess work-in-progress inventory between processes.
6. Waste of motion: Unnecessary operator movements that do not add value.
7. Waste of defects: Products that do not meet specifications and require rework, inspection, or customer complaints.

Many tools to perform Lean Management are available. This theoretical framework is chosen to elaborate more on Value Stream Mapping, 5S methodology, and Kanban.

2.1.2.1 Value Stream Mapping

Value Stream Mapping is a tool used in Lean Management to give a visual representation of the flow of materials and information. VSM distinguishes between value-adding and non-value-adding items in order to reduce activities that do not add value (Mukherjee, n.d.). Highlighting where value is added and where waste exists results in a diagram that provides a framework for optimizing the processes. The visual representation of the current or future situation of the process enables the identification of important information and bottlenecks (Watts, 2018). VSM is an effective tool for communicating a high-level view of processes.

2.1.2.2 5S methodology

The 5S methodology is a Lean Management tool. It is a systematic approach to organizing and standardizing that aims to reduce the amount of waste and improve the efficiency of the workplace. The approach consists of five steps (Khairunnisa et al., 2020):

1. Sort: Eliminating unnecessary items that are not needed in the current process from the workplace, distinguishing the needed and unneeded items, and eliminating the latter.
2. Set in order: Keeping needed items in the correct place for easy and direct access, creating effective and efficient storage methods.
3. Shine: Keeping the workplace clean.
4. Standardize: Maintaining the first three steps.
5. Sustain: Making a habit of maintaining the established procedures.

2.1.2.3 Kanban

Kanban is a Lean Management tool created to visualize and manage workflows efficiently. It works as a signal and response system. For example, signals like cards or bins are used to indicate when inventory or production levels reach a certain threshold. These signals activate the replenishment of inventory or start a production process while making sure that customer demand is met (Halton, 2022). Kanban boards are used to show visual representations of the product's status. These boards have different stages, for example, 'to-do', 'in progress', and 'done'. These boards show a clear overview of what the current status

is and what can be done (Kashyap, 2020). The signals provide visibility for both suppliers and buyers, improving communication and coordination between them.

The Kanban system is based on the just-in-time and pull principles, which result in minimizing waste and maximizing efficiency by only ordering when products are needed. This promotes efficient production and inventory control, and results in high productivity and capacity utilization (Kumar & Panneerselvam, 2007).

2.1.3 Six Sigma

The focus of Six Sigma is reducing variability in key processes to a level at which failure or defects are extremely rare (Montgomery & Woodall, 2008). This methodology aims to minimize failures and variations in processes to achieve a high level of quality. Six Sigma is based on a data-driven approach and statistical analysis. The structured DMAIC approach enables the organization to detect and eliminate waste. DMAIC stands for Define, Measure, Analyze, Improve, and Control (Wang, 2008).

2.1.3.1 DMAIC

DMAIC is a closed-loop process that reduces unproductive activities. It focuses on new measurements and applies technologies for continuous improvement (Wang, 2008). The DMAIC process consists of five stages:

1. Define: In this stage, the business problem and the goals that need to be achieved are clearly explained. The time horizon and scope of the problem are also defined. A SIPOC diagram could be created to give an overview of the critical aspects of the process.
2. Measure: In this stage, the specifications of the problem and goals are measured. Data is collected, and a plan is developed to decide what to measure and how to measure the performance indicators.
3. Analyze: In this stage, the causes of defects and sources of variation are identified to eliminate them. All root causes are searched for and prioritized.
4. Improve: In this stage, solutions to the problem are identified, tested, and implemented. The solutions should solve the root causes of the problems.
5. Control: In this stage, the changes are embedded, and sustainability is ensured. A strategy is developed to monitor and control the changes made to reduce variability.

2.1.3.2 SIPOC diagram

A SIPOC diagram is a tool that can be used to identify all the important aspects of a process. SIPOC stands for Supplier, Input, Process, Output, and Consumer (Marques & Requeijo, 2009). It is often used as a starting point for process improvement to make sure all key elements are considered and understood before any changes are made. This could help in the define phase of DMAIC to define the problems and show them clearly in a diagram.

2.2 Inventory management

Inventory management is an important process that consists of multiple activities. It involves monitoring, controlling, and ordering inventory to meet the estimated demand. Attention should be paid to efficiency and minimizing inventory costs. It is a balance between making decisions about the appropriate amount of inventory to keep in stock, when to order the new inventory, and how to manage the inventory to avoid stockouts or excess inventory.

To effectively manage inventories, various inventory policies can be used. For example, push or pull strategies, re-order point and re-order level systems, cycle inventory and economic order quantity models, safety stock management, seasonal inventory, forecasting models, just-in-time models, and ABC analysis.

2.2.1 Order strategy

Push and pull strategies refer to the direction of the inventory flow. In a push strategy, the company develops processes that start within the company and go toward the market. An example is forecasting demand and producing products based on forecasts (Corniani, 2008). On the other side, in a pull strategy, processes start from the market and go toward the company. An example is manufacturing products only when orders are placed.

A push strategy reacts to forecasts rather than actual demand, while a pull strategy is reactive as it responds to customer demand (Chopra, 2019). Before choosing an inventory policy, the strategic view of the company should be determined.

2.2.2 Order moment

Re-order point and re-order level systems involve making replenishment timing decisions. *ROL = ROP + inventory and ROP = (average demand * lead time) + safety stock* (Thomas, 2022). Two approaches could determine the ordering moment, the continuous review and periodic review approach. The continuous review approach involves reviewing stock levels continuously, and when the re-order level is reached, a new batch is ordered. The periodic review approach involves ordering at a fixed and regular time interval and changing the order quantity when an order is placed until the predetermined stock level is reached (Slack, 2007, p. 386).

2.2.3 Cycle Inventory

Cycle inventory is the average amount of inventory used to satisfy demand between the shipments of the suppliers. The size of the cycle inventory and how often the order is placed depends on the ordering and holding costs. The tradeoff is between ordering large quantities and having high holding costs but low replenishment costs or ordering more often in smaller batch sizes, which results in higher replenishment costs but lower holding costs (Chopra, 2019).

The economic order quality is the amount of cycle inventory that is ordered when stock needs replenishing. The EOQ level is determined when the total costs are the lowest. The total costs exist for the order and holding costs. The order cost decreases exponentially when the quantity increases, while the holding costs increase linearly when the order quantity increases (Slack, 2007, p. 376). The total costs are the sum of the ordering costs and holding costs, the order quantity for which the costs are less is the EOQ. The *EOQ formula = v((2* average demand* order cost)/ holding costs)* (Caldwell, 2022).

2.2.4 Safety stock

Safety inventory is held in case demand exceeds expectations. These are the extra items in stock to deal with the uncertainty in demand. Safety stock management makes sure there is enough safety inventory available. The tradeoff is between the extra cost of having too much inventory and the cost of losing sales through not having enough inventory (Chopra, 2019). Safety stock is not only used to deal with changing demand levels, but it can also compensate for uncertainties in the production process and unreliable suppliers or transport firms (Slack, 2007, p. 369). The formula *for safety stock = (max daily use * maximum lead time) – (average daily use * average lead time) (Roughan, 2023).*

2.2.5 Seasonal inventory

Seasonal inventory involves producing extra inventory during periods of low demand to have enough inventory during high-demand periods. The increase in demand is the predictable variety of the demand, this can be for example selling more ice cream on hot days. Producing more in periods of low demand can build up inventory for later. The tradeoff is between the costs of producing the extra seasonal inventory and the cost of having a more flexible production rate (Chopra, 2019).

2.2.6 Forecasting models

Forecasting models are used to estimate demand, on which inventory decisions could be based. The four forecasting methods are qualitative, simulation, causal, and time series (Chopra, 2019). Time series are the most common method. It involves estimating future demand based on historical demand, growth patterns, and seasonal patterns. Different time series methods are used depending on whether demand shows trends or seasonality. The forecasting error is used to measure the random component of the demand to show how inaccurate the forecast is.

2.2.7 Just-in-time model

Just-in-time models are inventory models that deliver items right before they are needed. This results in an inventory reduction. JIT models could provide cost-effective production and delivery. The supplier should deliver the necessary quantity at the right time and place. The suppliers' and customers' flexibility are important concepts when using these models. Both parties should be very flexible to make it work. This approach can help reduce inventory costs by decreasing the amount of inventory held at any given moment in time (Slack, 2007, p. 466). Simplification is an important concept in this approach.

2.2.8 ABC analysis

ABC analysis is a technique that categorizes items. The categorization is based on the Pareto principle for determining which items should be prioritized for inventory management (Ravander et al., 2014). Inventories should be divided into three categories, A, B, and C. The most focus and effort should be paid to managing inventory in category A and the least in category C.

Usage value, which is the usage rate multiplied by the individual value of an item, can also be used to control inventory and the ABC analysis (Slack, 2007, p. 388). Some products have a higher usage rate than others and are therefore more important to keep in stock. Items with a low value and low usage rate will not be important enough to keep large amounts in stock. Items with a high usage value should be controlled carefully, while items with a lower rate should be paid less attention to (Tanwari et al., 2000).

2.3 Implementation technique

ADKAR is a method for implementing changes. ADKAR stands for Awareness, Desire, Knowledge, Ability, and Reinforcement. Utilizing this method ensures correct implementation of solutions and increases the likelihood of successful change adoption (Lucidchart, 2019).

1. Awareness: The employees should know that change is coming. The less they know, the more resistant they will react.
2. Desire: Employees can understand why a change should be made but still may not want to change. When employees see the need for the change and understand its benefits, they will respond more enthusiastically and work hard to achieve the goal.

3. Knowledge: When a change needs to be made, employees should be equipped with the knowledge to initiate and sustain the change.
4. Ability: Understanding the change does not necessarily mean employees have the ability to change. To translate knowledge into ability, practice runs should be held and analyzed to identify what goes well and what does not.
5. Reinforcement: Ensure that employees do not fall back into old habits. This is an important step to maintain the implemented changes.

2.4 Summary

This chapter answers the following research question: *What are relevant techniques for process optimization in the purchasing department?* This question will be answered by providing an answer to the following sub-questions.

- *What are the best methodologies for implementing process optimization in the purchasing department?*

Process optimization methodologies focused on in this theoretical framework are; Business Process Modeling, Lean Management, and Six Sigma.

- *How can technology support process optimization in the purchasing department?*

Technology can help by providing modeling software or tools to make process optimization easier.

- *What is the most suitable modeling language for improving the processes in the purchasing department?*

BPMN is the most used low-code modeling language to model this kind of processes.

- *What kinds of inventory policies can be applied to improve the tool purchasing processes?*

These are policies that could help to manage inventory; cycle inventory, safety inventory, seasonal inventory, forecasting model, Just-in-time model, and ABC analysis.

3 Current situation

This chapter describes the current situation of the purchasing processes applied at Hankamp Gears. The current situation is described in order to identify bottlenecks that can be improved. The following research question will be addressed: *What are the current processes applied by the purchasing department at Hankamp Gears?*

Section 3.1 describes the current processes at Hankamp Gears. It describes the end-to-end business process and a more detailed view of the purchasing process of tools. The end-to-end process starts when an order is placed and ends when the customer receives it. These processes are visualized in BPMN models. The role of the suppliers and the role of data objects are described in this section. Section 3.2 focuses on how Hankamp currently manages its inventory. It focuses on the price, lead time, storage, and information system use. In section 3.3, the current performance is measured. Finally, section 3.4 provides a summary of the chapter that answers the research questions and associated sub-questions.

3.1 Current processes[1]

3.1.1 Explanation BPM

Figure 8 provides an overview of the different activities that Hankamp Gears performs in the end-to-end business process. The model is divided into three pools, representing the main participants in the process. The pools are further divided into lanes to depict the departments of Hankamp Gears and to depict the different types of suppliers such as material suppliers, tool suppliers, and supplier A/ supplier B.

Several sub-processes have been added to the model to ensure a clear understanding of the overall process flow and the relationships between departments and external participants. Creating a job traveler, the production process, and the materials ordering process are shown as a sub-process, because these activities consist of multiple irrelevant activities and tasks. For example, the production process contains many different steps for each type of gear. Every production procedure is different and this information is not relevant for this research. The research focus of this study is primarily on the purchasing process, other less important processes have been excluded to make the model better readable.

The data objects shown in the model represent physical items that are relevant to the process. For instance, the job traveler is made by the sales department. It is a physical document containing technical drawings, measurement reports, and all the operations that should be performed, along with other important information. Each product requires different operations, and all of them are noted on the job traveler. As each operation is finished, the operator updates the job traveler by signing it and updating the ERP system. Another important data object is the internal order. This is a written note by the technical specialist and contains all the necessary details of the to-be-ordered tool.

The ERP system plays an important role in documenting all the purchasing data throughout the process. However, the ERP system is not explicitly modeled in the end-to-end process because it would make the model less clear and readable. The ERP system is integrated into the entire process, all order specifications are filled in manually in the system. This ensures tracking of the progress of each order and provides

[1] *Certain parts of sentences in the process descriptions of the end-to-end business process and the purchasing process are highlighted in bold. These bold parts denote the activities or gateways in the business process models. This is done to enhance clarity and make it easier for the reader to understand the described model.*

information on the status of orders at any given time. Also, changes in delivery dates are updated in the system.

The main difference between the way of purchasing at supplier A or supplier B and other tool suppliers is shown in the models. One difference is that the tools of supplier A and B are ordered by the technical specialist, while the tools of other suppliers are ordered by the purchaser. Another difference is that the order confirmation is automated for orders from supplier A and B, while the other suppliers need the purchaser to send an email with the order details.

3.1.2 End-to-end business process model description

The end-to-end business **process starts** with the **order at Hankamp activity.** This could be either a repetitive order or a new order. The sales department receives the order request and performs the **send order confirmation activity**. Then, the sales department **creates and prints the job traveler.** For repetitive orders, the job traveler is already made and can be used again. The planner uses the job traveler to perform the **schedule jobs on machines activity**, after that the job traveler is forwarded to the purchaser.

The purchaser checks if all the required materials are available in stock. He has to answer the gateway question **''Materials in stock?''** If materials are missing, the purchaser performs the **order materials activity** so the materials will arrive on time before they are scheduled on the machines. If the materials are in inventory, the **production sub-process** can already start. The purchaser **receives an order confirmation** from the material supplier with the delivery date and **adds this data to the ERP system**. After performing these activities, the purchaser has to pay attention if the materials will be delivered on time. If the materials are not delivered by the prearranged date, the purchaser **contacts the supplier.**

Once all the materials are available and the machines are free, the **production sub-process** can start. After the production process is finished, the tolerances are measured to check if the gears reach the quality requirements. Then the products are packed and ready for shipment to the customer. An **invoice is created** by the sales department and the **gears are sent** to the customer. After the **invoice is paid**, the customers receive the gear. When the **receive gears activity** is performed the **process ends.**

During the production sub-process, issues such as tool breakage may arise. Then a new tool is needed and the gateway question **''Tool in inventory?''** should be answered. When the tool is not in inventory, the activity **order new tool** should be performed. This can happen in two ways, either through an EDI system, which involves less manual input and is easier or the tools could be ordered via an internal order. Only tools of suppliers A and B could be ordered through an EDI system, this is why the gateway question **''Tool from supplier A and B?''** is asked. If the answer is yes, the **scan bar code activity** should be performed and the **order is placed**. If the answer is no, an **internal order is created** by the technical specialist and **given to the purchaser**. The purchaser **adds the data** from the internal order to the ERP system and **sends an email with the order details** to the supplier. After **receiving an order confirmation** back from the supplier, the new **data is added to the ERP system** and the **order is placed.**

Once the tools are delivered the production process can continue and the orders can **be sent to the customers**. When the **receive gears activity** is performed the **process ends.** This end-to-end business process is modeled in Figure 8.

