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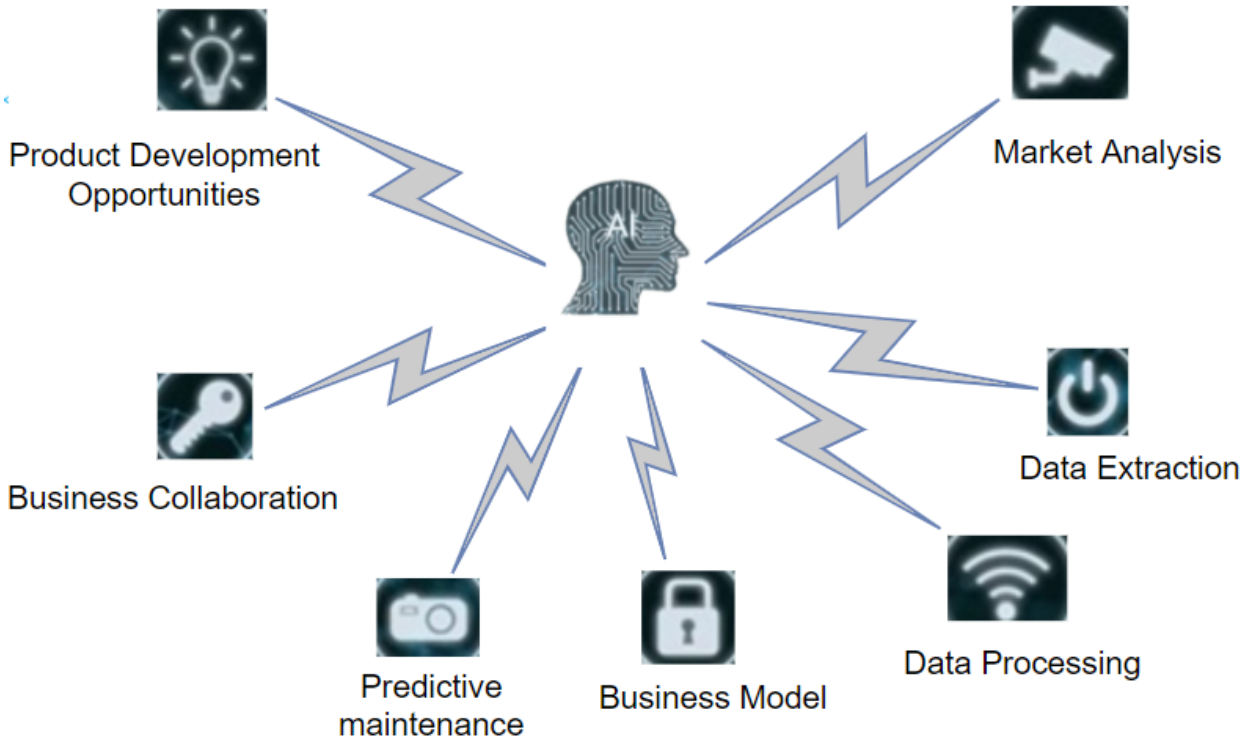

Designing a Business Model for Machine Learning Based Predictive Maintenance

Master of Science Thesis in the Master Degree Programs;
Product Development & Quality and Operations Management

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Gothenburg, Sweden 2020

Master of Science Thesis 2020:NN

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Abstract

This Master's Thesis examined the predictive maintenance industry and focused on designing a business model for machine learning based predictive maintenance. A machine learning-based start-up company offered intelligent energy analytics for predictive maintenance and wants to enter the pulp and paper industry. However, the organization had limited knowledge in how they could plan for identifying potential sources of revenue, the intended customer base and how their product compared to existing products. Their business areas were energy efficiency and predictive maintenance. The purpose was to design a suitable business model that included these aspects and to position the proposal against current state-of-the-art practice in the predictive maintenance industry. The study analyzed existing predictive maintenance solutions, the current business model and how it performs in comparison to competitors, and potential opportunities and threats. This was to acquire as much information as possible prior to the business model concept generation and screening stages.

Data was collected from interviews and a literature review. Several analysis were carried out to investigate external market factors and internal company factors, to identify essential constituents that had to be considered during the concept generation phase. By using the analyses as foundation, five different business model concepts were developed for the industrial partner. During the screening phase, the business model concepts were evaluated in comparison to the company's existing business model. Several models, hypothetically, outperformed the current business model. However, after elaborate reflections of these business models, it was necessary to terminate some of the concepts due to challenges related to a realistic implementation. The motive was that the eliminated concepts would have required a major resource allocation and since the company is a start-up, it has access to limited resources, thus restricting the available options. Consequently, only two business model concepts were selected as realistic suggestions. These models were discussed with the company for validation, which resulted in one of them being terminated but also in an additional business concept being generated. The new concept was combined with the remaining one, which became the final business model recommendation.

The study resulted in a business model concept that was derived from the conducted analyses and defined criteria. The concept focuses on adding value to the machine learning based start-up and its customers through sensors for extracting the data and licensing their software to an external party's platform to facilitate operations and reduce system complexity. As the concept had already been validated by the organization, a technology roadmap was established to provide

detailed information regarding how the company could implement the business model suggestion in practice. Since the initial objective was to design a suitable business model and identify revenue sources, customer segment and existing products, the study achieved its original purpose. The Thesis finished with a discussion on the elicited business model, positioning it against competing businesses that applied state-of-the-art practices for maintenance management. The report then ends with a conclusion and the authors' input regarding future research.

Keywords: Machine Learning, Business Model, Intelligent Analytics, Predictive Maintenance, Energy Analytics, Market Analysis, Roadmap, Benchmarking, SWOT, PEST, Process Industry.

