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Framework for Pre-cost Estimation Process Improvements

Metropolia University of Applied Sciences

Master of Engineering

Industrial Management

Master’s Thesis

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I never planned to pursue a master's degree, but I am glad I decided to. Balancing work and study was challenging, often requiring late-night sessions to keep up, yet these efforts were rewarding. I am amazed at how much I have grown since my bachelor's studies and how much I learned from my master’s studies. The thesis work and master's courses provided numerous innovative ideas that enhanced my professional capabilities, and learning from experienced teachers and peers introduced me to new strategies for tackling complex problems.

I am deeply grateful to my employer, the case company for this thesis, for allowing me to pursue my studies while working full-time and to apply my thesis to an existing business problem within my team. My sincere thanks also go to my colleagues and stakeholders for their support and creative ideas. Special thanks to my manager, whose exceptional mentoring and guidance were essential. Your excellent ideas and expertise in problem-solving have greatly influenced this thesis.

I also want to thank my instructors, Dr. Thomas Rohweder and M.A. Sonja Holappa, for their invaluable contributions to this thesis. Their insights and advice significantly shaped its direction and quality, and I am truly grateful for their guidance. Additionally, I appreciate all the Industrial Management teachers for their inspiring lectures, which have greatly enriched my educational journey.

Finally, yet importantly, I want to express my deepest gratitude to my friends and family. Your unwavering support and understanding during stressful times have been my strength pillars for this thesis. I especially want to thank my mother and father, who always believed in me, kept my motivation high, and whose inspiration and encouragement propelled me towards my studies and professional growth. I also want to thank my late grandfather, whose engineering mindset guided me toward my professional career from a young age.

Espoo, 26th of April 2024
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Abstract

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Given the recent global and regional disruptions in supply chains, the need for a more dynamic pre-cost estimation process became urgent for the case company. Material costs have been subject to significant fluctuations, making older pre-cost estimates inaccurate. The existing process in the case company was not dynamic enough to adapt to these rapidly changing situations. This thesis aims to address this issue by developing a more dynamic pre-cost estimation process for the case company, enabling the incorporation of cost forecasting and rapid changes into pre-cost estimates.

The thesis uses an applied research design with qualitative research methods. It consists of four stages. The first stage was the current state analysis, conducted through interviews, workshops, and observations. In this stage, the current strengths and weaknesses of the process were identified and categorised into topics. The topics were process and working methods, pre-cost forecasting, and data management. The pre-cost forecasting and the data management included the most crucial weaknesses. Therefore, those were chosen as the topics for the literature research. The literature research includes finding the best practices to improve or eliminate the weaknesses of the selected topics, and it was summarised into a conceptual framework, which was used as the basis for the next stage. The next stage included co-creating the initial frameworks for the pre-cost forecasting and data management improvements and creating the new, improved process flowcharts. In the final stage, these frameworks and process flowcharts were reviewed, improved, and verified in a workshop with the local business unit management team.

The outcome of this thesis is the pre-cost estimation process on a framework level. The final frameworks provide the case company with comprehensive directions on making the process more dynamic and the pre-cost estimates more accurate. This is expected to decrease negative cost slippage and provide more accurate offers based on forecasted costs.

Keywords:	Pre-cost estimation, Cost Forecasting, Forecasting Process, Forecasting Models, Data Management

Contents

List of Abbreviations

ERP:	Enterprise Resource Planning. Integrated software for the management of primary business processes
FVA:	Forecast value-added analysis. Used to evaluate the forecasting process.
MAD:	Means average error. Used to calculate forecast accuracy.
MAE:	Mean Absolute Error. Used to calculate forecast accuracy.
MAPE:	Mean absolute percentage error. Used to calculate forecast accuracy.
MPE:	Mean percentage error. Used to calculate forecast accuracy.
MSE:	Mean squared error. Used to calculate forecast accuracy.
PCOGS:	Pre-calculated Cost of Goods Sold. Sales use this value to determine the price of an offered product.
RMSE:	Root Mean Squared Error. Used to calculate forecast accuracy.
SCM:	Supply Chain Management. Process of managing the flow of goods and services.

1 Introduction

Cost forecasting can be a crucial element for certain companies' sales processes. It determines the profitable project sales price and keeps costs competitive with competitors' products. With effective cost forecasting, companies can gain a significant advantage over their competitors by offering the most optimised design at reasonable costs. Inaccurate cost forecasting can lead to loss of revenue or tender.

Before the recent changes in the business environment and regional and global crises, cost forecasting was more straightforward as the market was stable. The recently emerged crises have forced the companies to take a new approach towards cost forecasting. The material costs, which used to rise steadily and predictably, have become unstable and unpredictable, and for this reason, companies have started to pay more attention to trustworthy cost forecasting.

1.1 Business Context

The case company is a global leader in the technology industry. Their purpose is to enable a more sustainable and resource-efficient future with technology leadership in electrification and automation. Their local division in Helsinki manufactures and delivers large motors and generators for various industries.

The factory was established in 1889, but its functions were bought by a Swedish company in 1987. In 1998, a merger between the Swedish and Swiss companies made it part of the current multinational group. Nowadays, the group has operations in over 100 countries globally. Over 105,000 employees are working for the company, and the total revenue was over 29 billion in 2022.

The case company's synchronous machines division manufactures project-specific tailored large motors & generators, for example, for Metals, Mining, Marine, Power Generation, Gas, & Oil Industry applications. All the machines are manufactured based on the Engineered-To-Order principle, and no stock products exist. All the products need a cost estimation to determine the sales price. This leads to a need for a highly accurate cost estimation process, where the estimations can be tailored to each product's specific requirements while ensuring accuracy. Accuracy of the cost estimation is also crucial as the products are expensive, and for some clients, it can be a significant investment decision, leaving no room for error. If the cost estimates are at a level that is too high compared to the market level, the company loses revenue because of the loss of tenders.

1.2 Business Challenge, Objective, and Outcome

The product cost forecasts, which are called pre-cost estimates in the case company, are based on a tailor-made full-cost model and an Excel-based cost estimation tool. The current cost estimation tool was developed in 2010 from an earlier version, and it has not seen many updates since then. The tool calculates the costs using pre-determined values in the cost database. If a specific cost is not in the database, the user can input the value manually.

The pre-cost estimates include all the materials, labour, overheads, and provisions that define the final cost of the factory's product. The most important figure in the pre-cost estimation is the Pre-Calculated Cost of Goods Sold (PCOGS). PCOGS is the sum of all the mentioned values. The sales price is determined by adding a gross profit margin to PCOGS. This value is then transferred to the quotation and sent to the customer.

The current challenge is getting the PCOGS value closer to the actual Cost of Goods Sold value after completing the project. The case company follows these figures regularly, which are reported to the group headquarters. Before the recent regional and global disruptions, these figures used to be close to each other. After the market started to fluctuate drastically, the case company has had more frequent and higher negative cost slippage in the late stage of the projects, which is unacceptable due to the limited number of deliveries per measurement period. This is because the current cost estimation process is more suitable for more static market situation and the database is built around the average costing principle. Even though the market has already stabilised a bit, it is clear that the process cannot be continued in the same way and must be developed to be more dynamic to be ready for market dynamics, where future disruptions and geopolitics can be foreseen in the product cost estimates in a faster manner.

Additionally, the market demand has changed, and the demand for more complex products with long sale cycles has increased drastically. This leads to a need for a better understanding of the supplier market. However, the case company has monthly cost forecast meetings in which the category managers present the current forecast for the materials, but as the database does not support other than average costing, the figures from the meeting cannot be fully utilised. Instead, one figure based on the average from the forecasts is used.

The objective of this thesis is to develop a more dynamic and accurate pre-cost estimation process for the case company on a framework level, where order intake and delivery date would be considered in the pre-cost estimates for more accurate cost forecasting. The outcome of the thesis is the framework for the pre-cost estimation process improvements.

1.3 Outline of the Thesis Report on Hand

This thesis focuses on the current pre-cost estimation process in the case company.

The thesis is divided into seven sections. The introductory section outlines the business challenge, the objective, and the outcome. Section 2 discusses the research approach, including the project plan and data collection methods. Section 3 examines the current state of the pre-cost estimation process, presenting the key strengths and weaknesses of the current process. This is followed by Section 4, which includes a literature review and the conceptual framework for the thesis. Section 5 introduces the co-created frameworks for improving material cost forecasting and data management in the pre-cost estimates derived from Sections 3 and 4 outcomes. These guidelines are validated in Section 6 through example cases and feedback from the stakeholders and leadership team. The last section concludes the thesis, offering an executive summary, development path, next-step recommendations, and self-evaluation of the thesis credibility, with closing words.

2 Project Plan

The previous section introduced the business context, challenge, objective, and outcome of the thesis. This section presents the project plan for the thesis, which includes the research approach, research design, and data plan. The first part of the project plan is the research approach, which describes the procedure to collect, analyse, and interpret data. The research design describes and visualises all the steps needed to conduct the thesis. The last section focuses on the data and its collection methods, especially how and from whom it was collected.

2.1 Research Approach

According to Saunders et al. (2019), research is a process that is undertaken systematically with a clear purpose to find things out. There are multiple different research methods for various purposes, depending on the nature of the research. The first approach is called basic, fundamental, or pure research. This research focuses on expanding the knowledge about a process in business or management, which results in universal principles relating to the process. (Saunders et al., 2019, p. 40-46)

The other approach is called applied research. Saunders et al., states that this method’s primary purpose is to improve the comprehension of business or management issues. This, in turn, leads to effective solutions. This approach includes findings that have practical relevance and value for the organisation in which the research was conducted. (Saunders et al., 2019, p. 40-46)

To find practical solutions that improve operations in organisations, Kananen (2013) states that this can be achieved by combining development and research. Even though the study is linked to a practical business challenge and its improvement, the study can be considered scientific if it is appropriately documented and uses scientific methods. (Kananen, 2013, p. 20-22)

For this thesis, an applied research approach was chosen, with an emphasis on qualitative data collection methods. These methods include conducting interviews, facilitating workshops, analysing documents, and making observations. This diverse range of qualitative methods will enable a comprehensive understanding of the subject, ensuring the findings are detailed and firmly grounded in practical realities. The aim is to find the weaknesses in the current process and develop a framework for the parts of the process that need improvement by using best practices found in the literature.

2.2 Research Design

The objective of this thesis is to develop a more dynamic and accurate pre-cost estimation process for the case company on a framework level. To reach this objective, the thesis follows the research design consisting of four distinct steps illustrated in Figure 1.

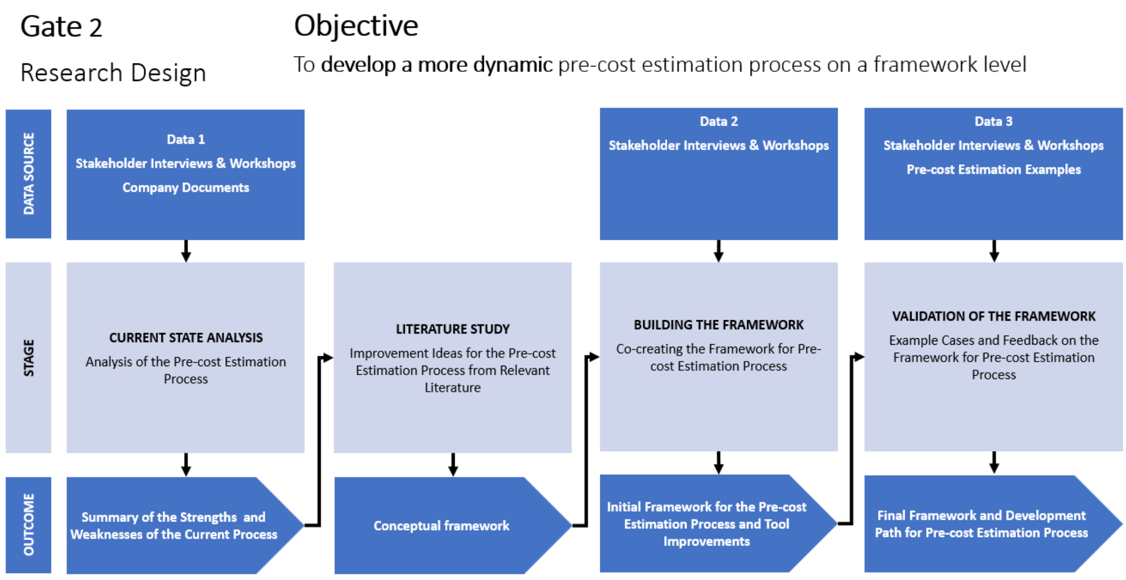

Figure 1 Research Design of the Thesis

The four stages illustrated in Figure 1 aim to increase the knowledge needed to conduct the thesis step by step. The next stage is always based on the findings from the earlier stage. After the final stage comes the outcome of this thesis, which will be based on everything researched and discovered during these stages.

The first stage of the thesis is to conduct the current state analysis. The main point of the current state analysis is to find the strengths and weaknesses of the current process. Without them, it is impossible to find best practices to improve the process as it is not yet known what should be improved.

The current state analysis includes the thesis's first data collection. The data is collected from various sources, including company documents, stakeholder interviews, and a process mapping workshop. The outcome from this stage is a summary of the current process and tool, emphasising its strengths and weaknesses.

The second stage is the literature study. The literature study uses the summary from the current state analysis as the basis. The primary purpose of the literature study is to find best practices from relevant literature, which will be used to improve the weaknesses discovered in the current state analysis. After best practices are identified from the literature, these are summarised into the conceptual framework.

The third stage consists of building the initial framework. The initial framework is based on the conceptual framework made during the literature study and the data collected during this stage. The data is collected through stakeholder interviews and workshops. The outcome from this stage is the initial framework for the pre-cost estimation process and tool improvements.

The final stage of the thesis includes validating the initial framework. In this stage, the initial framework is discussed with the relevant stakeholders through interviews and workshops, where they can give their final input before the thesis is concluded.

This stage also includes examples of past pre-cost estimations from sold materials with actual costing data in the ERP system. The example materials data is used to determine how the new pre-cost forecasting model created in this thesis suits the materials used in the case company.

2.3 Data Plan

As described in the previous section, the thesis includes data collected at three different stages. Data 1 is collected from the current state analysis. Data 2 is collected in the building of the framework stage, and data 3 is collected in the final validation of the framework stage.

The data is collected from various sources to ensure a background that is as comprehensive as possible for the thesis. The following Table 1 illustrates the different data contents, sources, informants, timing, and outcomes.

Table 1 Data Plan of the Thesis

Data Plan	Content	Source	Informant	Timing	Outcome
Data 1 Current State Analysis of the Pre-cost Estimation Process	• Current Pre-cost Estimation Process	• Interviews • Workshop • Internal documents	• Head of Cost Estimation • Cost Analysts • Plant Manager • Business Unit Cost Controller • 2x Sales Managers • 2x Product Managers • Order Fulfillment Manager • Production Planner • Product Platform Manager • Head of Sourcing • Head of Engineering	January	• Summary of the Current Strengths and Weaknesses of the Pre-cost Estimation Process
Data 2 Building the Framework for Pre-cost Estimation Process	• Initial Framework for Pre-cost Forecasting • Initial Framework for Data Management	• Interviews • Workshops	• Head of Cost Estimation • Cost Analysts • Production Planner	March	• Initial Frameworks for the Pre-cost Estimation Process Improvements
Data 3 Validation of the Initial Framework	• Example Case and Feedback on the Pre-cost Estimation Process Improvements • Improvement Ideas for the Initial Frameworks	• Interviews • Workshops • Pre-cost Estimation Examples	• Global Business Line Manager • Head of Cost Estimation • Plant Manager • Business Unit Cost Controller • Sales Manager • 2x Product Managers • Order Fulfillment Manager • Local Division Supply Chain Manager	March-April	• Final Framework and Development Path for Pre-cost Estimation Process

As presented in Table 1, Data 1 includes individual interviews with various stakeholders involved in the pre-cost estimation process. Additionally, this stage involves internal company documentation linked to the current pre-cost estimation process. The pre-cost estimation tool data is also studied and documented in this stage. The outcome for this stage is the summary of the current strengths and weaknesses of the pre-cost estimation process, which is presented to the involved stakeholders to validate the current state analysis findings.

Data 2 is the building of the initial framework. The data is collected through interviews and workshops with relevant stakeholders for comprehensive data collection. The collected data is used together with the data from the previous data collection stage to co-create the initial framework. This stage also includes using the conceptual framework as the theoretical basis to build the initial framework. The outcome of this stage is the initial framework for the pre-cost estimation process improvements.

The final stage of the thesis and the collection of data 3 includes the validation of the initial framework from the last stage. The initial framework is validated with relevant stakeholders, and for further validation, past data from actual projects is used to determine the accuracy of the new pre-cost forecasting model. These materials have actual cost data in the ERP system, and by using the FIT analysis, the accuracy of the pre-cost forecasting model can be determined.

The next section of this thesis focuses on the current state analysis of the pre-cost estimation process with analyses from the collection of data 1.

3 Current State Analysis of the Pre-cost Estimation Process

This section focuses on the current state analysis of the pre-cost estimation process in the case company. The parts of the current process are described in detail, after which the data findings are analysed and summarised.

The first part of the section introduces the current process and its steps. The second part is built around the observations and results from the data collection. The last part summarises everything. The research type and data collection were described in the previous section.

3.1 Overview of the Current State Analysis

The current state analysis was conducted using qualitative data collection methods. These methods include conducting interviews, facilitating workshops, analysing documents, and making observations. This diverse range of qualitative methods will enable a comprehensive understanding of the subject, ensuring the findings are detailed and firmly grounded in practical realities. The aim is to find the weaknesses in the current process and to later develop, in section 4 of this thesis, a framework for the parts of the process that need improvement by using best practices found in the literature as a part of the thesis without losing the existing strengths.

As there was no existing process flowchart, the current state analysis was started by going through company documents, and with a workshop in which the process flowchart was created with the head of the cost estimation and the cost estimation team. Creating an overview of the process makes it easier to research, as everything in and around it is clear.

The process was refined and confirmed in the interviews with the stakeholders. The interviews included stakeholders from all the departments connected to the pre-cost estimation process with inputs or by receiving outputs. The departments are described in more detail in 3.2 Current Pre-cost Estimation Process.

The internal company documents were reviewed to better understand the guidelines, development, and history of the pre-cost estimation process in the case company. This was done to ensure a thorough view of the process's current strengths and weaknesses. The data collected in the current state analysis can be seen in Table 2.

Table 2 Data Collection for Current State Analysis

Data Collected in the Current State Analysis					
Nr.	Source	Type	Topic	Time	Department
1	Internal document	Presentation	Cost Calculation process, guidelines & Full Cost Model principles	Accessed 10.1.2024	Cost Estimation
2	Internal document	Master Thesis	Developing product cost calculation process in engineer-to-order manufacturing (2014)	Accessed 11.1.2024	Cost Estimation
3	Internal document	Instruction	Order-delivery process for synchronous machines	Accessed 11.1.2024	Project Management
4	Multiple stakeholders	Workshop	Pre-cost Estimation Process Flow	9.1.2024 10:30-13:30	Cost Estimation
5	Head of Cost Estimation	Interview	Current state analysis	10.1.2024 10:30-12:30	Cost Estimation
6	Cost Analyst 1	Interview	Current state analysis	11.1.2024 10:00-12:00	Cost Estimation
7	Cost Analyst 2	Interview	Current state analysis	11.1.2024 10:00-12:00	Cost Estimation
8	Cost Analyst 3	Interview	Current state analysis	11.1.2024 10:00-12:00	Cost Estimation
9	Sales Manager	Interview	Current state analysis	11.1.2024 13:00-13:45	Sales
10	Plant Manager	Interview	Current state analysis	25.1.2024 09:30-10:30	Plant
11	Order Fulfilment Manager	Interview	Current state analysis	30.1.2024 08:30-09:00	SCM
12	Production Planner	Interview	Current state analysis	12.1.2024 10:30-11:15	SCM
13	Controller	Interview	Current state analysis	17.1.2024 15:00-15:45	Financing
14	Product Manager 1	Interview	Current state analysis	12.1.2024 14:00-14:45	Product Management
15	Product Manager 2	Interview	Current state analysis	17.1.2024 09:00-09:45	Product Management
16	Marketing and Sales Manager	Interview	Current state analysis	18.1.2024 13:00-13:45	Sales
17	Category Manager	Interview	Current state analysis	11.1.2024 15:00-15:45	SCM
18	Head of Sourcing	Interview	Current state analysis	16.1.2024 12:00-12:45	SCM
19	Product Platform Manager	Interview	Current state analysis	15.1.2024 14:00-14:30	Product Management
20	Head of Engineering	Interview	Current state analysis	15.1.2024 15:45-16:15	Engineering

As seen in Table 2, the current state analysis included internal documents, a workshop, interviews, and the author's observations. The interviews were face-to-face interviews with standardised open-ended questions. The informants included employees from all the departments that are part of the pre-cost estimation process. All the informants are listed in the table above.

The reason for choosing these people was to get a point of view from all the departments regarding the current strengths and weaknesses. The observations were done in the workplace by conducting conversations with various people working for the company. With the support of these people, a comprehensive amount of data was collected that set up a strong basis for the following stages of the thesis.

3.2 Current Pre-cost Estimation Process

The existing Pre-cost Estimation Process is divided into different departments in the case company, each with its own area of expertise and responsibilities. The process linked to the pre-cost estimation-related activities in the departments is described in more detail in the following subchapters. Figure 2 below illustrates the cost estimation process in the case company.

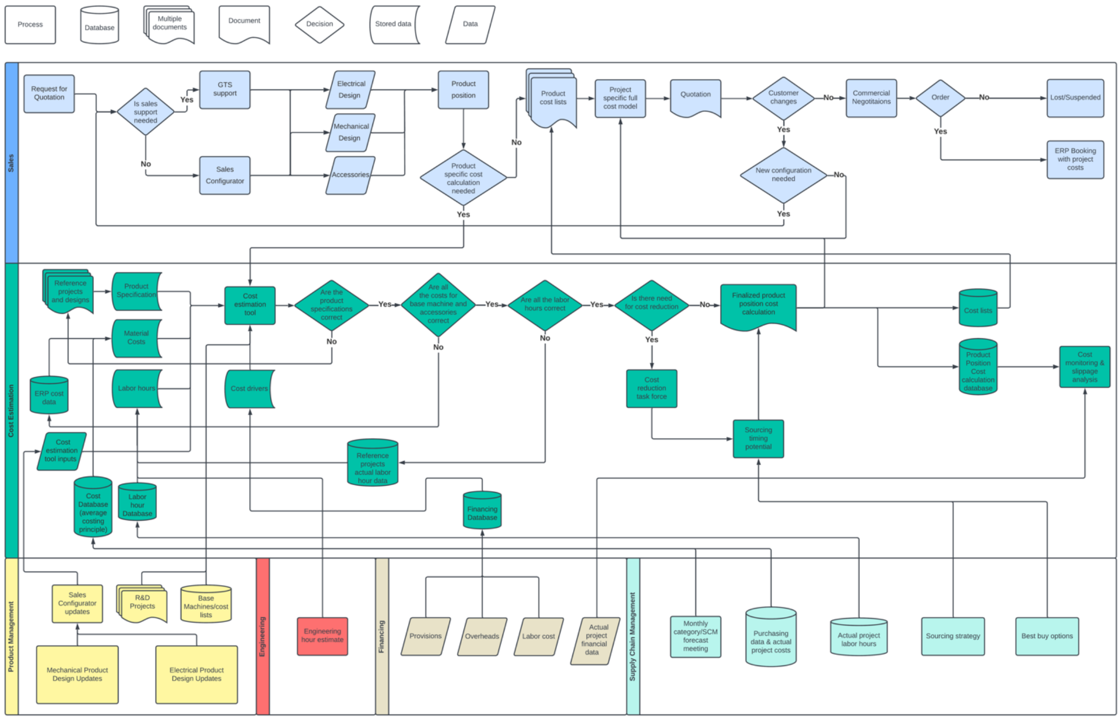

Figure 2 Current Pre-cost Estimation Process in the Case Company

The process illustration in Figure 2 was made from the cost estimation department's point of view and includes the other departments that contribute to the process. Moreover, this process has been implemented as part of the case company's new order delivery process. The departments included in the process are Sales, Cost Estimation, Product Management, Engineering, Financing, and Supply Chain Management.