3.1.3 Tool purchasing business process model description

Figure 9 illustrates a focused view of the purchasing process for tools. The **process starts** when a **tool breakage occurs**, prompting the need for a new tool. At this point, the gateway question **"Tool in inventory?"** must be answered. If the answer is yes, the **tool from inventory is used**, and the **production process can continue.** The **process ends** when the production process activity can start. However, if the answer is no and the tool is not in inventory, a **new tool must be ordered.**

As previously mentioned, an order can be accomplished through an internal order or an EDI system. When using the internal order method, the **internal order is first written** and **handed over to the purchaser.** The purchaser **receives the internal order** and manually **enters the data into the ERP system.** Once the data is in the system, an **email with the order details is sent** to the supplier. The supplier receives the email and must **add the data into their ERP system** as well. Following this, an **order confirmation can be sent**, and the **order is placed.**

In the case of ordering with the EDI system, the required **tool's barcode is scanned**. The system allows the **number of tools to be entered**, and the order is placed directly without the need for manual data entry into the ERP system. This process is the same for the suppliers as well. The supplier automatically **sends an order confirmation**, and the **order is placed.**

Subsequently, the process remains the same for different suppliers. The **invoice is sent** to the purchaser, and after **payment**, the **tools are sent.** The purchaser must ensure that the tools are **delivered on time.** Otherwise, they need to **contact the supplier** and **update the new delivery dates in the ERP system.** Once the **tools are received**, the production process can continue, and the overall tool purchasing **process is ended.**

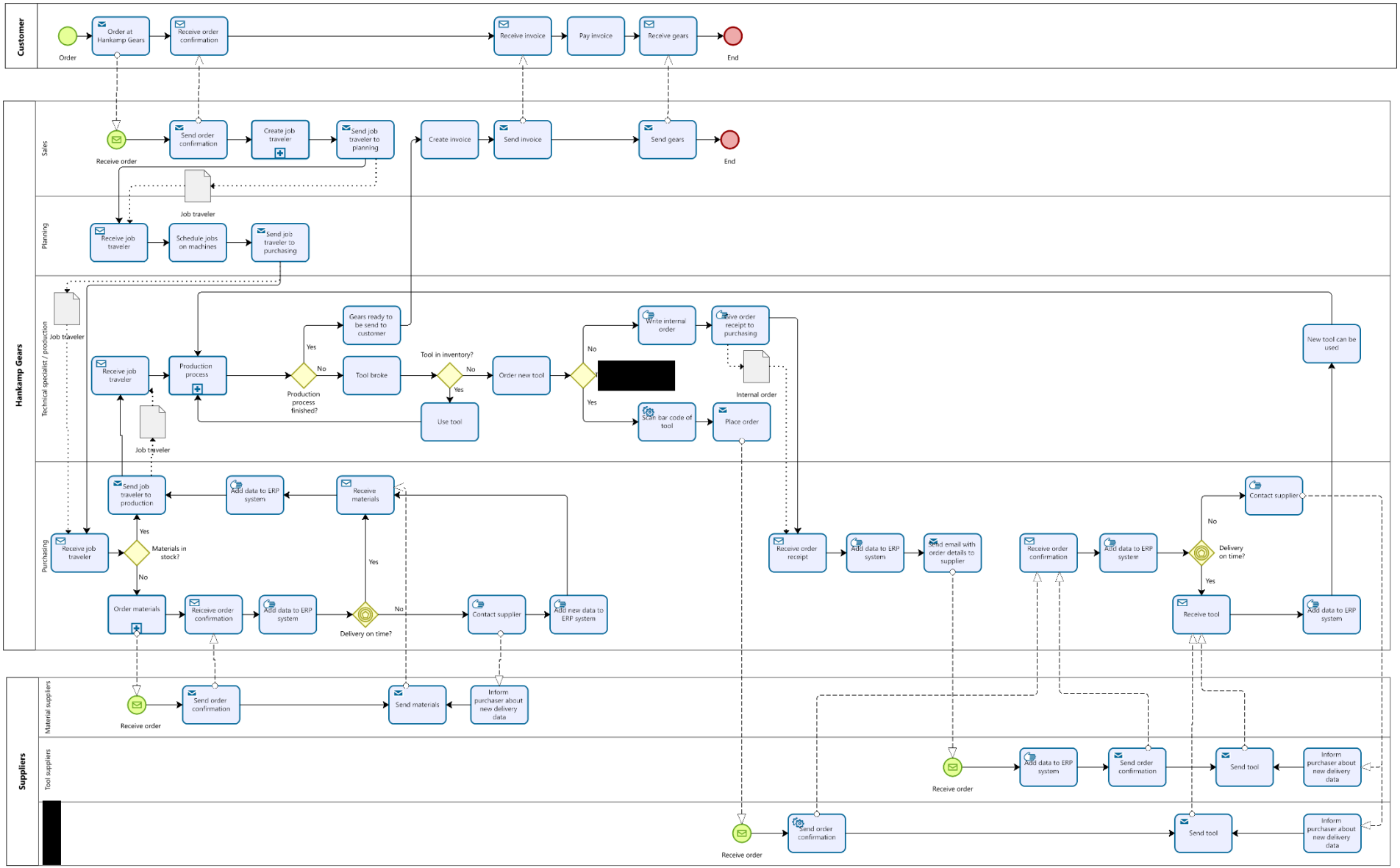

Figure 8: BPMN: End-to-end business process at Hankamp Gears

HANKAMP GEARS
Al meer dan 100 jaar in beweging

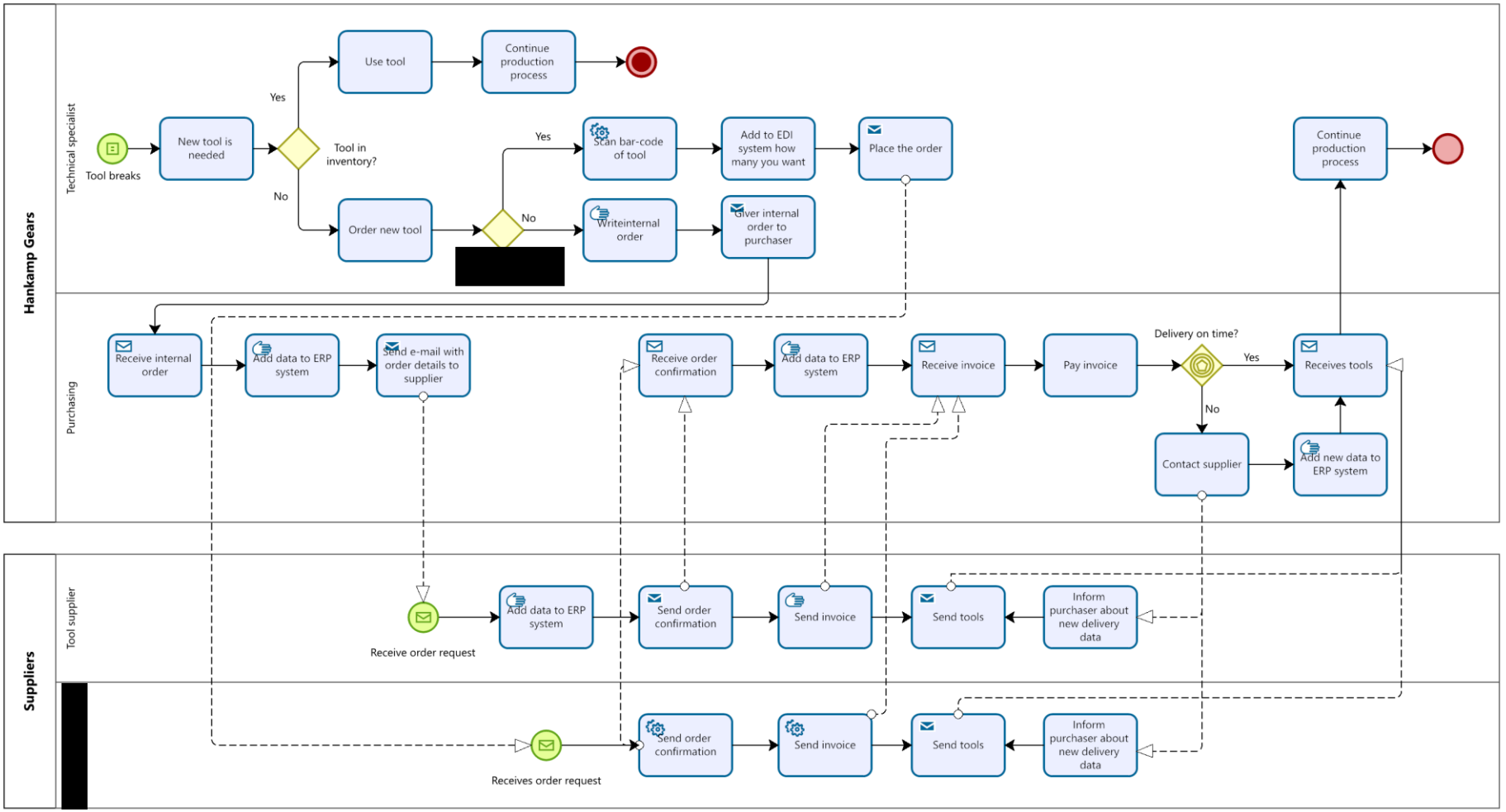

Figure 9: BPMN: The purchasing business process of tools at Hankamp Gears

3.1.3.1 Role of supplier A and B

Supplier A and B are the key tool suppliers for Hankamp Gears. The way of ordering tools is different in comparison with the other tool suppliers, therefore they are modeled separately in Figures 8 and 9. The integration of an EDI system is the reason why the ordering process differs from that of other suppliers. While the ordering process with other suppliers follows an approach where data is filled in manually and emails are sent between Hankamp and the suppliers. The EDI system connects the systems of the companies and allows for automated ordering without the need for manual data entry.

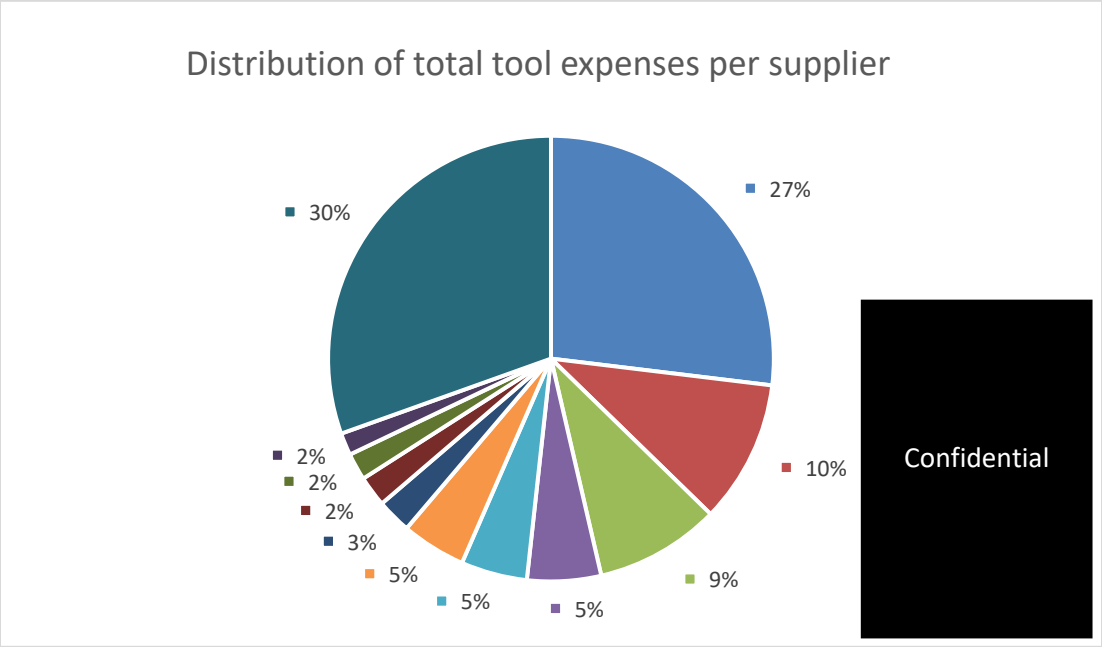

Figure 10: Pie chart of the distribution of total tool expenses per supplier (n=8925; data from 2019-2023; source: Hankamp)

Figure 10 illustrates a pie chart of the distribution of total tool expenses per supplier. The pie chart is based on the tool expense data from the last four years. Supplier A is by far the biggest tool supplier for Hankamp. In the last four years around 27% of the total tool expenses have been spent at supplier A. Hankamp has ordered from 51 different suppliers in the last four years, but more than 70% of the total money spent on tools is spent at the five largest suppliers.

Supplier	Order frequency	Percentage of grand total
Supplier A	3437	47%
Supplier B	1918	26%
Supplier C	427	6%
Supplier D	339	5%
Supplier E	149	2%

Table 1: Order frequency per supplier (n=8925; data from 2019-2023; source: Hankamp)

The top five largest tool suppliers based on the number of tool expenses in the last four years and the associated order frequencies are displayed in Table 1. Sandvik has the largest order frequency. As stated before, the ordering process at supplier A and B is different from the rest of the tool suppliers. The way of ordering is already more efficient compared to the way of ordering at other suppliers. This is a good starting point, as 72% of the orders are placed with these suppliers.

3.1.3.2 Role of data objects

The process makes use of two data objects, namely the job traveler and the internal tool order. The job traveler is involved in almost every step of the process and is signed off and passed to the next operation when the current one is completed. The information from the job traveler is then also added to the ERP system. Complete information should be added, including details such as delivery dates or any incidents of broken gears during the production phase.

The internal order is given to the purchaser when a new tool is required. The internal order is a written note prepared by one of the technical specialists. It should contain all the necessary details for ordering the specific tool, like the type and the amount. Sometimes the note may be incomplete, leading to more work for the purchaser because he has to search for additional information. Small orders are purchased immediately while larger expenses require approval from the management. The responsibility of determining the necessary number of tools to order lies with the technical specialist because he has the most knowledge of the requirements. However, he has to think carefully about this decision to make sure no unnecessary purchases are made.

3.2 Current inventory management

Inventory management is an important aspect of effective tool management. This includes determining the types of tools and optimal quantities to keep in inventory, as well as the most efficient storage locations. However, currently, Hankamp Gears has no inventory management system or policy regarding tool management. An inventory management policy takes into account various factors, including price, lead time, storage, and information systems.

3.2.1 Price

The variations in tool prices impact inventory management. Less expensive tools are often ordered in larger quantities, while more expensive tools are typically purchased only when needed. Careful consideration should be given to these large purchases. For instance, the least expensive tools may be priced at €0.02, but it has happened that tool worth €26,500 needs to be ordered. However, the average price of tools is around €100. Figure 11 shows a histogram of the tool price distribution. Tools priced above €800 are excluded from the histogram to avoid clutter and maintain a readable graph.

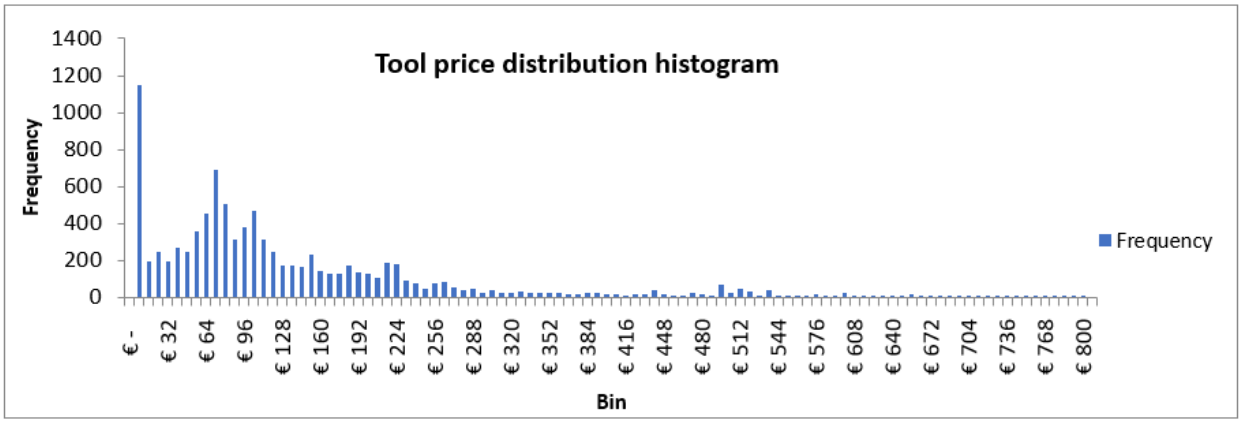

Figure 11: Tool price distribution histogram (n=9614; data from 2019-2022; source: Hankamp)

3.2.2 Lead time

Lead times vary among suppliers. Some suppliers can deliver tools quickly, while for others it may take several weeks to do so. This depends on the type of tool and supplier where the order is placed, but this is an important aspect to consider when managing inventory. If a tool breaks and no spare tool is available in inventory, a new tool needs to be ordered. However, until the tool is delivered, the production process for that gear cannot continue. Tools with short lead times can sometimes be delivered within a day, while for others with longer lead times, it may take some weeks. Currently, not much attention is paid to lead times when ordering tools. Often the estimated lead times are recognized but occasionally overlooked in practice. This lack of consideration can result in a production process that has to stop because they cannot work without the needed tools.

Certain tools can be substituted with others. The tools used in the production process could be chosen based on the user's preference and experience. In some cases, a slightly different tool can result in the same outcome. However, sometimes a small additional action may be required. When a tool breaks and it takes several weeks for a replacement tool to be delivered, an alternative tool can be used to avoid any delays in the production process.

3.2.3 Storage

Hankamp stores excess tools in a cabinet. There is no structure behind the tools that are in inventory. When a specific tool is ordered, often multiple tools are ordered simultaneously. The extra tools are then stored in the cabinet, and because of this, the cabinet has become increasingly crowded over time. The storage is labeled to indicate the location of the type of tool, but this information is not registered in the ERP system. Tool breakages or tool usage from the cabinet are also not registered in the ERP system and therefore no overview of the current tools in inventory is available.

Furthermore, tools could be stored in various locations throughout the organization. The tools could be stored in the areas where the tools are used instead of in the inventory cabinets. The lack of structure can result in difficulties in searching for the right tool when it is needed. This can lead to unnecessary tool orders, an increasing inventory, and loss of production time as the operator is searching for tools and not focusing on quality control and production.

3.2.4 Information systems

The ERP system stores all the information regarding tool orders, including the quantity and type of tools ordered, as well as the dates of the order and delivery. However, it is not added to the ERP system when a tool breaks or is removed from inventory for use in production. The result of this is that the system does not have a complete record of the tools still in inventory. This makes it hard to find tools and new tools often are ordered while they may still be somewhere at the company. The system does not provide information on the storage location of the tools within the inventory as well. The EDI systems of supplier A and B have the capability to show the number of items in inventory. However, the employees do not always record the usage of tools out of inventory, resulting in inconsistent and inaccurate information.

3.3 Current performance

The current performance is measured with the following KPIs:

- Tool expenses relative to turnover
- Total order frequency
- Number of suppliers
- Number of people involved in the purchasing process
- Number of automated tasks in the purchasing process

Year	Tool expenses relative to turnover	Total order frequency	Number of suppliers
2019	7%	2121	35
2020	7%	1923	37
2021	8%	1966	38
2022	9%	2050	34

Table 2: Performance indicators (n=9614; data from 2019-2022; source: Hankamp)

Table 2 summarizes the tool expenses, total order frequency, and number of suppliers for the past four years. As Hankamp Gears is a growing company, the tool expenses have increased. However, the company aims to decrease these expenses relative to the turnover. Hankamp desires to lower the total order frequency per year as well to reduce administrative work and ordering costs. Additionally, reducing the number of suppliers will make it easier to negotiate contractual agreements and standardize the purchasing process more effectively.

The number of people involved in the purchasing process is high. Several employees perform a part of the purchasing process, like for example booking orders in the ERP system. This results in a chaotic and unstructured way of working. Regarding automation, not many tasks are automated at the moment. While the EDI system features automated ordering with a barcode scanner, the rest of the orders are placed manually.

3.4 Summary

This chapter answers the following research question: *What are the current processes applied by the purchasing department at Hankamp Gears?* This question is answered by providing an answer to the following sub-questions.

- *What are the bottlenecks in the current processes?*

The bottlenecks in the current process are related to the process of purchasing and the lack of an inventory management strategy. The purchasing process works in a specific approach. In this way, many steps need to be performed like making the job traveler and scheduling the job on the machine before orders can be placed. This way of working takes some time and could lead to ordering too late and the products will not be delivered on time.

Another bottleneck is related to the physical data objects. The job traveler is printed and should be updated after every operation and moved to the next. This information also has to be added to the ERP system as well. This is double work and results in an inefficient way of working. The internal tool orders made by the technical specialists are often unclear and incomplete. Several emails or questions should be asked before it is clear what to order wherefore. The order has to be filled in manually in the ERP system

by the purchaser. For larger expenses, approval is needed, which is again not convenient to do via email or questions.

Another bottleneck is that many people are purchasing, it is not only the purchaser that places the orders but also other employees in the organization order supplies. This results in uncoordinated orders which are not purchased efficiently.

Another problem is that there is currently no inventory management policy. When a tool breaks and there is no spare part available, the production process cannot continue. This can result in late delivery for customers and will decrease customer satisfaction.

The existing inventory is not structured and tools are laid at different storage locations and cannot be found when they are needed. The current inventory levels cannot be seen in a system because this information is not recorded.

There are many different tool suppliers because of this it is hard to make contractual agreements. This means that there are no agreements about the price or lead times. This is not efficient and could result in higher tool expenses.

- *What is the desired situation for the processes?*

The desired situation is to lower the tool expenses by 10%. This can be accomplished by improving the purchasing process and implementing an inventory management policy. A way to achieve this is to work with fewer suppliers to be able to make contractual agreements with suppliers to lower the tool expenses. Another improvement is to establish a structured end-to-end process where only the purchaser places orders and other employees focus on their roles in the organization. An approach with less paperwork and more automation will improve the performance further.

In terms of inventory management, an effective policy for tool inventory is important. An inventory management system that monitors tool orders, usage, and locations can help with managing inventory levels. Knowing the exact number of tools in inventory can lead to better scheduling of tool orders and pre-ordering tools with long lead times to prevent delays in the production process.

4 Solution design

In this chapter, solutions are generated to solve or improve the bottlenecks which were found in the previous chapter. The following research question will be addressed: *What are the best solutions to optimize the purchasing department processes at Hankamp Gears?*

In section 4.1 the 'to-be' situation of the purchasing processes is researched and in section 4.2 this is done for the 'to-be' situation of the inventory management. These sections are divided into several sub-sections. The sub-sections in 4.1 elaborate more on the role of employees, information systems, and suppliers to reduce waste. The sub-section in 4.2 elaborate more on the storage locations, inventory management system, tool categories, and specific article numbers. Section 4.3 summarizes the result from the solution design phase. In section 4.4 a summary of this chapter that answers the research questions and associated sub-questions is written.

4.1 'To-be' purchasing processes

4.1.1 Identification of waste

Lean management techniques are used to optimize processes and eliminate waste. After analyzing the current tool purchasing processes, three types of waste have been identified: waiting, excess processing, and inventory.

- The waste of waiting occurs when a tool breaks and a replacement tool needs to be purchased. This is causing delays in the production process because the production cannot continue until the new tool arrives. Unnecessary tool breakage is also a problem as it results in waiting for a new tool as well.
- The waste of excess processing is a result of the lack of efficient system usage and standardization. Most data is manually added to the ERP system and noted on the job traveler or internal order. Both paper and the ERP system are used to record most data. Furthermore, some employees do not consider the appropriate tool choice, leading to the use of incorrect tools. Using the wrong type of tools reduces the tool lifetimes. This also contributes to excess processing waste.
- The waste of inventory arises from the absence of an inventory management policy, which leads to the unnecessary ordering and storage of spare parts in the cabinet. This results in increasingly crowded storage locations over time.

To minimize these types of waste, changes should be implemented concerning employees, information systems, and suppliers. Minimizing these types of waste will help to achieve the main goal of lowering the tool purchasing expenses. In order to achieve these waste minimization goals, several qualities are needed. These qualities, together with the accompanying goals, are modeled in Figure 12.

To **reduce the waste of waiting**, several qualities are needed, such as having an **effective inventory policy, ordering new tools on time**, and **having a clear division of roles and responsibilities**. This will contribute to reducing the waste of waiting and will eventually result in lower tool expenses. The goal of **reducing the waste of excess processing** can be achieved by **timely knowledge about tools**, **having a clear division of roles and responsibilities**, and **having a clear understanding about information systems**. **Increasing knowledge of information systems** also contributes to achieving the goal of **reducing the waste of inventory**.

Reducing these three types of waste helps to reach the main goal of having **lower tool expenses** relative to the turnover. Further research is conducted in this chapter on how to achieve these qualities.

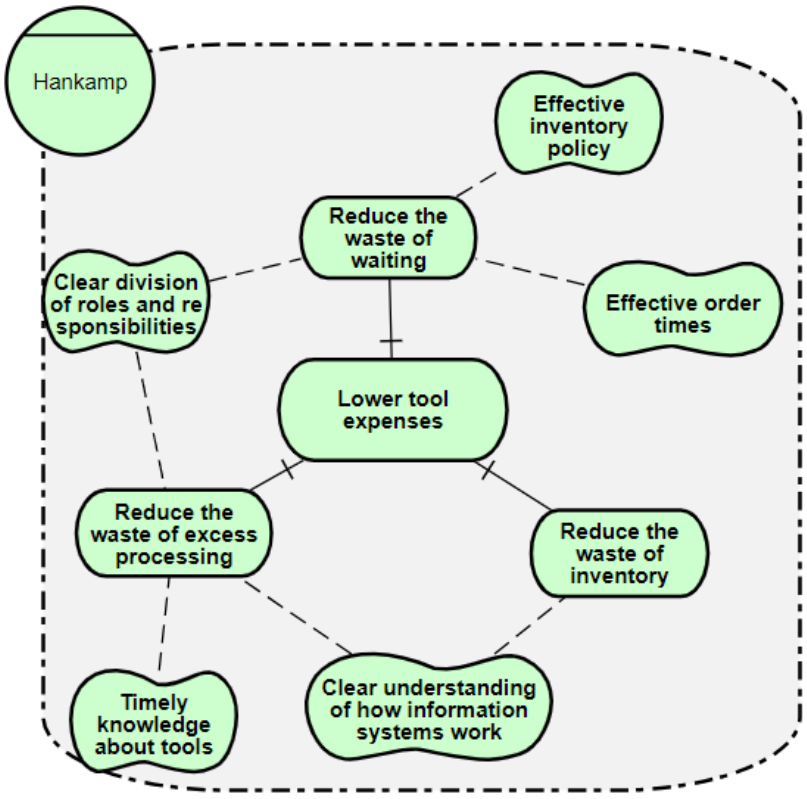

Figure 12: Goal-model for waste reductions

4.1.2 Employees

To establish an efficient purchasing process, all employees should know about their specific jobs and tasks within the organization. Each employee should be aware of their role in the process and how the tasks contribute to the overall process. When employees understand their responsibilities, they can perform the job more efficiently and effectively. This lead to performing tasks with fewer errors and delays, which results in a better output and a smoother and more streamlined workflow.

4.1.2.1 Role of the purchaser

It is recommended to assign a single person with the responsibility for purchasing to create a more structured process and improve efficiency. Currently, multiple employees are involved in various aspects of the purchasing process. For instance, one employee handles booking outsourcing orders in the ERP system, while another is responsible for ordering materials. Many other purchasing-related tasks are divided among different employees. This results in an unstructured process that requires effective communication between employees to determine what has already been done and what still needs to be completed.

A better understanding of the process can be achieved by assigning one purchaser the responsibility for all orders. This approach has several advantages:

- Better communication: Communication between employees becomes more focused and efficient when one person is responsible for ordering. It also benefits the suppliers, as they have a clear point of contact, reducing the chance of miscommunication.
- Centralized knowledge: When a single person is responsible for ordering, they become familiar with the organization its needs, suppliers, and ordering processes. This centralized knowledge enables informed decision-making, facilitates contract negotiations, and ensures consistency in the purchasing process.
- Enhanced negotiations: Having a single point of contact provides an opportunity to achieve good relationships with suppliers and negotiate terms, such as pricing or delivery terms. These contractual agreements could result in cost reductions for the organization.
- Accountability: Managing and tracking the process becomes easier when one person is responsible. This person can be held accountable for any miscommunications, delays, or disruptions. This leads to coming up with better solutions and minimizing the impact of the mistake on the organization.
- Focus on responsibilities: More time to focus on their responsibilities can be achieved by freeing up other employees of purchasing-related tasks. This increases the overall productivity of the organization and reduces the waste of excess processing.

However, it is important to implement an appropriate approval process for centralized ordering. This can be done through regular audits and by setting clear guidelines.

4.1.2.2 Role of the technical specialists

The technical specialists in each department are responsible for placing internal orders for new tools. They decide what tools to order, the quantities needed, and from which suppliers to order them. They also determine which tool should be used for each operation. Each technical specialist manages their tools differently, as they have different preferences for tool management.

Some machine operators use the wrong type of tools. For instance, they may use a drill intended for metal on aluminum materials instead of using a tool designed for aluminum. This results in shorter tool lifespans and increased costs for tool replacements. Each tool is assigned a number, which can be found in a handbook containing all the necessary specifications for correct tool usage. When tools are used correctly, their lifespans can be extended. Using the same tool for a longer time period leads to a reduction in tool expenses. Employees should be motivated to carefully consider their tool choices instead of simply using what they have always used.

The type of tool used in a machine can impact its capacity. Using higher-quality tools can increase machine productivity. For example, if a different tool can perform an operation four seconds faster and 300 items need to be produced, it saves a significant amount of time. The increased cost of the higher-quality tool will be offset in the long run.