3.2.1 Sales

The sales department is responsible for translating customer demand into details of the required products for the cost estimation department. The cost estimation department cannot create product-specific positions; all the data must come from the sales department. Figure 3 illustrates the relevant parts of the sales process linked to the pre-cost estimation process.

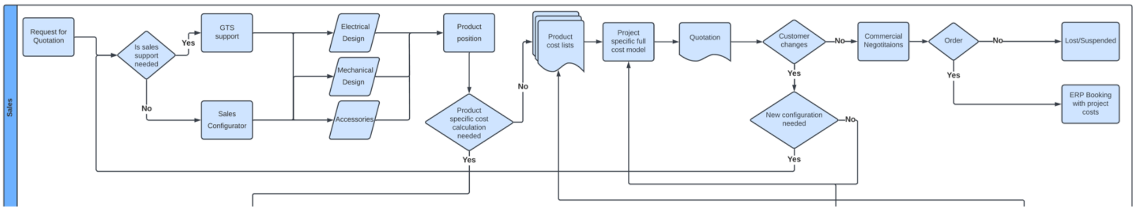

Figure 3 Sales Process Linked to the Pre-cost Estimation

As illustrated in Figure 3, the process starts with a Request for Quotation (RFQ) from customers to the sales department. The RFQ describes the customer's needs, but it can also include the technical specifications if the RFQ is made by a local sales unit. When the salespersons have received the RFQ, they will create the needed design in the sales configurator. If the sales case is unclear, they will contact Global Technical Support (GTS) for support in making the product position. The finalised product position includes electrical design, mechanical design, and accessories. If there is a need for product-specific cost calculation, the sales department sends an e-mail with all the needed data to the cost estimation department’s mailbox. This is the case if there is a need for specific calculations, and the Cost Estimation department's process for specific calculations will be described more closely in subchapter 3.2.2 Cost Estimation.

If there is no need for a specific cost calculation, sales can also use Product Cost Lists, which include pre-defined product costs defined by the product management and calculated already in the cost estimation department. From here, sales will move to the project-specific full cost model, which also considers the project-specific commercial terms and risks beyond the project estimate. After the sales have quoted the project, there might be customer changes, which sometimes require new configuration; hence, the process goes back to the beginning. If there are no customer changes, the sales will proceed to commercial negotiations, and from here, if the order is received, it is added to the ERP system with the pre-calculated costs. If the order is lost, it will be marked as “lost” or “suspended.”

3.2.2 Cost Estimation

The cost estimation department's primary responsibility is to create pre-cost estimates for any departments that need them, but mainly for the sales- and product management departments. Figure 4 below illustrates the process in the cost estimation department.

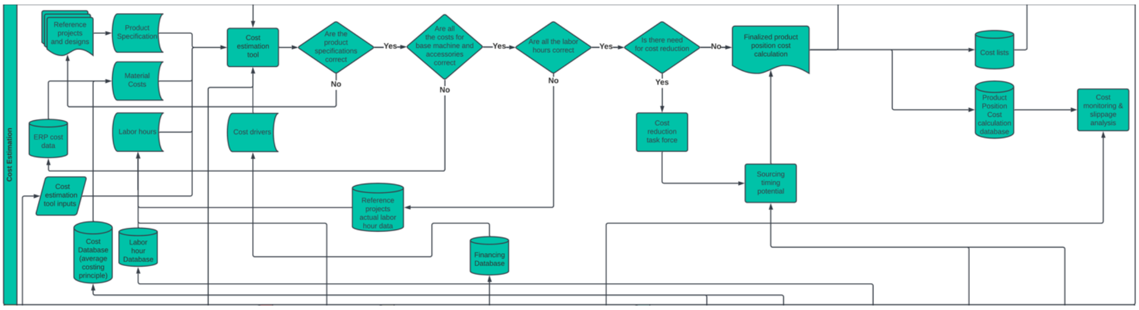

Figure 4 Cost Estimation Departments Pre-Cost Estimation Process

The process illustrated in Figure 4 only focuses on the current pre-cost estimation process. This process starts from the receival of the request from the sales department. This request includes the position for the sales tool from which the cost estimation template can be opened. The sales tool automatically exports mechanical, electrical, and accessories information to the template. The template is then updated with the newest database data by running a query. The databases are separate data files updated with the latest information monthly or when needed. The cost database is based on the average costing principle. Thus, the delivery time or materials costs from suppliers in different regions are not considered. Product specifications, labour hours, and cost drivers are based on inputs from various departments, which will be described in the following chapters in more detail.

When the template is updated, the cost estimation team member must verify the data in the template to check if the values are correct. The first thing to check is the product specifications. If the product specifications are inaccurate, the values can be updated manually. The proper information can be found in reference projects and designs. When correct, the base machine and accessories costs must be checked. The template brings most of the cost data from the databases, but there are some cases in which the costs are not in the database, and these must be manually added. The missing costs are searched from the ERP system by searching for reference project cost data from actual projects or asking for an estimate from the factory or relevant personnel. When all the costs have been added, the next step is to check that the labour hours are correct in the cost template. If some labour hours are missing, these are searched from the reference project's actual labour hour database.

When all of these are done, and the template has all the information, the cost calculation report is sent to the sales department for quotation. However, in some cases, especially when there is competition in the project offering, there is a need for cost reductions. As the cost database is based on the average costing principle, the cost reductions must be collected through a separate cost reduction task force. In the cost reduction task force, the responsible cost estimation team member and supply chain management team members go through the design and different parts of the product and look if there are alternative suppliers for the project. Usually, alternative suppliers can be used if the lead time for the product delivery is long and sourcing timing potential can be considered. Hence, the parts can be sourced from further away. After the task force has concluded, the cost calculation report and the cost savings report will be sent to the sales department.

The calculations are all saved into a product position cost calculation database from which all the calculations starting from the year 2000 can be found. The same process is used for product-specific cost calculation for research and development projects and product cost list calculations. The product management team defines the machines considered here. The cost list calculations are saved to a separate folder from where the cost list generator retrieves the information. If the project is sold and implemented, the actual costs of the project will be compared with the pre-calculated costs, and these will be analysed for slippage, but this is not in the scope of this thesis.

3.2.3 Product Management

The Product Management department is responsible for the mechanical and electrical product design and implementation to the sales configurator. They also choose which machines to involve in research and development projects and which to use as base machines. Figure 5 below illustrates these responsibilities.

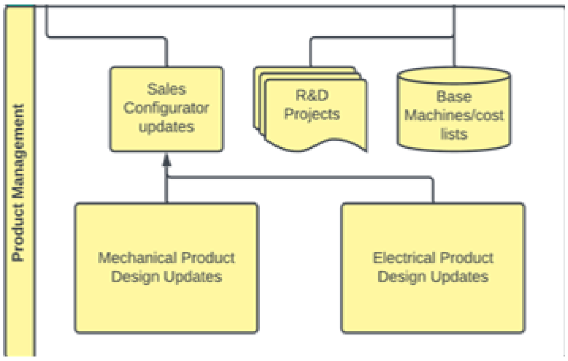

Figure 5 Product Management Inputs for the Pre-cost Estimation

As Figure 5 shows, the design updates are put into the sales configurator, from which the data will transfer to the pre-cost estimations. The research and development projects are part of the case company's innovations and continuous improvement of its competitiveness, and the cost estimates are made to determine the cost of the new products. Product management also defines which products will be used as base machines and includes them in the cost lists. Sales can use the cost lists to offer these products.

3.2.4 Engineering

The engineering department is responsible for the mechanical and electrical engineering hour estimates for the pre-cost estimates. Some base products have pre-defined hour estimates, but especially those that differ from the base products do not have a pre-defined estimate. These must be asked from the engineering department. The engineers use their expertise by comparing the offered product to the references and giving an estimate based on that. The estimate is then added to the cost calculation.

3.2.5 Financing

The financing department is responsible for the values of the cost drivers used in the pre-cost estimates. These cost drivers include Provisions, Overheads, and Labour costs. Also, the financing department is following the actual project financial data. Figure 5 below illustrates the values which fall under the responsibility of the financing department.

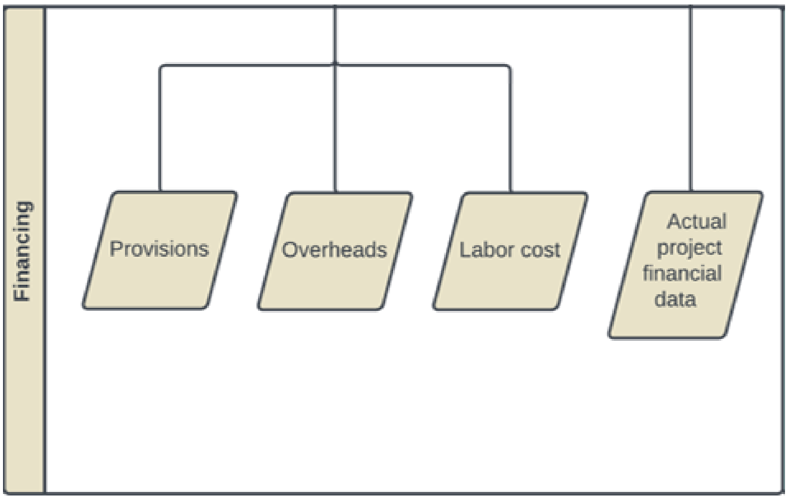

Figure 6 Financing Department Inputs for the Pre-cost Estimation

As Figure 5 shows, provisions, overheads, and labour costs are combined and then transferred to the financing database, which is saved to the cost drivers in the pre-cost estimation template. These cost drivers are updated at the beginning of the year to reflect the current costs. The actual financial data is linked to the project follow-up, but that is not within the scope of this thesis.

3.2.6 Supply Chain Management

The supply chain management department is one of the most important departments for the pre-cost estimation process as they provide all the estimates for the materials used as the basis for the pre-cost estimates. Figure 7 below shows the data inputs that the supply chain management department provides for the pre-cost estimates.

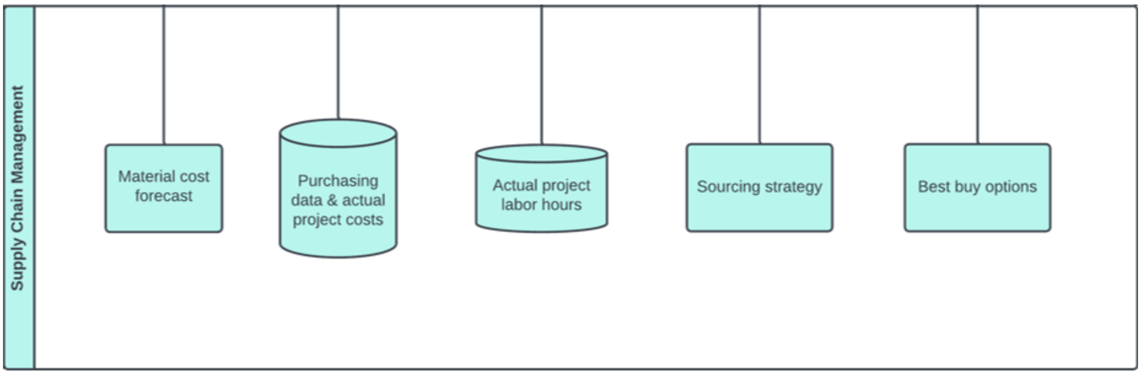

Figure 7 Supply Chain Management Inputs for the Pre-cost Estimation

As Figure 7 illustrates, the primary responsibility of the supply chain management department is to forecast, give actual data, and define the sourcing strategy and best buy options for the pre-cost estimates. The material cost forecast meeting is held every month, and there, the category managers give their best estimate regarding what the material costs will be soon. From this meeting, the cost estimation department transfers the average values for the materials in the cost database. Thus, the material cost forecast is only based on the average of the values, not the actual values. The supply chain management department is also responsible for the purchasing, and from there, the purchasing data from the actual projects is transferred to the database. They also follow the project's labour hours and make the manufacturing planning and fulfilment for the factory.

The pre-cost estimates do not consider the supply chain management department's project-specific sourcing strategy or “best buy” options unless a separate cost reduction task force is held. This was the case if there was a need for a cost reduction in the pre-cost estimate. Usually, in the sold projects which did not have a cost reduction task force, the sourcing strategy is made during the supply chain management kick-off. This means that compared to the pre-cost estimate, the project can achieve material cost savings during the implementation phase, raising the project's gross profit.

3.3 Strengths and Weaknesses of the Current Pre-cost Estimation Process

The findings from the current state analysis interviews are divided into tables according to the departments. All the tables include the strengths and weaknesses that emerged in the interviews with the representatives of the departments. Some of the strengths and weaknesses may resemble each other, but the interviews were conducted so that the representatives were unaware of the other answers. However, it became clear that the main strengths and weaknesses are widely known among the stakeholders. The findings will be in the same order as the subsections were in the previous chapter as follows:

1. Sales
2. Cost Estimation
3. Product Management
4. Engineering
5. Financing
6. Supply Chain Management

By following this order, the structure stays straightforward and easy to follow.

All the informants were asked the same questions, and it was clearly stated that the answer should be from their own and the department's point of view for this work. The questions that were asked during the interview were as follows:

1. From your point of view what do you see as the strengths in the current Pre-cost estimation process?

2. From your point of view, what do you see as the weaknesses/challenges in the current Pre-cost estimation process?

3. Does your department have tools/data sources that would benefit Pre-cost estimation process?

4. What changes or innovations do you think could be integrated into Pre-cost estimation process to enhance its effectiveness/accuracy?

5. Do you think that the current Pre-cost estimation process is serving the future needs of the company and customers?

These questions were chosen to achieve clarity and as comprehensive as possible data collection. Question four's results were derived from question two's answers. However, this made it more evident what changes the informants hope to see in the cost estimation in the future. The final question was meant to clarify all the topics discussed at the end.

3.3.1 Strengths and Weaknesses, Sales

Two informants from the sales department were interviewed. The informants have extensive work experience with the company and represent both the actual sales work and management. Table 3 summarises the strengths and weaknesses identified in the Data 1 collection.

Table 3 Main Strengths and Weaknesses from the Sales Department

S/W	Main Strengths and Weaknesses from Sales
S	Professional and experienced cost estimation team
S	Good response time
S	The report is clear and standardized
W	No best buy or alternative supplier options without task force process
W	Components have same costs for different sourcing times
W	The costs do not follow material indexes

As Table 3 shows, the main strengths are connected to the team, response time, and the report that is used. The current process works well enough for standard calculations and is transparent for all stakeholders. However, the recognised weaknesses show that the sales department is unsatisfied with current costs and the average costing principle. When asked about the cost-saving task force process, both informants stressed that it is time-consuming and confusing. Nevertheless, if the best buy options and the preliminary sourcing strategy could already be implemented during the pre-cost estimation, there would be no need for a separate process for cost savings.

3.3.2 Strengths and Weaknesses, Cost Estimation

Considering the objective of this thesis, the cost estimation department was the most crucial one, and they are responsible for the accuracy of pre-cost estimations. For this work, all the members of the cost estimation team were interviewed, and as the author is working as a cost analyst, a great deal of self-acquired information is available. However, the recognised strengths or weaknesses are not the author's opinions. Table 4 below summarises the recognised strengths and weaknesses of the interviews.

Table 4 Main Strengths and Weaknesses from the Cost Estimation Department

S/W	Main Strengths and Weaknesses from Cost Estimation
S	Uniform, independent, and motivated team
S	Team members come from various backgrounds and have a lot of knowledge
S	A lot of data available from various sources
S	Standardized process and tool
W	Data integration is manual and time consuming
W	There is no supplier, purchasing, or delivery date linked cost forecasting
W	Unclear and manual task force process
W	The database costs are not updated regularly for all components, and it is based on average costing principle
W	Some of the costs are missing from the database

Table 4 shows that the main strength is team dynamics. The team members have adapted well to the new fluctuating market situation and have done their best to consider the new costs. However, all the cost changes could not be considered as the costs fluctuated rapidly or the latest cost was not known during the pre-cost estimation. The other strength is that because of the long history of the company and the standardised process and tool, a great deal of data is available for the pre-cost estimations. However, all this data, especially the cost data during the fluctuating market situation, cannot be used as it does not reflect the actual costs.

The weaknesses found during the interviews follow the same pattern as those found in the other interviews. One of the main weaknesses is that even though a large amount of data is available, data integration into the database is slow and time-consuming. The available data is scattered in various programs and databases. The informants stressed that the data's naming is not standardised, and connecting the data is challenging and requires plenty of resources.

The second main weakness is the lack of the supplier, purchasing date, or delivery date linked cost forecasting. As the database is built around the average costing principle, the costs are not based on the actual values. Additionally, the task force process is unclear and manual for the cost estimation team. These impact the company's revenue as the pre-cost estimations do not follow the market. Hence, the purchased material can be more expensive than anticipated. On the other hand, sometimes, the materials can be purchased cheaper, resulting in positive slippage. However, products that are too costly can lead to loss of sales and revenue.

The last weaknesses identified were that not all the costs are included in the database or updated regularly. This usually leads to more manual work and a higher error rate in the cost estimations. However, this is currently on a manageable level.

3.3.3 Strengths and Weaknesses, Product Management

The data collection from the Product Management department was conducted by interviewing three informants. The informants were the product managers and product platform managers. Table 5 below summarises the identified strengths and weaknesses.

Table 5 Main Strengths and Weaknesses from the Product Management Department

S/W	Main Strengths and Weaknesses from Product Management
S	Overall cost accuracy of the estimations has been good recently
S	The estimations are done on a component level
W	The process is not dynamic enough considering the fluctuating market/geopolitical situation
W	Higher cost provisions are used because there are uncertainty in the estimates

As shown in Table 5 above, the informants are satisfied with the current accuracy level as the market has been stabilising recently. They are also satisfied that the calculations are done on a component level, enabling more accurate cost follow-ups. However, the weaknesses are directed the same way as in the other interviews. The main weaknesses were that the process was not dynamic enough, and they were not satisfied with the uncertainty in the calculations. Hence, higher cost provisions are used in the estimates.

3.3.4 Strengths and Weaknesses, Engineering

The engineering department provides mostly engineering hour estimates and helps the cost estimation team find good references. Fewer identified strengths or weaknesses were found; Table 6 below summarises the few.

Table 6 Main Strengths and Weaknesses from the Engineering Department

S/W	Main Strengths and Weaknesses from Engineering
S	Departments function effectively together
W	The engineering hour estimates are not correct sometimes

Table 6 illustrates that the main strength is linked to the effective practical cross-department functions. The main weakness is that the engineering hour estimates might not always be correct as there might be something that the engineers cannot notice in the pre-cost estimation phase.

3.3.5 Strengths and Weaknesses, Financing

The observations from the financing department informant interview are mostly related to the follow-up process of the finished projects. The financing department is not heavily involved in the pre-cost estimation process; they only provide the cost drivers. Table 7 below summarises the strengths and weaknesses found.

Table 7 Main Strengths and Weaknesses from the Financing Department

S/W	Main Strengths and Weaknesses from Financing
S	Cost model serves its purpose and enables cost monitoring
S	Pre-cost estimation report is well structured and clear
W	Too little data is transferred to the ERP system from the estimations
W	Order-delivery cost monitoring is mostly manual
W	Costs are divided according to the quantity which does not follow the ERP structure

As Table 7 indicates, the financing side is satisfied with the cost model and the report. However, the weaknesses are mostly linked to poor ERP-system data transfer. If all the data were transferred from the pre-cost estimation reports to the ERP system, the order-delivery monitoring could be automatic.

3.3.6 Strengths and Weaknesses, Supply Chain Management

Many informants stressed that supply chain management is the most important department for the pre-cost estimation process. They define the estimated purchasing costs for the materials, which are then used in the pre-cost estimations. Thus, the observations from these interviews were crucial for this thesis. Three informants from this department were interviewed to acquire comprehensive results. Table 8 below summarises the main strengths and weaknesses.

Table 8 Main Strengths and Weaknesses from Supply Chain Management

S/W	Main Strengths and Weaknesses from Supply Chain Management
S	The team is professional and cross department cooperation works well
S	Reporting has improved lately
W	Delivery date or different suppliers are not considered in the estimates
W	Production- or engineering capacity are not considered in the estimates
W	Database is based on average costs and does not consider all the available data

The illustrated strengths in Table 8 are related to the cost estimation team and the latest changes in the reporting. Before the disruptions in the supply chains, there was no regular reporting about the used costs in the pre-cost estimates, and the cost updates mainly followed inflation. Still, these were easy to check as the market was stable and significant cost fluctuations were rare.

The weaknesses follow the same pattern as in the observations from other departments. The main weakness that was recognised was that the pre-cost estimates did not consider delivery dates or different suppliers for materials. However, one informant stressed that to ensure that the pre-cost estimates would consider these, the production and engineering capacity should be followed, as this defines the required time for material sourcing.

The other major weakness is that the database is based on average material costs. The supply chain management department creates various forecasts every month. However, these forecasts can be inaccurate and would need to be improved.

3.4 Summary of the Findings

The objective of this thesis is to develop a more dynamic pre-cost estimation process for the case company on a framework level. For this reason, the observed strengths and weaknesses are divided into topics, which will then be used to identify the best practices from the literature. The decided topics with the related strengths and weaknesses can be seen in Table 9 below.