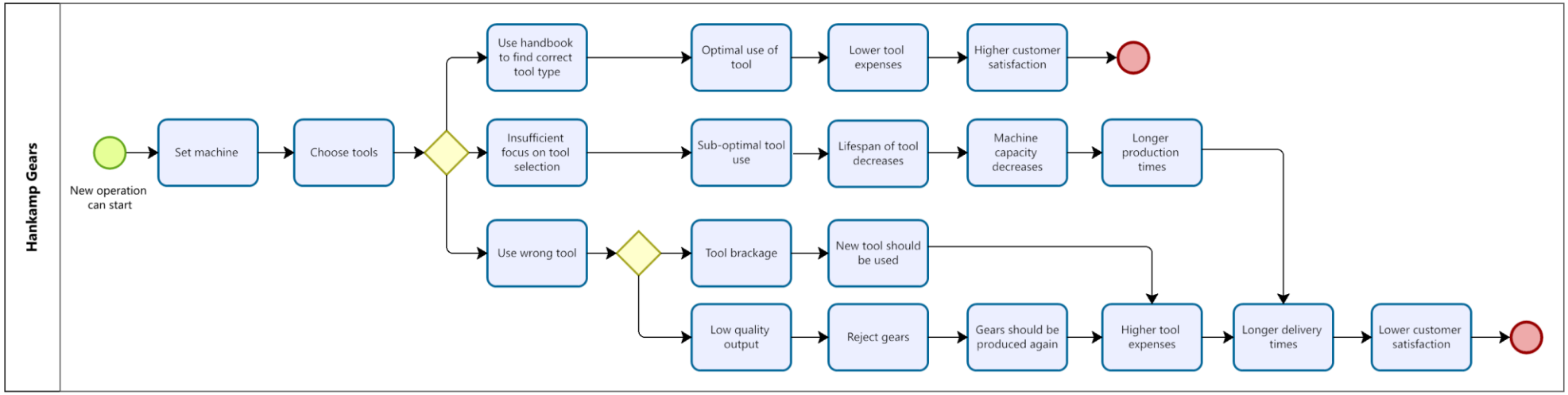

Figure 13: BPMN: tool selection process

In Figure 13, the process of tool selection is illustrated. When **starting a new operation** on a machine, the first step is to **set the machine** to the correct settings. After that, the appropriate type of **tools is chosen**. The tool selection process can be done in several ways, but for simplification purposes, only three ways are modeled.

The machine operator can **use a handbook** or another source to **search for the correct tool type** that will result in the **most optimal production** results. By choosing the tool optimally, the chances of early tool breakage are reduced, and the tool's lifespan is maximized. As a consequence, **tool expenses are lowered**, and **customer satisfaction is increased.**

Another approach to tool selection is to have **insufficient focus on the selection**. In this case, the chosen tool gets the job done and the output quality is acceptable, but the tool may be prone to early damage. This leads to a **decrease in the tool's lifespan** and a **reduction in machine capacity**, resulting in **longer production times**. All of these factors combined have a negative impact on the customer, as **delivery times become longer** and **customer satisfaction decreases**.

When no attention is paid to tool selection, the **wrong tool may be used**. This can result in either **tool breakage** or **low-quality outputs**. If the produced gears have inadequate quality and do not meet the required tolerances, **new gears need to be produced**, and the rejected gears must be discarded. This leads to **higher tool expenses**, **longer delivery times**, and ultimately a **decrease in customer satisfaction**.

In conclusion, effective tool management includes proper tool selection and usage. This is essential to make the process more efficient and reduce tool expenses. The technical specialists should be responsible for the tool selection and have to make sure all the machine operators make informed decisions regarding tools.

4.1.3 Information systems

The current information systems could be utilized more extensively to achieve a more efficient purchasing process. By leveraging the capabilities of the information systems and automating certain tasks throughout the end-to-end process, greater efficiency can be achieved.

4.1.3.1 EDI systems

To lower the tool expenses and make the purchasing processes more efficient several steps in the process could be automated. Supplier A and B its EDI systems eliminate administrative work by allowing technical specialists to order tools without the purchaser having to fill in the ERP system details and send emails to suppliers about order details. This type of system could be implemented for other suppliers where a lot of orders are placed, such as supplier C and supplier D, who have together delivered around 10% of the orders in the last four years. Although this is relatively less compared to supplier A (47%) and supplier B (26%), it could be a solution to make the process more efficient.

4.1.3.2 Automating orders

Another solution to reduce administrative work is to combine orders. Article numbers of tools that are ordered frequently can be found in the historical data. As the articles are ordered very frequently contractual agreements with the supplier about delivery and price can be made. This can result in overall lower tool expenses. Automatic ordering also reduces administrative work because the order should not be purchased manually but will be delivered automatically at the agreed moment. Although this approach can result in having a lot of tools in inventory because the need for specific tools is not constant.

4.1.3.3 Internal order template

For orders that still need to be purchased by the purchaser because there is no EDI system available for the suppliers, a different approach to ordering can be used. Instead of writing the internal order on a note and giving it to the purchaser, a template could be created where all the necessary order data can be filled in. The template can be sent to the purchaser and once the order is approved by him, it can be forwarded to the supplier. This reduces unnecessary internal communication about the specifications of the order and ensures that the technical specialist carefully considers what and where he orders. This is because the template contains all the needed information to place the order. When the template is convertible to the ERP system or connected to the ERP system, it reduces the administrative work as well.

An easier step towards digitalizing this process could be to send an email to the purchaser containing the internal order. This approach is more accessible and easy to implement, but still has the potential to significantly improve the process's performance.

4.1.3.4 Inventory management system

The number of ordered tools is already recorded, but tracking the number of broken and lost tools could help create a system to show what tools are still in inventory. If there is a system that contains all data about what is in inventory and the exact storage location, it is easier and faster to search for the required tool. An automatic reminder can be sent when only a few tools are left in inventory, so new ones can be ordered. This is already the case within the EDI systems, but employees often forget to record the removal of tools from inventory.

Inventory management systems can be implemented through various approaches. One option is to create a dashboard using tools like Excel or Power BI. This dashboard would display the inventory levels, and when specific tool types run low, it would generate reorder alerts. These alerts can be determined based

on historical data and expected demand. It is essential to consider the lead times of the items to ensure timely replenishment. Based on this information, the system can calculate the number of tools required in the safety stock for each item.

Another approach is to integrate inventory management into the existing ERP system. This integration could involve implementing inventory management or warehouse management functions. An important aspect of this approach would be that the employees have to register the usage of new tools from inventory in the system to maintain accurate records.

Alternatively, a more expensive option is to use a type of inventory management software system. For example, a software system like "Acctivate" (Stine & Stine, 2023) could be implemented. This software provides reorder alerts and generates reports on sales, inventory, and purchasing information. It also has dashboard functionalities to clearly present data and information. Furthermore, it includes barcoding and mobile systems that combine hardware and software to enable the use of barcodes.

These are all different options for implementing inventory management systems. However, further research into each approach is necessary, although it is beyond the scope of the current research due to time limitations.

4.1.4 Suppliers

Hankamp has ordered tools from 34 different suppliers in 2022. The wish of the company is to lower this number to reduce the amount of administrative work and tool expenses. Having fewer suppliers makes it easier to form contractual agreements and implement an inventory management policy. Research has been done on suppliers with the highest average delivery lateness and suppliers with the highest total tool expenses. An ABC analysis is conducted on the suppliers as well.

4.1.4.1 Average delivery lateness

Table 3 shows ten suppliers with the highest average delivery lateness. When Hankamp is placing an order, an order confirmation with the expected delivery date is sent back from the supplier. Both the expected and actual delivery dates are recorded in the ERP system of Hankamp. Based on this information, the average delivery lateness per supplier can be calculated.

Supplier	Order frequency	Average delivery lateness in days	Percentage of orders delivered on time	Percentage tool expenses of grand total
Confidential	12	48	8%	0.51%
	3	45	0%	0.41%
	2	33	0%	0.11%
	3	28	67%	0.14%
	9	21	11%	0.75%
	6	15	17%	0.70%
	8	14	25%	0.67%
	9	13	22%	0.18%
	6	12	17%	0.15%
	7	12	43%	0.53%

Table 3: Ten suppliers with the highest average delivery lateness (n=7476 ; data from 2019 – 2023; source: Hankamp)

The number of orders placed with these suppliers varies from 2 to 12 orders, which is quite low compared to other suppliers. For instance, supplier A, the supplier with the highest order frequency, has delivered around 4000 orders in the last four years.

Looking at the article numbers of these suppliers, it appears that most articles that were ordered are only available from these specific suppliers. Nevertheless, two article numbers, HKP213 and HKP068, have been ordered from other suppliers in the past. These articles are gear cutters. In Tables 4 and 5, the prices per gear cutter of the other supplier are given. For HKP213 the price at other suppliers is even lower and for article HKP068 the price is the same.

Article number: HKP213	Price per article
Confidential	€ 726.00
	€ 774.36
	€ 869.40

Table 4: Prices of article number HKP213 at different suppliers (n=7476 ; data from 2019 – 2023; source: Hankamp)

Article number: HKP068	Price per article
Confidential	€ 475.00
	€ 475.00

Table 5: Prices of article number HKP068 at different suppliers (n=7476 ; data from 2019 – 2023; source: Hankamp)

Opting for alternative suppliers with shorter lead times could be a possible solution but there are also negative sides to it. Searching for other suppliers is a time-consuming task as they must be added to the ERP system and quality checks need to be performed. For articles that are not ordered regularly, it may not be worth the effort to search for alternative suppliers.

The average lateness of supplier E and supplier F can be explained, as they had delivered one significantly late order while others were delivered on time or just a few days late. In Table 3 the percentage of on time deliveries can be seen. It may be beneficial to discuss the low percentage on time deliveries with the suppliers or search for alternative suppliers.

The percentage tool expenses of the grand total at these suppliers are all under 1%. The expenses are not very high so further research into these suppliers is not necessary. It may be more valuable to look at other suppliers to reduce the high tool expenses.

In conclusion, these suppliers often deliver late, but not many tools are ordered from them. When an item from these suppliers is needed, it may be better to search for alternatives from other suppliers or order in advance. Another finding is that alternative suppliers that are already in the ERP system can provide the items HKP213 and HKP068.

4.1.4.2 Total tool expenses

Supplier	Percentage tool expenses of grand total	Average delivery lateness in days	Average lead time in days	Total quantity of articles ordered
Confidential	32.94%	1	3	32214
	12.68%	9	50	188
	11.12%	1	4	5696
	6.56%	7	81	3118
	5.88%	2	7	2229
	5.72%	-1	68	108
	3.07%	3	24	134
	2.72%	7	63	71
	2.40%	1	19	11996
	1.98%	-1	15	532

Table 6: Ten suppliers with the highest total tool expenses (n=7476 ; data from 2019 – 2023; source: Hankamp)

In total, 83% of the total tool expenses are spent at the ten suppliers shown in Table 6. It is remarkable that more than half of the tool expenses are spent to the first three companies deliver most orders on time, with an average delivery lateness of only 1 day. Supplier C has an average delivery lateness of approximately 9 days. Out of 149 orders placed at supplier D, only 27% were delivered on time. Two orders were delivered exceptionally late, with delays of 150 and 129 days. Even when excluding these outliers, the average delivery lateness is still 8 days. The overall delivery reliability of supplier D is insufficient, resulting in a need for attention and improvement.

Supplier E has an average lead time of 81 days, which is relatively high compared to the other suppliers in Table 6. Considering the significant quantity of articles ordered from this supplier, it is advisable to take the longer delivery time into account. Maintaining inventory and paying extra attention to delivery times when ordering is recommended to ensure smooth operations.

Supplier F stands out in terms of the total quantity of articles ordered, compared to other suppliers with high tool expenses. This is mainly due to two article numbers, B004 and B006, which account for orders of 1000 and 2000 items respectively.

In conclusion, it is important for supplier C to improve their on-time delivery performance. When placing orders with supplier E, it is important to take into account the longer lead times associated with their deliveries.

4.1.4.3 ABC analysis

In Appendix D, an ABC analysis of the suppliers is conducted. Three colors are utilized to evaluate the importance of quality checks on each supplier. Suppliers marked in red require extra attention, due to late deliveries. Suppliers marked in orange perform not optimal, but because of their low importance to Hankamp they are not marked in red. These suppliers need less attention as it might not be worth the effort. Green suppliers, on the other hand, perform satisfactory.

In Figure 14, a decision tree is illustrated. This decision tree is used to determine the importance of a quality check on suppliers. First, a distinction is made between suppliers based on whether the percentage of tool expenses is above 1%. Suppliers with a higher percentage of tool expenses are considered more

important for having a great delivery performance compared to suppliers that deliver, for example, only once a year. Due to this reason, suppliers of greater importance have different delivery date conditions.

Suppliers with over 1% expenses are marked as green with a maximum delivery lateness of 4 days. When the delivery is between 4 and 8 days late, they are marked as orange. If the delivery is more than 8 days late, they are marked as red.

For suppliers with expenses under 1%, they are marked as green for a maximum of 10 days late delivery. They are marked as orange when the delivery is between 10 and 20 days late. If the delivery is over 20 days late, they are marked as red.

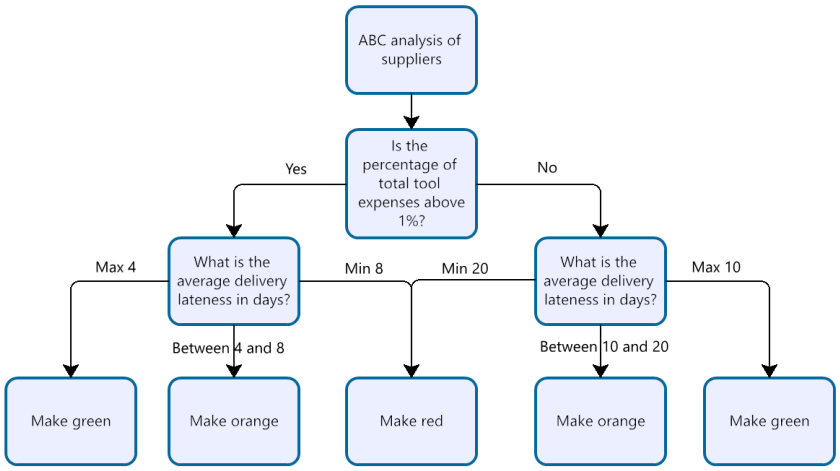

Figure 14: Decision tree of ABC analysis suppliers

4.1.5 Improved BPMN models

In Figures 15 and 16, the improved business processes of Hankamp Gears are illustrated. As part of the end-to-end business process, an inventory system has been implemented to effectively monitor and manage inventory levels. This system is implemented after **the tool breakage activity.** The **record of the tool in the system activity** is an extra activity in the business process. Whenever a tool is taken from the inventory, it is essential to update the system accordingly to maintain accurate information. This inventory system gives timely warnings to ensure that new tool orders are placed and delivered on schedule.

Moreover, a tool ordering template has replaced the **write an internal order activity.** This template significantly saves time for the purchaser as manual **data entry into the ERP system is eliminated.** All the necessary information is clearly presented in the template, minimizing the need for further communication and structuring the ordering process. When it is determined that the tool is not from supplier A and B, the **order template can be used**. This **template is sent** to the purchaser, he **receives the template** and instead of sending an email with order details and adding the data to the ERP system, he simply has to **approve the template** and the **order is placed.**

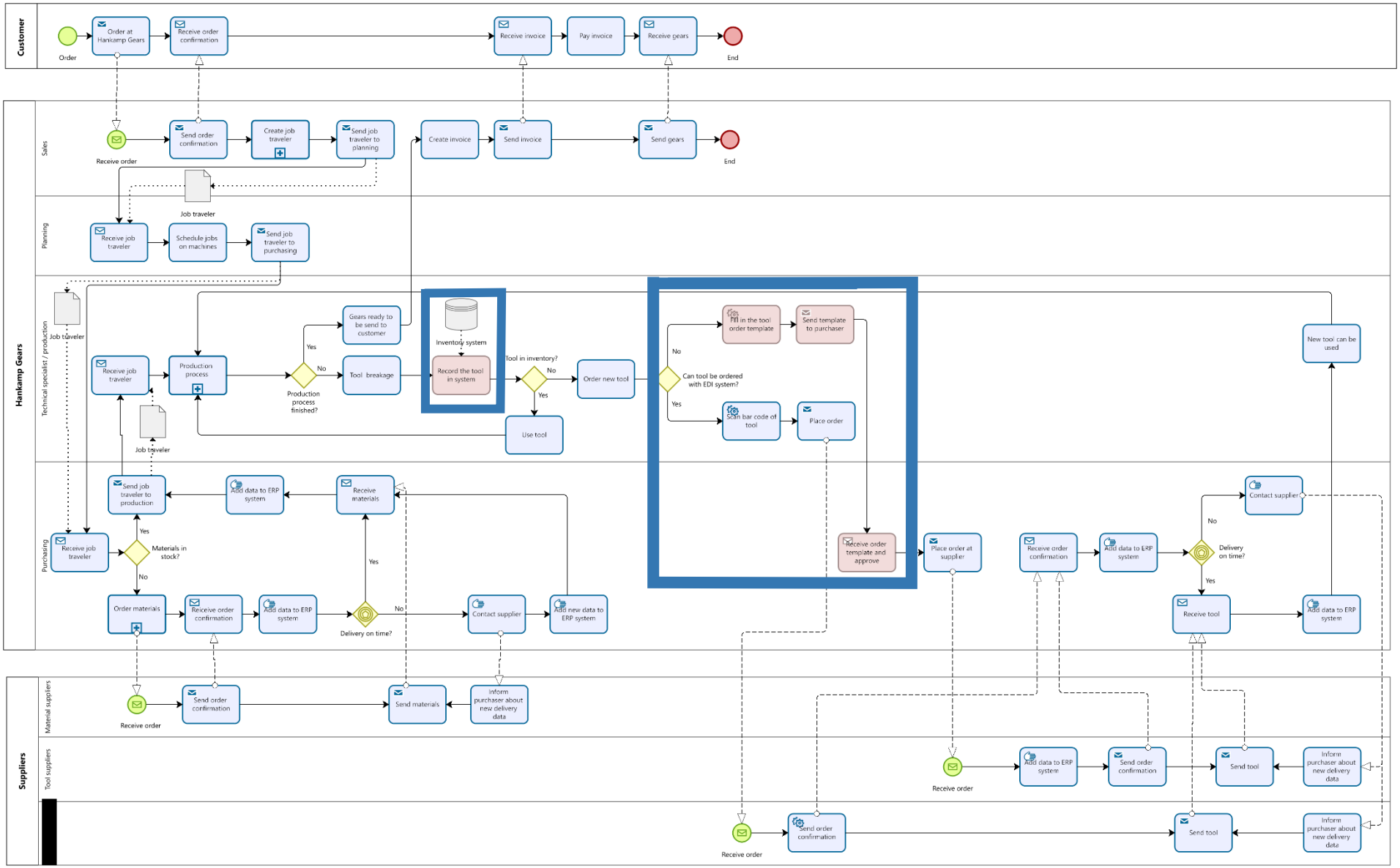

Figure 15: BPMN: Improved end-to-end business process of Hankamp Gears

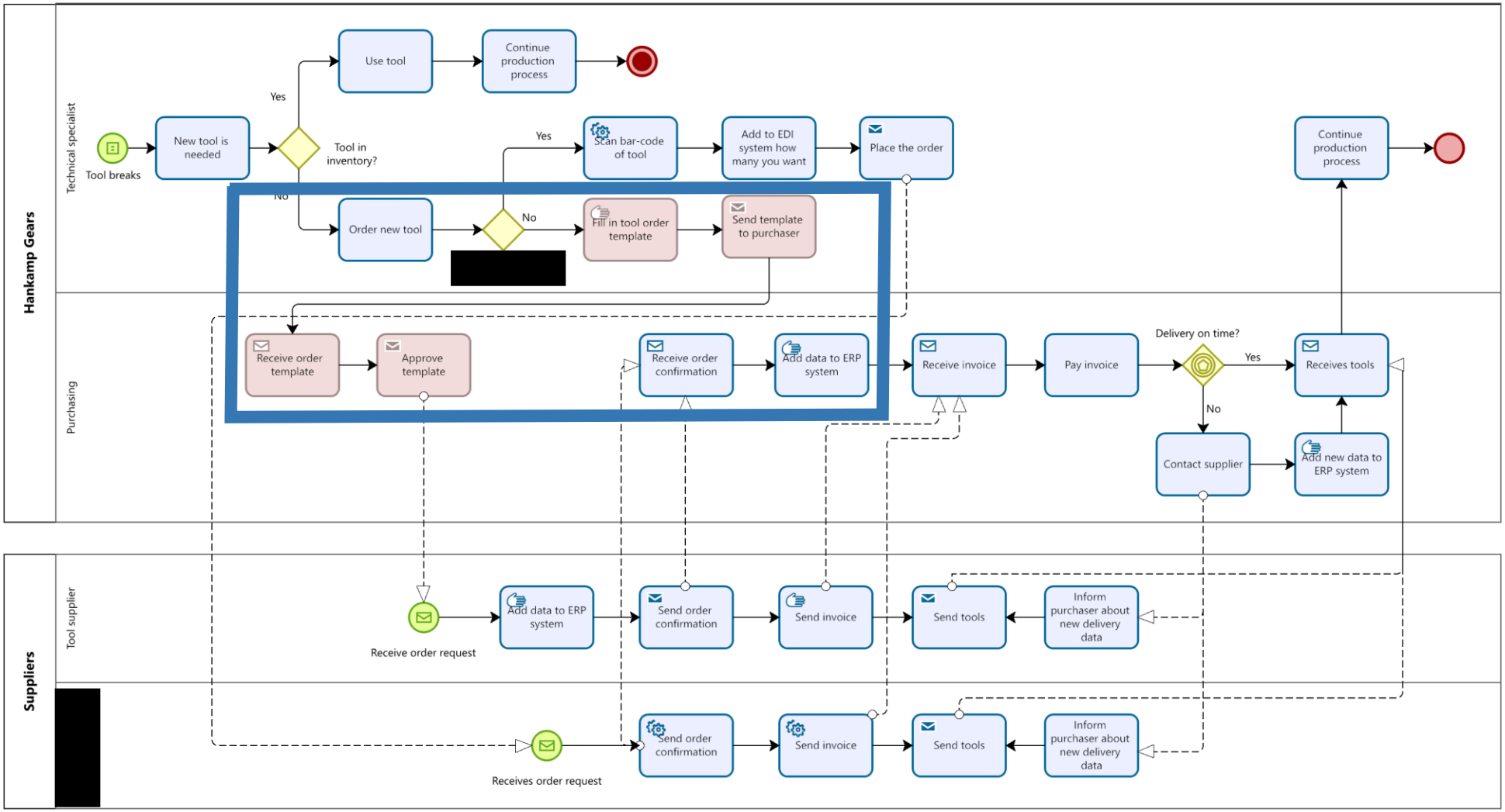

Figure 16: BPMN: Improved purchasing business process of tools of Hankamp Gears

4.2 'To-be' inventory management

4.2.1 Strategy

It is important for the company to first determine its objectives in order to establish an inventory management strategy. The objectives of Hankamp are to reduce tool expenses and to reduce the number of tools held in inventory. Just-in-time ordering is a great strategy to achieve these objectives. JIT models are inventory models that deliver items right before they are needed. This results in fewer tools in inventory and eliminates waste. When implementing a JIT ordering policy, it is important to pay attention to the planning and communication with the tool suppliers. Additionally, the company has to carefully manage potential risks, for example, risks of unexpected demand fluctuations or late deliveries.

The ABC analysis can be used to determine which tools should be given priority in the inventory management strategy. For frequently used tools, it may be useful to have a certain amount in inventory. The appropriate amount should be determined by taking into account the lead time and usage rate, other tools that are rarely purchased do not require as much attention.

4.2.2 Storage locations

The current tools in inventory are stored at different storage locations. There are several storage locations at the machines and a large central one. The operators have stored the needed tools close to the machines. This makes the storage process more difficult and unstructured, leading to longer search times for tools and decreased productivity when the machines are not running because a specific tool needs to be found first. There is little communication between the different departments in production, so it is unclear which tools are at which location.

Furthermore, there is no designated storage location for tools that are only used a few times but are still usable. Sometimes these tools are put back into the drawers, but most of the time, they are kept in the departments. In the departments, the employees know how long the tools have been used and for which operations it is still appropriate to use the tools again. For example, gears with strict quality requirements, such as those for the aerospace industry, must be produced with new high-quality tools to prevent failures in the end products.

To improve the situation, it is important to establish clear guidelines for tool storage. Tools specific to a particular department should be stored near that department, while tools used across multiple departments should be centralized in the larger central storage location. Tools should not be kept directly at the machines but rather in the storage drawers. This will reduce the time spent searching for specific tools.

Most tools are specific to a particular department and are not used in other departments. However, some tools, especially turning and measuring tools, are used across multiple departments. The problem arises when a person uses a tool and keeps it in their department, making it difficult for the next person who needs the tool to find it. To reduce search times for specific tools, a possible solution is to implement a system that keeps track of the last employee who has used the tool. In this way, the next person in need of the tool would know who to ask. By implementing such a system, the availability and accessibility of tools can be improved, minimizing search times and ensuring efficient utilization of tools across departments.

The 5S methodology can be implemented to organize the storage locations. Only necessary tools used in the production process are stored, while other tools that have been stored for years but have never been used should be eliminated or stored at another location for not frequently used tools. The storage drawers should be clearly labeled and arranged in a structured way, resulting in easy identification of different tool types. It is also important to maintain organized and clean storage drawers. A habit of following the established procedures should be developed to keep the storage clear and structured.

Tools that have been used but still can be reused should be labeled with information about the previous use, such as the duration of use and the type of operation they are used for. This will enable the employees to make informed decisions about whether the tools are appropriate for another operation.

Implementing these measures will improve the efficiency, structure, and overall productivity of the tool storage process within the production process.

4.2.3 Inventory management system

It becomes easier to obtain an overview of the tools present in the inventory by implementing an inventory management system. Currently, the inventory levels are not being recorded, except for tools ordered from supplier A and B. For these suppliers, the used tools can be recorded in the EDI system. It is recommended to implement a new system that records both the ordered and used tools, providing an overview of the current inventory levels. Additionally, reasons for a new tool being used and taken out of the inventory, such as tools being broken or missing, can be registered. This can be done to investigate the underlying causes and find ways to reduce tool expenses in the future.

Once there is an overview of the current tools in the inventory, the system can generate warnings when a tool is running low or even automate the ordering process. The timing of these warnings should align with the JIT ordering strategy to reduce inventory levels. The timing depends on different factors, such as the usage rate and lead times. Tools that are frequently used should be held in inventory in larger quantities. Tools with long lead times should be ordered in advance to account for the delivery time. By considering these and other factors, the system can optimize inventory levels and ensure timely replenishment of tools.

4.2.4 Tool categories

Tool category	Percentage tool expenses of the grand total	Percentage articles of grand total	Average price per article	
Gereedschap draaierij overig	46.92%	60.93%	€	60.07
Gereedschap vertandingsslijpen	21.36%	5.91%	€	618.73
Gereedschap frezerij	12.06%	10.44%	€	38.80
Gereedschap vertanding	9.33%	0.35%	€	749.25
Meetgereedschap	3.81%	0.51%	€	451.99
Gereedschap bankwerkerij	3.36%	20.60%	€	39.56
Woodward gereedschap	1.99%	0.91%	€	166.24
Gereedschap rondslijperij	0.89%	0.22%	€	305.71
Gereedschap Chroomsteden	0.15%	0.07%	€	41.38
Gereedschap draaierij beitelpl	0.14%	0.07%	€	52.44

Table 7: Data per tool category (n=7476 ; data from 2019 – 2023; source: Hankamp)

The different tool categories are shown in Table 7. The four largest categories account for approximately 90% of the total tool expenses. The average price per tool type varies significantly. Turning tools cost around €60, while gearing tools cost around €750. This information is valuable for developing an inventory policy because cheaper tools are typically ordered in larger quantities compared to more expensive tools.

- Around 91% of the turning tools are ordered from supplier A, while the remaining turning tools are ordered from twelve other suppliers.
- Around 90% of the gear grinding tools are ordered from supplier B, while the remaining gear grinding tools are ordered from six other suppliers.
- Around 93% of the milling tools are ordered from supplier C, while the remaining milling tools are ordered from four other suppliers.
- Around 53% of the gearing tools are ordered from supplier D, while the remaining gearing tools are ordered from three other suppliers.
- Around 45% of the measuring tools are ordered from supplier E, while the remaining measuring tools are ordered from nine other suppliers.
- Around 99% of the banking tools are ordered from supplier F, while the remaining banking tools are ordered from two other suppliers.
- The remaining categories are supplied by a single primary supplier.

Each category has a main supplier from whom the majority of the tools are ordered. The remaining tools are ordered from other suppliers. These suppliers should be given priority over other suppliers in the same tool category.

4.2.5 Article numbers with high order frequencies

After sorting the article numbers based on the highest tool expenses from the grand total, a list is created with the tools where the most money is spent to the tools where the least money is spent. The first 22 articles numbers are ordered from supplier A. Supplier A already has an EDI system in place, which records the inventory and facilitates the ordering of new tools. When looking at the third supplier with the highest number of orders, is supplier C. Combining orders of supplier C leads to reduced administrative work and transportation costs.

Article number	Average lead time in days	The sum of articles ordered	Number of orders	The sum of days between orders	The average number of days between orders	Average articles per order	Percentage of the average number of days between order /50
0220672	16	608	39	1251	32	16	64%
0220673	16	620	38	1409	37	16	74%
52459	15	669	35	1532	44	19	88%
01 65078	17	691	35	1547	44	20	88%
ZZ010156010633	16	468	34	1547	46	14	91%
52458	17	600	32	1532	48	19	96%
ZZ010156010627	18	448	30	1547	52	15	103%
91825	23	717	28	1456	52	26	104%
93183	24	392	22	1392	63	18	127%
0260113	27	368	19	1392	73	19	147%

Table 8: Article numbers of supplier C with high order frequencies (n=7476 ; data from 2019 – 2023; source: Hankamp)

In Table 8, you can find the most frequently ordered article numbers supplier C. Supplier C is the supplier with the highest number of orders, after supplier A and B. supplier A and B already have an EDI system in place, which facilitates inventory recording and enables the ordering process. Supplier C lacks such a system. To improve the efficiency of the purchasing process, a solution could be to plan the orders from supplier C in advance.