Table 9 Topic-Related Strengths and Weaknesses

Topic	Topic Related Strengths and Weaknesses	
Process & Working Methods	S	Professional and Experienced team
	S	Good response time
	S	Clear and standardized report with component level estimations
	S	Effective cross department cooperation
	S	Reporting has improved lately
	W	Task force process is unclear, manual, and time consuming
	W	The engineering hour estimates are not correct sometimes
	W	The process is not dynamic enough considering the fluctuating market/geopolitical situation
	W	Cost monitoring is mostly manual
Pre-cost forecasting	S	The accuracy of the calculations has improved lately
	W	No best buy or alternative supplier options without task force process
	W	Components have same costs for different sourcing times
	W	The costs do not follow material indexes
	W	Lack of supplier, purchasing, or delivery date linked cost forecasting
	W	Higher cost provisions needs to be used because there are uncertainty in the estimates and they are consumed
Data Management	S	A lot of data available from various sources
	W	Data integration is manual and time consuming
	W	The database costs are not updated regularly for all parts, and it is based on average costing principle
	W	Too little data is transferred into the ERP-system from the estimations
	W	Production- or engineering capacity are not considered in the estimates
	W	Some of the costs are missing from the database

The chosen topics illustrated in Table 9 are Process and Working Methods, Pre-cost Forecasting, and Data Management. Most of the weaknesses in the process and working methods are related to poor forecasting and data management. Resolving the weaknesses in pre-cost forecasting and data management will address the weaknesses in the process and working methods. Pre-cost forecasting and data management include mostly weaknesses, and it is crucial to correct these to bring the cost slippage caused by poor pre-cost estimations to an acceptable level.

The weaknesses in data management are also related to the ERP system, and these will not be considered in this thesis. The development will be done separately.

Some of the observations made during this thesis were related to the cost estimation tool and other related activities in the case company, but these were excluded from the scope of this thesis.

This concludes the Data 1 collection and the current state analysis part of this thesis. The following section focuses on the literature part of the thesis and will present ideas for improvement for the selected weaknesses.

4 Improvement Ideas for the Pre-cost Estimation Process from Literature

This section of the thesis focuses on ideas for improving the identified weaknesses during the current state analysis. The improvement ideas are collected from relevant literature and summarised as a conceptual framework at the end of this section.

The first part of the section focuses on ideas for improving cost forecasting. These include forecasting process, forecasting models, and forecasting accuracy. The second section focuses on ideas for improving data management. These include overall data management and data quality.

4.1 Improvement Ideas for the Forecasting Process

Forecasting is one of the most crucial aspects of business decision-making. It is a foundation for all decisions made when conducting efficient business in the modern world. It can be used, for example, to predict what to produce and how much production capacity is needed to achieve the forecasted production goal, where to invest, and what the company's future needs are. Poor forecasting can result in not achieving the future demand of the market and can even force the company out of business (Sanders, 2015, p. 4-6). The predictability of an event depends on several components. According to Hyndman and Athanasopoulos, the factors are 1. how well we understand the factors that contribute to it, 2. how much data is available, 3. how similar the future is to the past, and 4. whether the forecasts can affect the thing we are trying to forecast (Hyndman and Athanasopoulos, 2021).

According to Sanders (2015), there are two types of forecasts: long-term forecasts and short-term forecasts. Both are needed in business decision-making. The long-term forecasts help strategic planning, and the short-term forecasts help tactical decision-making. Improving the forecasts has led to significant advantages for companies. One of the main benefits is that accurate forecasts have helped companies lower their costs. Hence, it is an essential element of cost control. (Sanders, 2015, p. 4-6)

However, Hyndman and Athanasopoulos have differing views on this, and they have concluded that modern organisations have three kinds of forecasts. The first one is a short-term forecast, which is needed, for example, to schedule production. The second one is the medium-term forecast, which is required to determine future resource requirements. The third one is long-term forecast, which is used in strategic planning. (Hyndman and Athanasopoulos, 2021)

Correctly using the correct forecast is challenging for most of the companies. Even though there have been technological advancements in forecasting, it is still primarily based on human judgment. Companies use a combination of statistical forecasts, which are then adjusted according to management opinions. However, relying only on technology is not a good practice either (Sanders, 2015, p. 14-15). Organisations must develop a forecasting system that can consider the unpredicted future events. However, this kind of forecasting system requires the development of expertise in problem identification, a wide range of different methods, selecting the appropriate method, and refining these methods (Hyndman and Athanasopoulos, 2021).

Following a well-established forecasting process will help ensure the forecast's accuracy, which is the foundation for all the forecasts. Forecasts have basic principles, which are important as they can be understood as to what we can and cannot expect from a forecast. The first principle is that forecasts are rarely perfect. There are too many factors in the business environment to be considered when making a forecast without errors. However, although an ideal forecast can rarely be achieved, the goal is to maintain overall good forecasting accuracy. (Sanders, 2015, p. 17-18)

The second principle is that forecasts are more accurate for groups than for individual items. If the items are grouped, for example, according to their product families, the positives and negatives cancel each other out. Hence, the data in the group can be stable even though some individual items have differing or unstable values. (Sanders, 2015, p. 18-19)

The third principle is that short-term forecasts are more accurate than forecasts for a longer timeframe. In short-term forecasts, there is a smaller chance that the data will change, and the uncertainty is smaller. Hence, long-term forecasts are more prone to errors as the likelihood of different changes in the patterns and relationships is greater. (Sanders, 2015, p. 19)

These are essential points as they help set the forecasting goals. The expectation for long-term forecasts should be less than for short-term forecasts. However, it is necessary to note that if the short-term forecast is updated, the long-term forecast should also be adjusted. Lastly, there should not be frustration towards the inaccuracy of forecasts; instead, there should be a continuous drive towards the best result. (Sanders, 2015, p. 19)

4.1.1 Forecasting Process

Sanders (2015) has defined a forecasting process that should be followed to ensure a good forecast. These steps are presented in Figure 8 below.

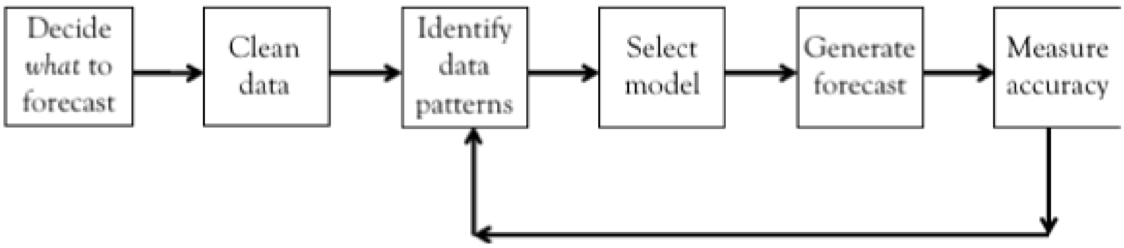

Figure 8 Forecasting Process (Sanders, 2015, p. 20)

As Figure 8 illustrates, the process starts with deciding what to forecast. A couple of problems need to be considered when determining the forecast scope. The first one is that the forecast must address the real problem. The forecast must always answer a question; there are different kinds of forecasts for different questions. The second point is that the time frame of the forecast must be considered, and the critical point is to collect the data at the most detailed level possible. The third point is that the user must consider when to collect the new data to correct the accuracy of the forecast. The last point is to decide the units of measure in the forecast. (Sanders, 2015, p. 20)

The forecasting process defined by Hyndman and Athanasopoulos (2021) follows the same basics as the one described above, with minor differences. Their proposed process starts with problem definition. This is defined as the most challenging part of the forecasting process. The requirement for a successful definition of the problem is an understanding of who requires the forecasts and how the forecast fits for the organisation. The person who makes the forecast needs to engage with the stakeholders who are involved in the process of collecting data, maintaining databases, and using the forecast. (Hyndman and Athanasopoulos, 2021)

The second step is to gather the information for the forecast. The two kinds of data that need to be collected are 1. statistical data and 2. the expertise of the people who collect the data and use the forecast. If there is no possibility of gathering enough data for the statistical model, then judgmental forecasting methods should be used. Also, because old data can be less valuable, sometimes it is necessary to use recent data. (Hyndman and Athanasopoulos, 2021)

The third step is to make a preliminary analysis. In this step, the person with the expertise to create a forecast should look through the data and analyse the consistent patterns or trends visible in the data. (Hyndman and Athanasopoulos, 2021)

The fourth step is to choose and fit the model to the data. The best model depends on the availability of historical data, the relationship between the relationships in the forecast and explanatory variables, and how the forecast will be used. Usually, it is a good practice to compare two or three models. The possible models that can be used are, for example, regression models, exponential smoothing methods, Box-Jenkins ARIMA models, Dynamic regression models, and Hierarchical forecasting. (Hyndman and Athanasopoulos, 2021)

The final step is to use and evaluate the performance of the forecast and the model. The evaluation cannot be adequately done before the data from what was forecasted becomes available. (Hyndman and Athanasopoulos, 2021)

4.1.2 Defining the Scope of the Forecast

When defining the scope of the forecast, a few issues need to be addressed. According to Sanders (2015), the first point is to address the real problem. A forecast is generated to answer a question, and the question and its answer must be straightforward. (Sanders, 2015, p. 20)

The second step is to define the forecasting period to be covered (Sanders, 2015, p. 20). Different types of models suit different time periods of forecasting. The critical question is whether the forecast is needed for a short, medium, or long period. With shorter and more frequent forecasts, it is essential to consider whether the forecast can be automated rather than done with manual work (Hyndman and Athanasopoulos, 2021).

The third step is to decide when the new data must be collected. Forecasts benefit from more frequent data collection as the data used needs to be as new as possible for an accurate forecast. The last point is to determine the units of measure. The forecast will be used to compare the actual results; hence, it is essential to have similar units of measure for easy comparison. (Sanders, 2015, p. 20)

4.1.3 Identifying Data Patterns

When data is collected, it can be analysed for existing data patterns. The key point is to identify which kind of data pattern exists in the data and then choose the suitable model to use. The most common data patterns are presented in Figure 9 below. (Sanders, 2015, p. 22)

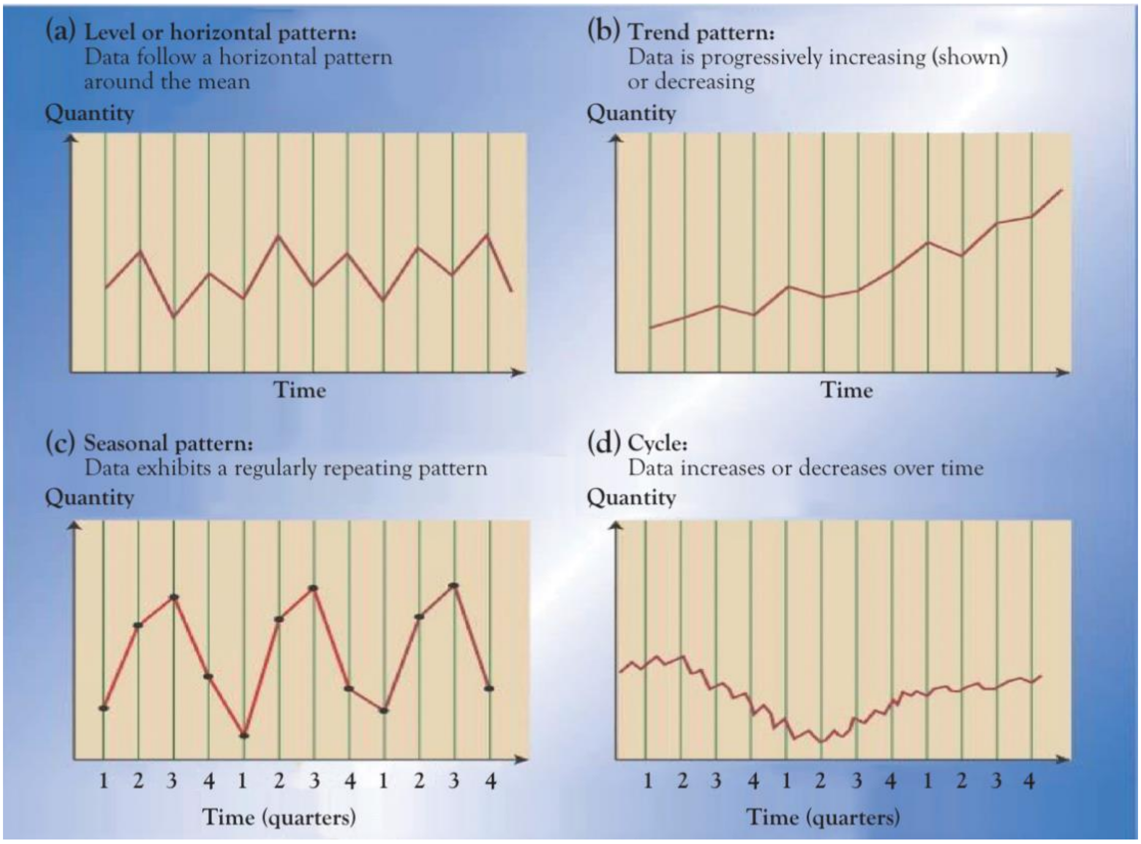

Figure 9 Common Data Patterns (Sanders, 2015, p. 23)

As presented in Figure 9, there are four common data patterns. The level or horizontal pattern is the simplest and exists if the data fluctuates around constant values. This one is also the easiest to predict. The trend pattern exists when the data points increase or decrease over time. The simplest type of trend pattern is a straight line. The seasonal pattern exists when the data shows that it regularly repeats itself. The repetition does not have to be for an extended period; it can also be just for a short period of time. The last data patterns are the cycles. The significant difference between seasonality and cycles is that the cycles do not have a predictable or repeating pattern. The cycles pattern is the hardest to predict. (Sanders, 2015, p. 22-23)

In addition to these, the data can include random variation. If the data contains a significant amount of random variation, it is harder to forecast. This random variation should be accounted for in the forecast. (Sanders, 2015, p. 23-24)

4.1.4 Model Selection

When the data patterns have been identified, it is time to select a suitable forecasting model. Choosing the most appropriate model that suits the identified data pattern is important. It is good to narrow the choice to two or three different models, which are then evaluated with historical data to determine the most accurate. (Sanders, 2015, p. 24)

According to Sanders (2015), four factors influence model selection. The first factor is the amount and type of available data. Different models require different kinds of data, and it is up to the person making the forecast to interpret the data amount. Some models do not need data, and sophisticated quantitative models, for example, require large amounts of data. (Sanders, 2015, p. 24)

The second factor to consider is the required accuracy of the forecast. The more sophisticated models are costly to develop, and whether it is worth the cost to create a complicated model for simple forecasting should be considered. The third factor is the length of the forecast horizon. Some models are better for short-term forecasting, and some are more suitable for long-term forecasting. It is crucial to make the right choice, as the wrong model can lead to inaccurate solutions. (Sanders, 2015, p. 24-25)

The last factor is the pattern recognition in the data. These patterns can quickly tell which model should be used. If the data is misinterpreted and the wrong model is chosen, the result will be an inaccurate forecast. (Sanders, 2015, p. 25)

4.1.5 Generating and Monitoring the Forecast.

When the model has been selected, it is time to generate the forecast. According to Sanders (2015), this is the easiest step in forecasting and should include some software. The data is inputted into the software, and if the model is selected correctly, the result should be an appropriate forecast. Even though this could be a press of a button on a computer, it should be noted that the user must understand what went into the computation. (Sanders, 2015, p. 25)

For example, forecasting software can be an Excel spreadsheet that is widely used in the business. However, the spreadsheets are not designed for statistical analytics, and proper forecasting software should be used. Most forecasting software can retrieve input data from Excel. Hence, the spreadsheet provides a valuable tool for better forecasting software. The factors that should be considered when choosing the forecasting software are as follows: 1. Capability, 2. Industry relevance, 3. Cost, 4. Scalability, and 5. Customer support. (Sanders, 2015, p. 26-27)

When a forecast is made and used, it is critical to follow its results and performance by comparing the forecasted value to the actual value. The monitoring results should enhance the forecasting process. Forecasting is a continuous process that should always be corrected when new data becomes available. (Sanders, 2015, p. 25)

4.2 Improvement Ideas for Forecasting Methods & Models

According to Sanders (2015), forecasting methods can be divided into two broad categories. These are presented in Figure 10 below.

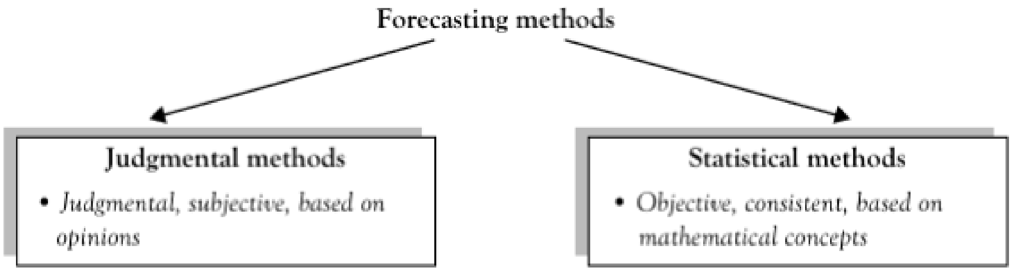

Figure 10 Categories of Forecasting Methods (Sanders, 2015, p. 51)

As presented in Figure 10, the two categories of forecasting methods are judgmental methods and statistical methods. These practices have many differences. To understand which model suits particular needs, one must understand the characteristics of the categories. (Sanders, 2015, p. 51)

4.2.1 Judgmental Methods

Judgmental forecasting methods, usually called qualitative methods, are based on opinions and individual judgment. These forecasts are made by the people in the company who have the latest information on the topic. Judgmental methods are subject to numerous human biases. Some examples of these are optimism or wishful thinking. Nonetheless, judgmental methods have some strengths; for example, these are highly responsive to the latest environmental changes, can include inside information, and can compensate for rare, unusual events. However, there are also weaknesses linked to these methods. The weaknesses include human cognitive limitations related to limited attention span, short-term memory, and difficulty understanding causal relationships. Other weaknesses include biases, which are linked to a lack of consistency, optimism, wishful thinking, and political manipulation. (Sanders, 2015, p. 51-52)

Judgmental forecasting methods are the most common that companies use, and studies have shown that 67 per cent of forecasts are made with these methods. There are multiple reasons for the widespread use, but the most important ones are that firstly, these are not based on mathematical methods, and people feel more comfortable using the methods, which can be done based on feeling and understanding. The second point is that people feel ownership towards a method which uses their opinions. The last point is that these are easier to explain to stakeholders involved in the process. (Sanders, 2015, p. 53)

4.2.2 Statistical Methods

Statistical forecasting methods are based on mathematics and statistics. They can manage large amounts of data and uncover complex relationships. These methods are also more consistent and objective. The advantage of using statistical forecasting methods is that they are objective, and the results are not subject to biases. The same result will always come from the same data. This is the opposite of the judgmental forecasting methods, as the results can vary even though the data would have been the same. (Sanders, 2015, p. 53-54)

According to Sanders (2015), statistical forecasting methods have improved performance by 18 per cent compared to judgmental methods. However, statistical methods are the primary forecasting method for less than 30 per cent of companies. This is because statistical methods are just as good as the data used in the calculations. In a modern-day environment, there might be a situation when the newest data was not incorporated into the dataset, and the results were wrong. (Sanders, 2015, p. 54-55)

However, statistical forecast methods have some strengths, which include, for example, that they are objective, consistent, can process large amounts of data, and can consider many variables with complex relationships. However, the weaknesses include, for example, that they are slow to react, only as good as the model and data are, costly, do not consider all the information, and require technical understanding. (Sanders, 2015, p. 55)

4.2.3 Using the Models in Practice

Both discussed matters have their strengths and weaknesses but are not mutually exclusive. This is an essential point, as both methods can complement each other (Sanders, 2015, p. 56). Figure 11 below summarises the strengths and weaknesses of both methods.

I. Judgmental (qualitative) forecasting methods	
Strengths	**Weaknesses**
• Responsive	• Limited attention span
• Include "inside" information	• Short-term memory
• Compensate for "one-time" or unusual events	• Not recognize relationships
• Provide user with a sense of "ownership"	• Biased (optimism, wishful thinking, political manipulation, lack of consistency)
II. Statistical (quantitative) forecasting methods	
Strengths	**Weaknesses**
• Many variables and complex relationships	• Only as good as the data and model
• Objective	• Slow to react to change
• Consistent	• Costly to model "soft" information
• Process large amounts of information	• Requires technical understanding

Figure 11 Summary of the Forecasting Methods (Sanders, 2015, p. 56)

As Figure 11 shows, the weaknesses in the other model can be corrected by using the other model, too. The forecasts should be made using forecasting models from both categories. This enables the person who made the forecast to compare different models. If the results are similar in both cases, this means that there is a good forecastability. (Sanders, 2015, p. 56)

4.2.4 Judgmental Models

Judgmental forecasting models should be used when there is no historical data or disruptions in the supply chain. These models are entirely based on individual or group opinions. (Sanders, 2015, p. 65)

One type of judgmental forecasting model is the executive opinion. In this forecast, stakeholders from different departments meet and make a forecast based on their expertise and opinions. This method does not have a structure and depends on the discussions and opinions. It can be used to modify existing forecasts to consider disruptions. Nevertheless, this method can consider the latest information, but the opinion of one group member can have more impact than other peoples’ opinions. However, all the group members' opinions should be considered in a good manner to get the best result. (Sanders, 2015, p. 70-71)

The other type of judgmental forecasting model is the Delphi method. This method aims to create consensus amongst experts on a specific topic. The process is structured and includes choosing the experts and asking them to provide answers anonymously. The questionnaire is sent to the experts, and when the results are summarised from the first questionnaire, the second one is sent with the initial findings. This process is repeated until a consensus is reached. The method assumes that even though the experts may not agree on everything, what they agree on will likely happen at some point. (Sanders, 2015, p. 72)

4.2.5 Statistical Models

Statistical models should be used when there is a lot of data available, and there is a possibility of using computations. These are purely based on the data and the model used. The main points to consider in these models are 1. the models do not have to be complicated, 2. trade-off stability with responsiveness, 3. input data must be clean, and 4. the software does not have to be expensive or complicated. The models can be divided into broad categories, as presented in Figure 12 below. (Sanders, 2015, p. 74-77)

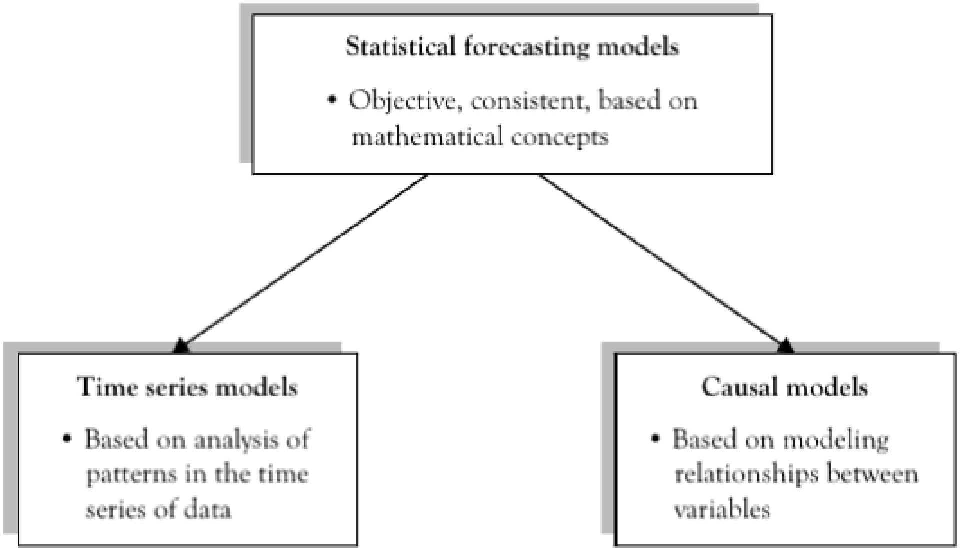

Figure 12 Statistical Forecasting Categories (Sanders, 2015, p. 77)