The average number of days between orders can be calculated for these ten article numbers, along with the average number of items ordered per order. By determining the average interval between orders and the appropriate order quantities. These article numbers can be scheduled for ordering every 50 days, ensuring the right quantities are delivered. The quantities per article number are in Table 9. It is recommended to make contractual agreements with supplier C about price and delivery.

Article number	How many articles to order every 50 days
0220672	10
0220673	12
52459	17
01 65078	17
ZZ010156010633	13
52458	18
ZZ010156010627	15
91825	27
93183	23
0260113	28

Table 9: Quantities to order every 50 days (n=7476 ; data from 2019 – 2023; source: Hankamp)

4.3 Results of solution design

The solution design phase has resulted in a list with potential solutions, which include the following options:

- Ensure clear storage locations and traceability of tools
- Enhance employees' tool knowledge
- Specify roles and responsibilities
- Establish contractual agreements with suppliers
- Digitize internal orders
- Implement a combined automatic ordering system
- Implement an inventory management system

4.4 Summary

This chapter answers the following research question: *What is the best solution to optimize the purchasing department processes at Hankamp Gears?* This question is answered by providing an answer to the following sub-questions.

- *What activities can be added/removed/changed to optimize the processes?*

An inventory management system could be added to the process to monitor and manage the inventory levels. The internal orders are currently written on a note, but this could be changed to an online template

which could be connected to the ERP system. By implementing an online order template the activity of manually adding the data to the ERP system could be removed.

- *How can the available Information Systems be applied to optimize the processes?*

The available information systems include the ERP system and the EDI systems from supplier A and B. Implementing additional EDI systems with other suppliers like supplier C and supplier D could be beneficial. An inventory management system can be integrated into the ERP system, enabling the recording of used tools and generating an overview of inventory levels. By leveraging this data about inventory levels, timely warnings can be sent. This results in the technical specialist knowing when it is necessary to order new tools. Another way to improve the efficiency of the purchasing process is by creating a template for internal orders that can be connected to the ERP system. This template reduces the need for manual input into the ERP system, making the overall process more efficient.

- *What kinds of inventory policies can be applied to improve the tool purchasing processes?*

JIT ordering can be implemented as a purchasing strategy. This strategy leads to reduced tool inventories and eliminates waste. This approach can be combined with ABC analysis to identify the critical suppliers, article numbers, and tool categories that require more focus. The tools should be systematically organized in storage locations per department. Tools of the same category should be stored together to make searching for a specific tool easier. The storage drawers should be used following the principles of the 5S methodology to maintain organization. To implement this inventory policy effectively, an inventory management system should be developed to capture and track the current inventory of tools. The system should also provide warnings when tool quantities are running low, so new ones can be ordered.

5 Solution results

In this chapter, we evaluate the possible outcomes of the solutions presented in chapter 4. The following research question will be addressed: *What is the expected impact of the chosen solutions?*

In Section 5.1, the estimated results of the key performance indicators after the implementation of the solution are presented. Section 5.2 introduces a goal model that offers a comprehensive overview of the activities and their corresponding goals. Section 5.3 provides a summary of this chapter.

5.1 Expected change in performance

The solutions identified in chapter 4 have an impact on various key performance indicators. The impact is further elaborated in detail for these KPIs:

- Tool expenses relative to turnover
- Total order frequency
- Number of suppliers
- Number of people involved in the purchasing process
- Number of automated tasks in the purchasing process

5.1.1 Tool expenses relative to turnover

The action problem addressed in this research is the high expenses associated with tool purchasing. The tool expenses relative to turnover are an important Key Performance Indicator due to the objective of reducing the tool expenses by approximately 10%, while maintaining or increasing its turnover.

When the tool expenses decrease by 10%, the formula to calculate the decreased tool expenses is as follows*: decreased tool expenses = original tool expenses * 0.90*. To determine the decrease in tool expenses relative to turnover, subtract the decreased tool expenses from the original tool expenses and express it as a percentage of the turnover*: decrease relative to turnover = (original tool expenses - decreased tool expenses) / turnover * 100.*

The average percentage of tool expenses relative to turnover over the past four years is 7.63%. When the tool expenses decrease by 10% while the turnover remains the same, the expected decrease in tool expenses relative to turnover is approximately 1%. If the turnover increases, the decrease relative to turnover will be even smaller.

Year	Decrease relative to turnover	Tool expenses relative to turnover	Expected tool expenses relative to turnover
2019	0.67%	6.72%	6.05%
2020	0.75%	7.47%	6.73%
2021	0.78%	7.75%	6.98%
2022	0.86%	8.57%	7.71%

Table 10: KPI: tool expenses relative to turnover (n=9614; data from 2019-2022; source: Hankamp)

It is difficult to predict exactly a decrease of 10% in tool expenses after implementing the solutions. This is because the solution consists of many small changes in the processes. The most important change for reducing tool expenses revolves around tool usage. Optimizing the use of each tool by using the right one for each operation will result in a reduced need for new tools. Additionally, storing the tools in the correct

locations and keeping them organized will minimize the number of missing tools and further contribute to lowering tool expenses.

5.1.2 Total order frequency

Assuming that the total order frequency remains unchanged after implementing the solutions. Implementing a JIT ordering strategy leads to an increase in separate orders, but on the other side, other measures decrease the number of separate orders. When a particular type of tool is running low, it directly needs to be ordered individually to make sure it arrives on time. However, despite the increase in separate orders, the overall number of used tool decreases due to longer tool utilization and fewer instances of missing tools.

Furthermore, combining orders from for example supplier C, results in reduced order frequency. Delivery of combined orders every 50 days minimizes the amount of separate orders.

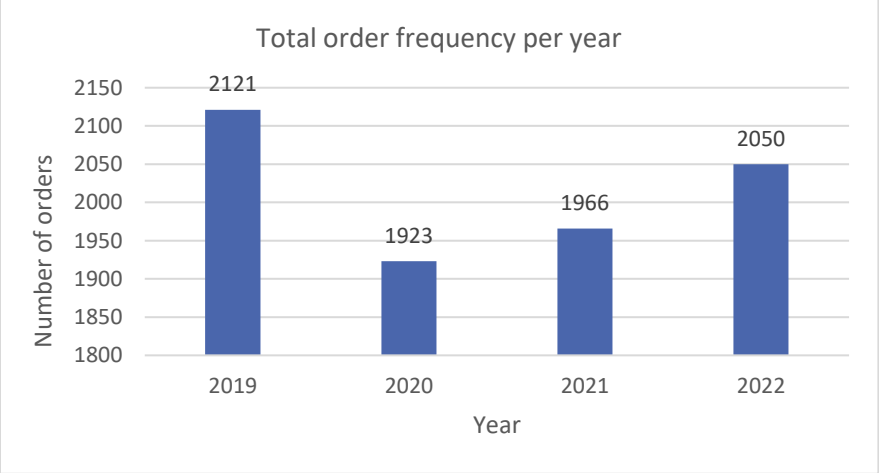

Figure 17: KPI: total order frequency (n=9614; data from 2019-2022; source: Hankamp)

5.1.3 Number of suppliers

Over the past four years, Hankamp has had an average of 36 different suppliers. At most of these suppliers orders have been placed with most years. This number is expected to remain relatively unchanged after the implementation of the proposed solutions.

For each tool category, a primary supplier has been identified, although in some cases, alternative suppliers are used for ordering tools that are either cheaper or not available from the main supplier. By focusing more on the primary suppliers and establishing contractual agreements, there is potential for reduced prices. This could lead to a greater difference in supplier importance for Hankamp, as some suppliers may only be required for specific tools while others hold greater importance.

The delivery performance of certain suppliers has been consistently poor. Further investigation is recommended to determine whether it would be worthwhile to investigate alternative options. Appendix D includes an ABC analysis of the suppliers based on delivery lateness and their overall supplier importance for Hankamp.

5.1.4 Number of people involved in the purchasing process

After the implementation of the solution, the task of ordering tools is now completely assigned to the purchaser. This leads to a well-structured overview of the orders, ensuring that accountability can be easily assigned in case of any issues. The technical specialists are responsible for ensuring that all machine operators make use of the correct tools and maintain the storage locations organized. Additionally, the technical specialists are tasked with initiating a request for new tool purchases, which must be approved by the purchaser.

5.1.5 Number of automated tasks in the purchasing process

The number of automated tasks within the process has been increased. The addition of an inventory management system and the replacement of internal order notes with an online template have resulted in a reduction in manual input and improved process efficiency.

5.2 Goal modeling

The main goal to achieve with this research for Hankamp is to lower the tool expenses. This is modeled in Figure 18, along with the sub-goals that need to be achieved and the activities required to reach those goals. The resources and qualities needed are also depicted in Figure 18.

5.2.1 Hankamp

There are four sub-goals within the Hankamp agent, all contributing to the main goal of lowering the tool expenses. These are:

- Better use of information systems
- Formation of contractual agreements
- Improvement of tool purchasing processes
- Implementation of inventory management

To achieve a **better use of information systems**, **internal orders could be digitalized**. This can be done in two ways, either by **creating an internal order template** connected to the ERP system or by **emailing the internal order** to the purchaser. For these activities, the employees should be **informed about the use of the information system** to understand the new way of ordering. The quality of being **eager to learn** can help with this activity. Another way to improve the use of information systems is **to implement traceability of tools** to ensure clear storage and reduce the search time for tools. The turning and measurement tools, which are often shared among employees, can be tracked **by adding a function to the ERP system**. This function can be a system where employees add which tool they have used out of the inventory, so the next employee who needs the tool knows who used it last. Before implementing this kind of function, **research needs to be conducted** to determine which tools are shared most frequently. The resource **tool data** is needed for this investigation. The implementation of **combined automatic ordering** could also help achieve a better use of information systems. To accomplish this goal, the tasks of **automating the orders** and **combining the orders** should be implemented. Before this can be done, **research should be conducted** to determine which suppliers and tools can be ordered together. The resource **supplier data** is needed for this investigation.

Forming contractual agreements can help lower the tool expenses. To form contractual agreements, an **agreement should be proposed** and **signed** together with the supplier. The agreement should have

benefits for both parties. Based on the **research of the suppliers**, potential **suppliers to form agreements with can be identified**.

Improving the purchasing process and making it more efficient will contribute to the main goal of lowering the tool expenses. The process can be improved by **increasing employees' knowledge about tool selection**. A better understanding of tools can result in increased capacity and longer tool lifespans. To achieve this, the employees should be **informed about the tool selection process**. The quality of being **eager to learn** can help with this task. Another goal that can improve the purchasing process is **enhancing the knowledge of employees regarding their roles and responsibilities**. By informing the employees about this, the process will be clearer for them, and they will know their role in it. It will be clear who is responsible for ordering and whom to ask questions.

Lowering the tool expenses can also be achieved by **implementing inventory management**. To achieve inventory management, two goals should be met. First, the **knowledge of the information system should be enhanced**, and second, the **inventory management system should be implemented**. Three types of systems can be implemented. An **inventory management software** program can be connected to the current ERP system to keep track of inventory and provide alerts when the inventory is low. This can also be accomplished by **adding an inventory management function to the existing ERP system**. Alternatively, **a separate dashboard can be created** to track inventory and ensure timely orders are placed.

5.2.2 Purchaser

Within the role of the purchaser, the task of **making the roles and responsibilities clear** is stated. This task is dependent on **enhancing the knowledge about the roles and responsibilities,** which, in turn, results in a **better implementation of inventory management** and **improves the tool selection processes.**

5.2.3 Employees in production

Within the role of the employees in production, three tasks are specified. The first task is to undergo **tool selection training** to **enhance the knowledge of tool selection**, which results in **an improved purchasing process.** The second task is to receive **training about information system use**, which **enhances the knowledge of the information system** and results in a **better use of the information system** and the **implementation of inventory management**. The third task is to **inform the employees in production about the roles and responsibilities.** These activities help achieve the **improvement of the purchasing process** and the **implementation of inventory management.**

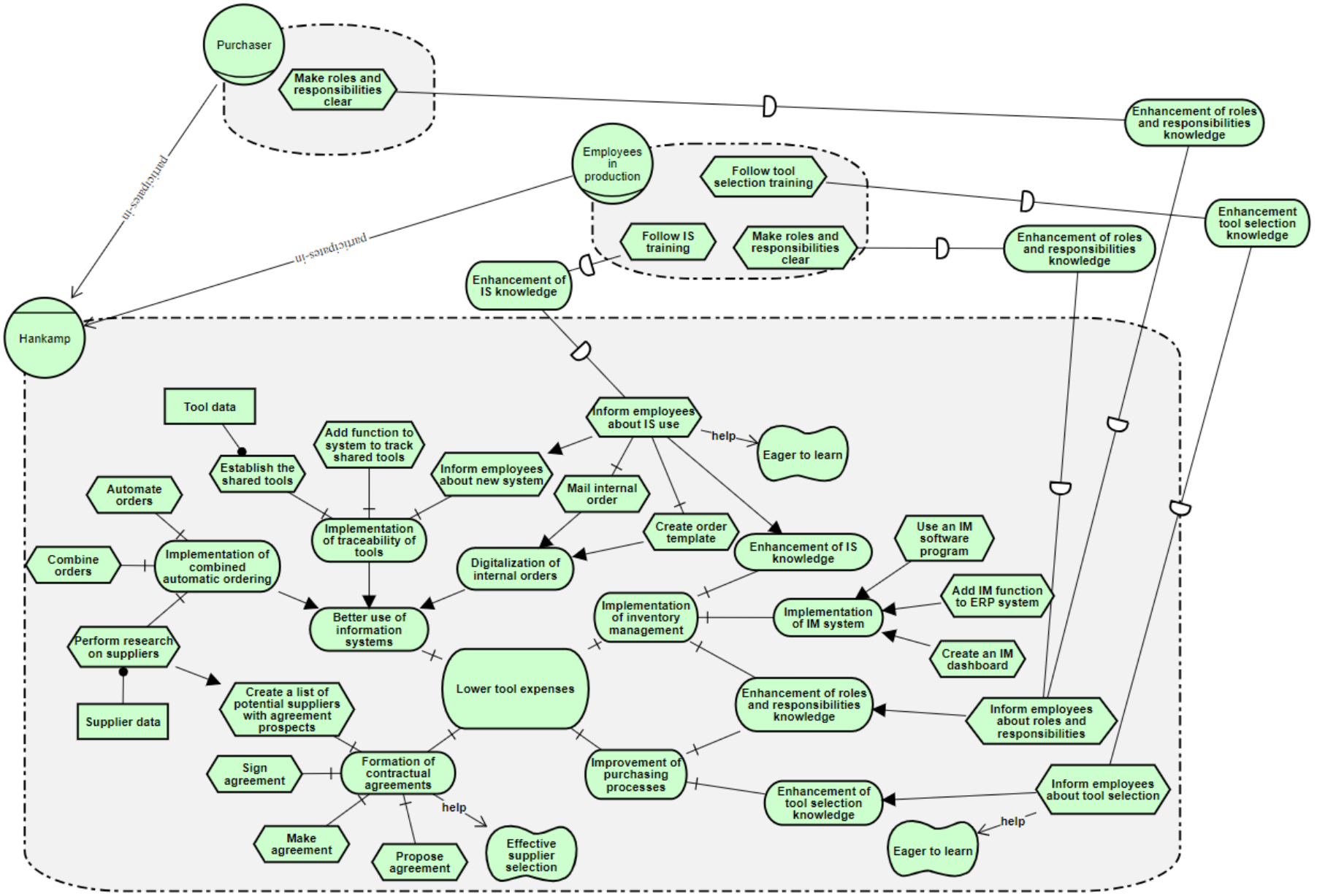

Figure 18: Goal-model

5.3 Summary

This chapter answers the following research question: *What is the expected impact of the chosen solutions?* This question is answered by providing an answer to the following sub-questions.

- *What is the effect on the performance indicators?*

The tool expenses relative to turnover are estimated to decrease by approximately 1% due to the implementation of the new solutions. This reduction is the result of a 10% decrease in tool expenses. The order frequency will remain unchanged, but there will be changes in how orders are managed. The difference between important suppliers and less important suppliers will be enlarged, but the number of suppliers will maintain the same.

It is important for all employees to have a clear understanding of their tasks related to purchasing to ensure efficiency and informed decision-making in the process. However, only one person, the purchaser, will have responsibility for managing the orders. Automation will play an important role in reducing manual input and enhancing the overall efficiency of the purchasing process.

- *What actions need to be taken to achieve the desired outcome?*

The main goal of Hankamp is to achieve lower tool expenses relative to its turnover. Several actions need to be taken to achieve this goal. The four sub-goals help to achieve the main goal. These sub-goals and their accompanying tasks are:

- Better use of information systems: digitalize internal orders, implement traceability of tools, implement automatic combined ordering
- Formation of contractual agreements: form agreements with suppliers and sign contracts
- Improvement of tool purchasing processes: enhance knowledge on roles and responsibilities, enhance knowledge on tool selection
- Implementation of inventory management: implement an inventory management system, enhance knowledge on information systems, enhance knowledge on tool selection

6 Implementation plan

In this chapter, a detailed implementation plan is developed to implement the identified solutions. The following research question will be addressed: *How to implement and evaluate the chosen solutions for the purchasing department processes at Hankamp Gears?*

When creating an implementation plan, it is important to consider six steps to ensure that the plan includes all the necessary components. Following these specific steps reduces the risk of gaps in the implementation strategy (Asana, 2022).

1. Define goals
2. Conduct research
3. Map out risks
4. Schedule milestones
5. Assign tasks
6. Allocate resources

Steps one and two have already been performed in previous sections. In section 3.4, the desired situation is described along with the corresponding goals that are intended to be achieved. In the solution design chapter, research is conducted to find solutions to achieve these predetermined goals. Section 6.1 focuses on change management, and section 6.2 maps out the potential risks that could arise. Following that, in section 6.3, a time plan is presented. And in section 6.4, an RACI analysis is performed. Section 6.5 shows the resource allocation, and 6.6 provides a summary of this chapter.

6.1 Change management

A important part of implementing the solutions is change management. Change management is a systematic approach to deal with organizational changes effectively. It involves planning, implementing, and monitoring changes to make sure the transition is smooth and disruptions are minimized (Lawton & Pratt, 2022). The objective of change management is to help with the successful implementation of new processes, systems, structures, or strategies within an company while minimizing resistance and maximizing employee acceptance and engagement.

ADKAR is a method for implementing change. ADKAR stands for Awareness, Desire, Knowledge, Ability, and Reinforcement. Utilizing this method ensures correct implementation of solutions and increases the likelihood of successful change adoption.

- Awareness: Firstly, employees should be made aware of the reasons for the change. When they understand the purpose behind the change, it becomes easier for them to adapt to the new approach. Employees should be informed about the desired reduction in tool expenses and the reasons behind this objective.
- Desire: Secondly, employees should be motivated to embrace the changes. It is important to explain the positive impact the changes can have on their work and ways of operating. This could include, for example, using tools more efficiently and increasing production capacity by utilizing the appropriate tools.
- Knowledge: Employees should be provided with the necessary knowledge to enact the change. This could involve courses on tool usage or providing information about how a new information system will function.

- Ability: Employees should feel confident that they have the required knowledge and capabilities to implement the desired changes. Assigning a responsible person, such as the purchaser, and making him available for questions, coaching, and support can help to build this confidence.
- Reinforcement: After the change is implemented, it is crucial to sustain it over the long term. The new situation should become the norm. This can be achieved by reinforcing the new behaviors and integrating the changes into the organization's systems and culture.

6.2 Risk assessment

Several risks could arise when implementing changes. It is important to actively address these risks and develop strategies to mitigate them during the implementation phase. With the implementation of a new digital solution, there is a risk of not fully utilizing it. Some employees may have been working for a long time and are used to their existing ways of working. It is also possible that only half of the employees will adopt the new digital solution while the other half continues to use internal order notes. This can lead to confusion for purchasers and result in an unstructured and chaotic ordering process. It is crucial to keep employees informed, engaged, and address their concerns regarding the changes. Introducing changes requires careful change management to ensure that employee satisfaction does not decrease.

In the case of the inventory management system, it is important to update the system whenever tools are taken. If employees fail to do so, the system will not reflect accurate data, leading to incorrect inventory levels. This can result in late orders or running out of specific tools due to delays in receiving alerts.

It is essential to provide comprehensive explanations of the systems to employees who need to use them. If employees do not understand the system or the reasons behind its implementation, the likelihood of unsuccessful adoption increases. The same applies for the tool uses courses, employees need to understand the purpose and importance of the training, or they may not pay attention or perceive it as unnecessary. In the worst-case scenario, employees may disagree with the changes and even decide to quit.

Caution should be exercised when starting contractual agreements with suppliers. It is important to carefully consider the desired outcomes of the agreements. If a supplier is dissatisfied with a proposal, this may have influence on future cooperation. Therefore, agreements should be made with long-term suppliers and must be mutually beneficial.

It can be advantageous to have one or a few large suppliers, but there is also a risk of supplier dependency. Relying on one or a few suppliers for all critical supplies exposes the organization to, for example, disruptions in the supply chain and price volatility.

In conclusion, recognizing and actively managing these risks during the implementation phase is important for successful change management. By addressing concerns, providing explanations and training, and carefully considering supplier agreements, companies can increase the likelihood of a smooth change with minimal potential disruptions.

6.3 Planning

It takes some time before changes are implemented and the results will be seen. It is important to implement and monitor the situation well to see if the results of the solutions will be the same as expected.

6.4 RACI analysis

The different roles and responsibilities for each task or activity should be well understood by employees in order to achieve optimal performance. Conducting a RACI analysis can help clarify the division of responsibilities. RACI stands for Responsible, Accountable, Consulted, and Informed. In the purchasing process of tools and inventory management, these roles can be divided as depicted in Figure 19. To implement these findings effectively, it is important to hold a meeting with employees to ensure that everyone is aware of their specific responsibilities and roles, as well as knowing whom to approach with specific questions.

RACI Matrix

Purchasing processes Hankamp Gears — Responsible, Accountable, Consulted, Informed

	Roles		
Task or activity	Purchaser	Technical specialists	Machine operators
Tool purchasing process			
Identify the need for a new tool		R+A	C
Determine the specific requirements	I	R+A	I
Approval for the purchase	R+A	I	
Place the order	R+A		
Contact the supplier	R+A		
Order arrival	R+A	I	I
Inventory management			
Checking inventory levels		R+A	
Identify the need for new tools	I	R+A	C
Place the order	R+A	C	
Storing the tools		R+A	I

Legend:	
R	Responsible (Person who is assigned to complete the task or activity)
A	Accountable (Person who make final decision making and is accountable for completion)
C	Consulted (person who is consulted before decision)
I	Informed (Person who is informed after decision making)

Figure 19: RACI Matrix of purchasing processes Hankamp Gears

6.5 Resource allocation

Resource allocation is an important aspect of implementing solutions, as several resources are needed to achieve the desired outcomes. These resources include time, personnel, technology, and financial investments.

When it comes to training employees, multiple resources are required. Training programs, materials, and tools are necessary to equip employees with new knowledge and skills. It is important to design the training program based on the employees' learning styles and requirements. Time is also a valuable resource, as training sessions need to be scheduled and planned when employees are available.

A budget is necessary for implementing information systems and training. The cost will vary depending on the type of information system being implemented. The process of implementing a new information system can take time, as it may involve potential system upgrades and integration with existing systems. Allocating enough time for planning, testing, and implementation is important to minimize disruptions to

ongoing operations. It is important to consider the return on investment when assessing the cost associated with acquiring and implementing new software, ensuring that the benefits outweigh the incurred costs.

6.6 Summary

This chapter answers the following research question: *How to implement and evaluate the chosen solutions for the purchasing department processes at Hankamp Gears?* This question is answered by providing an answer to the following sub-questions.

- *What factors should be taken into account when implementing the solutions?*

There are several factors that need to be taken into account before the solutions will be implemented successfully. These factors are:

- Change management
- Risk assessment
- Planning
- The roles and responsibilities
- Resource allocation

Change management is an important concept when it comes to implementing changes in an organization. The objective of change management is to minimizing resistance and maximizing employee acceptance and engagement to get the best results of the solutions. The ADKAR method helps ensure effective implementation and change adoption.

Implementing solutions can entail risks that must be addressed during the implementation phase. These risks may include underutilization of digital solutions, employee dissatisfaction, inaccurate inventory data, and potential supplier dependency. To minimize these risks, it is important to keep employees informed and engaged through effective change management. By managing these risks, the implementation process can proceed smoothly with minimal disruptions.

Planning is an important aspect of implementation. A timeline should be established to guide the implementation of changes, and it is important to closely monitor the changes to determine if they yield the desired results over time.

Employees should have a clear understanding of the roles and responsibilities for each task or activity. A RACI analysis is conducted to help clarify the division of roles and responsibilities. It is important to have a meeting with employees to effectively implement and ensure that everyone is aware of their specific roles and responsibilities.

Implementing solutions requires careful resource allocation to achieve the desired outcomes. Resources such as time, personnel, technology, and financial investments are important.

- *How can the chosen solution be effectively monitored?*

Throughout the implementation process, it is important to monitor KPIs to assess whether the desired results are being achieved. The expected outcomes of these KPIs are outlined in Chapter 5. Continuous measurement of these KPIs during the implementation process enables timely identification of any disruptions.

7 Preliminary validation

In this chapter, the impressions of the management of Hankamp Gears regarding the recommendations and implementation plan are described. Section 7.1 explains the method used to conduct this part of the research, and section 7.2 analyzes the results.

7.1 Method

The method used to gather the company's opinion on the proposed solutions is through interviews. The management of Hankamp Gears is informed about the possible recommendations and asked to provide their opinion. They are questioned about their thoughts on the solutions that they believe will improve the tool management processes best, as well as those that are unlikely to be implemented. Additionally, attention is given to evaluating the amount of effort required for each solution in relation to its potential improvements.

7.2 Results analysis

The results of these interviews are a list of potential solutions ranked based on their importance for Hankamp. The desired solutions are those that offer the most improvement with the least effort. These are the ranked solutions:

1. Specify roles and responsibilities
2. Establish contractual agreements with suppliers
3. Digitize internal orders
4. Ensure clear storage locations and traceability of tools
5. Enhance employees' tool knowledge
6. Implement a combined automatic ordering system
7. Implement an inventory management system

1) Ensuring clear roles and responsibilities for employees is important for Hankamp. When the new purchaser joins, it becomes even more important to establish clarity in these roles. Introducing a more efficient way of ordering can have a significant impact on the overall process. Since the new purchaser lacks prior experience with the purchasing process at Hankamp, there are various opportunities to implement a new and effective purchasing method without needing to change existing ordering habits.

2) There are no current contractual agreements in place with suppliers. Especially for suppliers with high tool expenses, negotiating price agreements would be highly beneficial. This straightforward solution has substantial impact and is therefore of great importance.

3) Digitalizing internal orders from written notes to email communication represents a relatively small change, yet it holds importance for Hankamp. Taking it a step further and implementing an online template can yield even greater improvements. This straightforward solution delivers significant results, ranking it third in terms of importance.

4) Ensuring clear storage and traceability of tools that are used at multiple departments can reduce search times and improve overall performance. Implementing this solution will be a complex task that requires careful consideration and further research.

5) Increasing the tool knowledge of employees can be achieved by sending them to external courses or train them internally. These approaches encourage employees to be more thoughtful in their tool

selection, which could increase the tool lifespans and production capacities. It is easy to educate the employees, but the successful implementation of new knowledge depends on effective change management.

6) Combining and automating orders from key suppliers has the potential to improve performance. However, relying on historical data for tool purchases can lead to inaccurate results due to the diverse production history. Additionally, some article numbers that are ordered very frequently could be a result of incorrect usage or frequent losses. Researching the causes behind the frequent orders should be conducted before proceeding with the combination and automation of orders.

7) The management of Hankamp has expressed their lack of interest in an inventory management system. A system that tracks inventory and provides alerts when stock levels are low is at the moment not desired. Consequently, this solution ranks seventh in terms of priority.

8 Conclusions and recommendations

This chapter gives the main conclusions of this research. Section 8.1 gives answer to the sub-research questions in order to answer the main research question. In section 8.2 the recommendations from this research are made for Hankamp. The discussion includes, limitations and further research, and is described in section 8.3 and section 8.4.

8.1 Conclusions

The aim of this research is to optimize the purchasing processes for tools with the objective of lowering the tool purchasing expenses. The main research question of this research is:

What are the optimal business processes affecting tool management for Hankamp Gears?

The main research question is answered by providing an answer to the following sub- research questions:

- *What are the current processes applied by the purchasing department at Hankamp Gears?*

Chapter 3 focuses on the current processes of Hankamp Gears, presenting BPMN models representing them. The current important processes in the purchasing department applied at Hankamp Gears are related to the end-to-end process, the purchasing process of tools, and inventory management. Currently, Hankamp has an end-to-end process that lacks structure and contains a lot of manual input. Creating a job traveler and scheduling the machines are steps that need to be taken before the materials can be ordered, which can result in ordering too late.

The purchasing process of tools is important so explain elaborately. This process has different methods of ordering new tools and also involves a lot of manual input. Ordering tools at supplier A and B goes via an EDI system, which orders the tools without the need for a purchaser. However, tools from other suppliers need to be ordered by an internal order to the purchaser, who adds it into the ERP system.

The current inventory management of Hankamp is random. There is no policy regarding tool management. Tools are ordered randomly and stored in storage cabinets at the machines or in a central location. Often, when a new order for a specific tool is placed, depending on the price and lead time, multiple tools are ordered and stored for later use.

- *What are relevant techniques for process optimization in the purchasing department?*

Relevant process optimization techniques can be found in the theoretical framework, which is explained in Chapter 2. Relevant process optimization techniques include Business Process Management, Lean Management, and Six Sigma. BPM is a technique that identifies business processes, analyzes them, and redesigns them to create optimal processes. BPM consists of six phases: process identification, process discovery, process analysis, process redesign, process implementation, and process monitoring and controlling. BPMN can be used to model the processes in the discovery and redesign phases. In BPMN, business processes are visualized in a detailed sequence of activities. Additionally, information flows are modeled to obtain a more complete overview of the business process.

Lean management is a technique that aims to minimize waste in business processes. There are seven types of waste in lean management: overproduction, waiting, transportation, excess processing, inventory, motion, and defects. The main goals of lean management are reducing costs, optimizing the use of resources, and creating a continuous workflow.

Six Sigma is a technique that focuses on reducing variability in processes to decrease the possibility of failures. This can be achieved by using the structured DMAIC approach, which stands for define, measure, analyze, improve, and control.