As Figure 12 illustrates, the categories are time series and causal models. Time series models are based on time series of data, meaning that the data lists data points between regular intervals. The advantages of time series models include excellent results and the fact that they are easy to automate and do not require much effort. Causal models assume that the forecast is linked to other environmental variables, and these variables must be identified to generate the forecast. (Sanders, 2015, p. 78)

According to Sanders (2015), time series models are easier to use. More time series model-based forecasting software is also available. Time series models function by analysing the input data and identifying patterns in the data set. (Sanders, 2015, p. 78)

Time series models identify the patterns in the data by analysing the historical data inputted into the calculation. The patterns are trend, seasonality, cyclicality, and irregular and random variation. (Sanders, 2015, p. 79)

The simplest forecasting method is the Mean. It works simply by taking the average from the data. Figure 13 below presents the formula for the mean forecasting model.

$$F_{t+1} = \frac{\Sigma D_t}{n}$$

$$F_{t+1} = [D_t + D_{t-1} + \cdots + D_{t-n}]/n$$

where
F_{t+1} = forecast of demand for next period, $t + 1$
D_t = demand for current period, t
n = number of data points

Figure 13 Mean Forecasting Model (Sanders, 2015, p. 80)

As presented in Figure 13, the result is a forecast of demand for the next period. The needed inputs are demand for the current period divided by the number of data points. This model works best with level data. It is suitable for forecasting stable and known materials. The advantage of this model is that the more data there is, the more stable the forecast becomes. The shortcoming of this model is that it does not separate the old and new data, which means those are equal in the calculation. (Sanders, 2015, p. 80-81)

Another statistical forecasting model presented by Sanders (2015) is exponential smoothing. It uses a particular weighted average to make the forecast. Sanders (2015) states that this model is easy to understand and provides reliable results. For this model, three inputs are needed. These inputs are 1. the current period’s forecast, 2. the current period’s actual value, and 3. the smoothing coefficient, which varies between 0 and 1. The equation for the exponential smoothing forecast is presented in Figure 14 below. (Sanders, 2015, p. 82)

$$F_{t+1} = \alpha D_t + (1 - \alpha) F_t$$

where

F_{t+1} = forecast of demand for next period, $t + 1$

D_t = actual value for current period, t

F_t = forecast for current period t

α = smoothing coefficient

Figure 14 Exponential Smoothing Model (Sanders, 2015, p. 83)

As shown in Figure 14, the formula contains four distinct values. According to Sanders (2015), the most critical thing in this model is to choose the correct value for α. The available forecasting software gives options for automating this selection, but the person making the forecast should understand where this value comes from. Low values are used in stable forecasts, and higher values, such as 0,7 or 0,8, are used in forecasts containing significant random variation. (Sanders, 2015, p. 83)

Another forecast model presented by Sanders (2015) is linear regression. This model assumes a linear relationship between the variables, making it suitable for creating a forecast when the relationship between them can be considered. The method uses mathematics to create a straight line through data points. The model and example are shown in Figure 15 below. (Sanders, 2015, p. 85)

$$Y = a + b X$$

where

Y = the variable we are trying to forecast called the **dependent variable**

X = the variable that we are forecasting called the **independent variable**

a = Y intercept of the straight line

b = slope of the straight line

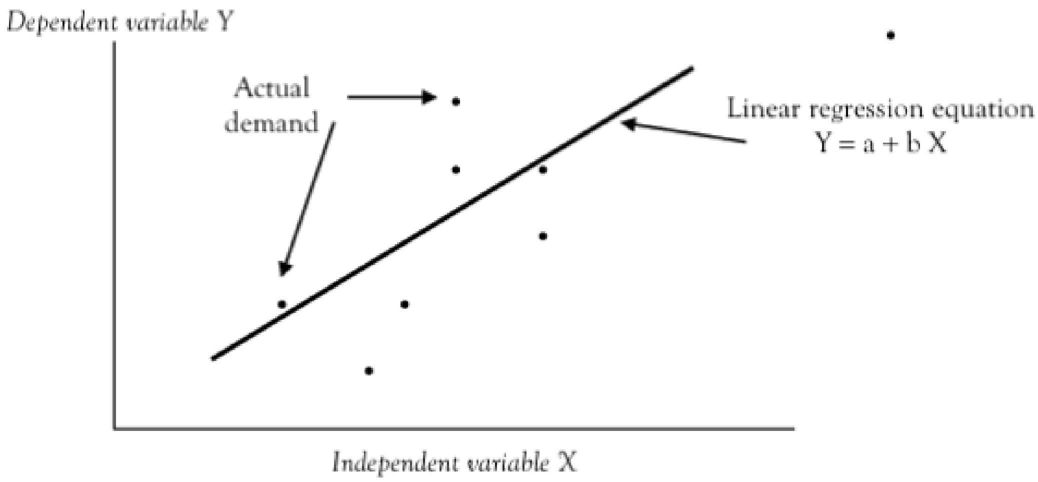

Figure 15 Linear Regression Formula and Line Example (Sanders, 2015, p. 85)

As shown in Figure 15, the straight line comes from the formula. First, a linear regression equation must be developed for this formula to work. After that, the forecasted variable can be computed. This method is easy to explain and use. (Sanders, 2015, p. 86)

The independent variables should be chosen based on logic and common sense. Also, these variables should have good forecastability. The forecasts should also include different economic variables, such as the inflation rate. These are available from public sources and make the forecast more trustworthy. (Sanders, 2015, p. 87)

4.2.6 Estimating Models

Work Breakdown Structure is a uniform and logical method for dividing the project into smaller components which are easily manageable. An accurate and reliable estimate can be developed when the project is divided into smaller components and the breakdown structure is clear. (Rad, 2001)

According to Rad (2001), range estimating is one way to increase early estimates. In range estimating, the approach is not just to provide one cost estimate; instead, there should be a range of different expected values. This model uses statistical fundamentals and estimates the cost by the probability of distinct values. The person making the estimate provides one value, but other experienced people should also provide pessimistic and optimistic values. Using these values, the possible value for the element can be determined by taking the average of the values. (Rad, 2001)

Expert judgment is one good technique to determine the possible value. The point in expert judgment is to consult more experienced personnel for their opinion on the possible value. One or more experts should be consulted for a trustworthy estimate. The experts should take the initial value and consider the details of the project by using their knowledge. This is based purely on the expert’s intuition and experience in past projects. Expert judgment is a good and reliable way to check the realism of the estimates. (Rad, 2001)

4.3 Improvement Ideas for Forecast Accuracy

Forecast error is the difference between forecasted and actual values when the project is realised. It is vital to measure forecast accuracy. Even though forecasts are rarely perfect, the main point is to have a good average performance. (Sanders, 2015, p. 32)

4.3.1 Forecast Accuracy Measures

The difficult things that are hard to forecast have low forecastability. In simple terms, forecastability refers to how easy or difficult it is to forecast something. For example, new materials and products have low forecastability as they do not yet have historical data. (Sanders, 2015, p. 32)

Before forecast accuracy can be measured, it must be understood how the model fits the needs. The best way to do this is to pick multiple models and test how they work with historical data. Then, it should be analysed which model fits the best. This tells the person forecasting which model works best with the historical data. The model fit can be evaluated when the forecast is analysed with the actual values. (Sanders, 2015, p. 33-34)

Out-of-sample evaluation is one way to predict the forecast's accuracy before the actual values become available. This method is presented in Figure 16 below.

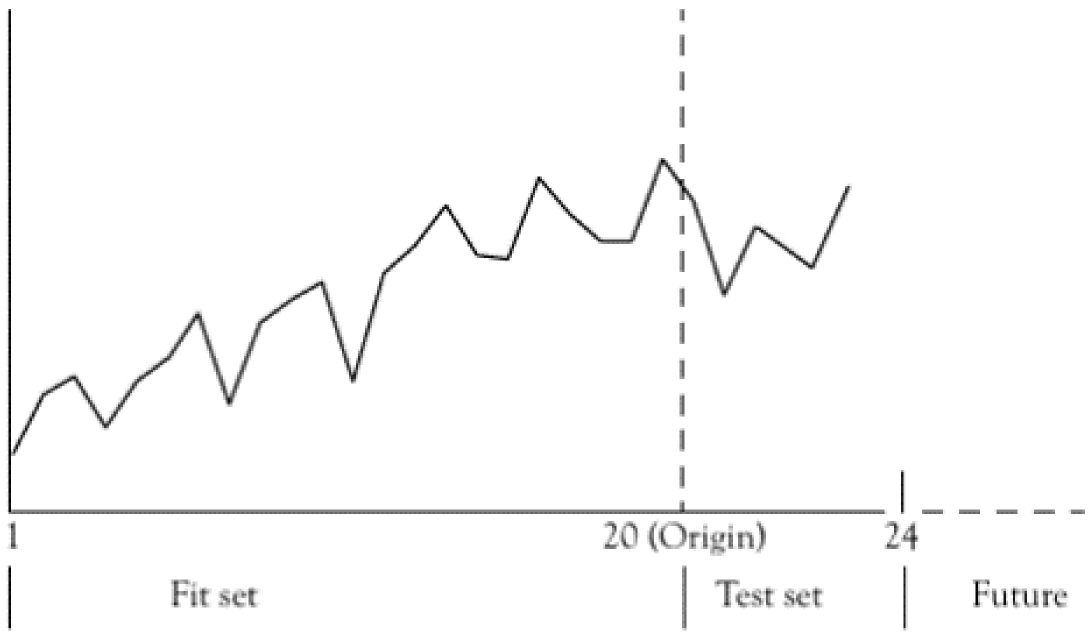

Figure 16 Out-of-sample Evaluation Example (Sanders, 2015, p. 35)

As shown in Figure 16, out-of-sample evaluation consists of a fit set and a test set. The evaluation can be made by dividing actual values between these two sets. The forecast is made according to the fit set, and the results are compared with the test set. (Sanders, 2015, p. 35)

According to Sanders (2015), the forecast accuracy can be measured by following these steps. 1. Statistically Describe the Data set; 2. Decide on Fit Period and Test Period, 3. Generate Forecasts for the Test Period; 4. Evaluate Forecasts for Test Period and Select Forecasting, 5. Forecast the Future, and 6. Continue Measuring the Future Accuracy (Sanders, 2015, p. 36-38)

The first step is to describe the data set statistically. Usually, this can be done with three common measures, which are the mean, range, and standard deviation. The mean is the average of the data set. This can be calculated by summing all the numbers in the data set and dividing the result by the quantity of numbers. In addition to this, the range, which is the maximum and minimum value of the data points in the used set of data, needs to be defined.

The last point is to calculate the standard deviation, which can be done by computing the squared difference of each observation divided by n-1. (Sanders, 2015, p. 36-38) Figure 17 below presents an example of this comparison.

	Data set A	Data set B
Mean	35	37
Range	16	18
Variance	5	12

Figure 17 Comparison of Example Data Sets (Sanders, 2015, p. 37)

As presented in Figure 17, the data sets regarding the mean and range are similar, but the variance or standard deviation differs. This indicates that data set A is likely easier to forecast and has better forecastability. (Sanders, 2015, p. 37)

When deciding on the fit and test periods, keeping the test period much shorter than the fit period is fundamental. The fit period should be at least two seasonality cycles to capture the patterns in the data. When generating the forecast in the next step, it is good to have multiple different models for the test period to evaluate the performance of the models. When the forecast models have been decided, the test period and forecast results can be compared. From this, the best-suited model can be used to forecast the future. Even in this stage, multiple models can be used to evaluate their performance continuously. The last step is to continue the measurement to get the best results. (Sanders, 2015, p. 37-38)

4.3.2 Forecast Error Measures

There are multiple different ways to calculate forecast error measures. According to Sanders (2015), there are two categories: standard error measures and relative error measures. Standard error measures are scale-dependent, and the most common are mean absolute deviation (MAD) and mean squared error (MSE). However, relative error measures are not scale-dependent and are based on percentages. The two most common are mean percentage error (MPE) and mean absolute percentage error (MAPE). (Sanders, 2015, p. 38-41)

Hyndman and Athanasopoulos (2021) propose two more scale-dependent error measures: mean absolute error (MAE) and root mean squared error (RMSE). These are both based on the same scale as the data and cannot be used to compare series with different units (Hyndman and Athanasopoulos, 2021).

All these are based on simple formulas, which are presented in Figure 18 below.

$$\text{MAD} = \frac{\Sigma\,|\,\text{actual} - \text{forecast}\,|}{n} \qquad \text{MPE} = 100\%\,\frac{\Sigma(\text{actual} - \text{forecast})/\text{actual}}{n}$$

$$\text{MSE} = \frac{\Sigma(\text{actual} - \text{forecast})^2}{n} \qquad \text{MAPE} = 100\%\,\frac{\Sigma\,|\,\text{actual} - \text{forecast}\,|/\text{actual}}{n}$$

$$\text{Mean absolute error: MAE} = \text{mean}(|e_t|),$$

$$\text{Root mean squared error: RMSE} = \sqrt{\text{mean}(e_t^2)}.$$

Figure 18 Forecast Error Measures Formulas (Sanders, 2015; Hyndman and Athanasopoulos, 2021)

As shown in Figure 18, MAD is based on absolute values, and as a result, the errors of opposite sides do not cancel each other, thus providing the total sum of the average error. The model with the lowest MAD should be used. MSE has an additional advantage compared to this: due to the squaring, the more significant errors are magnified. The model with the lowest MSE should be used. The relative error measures cannot deal with zero values, and the data should be cleaned properly before using these models. (Sanders, 2015, p. 38-41)

The best use of MPE is to see whether the forecast was over- or under-forecast. A positive MPE indicates that the forecasts are going under, and a negative indicates that they are going over. MAPE is like MPE but uses an average from the absolute percentage of errors. (Sanders, 2015, p. 38-41) When comparing the MAE and RMSE, the MAE is easier to understand and compute. Still, both are widely used and suitable methods (Hyndman and Athanasopoulos, 2021).

4.3.3 Forecast Value Added Analysis

Forecast value added (FVA) analysis is used to evaluate the performance of each step and participant in the forecasting process. According to Gilliland (2010), it is easy to understand and based on common sense. It indicates whether the efforts made in the forecasting process are adding or decreasing the value. The main point is to eliminate waste to save the company's resources. If the FVA is negative, that part of the process can be deleted. On the contrary, if the FVA is positive, that step can be kept in the process. (Gilliland, 2010, p. 82)

The easiest way to validate the forecast results is to compare them with the results of the do-nothing forecast or the naïve model. The naïve model provides a level of forecast that can be achieved without any systems or processes. The point of forecasting is to improve the accuracy compared to the naïve model. If the result of the forecast is worse than the one provided by the naïve forecast, it should be deleted from the process. (Gilliland, 2010, p. 84)

There are several commonly used examples of naïve forecasts. The first one is the random walk. The random walk or no-change model uses the last known value as the forecasted value. The second one is a seasonal random walk. This uses the last known value from the previous season as the new value for the next season. The last one is the moving average, which is the moving average value of the inventory. (Gilliland, 2010, p. 84)

4.4 Improvement Ideas for the Data Management

According to Bhatia (2014), data can be numerical quantities or a set of facts about an event or process. These have little meaning unless the data can be converted into relevant information. When the data sets are put into the correct order in an organised framework, they will have meaning. Organisations need data management to save time and resources or to gain a competitive advantage. (Bhatia, 2014)

4.4.1 Distributed Database

A distributed database is a database that is in multiple locations inside a network. The users can access their portion of the database in their location and update the data in the master database without interfering with the other databases. The duplication process duplicates the data from the distributed databases to the main central database, which looks the same. (Bhatia, 2014)

The challenge is to develop an efficient process to retrieve the data from the databases. Distributed query processing can be used to retrieve the data. The query retrieves the data and transfers it to the master database from the distributed databases; the main advantage is that it enables the organisation to access the data reliably and efficiently. One other advantage is the data reliability and availability. Even though one of the databases might fail, this does not affect the other databases, which continue to work correctly. (Bhatia, 2014).

4.4.2 Data with Outliers

Data that contains outliers, which are points of data that differ with unusually large or small values from the rest of the data, must be cleaned to achieve proper use. There are multiple options for outlier correction. The first option is to correct the outlier with a more typical value. When using the outlier correction in the forecasting, the user changes the historical data, and this should be used with caution. It is helpful to use automatic detection for the outliers, but the identified outliers should be corrected manually. (Gilliland. et. al., 2016)

The second option is to separate the data. This should be used only when the different sources of data are understood. The third option is to use the data with outliers in the forecasting process. One good model is the exponential smoothing model. Unlike the time-series model that uses the raw past data, the causal models are better suited for this. (Gilliland. et. al., 2016)

Ignoring the outliers leads to poor forecast results. Hence, the outliers should be considered. However, it also depends on the nature of the outlier and whether it should be considered (Gilliland. et. al., 2016).

4.4.3 Data Collection

In the modern business environment, a great deal of data is available for forecasting. However, it is necessary to remember that the forecast is based on the used data. The forecast's result will be just as good as the used data. It must be ensured that the data used in the forecast is credible and represents the future. The data that will be used must be cleaned and checked for accuracy. (Sanders, 2015, p. 21)

If data is missing from the database, this must be corrected. If the missing data is not corrected, the computations may assume the value as zero, and the forecast result may not be correct. One way is to replace the missing data with, for example, a moving average estimate from the past. (Sanders, 2015, p. 22)

The outliers in the data should be corrected and checked. These unusual values can be corrected with more typical values for a credible forecast. If these values are not corrected, they will result in incorrect forecast values, but first, the reason for the differing values needs to be checked. Also, the data must be constant and represent the same monetary values. (Sanders, 2015, p. 22)

4.5 Improvement Ideas for Data Quality

Organisations depend on the use of data nowadays. Business processes use data to support operational activities. Analysts review the data from day-to-day operations to run and improve the organisation's ways to achieve their objectives. An organisation needs systems to control the risk associated with poor data quality. (Loshin, 2014)

4.5.1 Data Quality Monitoring

According to Stanley & Schwartz (2024), a successful data quality monitoring must deliver across four dimensions. When the data quality monitoring does not alert on the real issues, the result is called a false negative. When the system alerts about a problem the user does not care about, it is called a false positive. This can lead to users becoming tired of the alerts. This is called alert fatigue (Stanley & Schwartz, 2024). The four dimensions are presented in Figure 19 below.

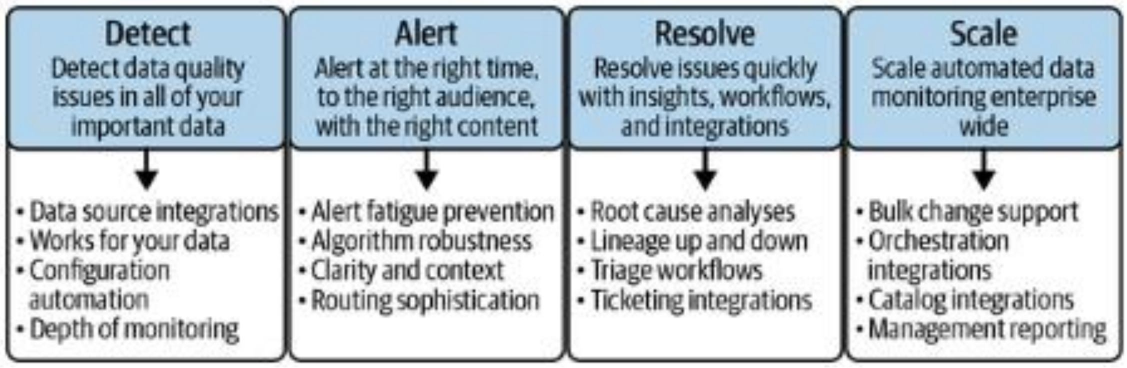

Figure 19 Four Dimensions of Data Quality Monitoring (Stanley & Schwartz, 2024)

As Figure 19 illustrates, the first dimension is that it must detect the quality issues in all the critical data. The second dimension is that it must alert the right people in a timely manner. The third dimension is that it must help resolve issues quickly and efficiently. The final dimension is that it must be scalable. Successful data quality monitoring system adoption does not cause alert fatigue. One of the reasons why companies fail with the adoption of data quality monitoring systems is that it causes alert fatigue. (Stanley & Schwartz, 2024)

4.5.2 Data Observability

Data observability is a vital part of the data quality strategy. According to Stanley & Schwartz (2024), it should answer the following questions:

- Does this table still exist?
- Have there been any adverse changes to the schema of the table?
- Has the table been updated recently?
- Is the volume of data in the table consistent with my expectations?

(Stanley & Schwartz, 2024)

These are important for data quality as they can tell whether the user trusts their data. Some data issues can be detected with observability alone. They can be observed by regularly looking at the metadata and capturing the needed information. (Stanley & Schwartz, 2024)

The questions must be modified to meet the company's and user's needs. For example, the question “Has the table been updated recently?” can mean many things when talking about what recently means. Some tables are updated multiple times daily, but others are updated once every month. However, data observability does not solve the data quality issue; instead, it checks the data flow. (Stanley & Schwartz, 2024)

4.5.3 Approaches to Manual Data Quality Monitoring

There are three common ways to apply data quality monitoring in the company. These are manual detection, rule-based testing, and metrics monitoring. While these can be implemented separately, most companies mix all three simultaneously. Each of the strategies is valuable but has its setbacks. (Stanley & Schwartz, 2024)

Manual data quality detection has been around since data has been available. However, this technique has become increasingly difficult as the amount of data has increased drastically. Some businesses have intentional manual reviews for the data. These can be sport-checking, reviewing summaries, or looking at visualisations. These are not generally sufficient for data quality monitoring and only work when the amount of data is small and straightforward, for example, in a spreadsheet. Usually, manual data quality detection happens by accident when the user stumbles upon a data quality issue. (Stanley & Schwartz, 2024)

Relying on manual data quality detection is not sufficient. Usually, the issues are found long before they have occurred and have already been used in the system. Furthermore, manual data quality detection focuses only on the data inside the project's scope. Manual work can worsen the teams' effectiveness and lower their morale. However, manual data quality detection can also add value. Humans can combine different data in a way automated algorithms cannot. The final goal is, however, to reduce the manual work and automate the process. (Stanley & Schwartz, 2024)

Rule-based testing can be done by implementing deterministic rules to the data to validate that it works properly. The data either passes or fails the test. The rules should have a scope, a type, and several constraints. The applied rules are essential to data quality monitoring and are less prone to errors than humans. Rules effectively identify the historical data quality issues that have existed in the data from the beginning. (Stanley & Schwartz, 2024)

The rules can also identify minor problems in large tables. However, the rules-based testing has some shortcomings. The scope can be too narrow or wide, the constraints can be incorrectly specified, and the wrong type of rule can be selected. The user must maintain the rules to ensure that these are up to date when new data becomes available. (Stanley & Schwartz, 2024)

Metrics monitoring is essential when the user must pay attention to a specific data part. One way to implement metrics monitoring is time series metrics monitoring. The time series modelling evaluates the history of the values and then predicts what the future value should be. When correctly applied, this monitoring system can detect if the values suddenly exceed the expected threshold. This removes the need for the user to set up a static range for the data, and a well-calibrated time-series model works for a variety of data. (Stanley & Schwartz, 2024)

4.6 Conceptual Framework

The ideas generated from the literature review were summarised into a conceptual framework that outlines the key concepts and themes central to this thesis. This framework is visually represented in Figure 20 below, providing a clear and concise overview of the key ideas used in the following chapters.

Conceptual Framework

Improving the Pre-cost Forecasting

Forecasting Process

1. Define the Scope of the Forecast
2. Identify the Data Patterns
3. Generate the Forecast

(Sanders, 2015. Hyndman & Athanasopulos, 2021)

Forecasting Models

1. Choose the Correct Forecasting Method According to Data Patterns
   a) Judgmental Methods
   b) Statistical Methods
   c) Range Estimating
   d) Expert Judgment

(Sanders, 2015. Rad, 2001)

Forecasting Accuracy

1. Measure the Forecast Error & Accuracy
2. Statistically Describe the Data Set
3. Decide on Fit Period and Test Period
4. Generate the Forecasts Test Period
5. Evaluate Forecasts for Test Period and Select Forecasting Model
6. Forecast the Future
7. Continue Measuring the Future Accuracy

(Gilliland, 2010. Hyndman & Athanasopulos, 2021. Sanders, 2015)

Improving the Data Management

Data Handling

1. Collect Credible Data
2. Correct the Missing Data in the Database
3. Correct the Data with Outliers with more Typical Values
4. Organize the Data
5. Distribute the Databases
6. Create Automatic Query

(Bhatia, 2014. Gilliland, et. al., 2016. Sanders, 2015)

Data Quality

1. Establish Data Quality Monitoring System
   a) Detect the Quality Issues
   b) Alert if there are Issues
   c) Resolve the Issues
   d) Scale to all Data
2. Ensure that the Data is Observable
3. Create Data Monitoring Metrics and Rules
4. Manually Correct the Defect Data

(Stanley & Schwartz 2024. Loshin, 2011)

Figure 20 Conceptual Framework

As shown in Figure 20, the conceptual framework is divided into two topics: improving pre-cost forecasting and data management. These are further divided into smaller sections. The sections on improving pre-cost forecasting are the forecasting process, forecasting models, and forecasting accuracy. The sections on improving data management include data handling and data quality.

The presented conceptual framework will be used in section 5 of the thesis when the initial framework for pre-cost estimation process improvements is created. Furthermore, the conceptual framework will guarantee a professional literature-based solution for the business problems identified in the current state analysis.

5 Building the Framework for Pre-cost Estimation Process Improvements

This section is focused on the co-creation of the initial framework for the pre-cost estimation process improvements. The first section introduces the overview of the framework building and how it was created. The latter sections describe the initial process improvement for pre-cost forecasting and data management.

5.1 Overview of the Framework Building

The objective of this thesis is to develop a more dynamic pre-cost estimation process on a framework level. The frameworks are first built as step-by-step guidelines by following the structure of the conceptual framework. In the end, the summary is presented with process flowcharts for a comprehensive understanding of the new process. The added functionalities for the process are described in more detail for clarity. In addition, the current process is presented to provide a deeper understanding of the required changes to make the process more dynamic.

The new framework was created by utilising the improvement ideas from the conceptual framework to the current process, and it was developed together with the head of the cost estimation and the cost estimation team. Additionally, a production planner was interviewed shortly to include their opinion on the initial framework. With these steps, it was confirmed that the new framework would suit the case company's needs. One informant stressed that even though the process would need to be redone, it would be crucial to keep the process straightforward and easily updateable. Furthermore, it was decided that the new process would need only to utilise the currently available data.

The framework was developed in weekly meetings with the cost estimation team. The weekly meetings included reviewing the current state analysis, ideas from the literature, and development ideas for the initial framework.

5.2 Building the Framework for Pre-cost Forecasting

The building of the new framework for pre-cost forecasting started with making a process flowchart of the current process. The current process is presented in Figure 21 below.

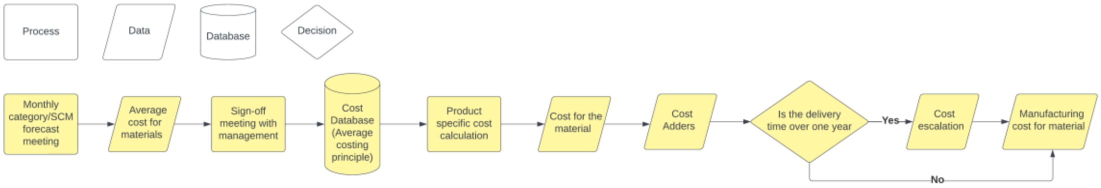

Figure 21 Current Pre-cost Forecasting Process in the Case Company

As illustrated in Figure 21, the current process does not include any forecasting. The monthly category supply chain management forecast meeting data is averaged into the database after the sign-off meeting with management. The data is then transferred into the database, which is based on the average costs. From there, the data is used in the project-specific cost calculations. The only part that changes the costs, depending on the delivery date, is the cost escalation if the delivery time is over a year.

5.2.1 Forecasting Scope

The first step was to decide the forecasting scope. The components were divided into three distinct categories according to their characteristics. The categories are presented in Table 10 below.

Table 10 Initial Framework for Forecasting Scope

Forecasting scope
A. Main components (Copper, Shaft, E-steel, Frame, Cooler etc.) • Copper, Shaft, Electrical steel, Frame, Cooler, Special bearings etc. • Typical % of machine cost: 70% • Separate forecasts for regions (Europe, China, India, etc.) B. Other inventory and itemised materials • Accessories, non-machine specific materials etc. • Typical % of machine cost: 25% C. "Other" materials • Nuts, Bolts, Washers etc. • Typical % of machine cost: 5%
Literature: (Sanders, 2015. Hyndman & Athanasopulos, 2021)

Table 10 illustrates the distinct categories: main components, other inventory and itemised materials, and "other" materials. Based on the historical project costs, the main components are the most significant cost factor of the machine cost; typically, those account for 75 per cent of the machine's cost. These materials include, for example, copper, shaft, electrical steel, and frame. The forecasts would be divided further for separate regions. This would enable the case company to consider different purchasing regions already in the pre-cost estimation phase without the task force process. However, the lead time would have to be considered as the sourcing from the different regions takes different times.

The second category is the other inventory and itemised materials. These are, for example, the accessories and the non-machine-specific materials. Similarly, based on historical projects, these materials account for 25 per cent of the machine costs. These would not need separate forecasts for regions as these materials are usually bought from nearby manufacturers. The final category is the "other" materials. These materials are not specified in the pre-cost estimates; instead, these are usually put into lump sums, considering all the materials taken from inventory. These account for only about five per cent of the machine costs.

This categorisation of the components helps to make the forecasting process more straightforward as the components in the same category have similar characteristics, and the forecasts can be similar inside the categories.

5.2.2 Data Sources

The second step in the new framework was to define the data source from which the forecast data would be collected. The data sources were divided according to categories. Table 11 below shows the different data sources for the categories.

Table 11 Initial Framework for Data Sources

Category	Data Sources
A. Main components	• Monthly Category/SCM Meeting • Historical Purchasing data • ERP system data
B. Other inventory and itemised materials	• ERP system data • Supplier cost lists
C. “Other” materials	• ERP system data
Literature: (Sanders, 2015)	

As Table 11 shows, the categories have different data sources. The main components would get most of the data from the monthly category supply chain management meeting, in which their landed costs are discussed. This, combined with the historical purchasing data and enterprise resource planning (ERP) system data, would guarantee the usage of credible data based on actual costs.

The other inventory and itemised materials would get most of their data from the ERP system. However, the materials could also use the cost lists provided by the suppliers. The cost lists are usually valid for one or two quarters, after which they are updated. The most crucial point is that the costs must be updated every time a recent cost list is acquired or the ERP system data changes.

The “other” materials would solely use the ERP-system data as the forecast basis. These materials are usually stable, and the fluctuations do not have such a significant impact as these account for a small part of the total machine cost.

More about data management can be found in section 5.3, Building the Framework for Data Management

5.2.3 Forecasting Methods, Models, Frequency & Length

The next step was to decide the forecasting method, model, frequency, and length for the distinct categories. As the components inside the categories have similar characteristics, similar forecasts can be used for all the materials with only minor changes depending on the amount of data available. Table 12 below illustrates the different forecasting methods, models, frequencies, and lengths defined for the categories.

Table 12 Initial Framework for Forecasting Methods, Models, Frequency, and Length

Category	Forecasting Methods	Forecasting Models	Forecasting Frequency	Forecasting Length

A. Main components	• Statistical
	• Judgmental
		• Linear regression
		  • Y = a + b X
		    • Y = dependent variable
		    • X = independent variable
		    • a = Y intercept of the straight line
		    • b = slope of the straight line
		• Executive opinion
			• Once a month
			• When the costs become more stable once a quartal
				• Long forecast
				• Medium forecast

B. Other inventory and itemised materials	• Statistical	• Linear regression • Y = a + b X • Mean	• One to two times per year	• Short forecast
C. “Other” materials	• Estimating Models	• Range estimating • Expert judgment	• Once a year	N/A
Literature: (Sanders, 2015. Rad, 2001)				

Table 12 demonstrates that the categories have different methods, models, frequencies, and lengths according to their characteristics. The main components would use statistical and judgmental methods in the forecasting. The primary statistical model would be linear regression. It was chosen as it suits forecasting according to trends. The judgmental model would be the executive opinion. This is already in use in the case company in the form of the sign-off meeting with the management, and this will be used in the future as this allows the management to change the costs used in the pre-cost estimation before these are published. The forecasting frequency would be once a month, and when the costs become more stable, once a quartal. The forecasting length for the main components would be long and medium as the costs are sometimes needed for a delivery date over two years from the offering date.

The other inventory and itemised materials would also use linear regression as the statistical forecasting method, but they would also use the mean. These components remain stable, and the cost lists are valid for half a year. Therefore, they would only have to be forecasted once or twice yearly. The forecast would only have to be short for the same reason.

The ”other” materials category would utilise estimating models as the method. The chosen forecasting models are range estimating and expert judgment because these parts are almost impossible to calculate precisely. Therefore, a lump sum would be estimated by deciding its range for different machines, and then, using expert judgment, an appropriate value could be used. This value would not have a forecasting length as it would remain the same until it would be re-evaluated once a year.

5.2.4 Forecast Accuracy & Error Measures

The last step in the pre-cost forecasting framework was to define the accuracy and error measures for the forecasts. The forecast accuracy and error measures are presented in Table 13 below.

Table 13 Initial Framework for Forecast Accuracy and Error Measures

Category	Forecast Accuracy Measures	Forecast Error Measures

A. Main components	• Statistical set
	  • MEAN
	  • The range
	  • Standard deviation
	• “Fit” analysis
	• Out-of-sample evaluation
		• Mean squared error (MSE)
		• Forecast value added (FVA) analysis

B. Other inventory and itemised materials	• “Fit” analysis • Out-of-sample evaluation	• Mean absolute deviation (MAD) • Naïve forecast
C. “Other” materials	N/A	• Mean percentage error (MPE)
Literature: (Gilliland, 2010. Hyndman & Athanasopulos, 2021. Sanders, 2015)		

It is important to note that the forecast should increase pre-cost estimation accuracy without losing the existing process's strengths and agility. The accuracy and error measures presented in Table 13 above will ensure this by providing feedback on how accurate the initial forecast was. The accuracy measures for the main components category would start from a statistical description of the data set by defining the mean, the range, and the standard deviation of the data set. Then, the forecastability of the data set can be measured. The main components would also include “fit” analysis and out-of-sample evaluation. The fit analysis would consist of historical data, which would be divided into fit and test sets. This would be used to measure the accuracy of the forecast by using actual data. The error measures for the main components would include mean squared error (MSE) and forecast value-added analysis (FVA). The MPE would tell how wrong the forecast was, and by utilising the FVA, the pointless parts of the forecast could be removed.

The other inventory and itemised materials would utilise the same "fit" analysis and out-of-sample evaluation as the main components. However, the forecast error would be measured with mean absolute deviation (MAD) and Naïve forecast. Naïve forecast would tell whether the forecast was more accurate than doing nothing. "Other" materials did not have forecasts; hence, the only thing that should be measured is the mean percentage error (MPE), and the values would be corrected accordingly.

5.2.5 Summary of the Initial Framework & Process Flowchart for Pre-cost Forecasting

The previous sections presented all the parts of the initial framework for pre-cost forecasting. Table 14 below summarises these proposals.

Table 14 Summary of the Initial Framework for Pre-cost Forecasting

Topic	A. Main Components	B. Other inventory and itemised materials	C. "Other" materials
Forecasting Scope	• Copper, Shaft, Electrical steel, Frame, Cooler, Special bearings etc. • Separate forecast for different purchasing regions	• Accessories, non machine specific materials etc.	• Nuts, Bolts, Washers etc.
Typical % of machine cost	70%	25%	5%
Data Source	• Monthly Category/SCM Meeting • Historical Purchasing Data • ERP system data	• ERP system data • Supplier cost lists	• ERP system data
Forecasting Method	• Judgmental • Statistical	• Statistical	• Estimating Models
Forecasting Model	• Linear regression • Executive opinion	• Linear regression • Mean	• Range estimating • Expert Judgment
Forecast Frequency	• Once a month • When the costs become more stable once a quartal	• One to two times per year	• Once a year
Forecast Length	• Long- and Medium Forecast	• Short Forecast	N/A
Forecast Accuracy Measures	• Statistical set • "FIT" analysis • Out-of-Sample evaluation	• "FIT" analysis • Out-of-Sample evaluation	N/A
Forecast Error Measures	• Mean Squared Error (MSE) • Forecast Value Added (FVA)	• Mean Absolute Deviation (MAD) • Naïve forecast	• Mean Percentage Error (MPE)

Table 14 above describes the whole framework. By utilising this framework, pre-cost forecasting is expected to become more accurate. The summary includes all the previous steps and will be presented to management in the validation workshop. This framework would also remove the weaknesses found during the current state analysis from the process. The weaknesses are presented in Table 15 below.

Table 15 Pre-cost Forecasting Weaknesses

Topic	Topic Related Weaknesses	
Pre-cost forecasting	W	No best buy or alternative supplier options without task force process
	W	Components have same costs for different sourcing times
	W	The costs do not follow material indexes
	W	Lack of supplier, purchasing, or delivery date linked cost forecasting
	W	Higher cost provisions needs to be used because there are uncertainty in the estimates and they are consumed

As presented in Table 15, the framework would help to add alternative sourcing options without the task force process, as the different regional options would be available. The components would be based on different purchasing times as every main component would have the forecasted costs. This would help to link the costs to the material indexes by providing the supply chain team with tools to compare the material indexes to the forecasted costs and decide which one to follow. When there is data from the new calculations, and the accuracy has improved, management can decide to remove the higher cost provisions.

The process flowchart was also remade to include all the steps from the initial framework. The initial proposal process flowchart is presented below in Figure 22.

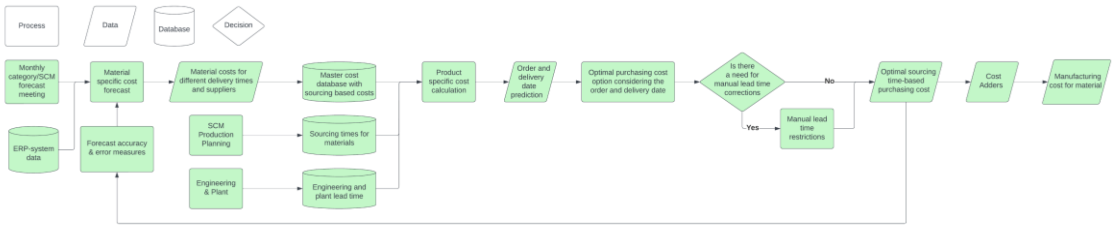

Figure 22 Initial Improved Pre-cost Forecasting Process

As Figure 22 illustrates, the new process would differ from the current one in several ways. The first difference is that the new process would include additional inputs from the ERP system data. The next step would be the cost forecast using the frameworks proposed before. The forecasts would create material costs for different delivery times and suppliers. From here, the information will go to the database; the initial proposal for data management and database structure will be described in more detail in the next section.

Compared to the original process, the significant change was incorporating sourcing times for materials and engineering and plant lead time databases into the pre-cost estimation. Without these, estimating the lead time of specific materials would be impossible. The figures are available in the case company and used by other departments daily. The next step would be for sales to specify the foreseen order and predicted delivery date. The predicted order date is needed to calculate the time to deliver the machine after the purchase order is available.

When these are known, the optimal material cost option can be calculated. However, it is crucial that there is an option to manually add lead time restrictions to ensure that it is possible to use the materials with longer lead times. The optimal sourcing time-based material cost would be available when these are clear. This will be the manufacturing cost of the material after the cost provisions are added and used in the pre-cost estimation. The optimal sourcing time-based values would be used in the forecast accuracy and error measures to make the forecasts more accurate.

5.3 Building the Framework for Data Management

The initial framework for data management was built similarly by creating the current process in a process flowchart. This flowchart is presented in Figure 23 below.

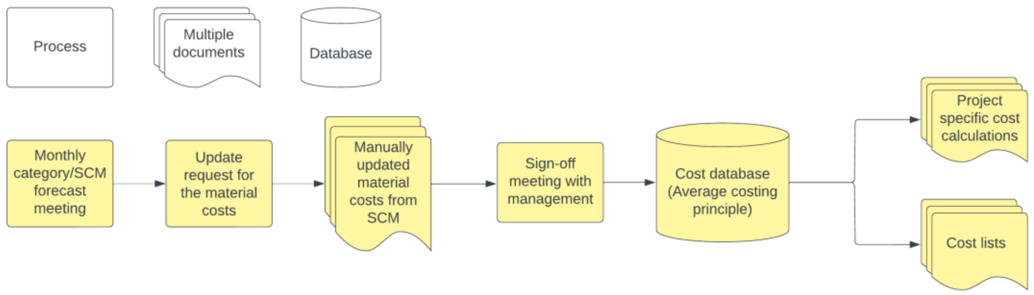

Figure 23 Current Data Management Process

As Figure 23 illustrates, the current process involves a significant amount of manual work. Data is manually requested to be updated after the monthly category and supply chain management meeting. When the manually updated costs are received from the category managers, a sign-off meeting is held with the case company management. When management approves the new costs, the average costs of the materials are transferred into the cost database. When updated on the network drive, the costs become available for the project-specific cost calculations and cost lists from the cost database.

5.3.1 Data Handling

The first step in the new data management framework was to create new data handling measures. The materials were divided into the same categories as in the pre-cost forecasting framework for data handling: main components, other inventory and itemised materials, and “other” materials. The initial data handling framework is presented in Table 16 below.

Table 16 Initial Framework for Data Handling

Category	Data source	Data correction	Outlier corrections	Database	Data retrieving	Update frequency
A. Main components	• Monthly Category/SCM Meeting • Historical Purchasing data • ERP system data	• Historical data • Supplier offers		• Organize the data into distributed databases according to material group	• Automatic query to retrieve the data from the separate databases to the development database	• Once a month (when the costs become more stable once a quartal)
B. Other inventory and itemised materials	• ERP system data • Supplier cost lists			• Create own database and connect the data with ERP-system data and supplier cost lists with unique identifiers	• Automatically synchronise the data to the master database if the data is updated	• Preferably one to two times per year • If data is updated
C. "Other" materials	• ERP system data	• N/A		• Create own database and connect the data with master database		• Preferably once a year • If data is updated
Literature: (Bhatia, 2014. Gilliland, et. al., 2016. Sanders, 2015)						

As Table 16 illustrates, the data handling would start from the same data sources defined in the initial pre-cost forecasting data source framework. The data for the main components and other inventory and itemised materials would have to be corrected with historical data. In addition, the data could be corrected with supplier offers. The ”other” materials would not need data corrections as these are range estimated.

Due to the current geopolitical challenges, the main components and other inventory and itemised material data contain many outliers. These outliers must be corrected using the same historical data and supplier offers as the data corrections would use. This is crucial as some materials were bought during the highest price peaks and do not reflect the current prices.

The main components category would be divided into separate material group-based databases. The category managers would maintain and update these databases after the monthly category and supply chain management forecast meeting and according to their latest knowledge. The data would be transferred into a separate development database using automatic query. The development database is necessary as the new costs cannot be published in the project-specific cost calculations and cost lists before the sign-off meeting with management. When the new costs have been approved, the development database data will be copied into the master database.

The other inventory and itemised materials would have a separate database in which they are connected to the ERP system data and the supplier cost lists with unique identifiers, such as material codes. The data would be automatically synchronised to the master database if the data in this database is changed, as these are not in the scope of the sign-off meeting. “Other” materials would also have separate database, and if the data is changed, these are synchronised to the master database. The update frequency would preferably follow the same as the forecasting frequency defined in the initial framework for forecasting methods, models, frequency, and length.

5.3.2 Data Quality Monitoring

The second step in the initial data management framework is data quality monitoring. Data quality includes vital points needed to ensure that the data is correct and that the quality does not cause wrong results in the pre-cost estimates. The initial framework for data quality is presented in Table 17 below.

Table 17 Initial Framework for Data Quality Monitoring

Category	Data quality monitoring system	Data observability	Manual data corrections
A. Main components	• Detect data quality issues by monitoring the values • Alert the user if the values differ • Resolve by correcting the data with manual data corrections • Use for all the data	• Check if the tables still exist • Save the update dates of the data • Follow the data volume	• Rule-based testing • Metrics monitoring
B. Other inventory and itemised materials			
C. “Other” materials			
Literature: (Stanley & Schwartz 2024. Loshin, 2011)			

Table 17 demonstrates that data quality monitoring would apply to all material categories. The data quality monitoring system would automatically detect data quality issues and alert the user if the values differ from the defined amount from the previous value. The defect data would have to be corrected manually using manual data correction measures. The manual data correction measures include rule-based testing and metrics monitoring. The rule-based testing is based on pre-determined rules that must be met so that the data quality does not alert the user. The case company should define these rules. The metrics monitoring functions similarly using the forecast data acquired in the pre-cost forecasting accuracy measures defined before.

Data observability would be monitored by following the table structure and ensuring the previous tables still exist. Data tables must contain an updated timestamp with the date for the users to ensure that all data tables are up to date. Data volume would stay constant, and if there were changes in the data volume, the user would have to investigate this to determine if there is some problem in the queries that makes the data volume larger than before. These all would have to be scaled for all the data.

5.3.3 Summary of the Initial Framework & Process Flowchart for Data Management

All the measures for the data management were described in the previous sections. The summary of the measures is presented in Table 18 below.