- *What is the best solution to optimize the purchasing department processes at Hankamp Gears?*

In Chapter 4, the solution design chapter, research has been done on employees, information systems, and other aspects to possibly improve the tool management processes.

Research has been conducted on the employees of Hankamp. The results indicate the importance of clearly explaining roles and responsibilities to everyone involved in the processes. It is also recommended to encourage employees in production to think more about which tool to use.

Research on information systems has led to the suggestion of expanding their use. Implementing more EDI systems with frequently ordered tool suppliers can improve processes. Repetitive orders for specific tools that are used frequently can be combined and automated, reducing administrative work. Creating an internal order template or sending internal orders via email instead of using notes can provide better visibility and decrease administrative work. Additionally, implementing an inventory management system can help track inventory levels and send notifications when certain tools are running low and need to be reordered.

Research on suppliers has resulted in a list of potential suppliers for contractual agreements, as well as identifying areas where suppliers need to improve their performance. For instance, suppliers with consistently late deliveries can be approached to prioritize timely delivery.

Regarding tool storage, research has been conducted to find a suitable solution. Tools specific to a particular department should be stored within that department, while shared tools should be kept in a central storage location. These tools should be traceable by requiring users to update the system when they use a specific tool, so the next person in need of the tool knows its usage history. Implementing the 5S methodology can help maintain structured storage locations.

- *What is the expected impact of the chosen solutions?*

In Chapter 5, the results of the solutions are predicted, the expected impact on performance indicators is shown, and goal models are created. The implementation of new solutions is expected to result in a decrease of approximately 1% in tool expenses relative to turnover. This reduction is the result of a 10% decrease in tool expenses. It is expected that the order frequency will remain unchanged, but there will be changes in how orders are managed. The distinction between important and less important suppliers will be further emphasized, but the number of suppliers will remain the same.

To ensure efficiency and informed decision-making in the purchasing process, it is important for all employees to have a clear understanding of their tasks related to purchasing. However, the responsibility for managing the orders will lie with the purchaser. Automation will play a significant role in reducing manual input and improving the overall efficiency of the purchasing process.

The solutions are expected to help achieve several goals, including better use of the information system, formation of contractual agreements, improved purchasing process, and implementation of inventory management.

- *How to implement and evaluate the chosen solution for the purchasing department processes at Hankamp Gears?*

The proposed solutions can be implemented by considering several components, including defining goals, conducting research, mapping out risks, scheduling milestones, assigning tasks, and allocating resources. These steps are more elaborated on in Chapter 6. It is important to consider change management alongside these components. Change management plays an important role in ensuring the successful implementation of new processes, systems, structures, or strategies within a company, while minimizing resistance and maximizing employee acceptance and engagement.

To evaluate the effectiveness of the solutions, monitoring various KPIs can be done to assess whether the desired results are being achieved. Continuous measurement of these KPIs throughout the implementation process allows for timely identification of any disruptions.

8.2 Recommendations

Based on the results obtained from this research, the following recommendations are suggested for Hankamp:

- It is recommended to specify the roles and responsibilities of the employees and the purchaser. This could result in better and more effective communication among them, improve accountability, and lead to a more effective workflow with better collaboration. It aligns individual efforts with organizational objectives and contributes to the overall success of the company.
- It is recommended to establish contractual agreements with certain tool suppliers. Suppliers that Hankamp frequently orders from are of great importance. It could be beneficial to make agreements with these suppliers, for example, regarding price to lower tool expenses. Agreements about delivery times could also be made with suppliers who have a high average delivery lateness to ensure more on-time deliveries.
- It is recommended to digitalize the internal tool orders. This results in less administrative work and reduces the possibility of making mistakes. It ensures that technical specialists think twice about what to order, how many, and from which supplier, enabling more informed decision-making.
- It is recommended to ensure clear storage locations and traceability of shared tools. Having clear storage locations results in less time spent searching for tools and creates more structure. Storing shared tools at a central location and recording the last person who used the tool will reduce search times. Reducing search times could increase machine capacity.
- It is recommended to enhance employees' tool knowledge about tool selection. This can be done by providing internal or external courses. By putting more effort into the tool selection process will result in fewer tool breakages, longer tool lifespans, and increased production capacity.
- It is recommended to look for certain suppliers and tools that can be ordered together. When certain type of tools are ordered regularly, these orders can be combined and automated. Making agreements about this with suppliers can also involve negotiating price agreements. This method of ordering will reduce the number of separate orders and potentially decrease tool expenses.
- It is recommended to explore possible inventory management systems. These systems could help track inventory levels and provide warnings when certain types of tools are low in stock, allowing for timely reordering. This is especially convenient for tools with long lead times.

8.3 Limitations

There are some limitations within this research. The following limitations have been identified:

- Time limitation: This research was conducted within a ten-week interval. As a result, only recommendations for an implementation plan are provided. The actual implementation of the solutions is not performed.
- Data limitation: Limited data was available for this research. No data was available regarding the inventory of tools, including information on how many tools are currently in stock. Additionally, No data was available on the search times for tools and data about the lifespan of tools is not available as well.
- Inaccurate data: The data used in this research spans from 2019 to 2023. The outbreak of Covid-19 in 2020 had impact on the used data. This may have led to inaccurate results when analyzing repetitive orders, as fewer orders were placed during the Covid-19 period. Another source of data inaccuracy is the manual process of adding orders to the system. Sometimes, when employees are absent due to sickness or vacation, the delivery date may be added to the system at a later time. This discrepancy between the actual delivery date and the date recorded in the system can affect the accuracy of the data.

By acknowledging these limitations, it is important to consider their potential impact on the findings and conclusions of this research. For example, when more data was available, more research could be performed on the tools in the inventory and how many tools were, on average, in stock. The lifespan of tools could be researched more thoroughly, and even the search times could be looked at. Researching these topics could be beneficial for this study and could lead to interesting findings that would further improve the tool management processes.

8.4 Further research

The following suggestions for further research have been identified:

- Investigation of tool usage: When implementing an inventory management system, further research can be conducted to explore the reasons behind the need for new tools. This research can examine factors such as tool breakage due to wear or incorrect usage, as well as instances where tools are lost. By documenting the reasons for ordering new tools in the inventory management system, a deeper understanding of tool usage can be gained. Investigating these reasons can provide insights into why new tools are frequently ordered and help identify potential solutions to reduce the number of tools ordered.
- Supplier evaluation: While the current research primarily focuses on suppliers' delivery performance, further research can be conducted to evaluate suppliers based on other criteria, such as quality and tool availability. This research can contribute to the company's goal of reducing the number of tool suppliers.
- Selection of inventory management software: When implementing inventory management within the organization, there are multiple approaches and software options available. Further research should be conducted to determine the most suitable software or identify additional functions that can be integrated into the existing system. This research will help identify the best inventory management solutions for the organization.
- Optimization of storage locations: Further research can be done to determine the optimal storage methods for tools. This research can explore different approaches, such as evaluating the benefits

and drawbacks of a larger central storage location versus multiple smaller storage locations within departments. Factors such as accessibility, inventory duplication, and overall storage capacity should be considered to determine the most effective storage strategy.

- Research on outsourcing and materials: The current research does not focus on materials and outsourcing practices within the purchasing process. Further research in these areas can lead to additional improvements. Investigating the impact of materials and outsourcing on inventory management can help optimize the overall process and identify potential areas for enhancement.

By conducting further research, Hankamp can gain valuable insights and develop strategies to improve their performance even further.

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Appendices

Appendix A

What are the optimal business processes affecting tool management for Hankamp Gears?							
Knowledge problem	Type of Research	Research population	Subjects	Research strategy	Method of data gathering	Method of data processing and analysis	Action plan
1. What are the current processes applied by the purchasing department at Hankamp Gears?	Descriptive	Hankamp Gears	Employees	Qualitative research	Interviews, observations (cross-sectional)	Visual representation of the process in BPMN,	Interview employees→ Observe the processes→ Generate overviews of BPM
2. What are relevant techniques for process optimization in the purchasing department?	Descriptive	Literature	Database	Qualitative research	Literature study (cross-sectional)	Theoretical framework	Research→ SLR→ Literature study→ Describe theoretical framework→ Answer sub questions
3. What are the best solutions to optimize the purchasing department processes at Hankamp Gears?	Descriptive	Purchasing department	Employees, data	Quantitative research	Data from the ERP system, interviews (cross-sectional)	Data analysis, graphs and tables, descriptive text with the best solution	Data gathering→ Data preparation→ Data analysis → Write a conclusive text
4. What is the expected impact of the chosen solutions?	Evaluative	Purchasing department	Employees, data	Quantitative research	Data from the ERP system and results from the analysis in question 3 (longitudinal)	Data analysis, graphs and tables, descriptive text with the outcomes	Analyze the chosen solution→ Write about the improvements in the process
5. How to implement and evaluate the chosen solutions for the purchasing department processes at Hankamp Gears?	Explanatory	Hankamp Gears	Employees, data	Qualitative research	Interviews, observations (longitudinal)	Implementation plan, recommendations, and evaluation story	Interview employees→ Observe → Write implementation plan→ Write recommendations→ Evaluate the solution

Table 11: Elaborated research design

Appendix B

Flow objects:	*Symbol:*	*Description:*
Start event		Used to trigger processes
Intermediate event		Used to delay processes or can be triggered during process executions
End event		Used to signal the termination of processes
Activity	  *Activity types (Weske, 2012, p. 215)*	Units of work that could contain a symbol in the left upper corner to specify the kind of activity
Sub activity		Activities with an internal structure
Gateway	  *Gateway types (Weske, 2012, p. 225)*	Decision point, could contain a symbol to specify the type of gateway

Table 12: Flow objects (source: Bizagi Modeler)

Artifacts:	*Symbol:*	*Description:*
Data object		Used to indicate digitalized information and physical objects

Datastore		Used to indicate information systems where data is stored
Group		Used to group elements of a diagram

Table 13: Artifacts (source: Bizagi Modeler)

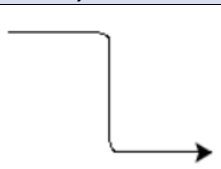
Connecting objects:	*Symbol:*	*Description:*
Sequence flow		Used to show the order business activities will be performed in
Association		Used to associate information and artifacts with flow objects
Message flow		Used to show the flow of messages between two entities (entities are represented by pools)

Table 14: Connecting objects (source: Bizagi Modeler)

Appendix C

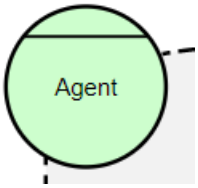
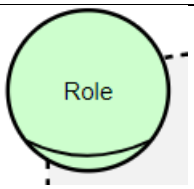
Actors:	*Symbol:*	*Description:*
Agent		An abstract characterization of the behavior of a social actor within some specialized context or domain of endeavor
Role		An actor with concrete, physical manifestations, such as a human individual, an organization, or a department

Table 15: Actors (Dalpiaz et al., 2016)

Actors association links:	*Symbol:*	*Description:*
Participates-in		Represents any kind of association, other than generalization/

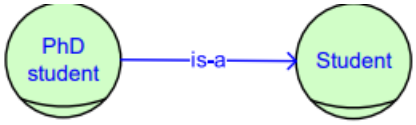
		specialization, between two actors
Is-a		Represents the concept of generalization/ specialization

Table 16: Actor association links (Dalpiaz et al., 2016)

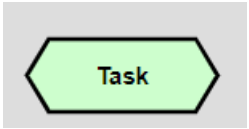
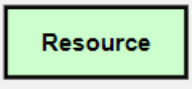
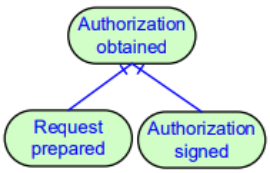
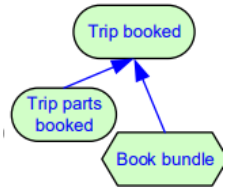
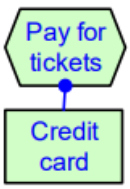
Intentional elements:	*Symbol:*	*Description:*
Goal		A state of affairs that the actor wants to achieve and that has clear-cut criteria of achievement
Task		An attribute for which an actor desires some level of achievement
Quality		Represents actions that an actor wants to be executed, usually with the purpose of achieving some goal
Resource		A physical or informational entity that the actor requires in order to perform a task

Table 17: Intentional elements (Dalpiaz et al., 2016)

Intentional element links:	*Symbol:*	*Description:*
Refinement	 AND  OR	Links goals and tasks hierarchically
Needed-by		Links a task with a resource and it indicates that the actor needs the resource in

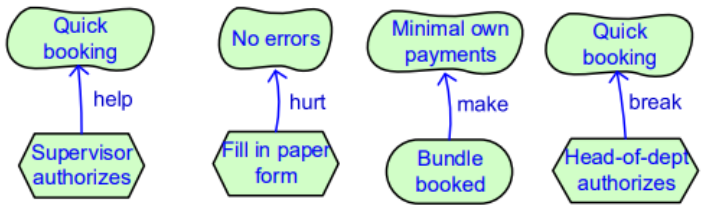
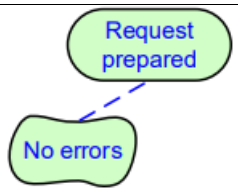
		order to execute the task
Contribution		Links represent the effects of intentional elements on qualities, and are essential to assist analysts in the decision-making process among alternative goals or tasks
Qualification		Relationship relates a quality to its subject

Table 18: Intentional element links (Dalpiaz et al., 2016)

Appendix D

Supplier	Percentage of total tool expenses	Percentage of total order frequency	Average of Delivery lateness	Average of Lead time
Confidential	32.94%	46.98%	1	3
	12.68%	2.04%	9	50
	11.12%	26.22%	1	4
	6.56%	1.82%	7	81
	5.88%	4.63%	2	7
	5.72%	0.89%	-1	68
	3.07%	1.56%	3	24
	2.72%	0.79%	7	63
	2.40%	5.84%	1	19
	1.98%	1.89%	-1	15
	1.37%	0.75%	3	8
	1.20%	0.12%	4	38
	0.93%	0.45%	4	9
	0.92%	0.83%	3	7
	0.89%	0.27%	5	25
	0.80%	0.29%	1	6
	0.75%	0.18%	2	40

Confidential	0.75%	0.12%	21	83
	0.70%	0.08%	15	89
	0.67%	0.11%	14	121
	0.66%	0.93%	0	2
	0.60%	0.16%	1	6
	0.53%	0.10%	12	32
	0.51%	0.22%	48	62
	0.43%	0.05%	5	39
	0.41%	0.04%	45	66
	0.34%	0.10%	6	11
	0.33%	0.22%	0	2
	0.29%	0.33%	1	13
	0.26%	0.57%	0	5
	0.25%	0.21%	11	27
	0.18%	0.30%	13	22
	0.15%	0.05%	1	30
	0.15%	0.15%	12	21
	0.14%	0.26%	3	4
	0.14%	0.04%	28	68
	0.11%	0.03%	33	39
	0.09%	0.21%	1	2
	0.07%	0.04%	-1	18
	0.06%	0.01%	0	2
	0.06%	0.01%	0	6
	0.05%	0.01%	1	4
	0.04%	0.01%	-23	12
	0.03%	0.01%	3	4
	0.01%	0.04%	0	26
	0.01%	0.01%	12	40
	0.01%	0.01%	1	4

Table 19: ABC analysis on tool suppliers (n=7476; data from 2019 – 2023; source: Hankamp)