Table 18 Summary of the Initial Framework for Data Management

<table>
<tr><th>Topic</th><th>A. Main Components</th><th>B. Other inventory and itemised materials</th><th>C. "Other" materials</th></tr>
<tr><td>Data Source</td><td>• Monthly Category/SCM Meeting
• Historical Purchasing Data
• ERP system data</td><td>• ERP system data
• Supplier cost lists</td><td>• ERP system data</td></tr>
<tr><td>Data Correction</td><td colspan="2" rowspan="2">• Historical data
• Supplier offers</td><td rowspan="2">• N/A</td></tr>
<tr><td>Outlier Corrections</td></tr>
<tr><td>Database</td><td>• Organize the data into distributed databases according to material group</td><td>• Create own database and connect the data with ERP-system data and supplier cost lists with unique identifiers</td><td>• Create own database and connect the data with master database</td></tr>
<tr><td>Data Retrieving</td><td>• Automatic query to retrieve the data from the separate databases to the development database</td><td colspan="2">• Automatically synchronize the data to the master database if the data is updated</td></tr>
<tr><td>Update frequency</td><td>• Once a month (when the costs become more stable once a quartal)</td><td>• Preferably one to two times per year
• If data is updated</td><td>• Preferably once a year
• If data is updated</td></tr>
<tr><td>Data quality monitoring system</td><td colspan="3">• Detect data quality issues by monitoring the values
• Alert the user if the values differ
• Resolve by correcting the data with manual data corrections
• Use for all the data</td></tr>
<tr><td>Data observability</td><td colspan="3">• Check if the tables still exist
• Save the update dates of the data
• Follow the data volume</td></tr>
<tr><td>Manual data corrections</td><td colspan="3">• Rule-based testing
• Metrics monitoring</td></tr>
</table>

Table 18 summarises the initial framework. This framework would make the values used in the pre-cost estimation process more trustworthy and enhance data quality. Improving the data quality is expected to make the pre-cost estimates more accurate and follow the up-to-date costs.

It is expected that the framework would remove weaknesses if implemented correctly. The weaknesses found in the current state analysis are presented in Table 19 below.

Table 19 Data Management Weaknesses

<table>
<tr><th>Topic</th><th colspan="2">Topic Related Weaknesses</th></tr>
<tr><td rowspan="5">Data Management</td><td>W</td><td>Data integration is manual and time consuming</td></tr>
<tr><td>W</td><td>The database costs are not updated regularly for all parts, and it is based on average costing principle</td></tr>
<tr><td>W</td><td>Too little data is transferred into the ERP-system from the estimations</td></tr>
<tr><td>W</td><td>Production- or engineering capacity are not considered in the estimates</td></tr>
<tr><td>W</td><td>Some of the costs are missing from the database</td></tr>
</table>

The initial framework for data management would consider all the weaknesses presented in Table 19. The data integration would be automated, the database costs would be updated regularly, and all the known costs would be added to the database. If the framework from the pre-cost forecasting were used, the database would no longer be based on the average costing principle.

The point that not enough data is transferred to the ERP system was not considered as it is outside the scope of the thesis.

The process flowchart, including the initial framework, was remade to incorporate these changes. It is presented below in Figure 24.

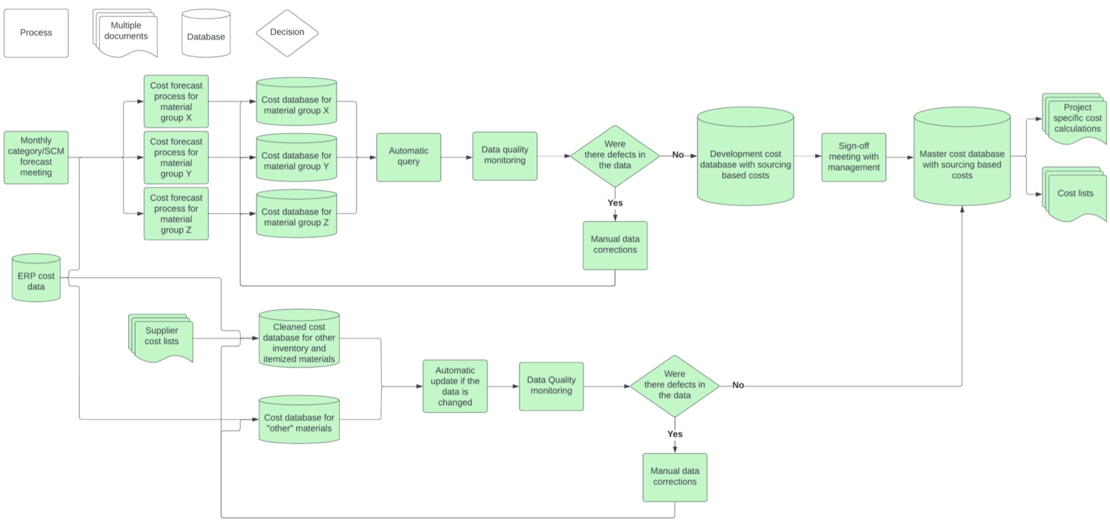

Figure 24 Initial Data Management Process with Improvements

Figure 24 above demonstrates the new data management process with the improvements from the proposed frameworks. The new process also includes the cost forecast for different materials in the main components category. This is essential as the cost forecast must be done before the data is transferred into the databases.

Also, the new process includes the development cost database with sourcing-based costs. This database would be used to make example pre-cost estimates for the management, which would be presented in the sign-off meeting. This would clarify the changes the new costs caused for the example machine pre-cost estimations. This could be shown as a percentual change together with the changed material costs.

This concludes the Data 2 collection and initial framework-building phase for the thesis. The following section is focused on the initial framework validation, received feedback, and pre-cost estimation example cases.

6 Feedback on the Pre-cost Estimation Process Improvements & Example Case

This section presents the validation of the initial framework, management's feedback, and example cases. The first part is focused on an overview of the initial framework validation and management's feedback. The second part introduces examples of pre-cost forecasting cases using an out-of-sample evaluation of real-world example material.

6.1 Overview of the Initial Framework Validation

The initial framework was validated together with the management team of the local business line. The validation was done in a workshop where the thesis and results were presented. The workshop began with an introduction to the thesis's overall scope, focusing on the research design and data planning. Next, the results that had been collected, the process flowcharts created during the current state analysis, and the conceptual framework were reviewed. After these reviews, the initial frameworks for cost forecasting and data management developed in the initial phase of framework building were evaluated. The validation workshop participants included a Global Business Line Manager, a Head of Cost Estimation, a Plant Manager, a Business Unit Cost Controller, a Sales Manager, two Product Managers, an Order Fulfilment Manager, and a Local Division Supply Chain Manager.

The initial frameworks were presented in summarised forms with the new process flowcharts and compared to the current process flowchart for clarity. All the comments during the workshop were collected, and the initial frameworks were changed following these comments and ideas for improvement. The enhanced frameworks will be presented as the final frameworks for the pre-cost estimation process improvements.

6.2 Feedback Received and Corrections to the Initial Frameworks

The management team was happy with the thesis and results and eagerly awaited the implementation phase. Even if the costs stabilise, having a more dynamic process is beneficial to reduce the risk of inaccurate estimations as global and regional disruptions might arise again. One informant was concerned about whether the process remains simple and easily updateable and whether there are unnecessary steps in the new framework and process. The concern was discussed, and it was decided that the tools needed to implement the framework and the process should be reviewed to ensure it is kept as simple as possible. Additionally, the changes made during the implementation phase must be documented well.

Both initial frameworks were verified and accepted as they were in the initial proposal phase. The only change that the management required was in the outputs of the pre-cost forecasting process flowchart. The required outputs were the validity of the cost for material and the foreseen project schedule. The new process flowchart is illustrated in Figure 25 below.

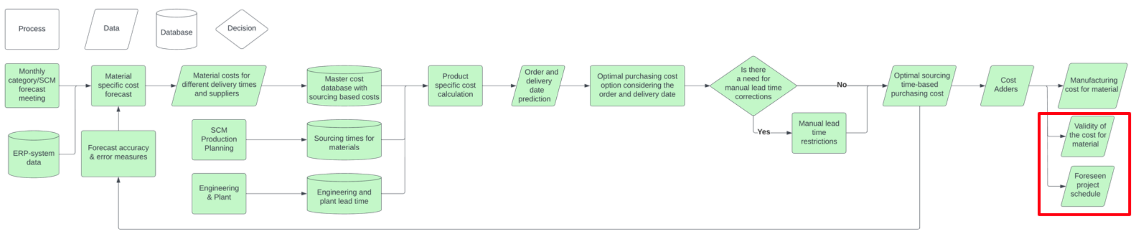

Figure 25 Pre-cost Forecasting Process with Added Outputs

As Figure 25 illustrates, the new outputs would be situated at the end of the process. All this data is created during the process; hence, it is simple to add these outputs as they do not require more data or modifying the process.

6.3 Example Cases

The example cases were made to validate the pre-cost forecasting models. The data for the example cases are actual cost data from the case company's realised projects. The exact values of the data were anonymised for confidentiality reasons; hence, the calculations are based on percentages. The examples represent the drive- and non-drive end of a generator frame. The generator is a mid-sized regular model that is sold in large numbers. The data timeframe is four and a half years, and the data was cleaned before it was used. Data cleaning consisted of removing the zero values and wrong dates.

The test set was divided into a "FIT" set and a test set. The "FIT" test consisted of three seasonal cycles, and the test set consisted of one and a half seasonal cycles. The example case D is illustrated in Figure 26 below.

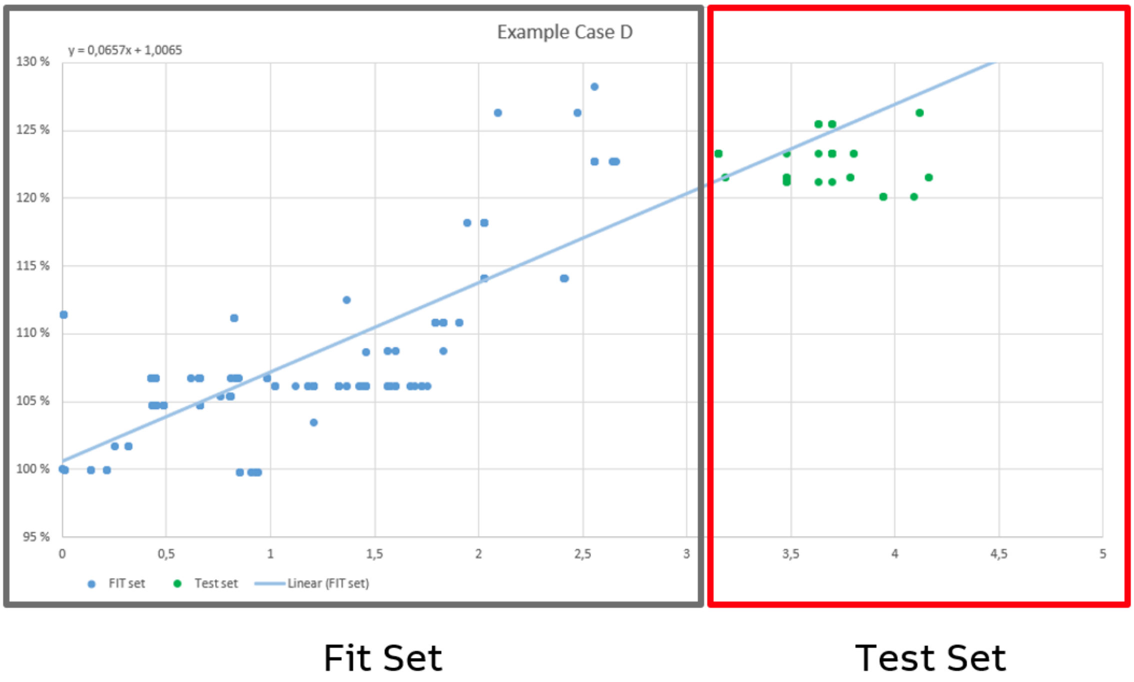

Figure 26 Pre-cost Forecasting Example Case D

As illustrated in Figure 26, the fit set gives the linear trend line, which was used to forecast two cycles. The example shows that even though there is a great amount of scattering in the data values, the linear regression forecast would have been close to the actual values. However, because of the scattering, the forecastability of the example data is not great.

The other example case was the same generator's other frame-end. Example case N is illustrated in Figure 27 below.

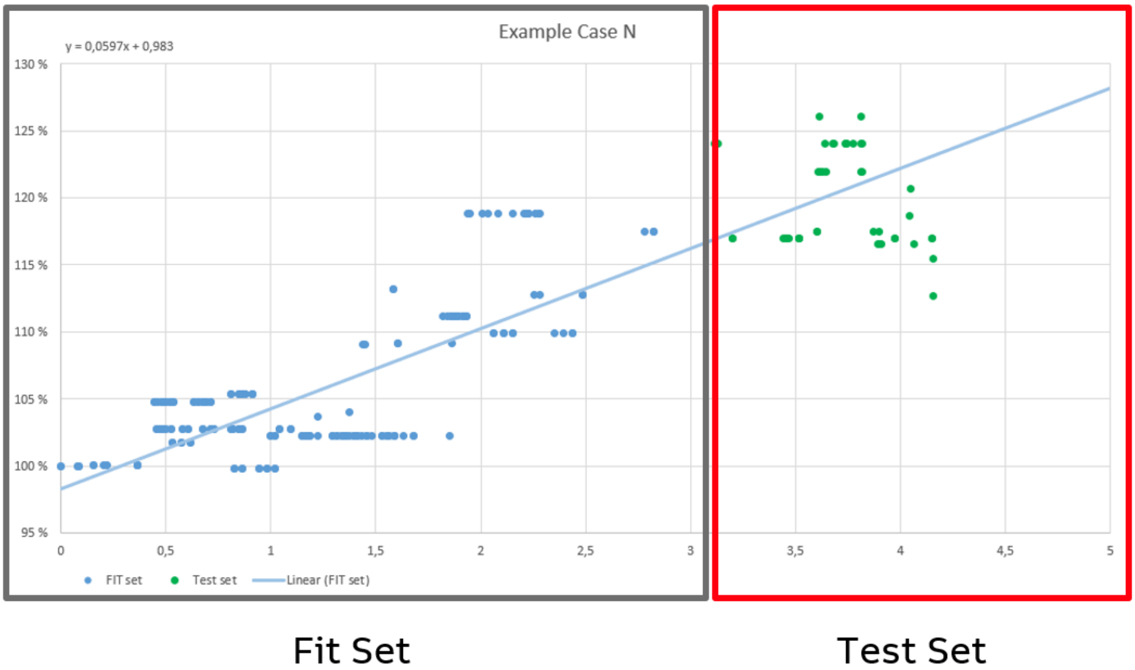

Figure 27 Pre-cost Forecasting Example Case N

As shown in Figure 27, the results from this pre-cost forecast example are like those from example case D. The linear regression forecast taken from the fit test is close to the actual values. This would have been a good forecast, as the average values would have been close to the actual values.

The data's problem was that it included multiple European vendors. As defined in the pre-cost forecasting framework, the forecasts will be more accurate if made separately for different vendors in different regions.

6.4 Summary of the Final Framework for Pre-cost Estimation Process Improvements

The framework was validated in the workshop with the management team, and no changes were made to the initial co-created frameworks. The final framework is presented in Table 20 below.

Table 20 Final Framework for Pre-cost Estimation Process Improvements

Topic	A. Main Components	B. Other inventory and itemised materials	C. "Other" materials
Forecasting Scope	• Copper, Shaft, Electrical steel, Frame, Cooler, Special bearings etc. • Separate forecast for different purchasing regions	• Accessories, non machine specific materials etc.	• Nuts, Bolts, Washers etc.
Typical % of machine cost	70%	25%	5%
Data Source	• Monthly Category/SCM Meeting • Historical Purchasing Data • ERP system data	• ERP system data • Supplier cost lists	• ERP system data
Forecasting Method	• Judgmental • Statistical	• Statistical	• Estimating Models
Forecasting Model	• Linear regression • Executive opinion	• Linear regression • Mean	• Range estimating • Expert Judgment
Forecast Frequency	• Once a month • When the costs become more stable once a quartal	• One to two times per year	• Once a year
Forecast Length	• Long- and Medium Forecast	• Short Forecast	• N/A
Forecast Accuracy Measures	• Statistical set • "FIT" analysis • Out-of-Sample evaluation	• "FIT" analysis • Out-of-Sample evaluation	• N/A
Forecast Error Measures	• Mean Squared Error (MSE) • Forecast Value Added (FVA)	• Mean Absolute Deviation (MAD) • Naïve forecast	• Mean Percentage Error (MPE)
Data Correction Outlier Corrections	• Historical data • Supplier offers		• N/A
Database	• Organize the data into distributed databases according to material group	• Create own database and connect the data with ERP-system data and supplier cost lists with unique identifiers	• Create own database and connect the data with master database
Data Retrieving	• Automatic query to retrieve the data from the separate databases to the development database	• Automatically synchronise the data to the master database if the data is updated	
Update frequency	• Once a month • When the costs become more stable once a quartal	• Preferably one to two times per year • If data is updated	• Preferably once a year • If data is updated
Data quality monitoring system	• Detect data quality issues by monitoring the values • Alert the user if the values differ • Resolve by correcting the data with manual data corrections • Use for all the data		
Data observability	• Check if the tables still exist • Save the update dates of the data • Follow the data volume		
Manual data corrections	• Rule-based testing • Metrics monitoring		

As Table 20 illustrates, the final framework follows the initial framework. This framework is expected to make the case company's pre-cost estimation more accurate and dynamic. It suits the current market with regional disruptions and fluctuating costs.

The final process flowcharts are illustrated in Figure 28 below.

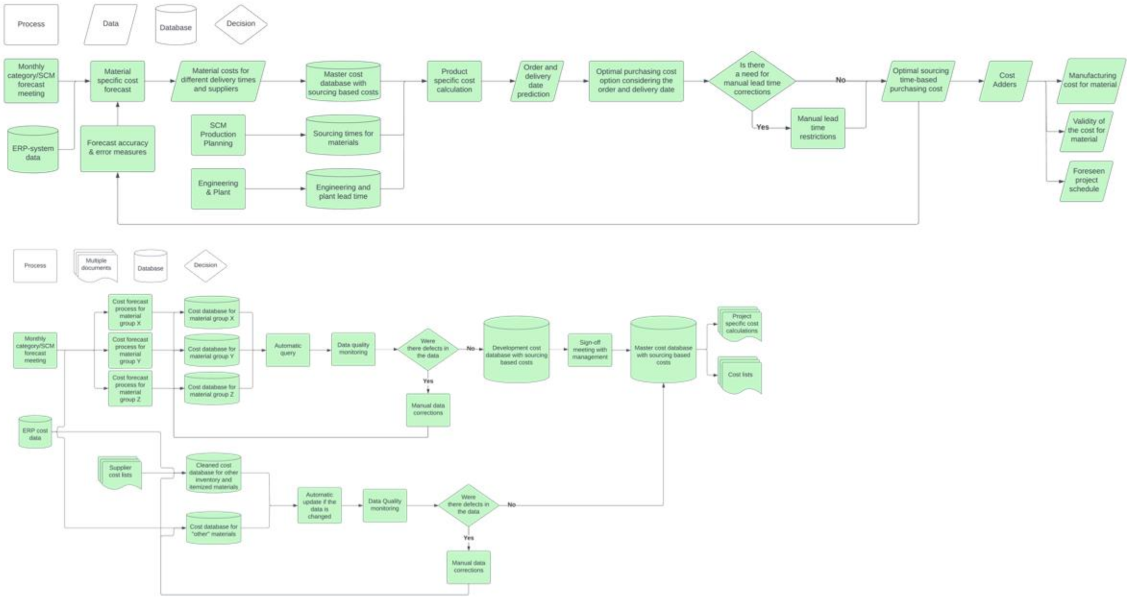

Figure 28 Final Process Flowcharts with Improvements

Adding the changes illustrated in Figure 28 to the current process is crucial. Without these changes, the process is not dynamic enough, as it does not currently consider all the inputs available in the case company. Also, this process would ensure the increased accuracy and overall efficiency of the RFQ to offer cycle and dynamic functionalities for the pre-cost estimation without the need for a separate task force process by incorporating the forecasted costs into the databases.

7 Discussions & Conclusions

This is the last section of the thesis. It presents the executive summary, development path and next step recommendations, self-evaluation of the thesis credibility, and closing words.

7.1 Executive Summary

This thesis focused on developing a more dynamic pre-cost estimation process framework for the case company. The reasoning behind the chosen topic was that the case company had experienced negative cost slippage in the realised projects and that the offers were too high level compared to the competitors, which led to a loss of sales. It was also noticed that the current pre-cost estimation process is not dynamic enough for the fluctuating market with regional disruptions in the supply chain. By implementing the outcome of this thesis, pre-cost estimation on a framework level, the case company can make the process more dynamic and forecast the changes more rapidly and accurately.

The thesis's research design consisted of four stages. The first stage was to conduct a current state analysis. The current state analysis consisted of stakeholders' interviews, a workshop in which the process flowchart was made, and research of the company documents regarding the pre-cost estimation process. This stage also involved the authors' observations. The informants were chosen from the departments connected to the pre-cost estimation process. The outcome of this stage was the process flowchart and the strengths and weaknesses of the current process. The strengths and weaknesses were categorised into the process and working methods, pre-cost forecasting, and data management. The process and working methods included weaknesses that can be eliminated by developing pre-cost forecasting and data management; hence, pre-cost forecasting and data management were chosen as the primary research points of the literature study.

The best practices for the recognised weaknesses were studied in the next section of the thesis, which was the literature review. This section included best practices and ideas from the literature on improving or excluding the recognised weaknesses from the process. In the end, the literature research was summarised as a conceptual framework. The conceptual framework included ideas for the forecasting process, forecasting models, and forecasting accuracy for improving pre-cost forecasting. The conceptual framework for improvement of the data management included data handling and quality.

The following section focused on co-creating the initial frameworks for the pre-cost estimation process improvements. This stage was conducted in weekly meetings with the pre-cost estimation team, the head of the cost estimation, and in an interview with a production planner. The initial pre-cost forecasting framework included frameworks for forecasting scope, data sources, forecasting methods and models, forecasting frequency, forecast length, forecast accuracy, and error measures. The initial data management framework included frameworks for data sources, data and outlier correction, databases, data retrieving, update frequency, and data quality monitoring systems with data observability and manual data corrections.

In addition to these, process flowcharts were made for pre-cost forecasting and data management. These included flowcharts for the current and improved processes for clarity.

The initial frameworks were validated in a workshop with the local division management team. The workshop presented the entire thesis to the management team, including the initial frameworks and process flowcharts. The frameworks were unchanged, and the management required more outputs for the pre-cost forecasting process. After the frameworks were accepted and the process flowcharts corrected, the initial frameworks were summarised as the final frameworks.

In addition, example cases from actual project data from the case company were created. The example cases showed that linear regression works for the data and can be used in the forecasting process. The last part was to create a development path for the implementation phase. The implementation phase supplies the case company with a clear path to implement the process changes step-by-step. The development path is presented in the next chapter.

The final frameworks provide the case company with comprehensive directions on making the process more dynamic and the pre-cost estimates more accurate. This is expected to decrease negative cost slippage and provide more accurate offers based on forecasted costs.

7.2 Development Path & Next Step Recommendations

The case company's management team requested the development path. It was created with the principle that the previous step for the selected scope must be completed before the next one can be started. The development path is presented in Table 21 below.

Table 21 Development Path with Priorities

Priority #	Development Task Focus
1	Adding Regional Alternatives for the Main Components to the Existing Database and Tool
2	Implementation of the Pre-cost Forecasting Models
3	Distributed Database Structure and Updating the Cost Data for all Categories
4	New Tool with Time-based Pre-cost Calculations, Sourcing Times, and Foreseen Project Schedule
5	Data Quality Monitoring System

As Table 21 shows, the most crucial topic and focus would first be adding the regional alternatives for the main components to the existing database and tool to ensure fast implementation of findings to ongoing RFQs and cost lists. This would allow the pre-cost estimation team to calculate the main components with different costs depending on the project's lead time. However, before step four is completed, this must be done manually as the cost estimation template cannot yet calculate the sourcing times for the materials.

The next step would be to implement the pre-cost forecasting models into the process. This would have to be done with the category management team to ensure suitable forecasting models and responsibilities for the teams. After this, it would be possible to implement the distributed database structure in the cost estimation tool. At the same time, all the data would be updated and organised to ensure the correct input data for the calculations.

After these steps, the new tool with time-based pre-cost calculations, sourcing times, and a foreseen project schedule can be developed. The new tool would have a similar report for the sales but with added values to clarify and visualise the calculations.

The last step would be to implement the data quality monitoring system in the process. The data quality monitoring will be done manually before this, but this could be automated when all the previous steps are ready. To ensure fast implementation, ramp-up should be done selectively and not wait for all to be ready before the release for the live cases. For example, the data updating date could be added to the database structure. It would tell the user when the data was updated, leading to enhanced tracking.

For the next step recommendations, the case company should focus on other weaknesses in the process after and during the implementation of the frameworks. The first recommendation would be to focus on the incorrect labour and engineering hour estimates and the reason behind these. More labour and engineering hours have been spent on the projects lately, and there have been overruns compared to the initial estimate given during the pre-cost estimation phase. These issues should also be addressed to achieve more accurate pre-cost estimates.

The second recommendation is to research more sophisticated cost forecasting models and software when the initial results from the cost forecasts using the new frameworks start to come in and the accuracy can be evaluated.

The third recommendation is to extend the use of detailed findings from the forecast error measures and project-specific order-delivery cost monitoring, primarily focusing on outliers. Also, cost monitoring is mainly manual, and automating this process would give an earlier and improved overview of the expected results of individual projects over time.

This is connected to the fourth recommendation, which is to research the possibility of transferring more information to the ERP system used in the case company. Currently, only a few total values are transferred from the pre-cost estimate to the ERP system, and these values do not provide detailed information on how the project was realised at the component level. If there were a possibility of transferring more information to the ERP system, the case company could compare the estimated and actual values more efficiently and, in more detail, directly there. The next step recommendations are presented in Table 22 below.

Table 22 Next Step Recommendations

#	Next Step Recommendations
1	Increase the Accuracy of Engineering and Labour Hour Estimates in the Pre-cost Calculations
2	Research More Sophisticated Cost Forecasting Models and Softwares
3	Extend the Use of Forecast Error Measures to Order-delivery Cost Monitoring
4	Research the Possibility to Transfer More Data to ERP-system from the Pre-cost Estimates

Table 22 presents the recommended next steps, making the pre-cost estimations even more accurate while improving the project-specific order-delivery cost governance process. The recommendations are not in a particular order and can be done separately. The first two recommendations are the only ones under the pre-cost estimation teams' responsibility; the others are the responsibility of other departments.

7.3 Self-evaluation of Thesis Credibility

As defined by Aityan (2021), credible research must include a meaningful problem, a clearly defined and needed purpose, employ appropriate methods and procedures, and have properly derived and supported conclusions resulting from logical analysis and answer the questions in the problem statement. It also must be adequately presented and be based on the scientific method.

The thesis was conducted because the case company had a meaningful problem with the pre-cost estimations. The thesis was needed, and the purpose was to improve the current pre-cost estimation process by providing the case company with frameworks to improve the process. The work followed an applied research design with qualitative data collection methods. The current state analysis was conducted through various interviews, workshops, and observations. All the informants were managers with extensive work experience with the company and experience working in multiple positions.

The improvement ideas for the weaknesses found in the current state analysis were taken from credible literature related to the topic. The improvement ideas from the literature were used to co-create the initial frameworks and new process flowcharts. The initial frameworks were co-created with the head of the cost estimation and the rest of the team, who are highly professional and have extensive work experience with the company. The initial frameworks and process flowcharts were reviewed with the case company management team and improved according to their comments.

The thesis follows a clear step-by-step structure and is based on scientific methods. Furthermore, the author does not include personal opinions. Everything mentioned above ensures the thesis's credibility.

7.4 Closing Words

The thesis was highly relevant to the case company due to the new dynamics created by geopolitical and regional disruptions. Before it was decided that the process would be improved as a part of this thesis, a significant amount of work had already been done to improve the accuracy of the pre-cost estimates. Still, those were not effectively utilised to their full potential. When it became clear that the process could be enhanced as a part of the thesis, the case company permitted the author to use all the resources needed to make the thesis. Furthermore, already in the validation workshop of the initial frameworks, the management team asked when the implementation phase of the new frameworks could be started, and one informant stressed that it is highly crucial to implement the complete framework as a part of the case company's process.

Pre-cost estimate accuracy is crucial for the case company, and it is essential that the process is dynamic in the current business environment and must be able to adapt quickly to changes in the supply chain. During the study, the other departments in the case company showed a great interest towards the thesis work and its results. There are many ideas on how to continue the work in cost estimation and other departments. In the end, the improvement and development of the processes are continuous, and the work will continue during the implementation phase and after the frameworks from this thesis have been employed as a part of the current process.

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Appendices

Appendix 1: Field Notes from Current State Analysis

Question 1: From your point of view what do you see as the strengths in the current Pre-cost estimation process?

Sales 1

- Läpinäkyvyys ja myynti näkee mistä myyntipositioiden kustannukset muodostuvat
- Standardisoitu kustannusraportti mahdollistaa vertailun vanhojen ja uusien laskelmien kesken
- Laskelmapyyntöjen vasteaika on hyvä
- Positiokohtaisten laskelmien tarkkuus oli hyvällä tasolla

Sales 2

- Kokenut ja ammattitaitoinen kustannuslaskentatiimi
- Vasteaika on ollut hyvällä tasolla
- Kustannuslaskenta raportti antaa hyvän näkemyksen myyjälle kustannukategorioista mukaan lukien rivikohtaiset komponentit, riskit, provisiot ja yleiskustannukset

Cost Estimation 1

- Tiimi toimii yhdenmukaisesti
- Tiimin toimialue määritelty hyvin kustannuslaskenta prosessin kannalta
- Työkalun pitkä historia
- Työkalu helposti muokattavissa
- Luotettavaa dataa on saatavilla eri lähteistä
- Tuoterakenteet on dokumentoitu tukevien työkalujen kautta
- Uusi tilaustoimitus prosessi määrittää selkeästi kustannustiimin käyttämisen tarjousvaiheessa
- Käytössä ABC (Activity Based Costing)

Cost Estimation 2,3 & 4

- Motivoitunut tiimi
- Tiimin jäsenillä monipuolista osaamista ja näkemystä
- Itsenäinen ja työskentely ryhmässä toimii tehokkaasti
- Vakiintuneet käytännöt ja työkalun pitkä historia
- Historiadataa paljon saatavilla
- Hyvä sidosryhmien tuntemus
- Excel pohjainen ennakkokustannusarviointi työkalu helposti muokattavissa
- Tuotedataa paljon saatavilla
- Tuoterakenne hyvin dokumentoitu tukevissa työkaluissa

Plant 1

- repetitive and quite standardized process with good team

SCM 1

- Hyvä yhteistyö ihmisten välillä
- Korkea ammattitaito ja päteviä ihmisiä tiimeissä

SCM 2

- Laskelmien nopea toimitusaika
- Tiimillä hyvä palveluhenki
- Työnjälki on laadukasta
- Raportointi on kehittynyt viime aikoina parempaan suuntaan

SCM 3

- Laskentatyökalu on hyvä ja sopii organisaatiolle.
- Raportti pohja on pysynyt samanlaisena vuosia, joten vanhoja laskelmia on helppo verrata uusiin
- Ammattitaitoinen laskentatiimi
- Funktiot toimivat hyvin yhdessä
- Hintapäivitykset hoituvat nopeasti
- Materiaalien hintaennustukset on saatu hyvin välitettyä kustannustiimille

SCM 4

- Laskentapohjan raportti on selkeä ja oston on helppo katsoa sieltä ennakkokustannuksia
- Ammattitaitoinen tiimi

Financing 1

- Kustannusmalli palvelee tarkoitusta. Mahdollistaa margin slippagen seuraamisen eri parametreille (Materiaalit, Labour, Overheads).
- PCOGS laskelman kustannusrakenne on hyvä. Hyvin jäsennelty ja kustannuserät eritelty.

Product Management 1

- Kustannuslaskentamalli on ketterä ja suhteellisen tarkka räätälöityihin tuotteisiin
  - Projekti/konekohtaisten kustannusten hallinta nykyisellä työkalulla on tehokasta
  - Massa-ajot/päivitykset esim kustannuslistoille toimii hyvin
- Tiimillä vahva osaaminen tuotteista ja kustannusrakenteesta
- Kustannusmalli on ollut pitkään käytössä ja tuotekohtaisten kustannuskehityksen seuranta mahdollista komponenttitasolla

Product Management 2

- Vaikka prosessi ollut manuaalinen vasteaika on ollut hyvä
- Kokonaistarkkuus ja granulariteetti on ollut hyvä. Laskelma lasketaan komponenttitasolla, joten näiden kustannukset on ollut selkeitä, eikä vain kokonaisuus ole nähtävissä.
- Työkalussa on olemassa ominaisuus, joka palvelee myös keskiarvoistettua hinnoittelua tietyille konetyypeille. (Hintalistat standardeille koneille)
- Laskennalla pitkä historia ja työkalu pysynyt vakioituna

Product Management 3

- Ennakkokustannuslaskelman tuloste on visuaalinen ja helposti luettava
- Excel pohjainen tuloste on helposti muokattavissa esim. R&D projekteissa tunteja laskettaessa
- Työkalulla on pitkä historia ja pysynyt samankaltaisena
- Hyvä ja osaava tiimi

Engineering 1

- Funktioiden yhteistyö toimii hyvin
- Manuaalisesti käytyjen eri skenaarioiden läpikäynti on tehokasta ja yleensä on päästy hyvään lopputulokseen

Question 2: From your point of view what do you see as the weaknesses/challenges in the current Pre-cost estimation process?

Sales 1

- Hintalistat eivät ole olleet käytössä viime vuosina
- Task force/kustannussäästö prosessi on hankala ja sekava. Vie liikaa aikaa ja usein viimeisissä neuvotteluissa aika on kortilla
- Ylimääräiset kustannusvaraukset kertautuivat koska kustannuslaskenta ja myynti laittoi omia varauksia kustannuksiin
- Laskennassa oli joskus virheitä tuntien ja materiaalikustannusten osalta
- Laskelmilla samat kustannukset toimitusajasta riippumatta
- Spesiaalikomponenttien hinnoittelu ja valinta vaikeata. Myyntikonfiguraattorin varustemäärittely ei ole tarpeeksi tarkkaa ja tieto ei siirry laskennalle tehokkaasti
- Komponenttien hinnoittelu ei ole yhteneväistä kaikkien laskijoiden kesken
- Erikoispositioiden hinnoittelukyselyt eivät ole tarkkoja ja laskijoiden kesken on eroa
- Kustannukset eivät seuraa materiaali indeksejä

Sales 2

- Myyjillä ei ole näkyvyyttä best buy vaihtoehtoon pidemmän toimitusajan projekteille. Komponenttitasolla eri toimitusajoille. Optimikustannusten käyttäminen kaikissa laskelmissa ilman aikaa vievää task force prosessia. Projekteja on menetetty liian hitaan prosessin ja korkeiden kustannusten takia.
- Myyjät ei näe pääkomponenttien tarkempaa dataa esim painoa tai mihin laskenta perustuu
- Laskentakaavojen sisällyttäminen printouttiin jotta myyjä pystyisi muuttamaan itse parametrejä.
- Myynti ei näe mihin indekseihin kustannukset perustuvat (etenkin kupari ja teräs). Myynti tekee usein indekseihin sidottuja materiaaliklausuuleja. Asiakkaillakin näkyvyys näihin indekseihin

Cost Estimation 1

- Olemassa oleva työkalu on rakennettu stabiiliin toimittaja kenttään eikä palvele nykyisessä geopoliittisessa ja dynaamisessa markkinaolosuhteissa
- Ostojen todellista ajoitusta ei oteta huomioon positiokohtaisessa laskennassa ilman manuaalisia korjauksia missä vaaditaan usean funktion yhteistyötä
- Lyhyt myynti ja normaalin toimitusajan myynnin vaikutusta ei oteta huomioon (kohta 2.)
- Data on hajallaan ja määritelmät eivät aina ole linjassa. Datan systemaattinen käyttäminen ilman lisätutkimusta ei ole tehokasta/luotettavaa
- Pre-cost laskelma ei vastaa ERP systeemin kirjattujen saatujen kauppojen kustannusrakennetta
- Eri funktiot näkevät haasteet toisinaan liikaa omalta näkökannaltaan unohtaen kokonaisuuden
- Projektien ja positioiden toteutuneita kustannuksia tarkastellaan yksittäin eri tulokulmista, kun tavoitteena tulisi olla keskimääräisesti mahdollisimman oikea tulos.
- Dynaamisen markkinatilanteen vaikutusta kustannuslaskentaan tulee huomioida enemmän

Cost estimation 2, 3 & 3

- ERP järjestelmän materiaalinimikkeet eivät ole yhtenäisiä tai yksiselitteisiä
    - Laakereissa, öljykoneikoissa tms. erityisesti ongelmia
- Aikafunktiota ei oteta huomioon laskennassa paitsi eskalaatio prosenttina pitkissä toimitusajoissa
- Työkalun pohja ei päivity automaattisesti
- Vanhat revisiot eivät tallennu myyntikonfiguraattoriin, ellei myyjä tee uutta positiota
- Muutoksia ei aina kerrota selkeästi, jos positio päivittyy asiakasmuutosten takia
- Tietokannan päivitys on manuaalista työtä, joka on työlästä ja aikaavievää
- Kaikkia tietokannan kustannuksia ei päivitetä aktiivisesti
- Osa tietokannan kustannuksista on arvioita
- Manuaalisten korjausten päivitys vanhoissa laskelmissa vaatii paljon työtä massapäivityksissä
- Kustannuslistakoneiden päivittäminen on hankalaa
- Ennakkokustannus työkalun tietokanta ei vastaa ERP systeemin tietokantaa
- Tietokanta ei ole tarpeeksi laaja vaan sieltä puuttuu tietoja esim. eri toimittajat
- Uusimmat kustannustiedot ei aina välity kustannuslaskenta tiimille asti

Plant 1

- Systems cannot handle business environment changes. Planned for "stable" business environment. Because of long throughput times and volatility on cost, it is not sufficient anymore.
- Adjustment cycle is naturally quite long and flat costing principle over time does not work well enough (business view)
- Does not support well enough development plans, forecasting, controls etc.

SCM 1

- PCOGS raportti on hankala lukea harjaamattomalle silmälle
- Työkalut eivät ole kovin käyttäjäystävällisiä tiimin ulkopuolisille henkilöille
- PCOGS laskelma ei käytä kuin yhtä lukua kustannuksia arvioitaessa ja se ei ota huomioon eri toimittajia tai aikamäärettä
- Task force prosessi on manuaalinen ja aikaa vievä
- Laskenta ei ota huomioon valmistuksen tai suunnittelun kapasiteetteja

SCM 2

- Toimitusaikaa ei oteta huomioon laskentavaiheessa
- Komponenttien eri toimittajia ei oteta huomioon laskennassa ilman raskasta task force prosessia
- Tuotannon- ja suunnittelun kapasiteettia ei oteta huomioon laskennassa

SCM 3

- Materiaalien hintaennustus on välillä vaikeaa ja mahdolliset toimittaja vaihtoehdot eivät aina toteudu ollenkaan tai suunnitellussa aikataulussa niin ennuste voi olla liian matala
- Ajan funktiota ei oteta aina huomioon hinnoissa
- Eri sovellukset otetaan vain joskus huomioon hinnoissa
- Kaikki tieto ei välity kustannuslaskenta tiimille asti
- Vanha data ei ole aina vertailukelpoista
- Vaikea arvioida hintoja, kun ei ole varmaa tietoa valmistuksesta, organisaation tahtotilasta tai ajasta tilauksen tullessa
- Task force prosessi on raskas/aikaavievä

SCM 4

- Ennakkokustannuslaskelman raportti ei ole aina projektikansiossa
- Raportissa ei tule selville millä toimittajan hinnalla komponentit o laskettu
- Raportissa ei selviä laskentakaavat tai kappalemäärät
- Raportissa ei ole selvästi merkitty, jos komponentit on laskettu ostettavaksi kaukomailta

Financing 1

- Ennakkokustannuslaskelmalta viedään vain 4 eri kustannusta ERP-järjestelmään. Ei mahdollista suoraa jälkiseurantaa
- Materiaalipuolen hierarkia puuttuu osin
- Jälkiseuranta on suurimmilta osin manuaalista ja siihen tarvitaan aina kustannustiimin inputtia.
- Ennakkokustannuslaskelman suunnittelukustannus ei ole samalla lailla ERP-systeemissä.
- Projektin kustannukset on jaettu kaikille projektin koneille ennakkokustannuslaskelmalla, mutta ei ERP-systeemissä
- Komponenttien tarkempaa hinnoittelua ei ole listattuna PCOGS raportissa ja nykyisen OBL laskeminen uusilla kustannuksilla ei ole mahdollista ilman paljoa työtä
- Laskelmalla ei oteta huomioon komponenteille eri toimitusaikoja ja toimittajia
- Kustannuslaskelmalla vain yksi luku huomioi pitkiä toimitusaikoja.

Product Management 1

- Massa-ajot/kustannuslistat eivät ole tällä hetkellä systemaattisessa ylläpidossa (Vanhojen listojen käyttö lopetettiin 2/2022). Projektikohtainen kustannuslaskenta kaikille tarjottaville projekteille aikaa vievää.
- Laskentaan ei ole integroitu best buy/useita toimittaja vaihtoehtoja
- Laskennassa ei oteta huomioon aika funktiota, best buy ja commodity ennusteessa
- Roope kustannusmalli ei tue muita kuin THW/Nestori datarajapintaa, pitäisi tukea myös ADEPT/Cuusamo tuotedataa (Kestomagneettikoneet- ja induktiokoneet). Ei kata koko PT portfoliota
- Uusien tuotteiden kustannusmallin rakentaminen tuotekehitysvaiheessa ei ole aina tuettu (käytännön haaste R&D projekteille ei aina saada nimettyä kustannuslaskijaa tai SCM inputit tarkentuvat projektin aikana designin valmistuessa)

Product Management 2

- Malli ei tue nopeita kustannusmuutoksia
- Työ on suurilta osin manuaalista ja vie paljon resursseja ja aikaa päivitysten ja kustannuslaskennan osalta
- Komponentteja ja toimittajia on todella laaja skaala. Kaikkia komponentteja ei ehditä päivittämään joka kuukausi ja hinnoista vastaavat kategoria managerit eivät päivitä hintoja itse vaan ne tulevat erillisen prosessin kautta ja voivat jäädä kokonaan päivittämättä.
- Käytämme laskennassa vain vakiotoimittajia
- Koska laskennassa on epävarmuutta niin laitamme varmuusmarginaalia päälle mikä nostaa kustannuksia.

Product Management 3

- Tulosteessa ei ole taustadatan oletuksia ja tarkempia hintoja
- Laskenta perustuu yleensä keskiarvoihin eikä tarkkaan dataan
- Kaikilla eri tehtailla ei ole yhtenevät laskentapohjat
- R&D puolella ei ole enää omaa kustannuslaskentaa

Engineering 1

- Optimaalisen referenssin löytäminen ja näkökannan määrittely on välillä työlästä
- Suunnittelutuntien arviointi on usein manuaalista ja prosessi ei ole vakioitu. Arviointikyselyt työllistävät suunnittelua.
- Tuntiarvio työkalun arvio ei aina osu kohdilleen
- Tuntiarviot ovat henkilösidonnaisia

Question 3: Does your department have tools/data sources that would benefit Pre-cost estimation process?

Sales 1

- Toimittajien tarjoukset
- Myynnin tuen kustannustiedot
- ERP systeemi
- MOGE browser
- Salesforce

Sales 2

- Eri materiaali indeksit esim. BMI material index

Cost Estimation 1

- Myyntipositioiden tilaus- & toimitusaikataulu
- Saatujen tilausten suunnitteluvaiheen palaute
- Kriittisten ostojen palaute
- Tyypilliset tuotannonsuunnittelun alkupään ajoitukset koneluokittain
- Tyypilliset hankinta aikataulut & kustannukset kriittisille komponenteille alueellisesti
- ERP systeemin datan automaattinen käsittely/käyttö

Cost estimation 2, 3 & 4

- Omat työkalut hyvin käytössä ja jaettu tiimin kesken. Työkalujen käyttö yhteneväistä.
- Muiden osastojen työkalut voisivat hyödyntää tiimiä ja tehdä prosessia tehokkaammaksi

Plant 1

- Procurement widely would need easier tools for target setting and follow-up + feedback loop to fasten changes for costing.

SCM 1

- Tuotannonsuunnittelun työkalut (Toimitusajat materiaaleille)
- Kategoria managereiden hintalistat
- Forecast palaverin data.

SCM 2

- Läpimenoaika excelit
- Tuotannon kapasiteetti excelit
- SAP ennusteet
- Erilaiset raportit esim. Jättämälaskenta, oston ennusteet, Free to Sell

SCM 3

- Materiaalien hintaennusteet globaalilla ja paikallisella tasolla. Perustuu globaalia indeksiä syvempään analyysiin
- Toimittajien tarjoukset ja markkinatieto

SCM 4

- ERP systeemin ZPDR haku
- RFQ tarjouskyselyt

Financing 1

- ERP-system data

Product Management 1

- Design optimiser in R&D/Technology
- Adept/Cuusamo/RUCA
- Reference machines' market price/target cost data (Could this be in the future in Cuusamo?)
- PM machines product data (today in Excel, future?)
- SCM best buy input data for cost model (BOM cost savings stream), Monthly material signoff inputs per category.
- OBL savings: As sold vs. Actual purchased comparison per component per positions (Input data from Roope PCOGS and ERP system actual data), monthly follow ups.

Product Management 2

- Kategoria managereiden tiedot

Product Management 3

- Aikoinaan kokeilussa on ollut Apriori millä laskettiin 3D osien kustannuksia
- Kisssoft
- Mexcelit

Engineering 1

- Tuntiarviotyökalu
- Referenssikanta
- Teamcenter

Question 4: What changes or innovations do you think could be integrated into Pre-cost estimation process to enhance its effectiveness/accuracy?

Sales 1

- Komponenttien tarkempi kustannusperuste esim. kilohinta tms.
- Task force/kustannussäästö prosessin integrointi laskentaan
- Alustavan hankintastrategian integrointi laskentaan
- Materiaali indeksien lisääminen laskentaan
- Jos laskenta antaisi aina best buy vaihtoehdon, mutta lyhyemmällä toimitusajalla hinta olisi korkeampi

Sales 2

- Myynti saisi automaattisesti myyntikonfiguraattorista oikeat kustannukset koneille ja varusteille ilman kustannuslaskennan konsultointia. Sitä kautta myös pidemmän toimitusajan” Best Buy” kustannusvaikutukset.
- ERP-systeemin ja laskennan automaattiset päivitykset

Cost Estimation 1

- Markkinadynamiikan ohjelmointi sekä kustannuksiin että hankinta strategiaan
- Proaktiivinen kustannusten tarjoaminen myynnille ajan funktiona
- ERP projektimoduulin osittainen käyttöönotto ja siihen liittyvät muutokset kustannuslaskennan työkaluun seurattavuuden parantamiseksi
- Myyntivaiheessa todettujen riskien ja mahdollisuuksien proaktiivinen seuranta/ratkaisu projektin alkuvaiheessa

Cost estimation 2, 3 & 4

- Tietokannan automaattinen päivittäminen ERP systeemin ja tukifunktioiden tiedoilla
- Aikafunktion ja eri toimittajien integrointi tietokantaan
- Tietokannan laajentaminen kattamaan enemmän eri tuotteita
- Ennakkokustannuslaskentatyökalun pohjan automaattinen päivittäminen
- Pienten muutosten automatisointi, jotta jokaista revisiota ei tarvitse pyytää uudestaan kustannuslaskennan kautta.
- ” One click calculations.”
- Tuotteiden oikeiden tietojen haku heti pohjaan
- Budjettitarjousten automatisointi myyntikonfiguraattorista (CPQ-tool)

Plant 1

- Material cost forecast on timeline, with adequate level of details
    - linked to delivery project timeline on "correct level.”
    - Timelines for cheap and fast
    - OBL, Forecast, offering, opening quotation.
    - Linked on cost timeline on timeline of when cost occurs example: copper cost vs frame.
- Follow-up opportunities for open OBL (As-SOLD vs purchased + forecast and thus impact to expected margin)
- Finance: Impacts to current OBL against as sold, and connection to financial forecasting, meaning delta to previous forecast and naturaly to original baseline)
- Purchasing targets and feedback loop to purhaser, fc if possible

- Impacts to FC (open quotations - not needed if short time for open quotaions, impact to new quotations)
- Fixed mechanism for production hours - in line with production planning and/or references. Split on needed level.
- Std procedures/checklists for master data management
- Daydreams - scenario work
- Myynnin tarpeet: eri hinnat eri toimitusajoille, splitit kustannuselementeille, ehdotukset mistä voisi lisätyökllä löytää kilpilukykyö (task-force tms)

SCM 1

- PCOGS laskelma helppolukuisemmaksi
- Hankinnan tietojen listaus toiselle sheetille
- Best buy vaihtoehtojen lisääminen kustannuslaskentaan ja tämän automatisointi
- Alustava hankintasuunnitelma jo kustannuslaskentaan
- Projektien jälkiseurannan raportointi

SCM 2

- Läpimenoaika ja toimitusajan alustava laskenta
- Alustavat toimittajavalinnat

SCM 3

- Automaattinen materiaalikustannus indeksien seuranta
- Tekoälyn hyödyntäminen laskennassa
- Task force prosessista luopuminen ja best buy vaihtoehtojen integroiminen laskentaan

SCM 4

- Laskentakaavat ja kappalemäärät raporttiin
- Alustava hankintasuunnitelma

Financing 1

- Ennakkokustannuslaskelman komponenttien kustannusten vienti ERP-järjestelmään ainakin osin.
- Ennakkokustannuslaskelman rakenne vastaamaan ERP-systeemin rakennetta
- Myytyjen koneiden uusien laskelmien automatisointi ennustetta varten.
- Toimitusajan huomioonottaminen ennakkokustannuslaskelmalla

Product Management 1

- Roope kustannusdatan liittäminen ERP systeemin materiaali masteriin (haasteena räätälöidyt tuotteet, miten voisi tukea?)
- Best buy datan ja ehtojen integrointi kustannuslaskentaan
- Ajan funktion integroiminen kustannuslaskentaan
- ADEPT/Cuusamo/RUCA linkitys kustannusmalliin
- Kustannusmallin historiatietojen ja kustannuskehityksen seuranta (tänä päivänä referenssikoneiden kautta)
- Kustannusparametrien läpinäkyvyyden lisääminen esim. kg hinnat tms.
- Valittujen tuotteiden projektikohtaisen PCOGS laskelman integrointi myyntikonfiguraattoriin.

Product Management 2

- Prosessin ja työkalun automatisointi
- Yhtenäinen tietokanta mihin hinnoitteluvastaavat syöttävät arvoja, kun hinnat muuttuvat ja ne päivittyisivät suoraan työkalun tietokantaan
- Mahdollisuus best buy optioden käyttöön sekä niiden vaikutus koneen toimitusaikaan mukaan jo ennakkokustannuslaskennassa.
- Tukevissa työkaluissa hinnoittelu kohdilleen, jotta myynti saisi sieltä valmiiksi kustannuksen

Product Management 3

- Kustannuvaikutukset näkyviin tukeviin työkaluihin esim. sähkölaskentaan tietoa miten uraluvut vaikuttavat
- Tekoälyn hyödyntäminen kustannuslaskennassa
- Peruslaskennan automatisoint

Engineering 1

- Työkalu mistä saisi eri vaihtoehdot läpimenoajalle ja hyvän referenssin vaihtoehdon.
- Sähkötekninen optimointi jo tarjousvaiheessa
- Suunnittelutuntiarvioiden kirjaaminen ERP-järjestelmään

Question 5: Do you think that the current Pre-cost estimation process is serving the future needs of the company and customers?

Sales 1

- Isossa kuvassa laskentaprosessi on hyvällä kannalla.
- Myynnin tarve saada mahdollisimman tarkat ja oikeat kustannukset jotta hinnoittelu osuu kohdilleen ja projekti tuottaa voittoa.

Sales 2

- Toimii hyvin nyt. Tulevaisuudessa ilman muuta toiveena päästä automatisoituun prosessiin missä myynti pystyy tarjousta tehtäessä hakemaan oikeat kustannukset ilman erillisiä sähköposteja ja full cost näkyvyys, best buy vaihtoehdot ja kriteerit.

Cost Estimation 1

- Johtuen dynaamisesta markkinatilanteesta projektikohtaisesti oikein arvioitu kustannus on entistä tärkeämpää. Jos näin ei tapahdu niin saamme kaupat mitkä on laskettu liian matalilla kustannuksilla ja menetämme kaupat mitkä on laskettu liian korkeilla kustannuksilla.
- Tämänhetkinen malli soveltuu staattiselle markkinatilanteelle, johon ei näyttäisi olevan paluuta.

- Asiakaspalvelun vasteajan parantamiseksi tehdasmyynnin budjetti kustannuslistojen laajentaminen tyypillisiin moottoreihin kannattaisi harkita, vaikka applikaatio kohtaisilla paketeilla standardi listojen optioksi

Cost estimation 2, 3 & 4

- Tämänhetkinen prosessi ei palvele tarpeeksi tehokkaasti
- Nykyinen laskentaprosessi ja työkalu ei tue muuttuneen geopoliittisen tilanteen takia tulleita nopeita kustannusmuutoksia tarpeeksi ilman manuaalista korjausta.
- Tulevaisuudessa voi tulla samanlaisia häiriöitä toimitusketjuun minkä takia työkalun pitäisi ottaa nämä muutokset nopeammin huomioon

Plant 1

- Not enough

SCM 1

- Kustannuslaskenta on hyvällä tasolla, mutta prosessia voisi parantaa.

SCM 2

- Tällä hetkellä prosessi vaatii kehittämistä (katso yllä)
- Ilman kehitystoimia prosessin ja työkalun laatu ja tulos on huonoa

SCM 3

- Laskenta on riittävän hyvällä tasolla
- Laskentaprosessi on parempi kuin toisella läheisellä divisioonalla

SCM 4

- Nykyinen laskentaprosessi ei ole tarpeeksi tarkka ja yrityksen etuja palvelisi tarkempi laskenta

Financing 1

- Ei. Nykyinen malli on liian staattinen nykyisessä markkinatilanteessa ja muutokset pitäisi saada nopeammin integroitua kustannuslaskentaan.

Product Management 1

- Kustannuslaskentaprosessi toimii hyvin, mutta on työläs, jos kaikki laskenta tehdään projektikohtaisesti.
- Laaja historiadata ja referenssikanta eri tuotteista kustannuslaskennassa.
- Kustannuslaskentaa pitäisi kehittää vastaamaan paremmin ja tarkemmin dynaamiseen markkinatilanteeseen.

Product Management 2

- Jollain tasolla kyllä, mutta haasteita on paljon. Prosessi liian manuaalinen ja tämä tuottaa epävarmuutta.

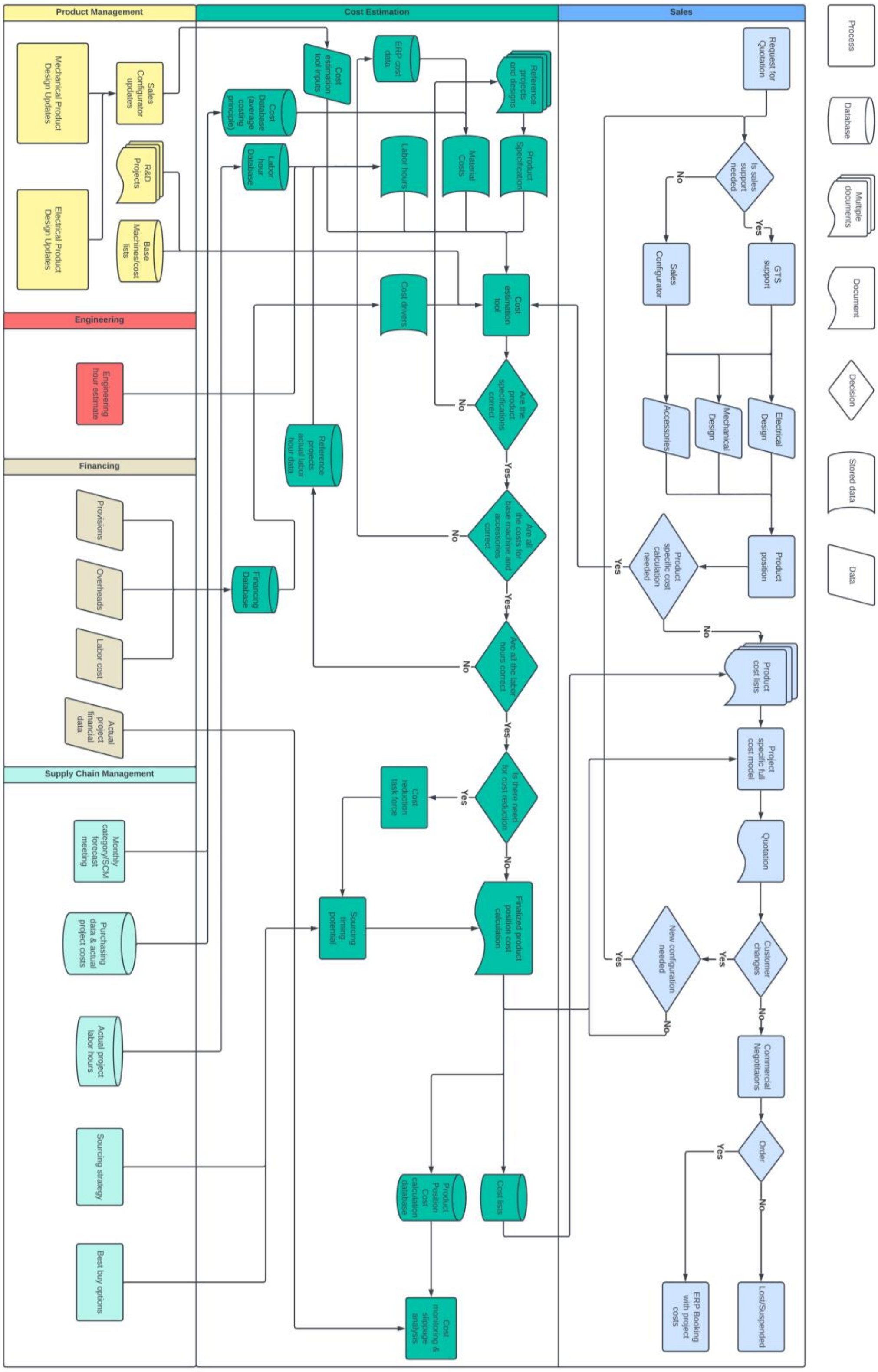
Product Management 3

- Kohtuullisesti. Kokonaisuutena kustannuslaskenta on hyvällä kantilla, geopoliittisesta tilanteesta huolimatta

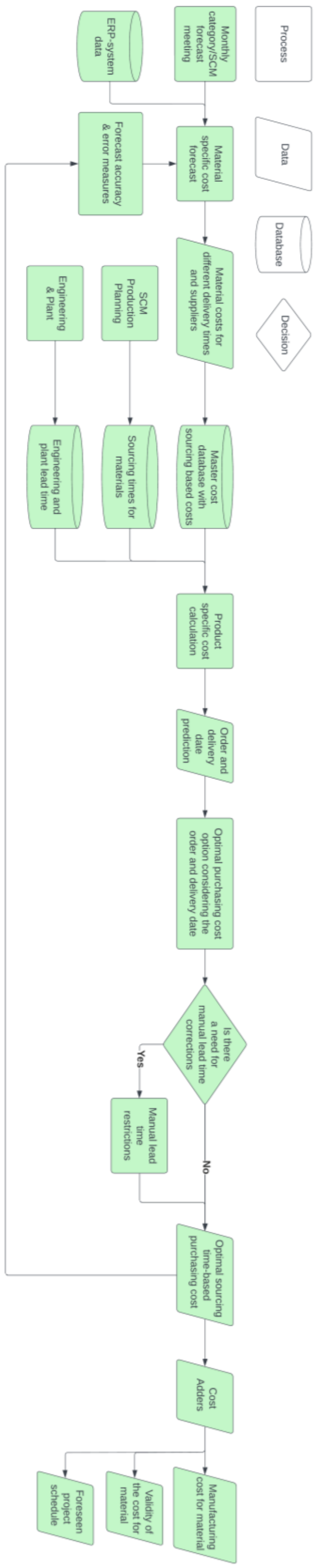
Engineering 1

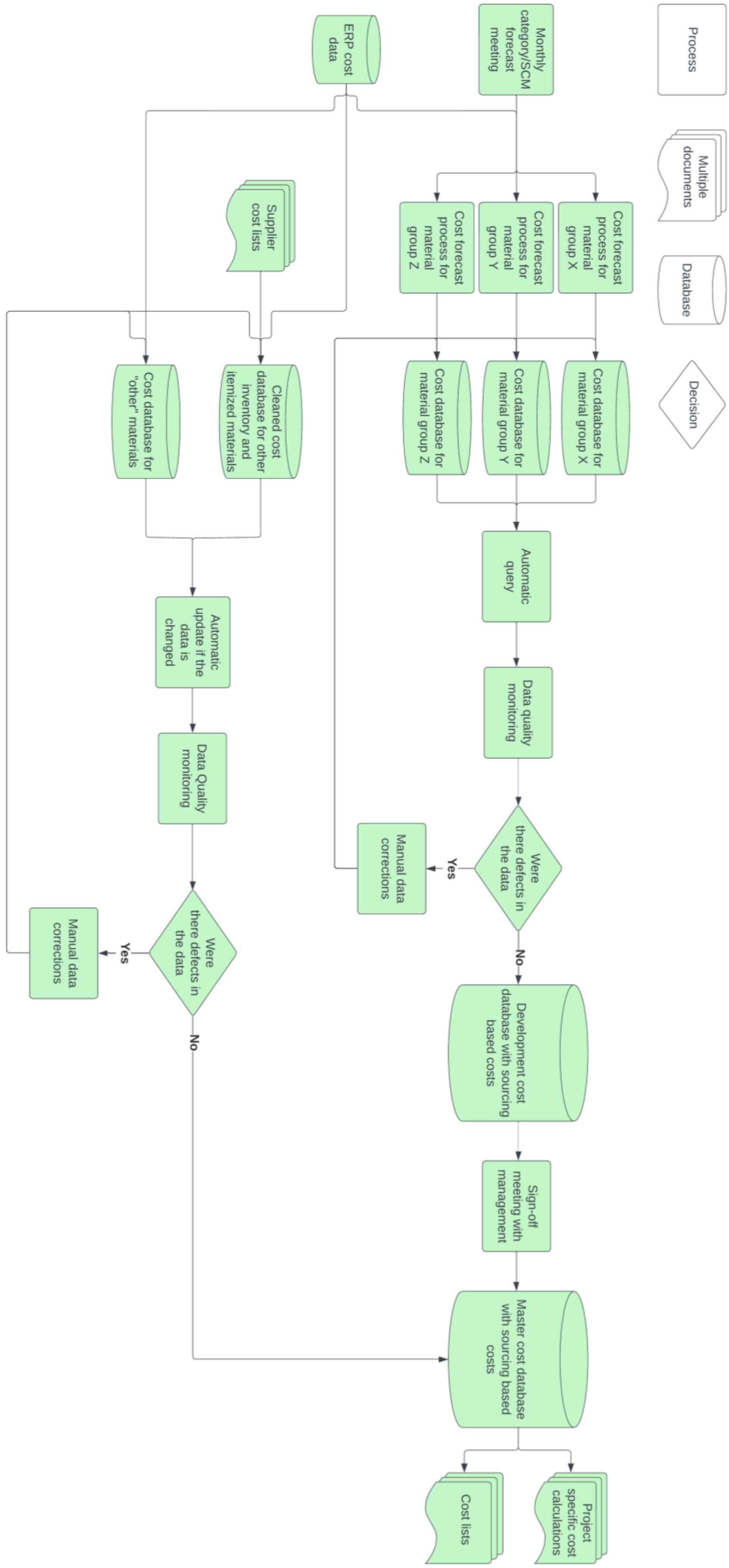
- Laskentaa voisi tarkentaa ja eri vaihtoehdot olisi hyvä ottaa huomioon.
- Suunnittelutuntien arvioita verrattuna toteumaan olisi hyvä seurata tarkemmin

Appendix 2: Current State Analysis Process Flowchart



Appendix 3: Final Framework Process Flowcharts




Process
Multiple documents
Database
Decision
Monthly category/SCM forecast meeting
ERP cost data
Cost forecast process for material group X
Cost forecast process for material group Y
Cost forecast process for material group Z
Supplier cost lists
Cost database for material group X
Cost database for material group Y
Cost database for material group Z
Cleaned cost database for other inventory and itemized materials
Cost database for "other" materials
Automatic query
Data quality monitoring
Were there defects in the data
Yes
Manual data corrections
No
Development cost database with sourcing based costs
Sign-off meeting with management
Master cost database with sourcing based costs
Project specific cost calculations
Cost lists
Automatic update if the data is changed
Data Quality monitoring
Were there defects in the data
Yes
Manual data corrections
No

Appendix 4: Final Framework

Topic	A. Main Components
Forecasting Scope	• Copper, Shaft, Electrical steel, Frame, Cooler, Special bearings etc. • Separate forecast for different purchasing regions
Typical % of machine cost	70%
Data Source	• Monthly Category/SCM Meeting • Historical Purchasing Data • ERP system data
Forecasting Method	• Judgmental • Statistical
Forecasting Model	• Linear regression • Executive opinion
Forecast Frequency	• Once a month • When the costs become more stable once a quartal
Forecast Length	• Long- and Medium Forecast
Forecast Accuracy Measures	• Statistical set • "FIT" analysis • Out-of-Sample evaluation
Forecast Error Measures	• Mean Squared Error (MSE) • Forecast Value Added (FVA)
Data Correction	• Historical data • Supplier offers
Outlier Corrections	
Database	• Organize the data into distributed databases according to material group
Data Retrieving	• Automatic query to retrieve the data from the separate databases to the development database
Update frequency	• Once a month • When the costs become more stable once a quartal
Data quality monitoring system	• Detect data quality issues by monitoring the values • Alert the user if the values differ • Resolve by correcting the data with manual data corrections • Use for all the data
Data observability	• Check if the tables still exist • Save the update dates of the data • Follow the data volume
Manual data corrections	• Rule-based testing • Metrics monitoring

Topic	B. Other inventory and itemised materials
Forecasting Scope	• Accessories, non machine specific materials etc.
Typical % of machine cost	25%
Data Source	• ERP system data • Supplier cost lists
Forecasting Method	• Statistical
Forecasting Model	• Linear regression • Mean
Forecast Frequency	• One to two times per year
Forecast Length	• Short Forecast
Forecast Accuracy Measures	• "FIT" analysis • Out-of-Sample evaluation
Forecast Error Measures	• Mean Absolute Deviation (MAD) • Naïve forecast
Data Correction	• Historical data • Supplier offers
Outlier Corrections	
Database	• Create own database and connect the data with ERP-system data and supplier cost lists with unique identifiers
Data Retrieving	• Automatically synchronise the data to the master database if the data is updated
Update frequency	• Preferably one to two times per year • If data is updated
Data quality monitoring system	• Detect data quality issues by monitoring the values • Alert the user if the values differ • Resolve by correcting the data with manual data corrections • Use for all the data
Data observability	• Check if the tables still exist • Save the update dates of the data • Follow the data volume
Manual data corrections	• Rule-based testing • Metrics monitoring

Topic	C. "Other" materials
Forecasting Scope	• Nuts, Bolts, Washers etc.
Typical % of machine cost	5%
Data Source	• ERP system data
Forecasting Method	• Estimating Models
Forecasting Model	• Range estimating • Expert Judgment
Forecast Frequency	• Once a year
Forecast Length	• N/A
Forecast Accuracy Measures	• N/A
Forecast Error Measures	• Mean Percentage Error (MPE)
Data Correction	• N/A
Outlier Corrections	
Database	• Create own database and connect the data with master database
Data Retrieving	• Automatically synchronise the data to the master database if the data is updated
Update frequency	• Preferably once a year • If data is updated
Data quality monitoring system	• Detect data quality issues by monitoring the values • Alert the user if the values differ • Resolve by correcting the data with manual data corrections • Use for all the data
Data observability	• Check if the tables still exist • Save the update dates of the data • Follow the data volume
Manual data corrections	• Rule-based testing • Metrics monitoring