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Simon Braun and Venkata Ratan Deep Eli, Gothenburg, September 2020

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Chapter 1

Introduction

The introduction covers the Background of the thesis, along with a description of the company that proposed the topic. Furthermore, it includes the Purpose of the Thesis, Problem Definition with a formulation of research questions, as well as the Scope and Limitations.

1.1 Background

Generic machines and equipment require some form of maintenance to function properly for a longer time horizon. The maintenance industry is permeated by the need to minimize downtime, reducing costs and increasing performance. It is essential to decrease the costs related to downtime and defective products, in particular in highly competitive manufacturing industries. As the amount of available data is increasing, the traditional decision-making process regarding maintenance management, scheduling and quality enhancement has changed [1]. One of the most prominent strategies to address this situation, is by utilizing machine learning. Machine learning can enable more effective solutions, using newly introduced state-of-the-art algorithms and the evolving capability of software and hardware based solutions. There exists three major strategic approaches to managing maintenance.

1. *Run to failure*: Maintenance is conducted with a reactive intervention i.e. after failure has occurred. Consequently, this approach results in increased costs and downtime as the cost from failure generally exceeds those that arise from a planned activity used proactively.
2. *Preventive maintenance*: A preventive maintenance approach focuses on executing predefined maintenance operations that are congruous with a planned schedule. This schedule can be based either on time or amount of carried out processes. Implementing this strategy could prevent many failures, but

unnecessary maintenance activities would still be prevalent, resulting in a waste of resources and incurred costs.

3. *Predictive maintenance*: Maintenance operations are performed depending on the state of the monitored parameters and measures e.g. health status of a machine or equipment. This approach enables the company to identify failures, potential deterioration, plan and conduct adequate interventions. By using available data, predefined health factors and statistical methods, failures will be prevented with minimal resource allocation.

Many companies are currently applying the *preventive maintenance* approach to manage equipment and machines. This approach consumes less resources than the traditional *run to failure* approach, but it still generates excess waste of resources [2].

Predictive maintenance can enable precise maintenance planning to prevent failures, both predictable and unpredictable. This yields several advantages e.g. extended life-cycle of assets and equipment, increased safety, more efficient use of spare parts and reduced amount of wasted resources [3], [4]. Predictive maintenance often relies on connecting devices and objects with built-in sensors and use of analytics. This kind of maintenance approach is generally being used in, so called, Industry 4.0 environments. In 2018, the global predictive maintenance market was estimated to 2804.38 million USD and is expected to grow by more than 30 percent annually until 2026. The main driving forces behind the expansion of predictive maintenance industry are the needs to improve the uptime of equipment, reducing maintenance costs and increase investment in predictive maintenance projects. Some companies are examining the possibility of integrating industrial IoT and AI with predictive maintenance, to monitor machines and equipment in real-time [4].

1.2 A machine learning based start-up company

The Thesis proposal was provided by a machine learning-based start-up company that was founded in 2019. It has been decided to give anonymity to the company due to sensitive information and confidentiality. The industrial partner operates in two major business areas, energy efficiency and predictive maintenance. The company provides machine learning algorithms for intelligent energy analytics and control of electricity flow. Start-up companies are generally characterized by having limited organizational capabilities and access to less resources than normal companies. This is one of the major causes to this Thesis proposal, as they may not have the resources to conduct this project by themselves. The organization wants to investigate the market landscape. The start-up company is a prominent organization and has been recognized by various companies for its potential. It has received several awards, along with funding from various investors. Addition-

ally, the company has been selected to enter a EU initiative for accelerating the transformation towards a more electrified society.

1.3 Purpose

The purpose of this Master's Thesis is to design a business model for machine learning based predictive maintenance, mainly in the pulp and paper industry. This requires an extensive analysis of the maintenance market, mapping existing methods for maintenance management, current actors, customers and stakeholders. Furthermore, it is necessary to identify potential business opportunities for machine learning algorithms that uses energy measurements. Finally, a competitive business model will be generated at the end of the study.

1.3.1 Problem definition

The machine learning based start-up wants to enter the pulp and paper industry and the problem lies in knowing how they should plan for identifying potential sources of revenue, the intended customer base, how their products perform compared to competitors, and details regarding financing. The use of digital technologies demand an adequate business model that provide new revenue and value-producing opportunities. Four research questions were formulated to define the trajectory of the study.

- **RQ1**: *What kind of maintenance solutions are currently being used in the predictive maintenance industry?*
- **RQ2**: *What is the machine learning based start-up company's current business model and what do its competitors' business models look like?*
- **RQ3**: *What are the challenges and benefits for competitors?*
- **RQ4**: *How could a new business model be designed and how could it affect the company's customer base, product features and revenue stream?*

1.4 Scope of the Thesis

The scope of this study is narrowed to the predictive maintenance market. Furthermore, the predictive maintenance market is preliminary restricted to the pulp and paper industry for this report. The targeted market segment was limited and scoped after several discussions between the Master's Thesis group and the industrial partner.

1.5 Limitations

There are several constraints that affects the report. These are related to time, selected industry and market, and the type of approach that will be undertaken. The project is limited to a time period of six months, ranging from March to September. The market research is only focusing on the predictive maintenance market. In addition, the study will research the process industry, primarily focusing on the pulp and paper industry.

Chapter 2

Literature review

This chapter presents pertinent theory and definitions for the report. Different areas of literature have been researched and reviewed. The content aims to facilitate the understanding of the report by establishing a foundation for the various areas of the study. The chapter initiates with an introduction to predictive maintenance, machine learning and then continues by giving a broad perspective of a business model and product plan.

2.1 Predictive maintenance

There exists various types of predictive maintenance methods and not all are permeated by the usage of machine learning systems. AI-based systems are characterized by several challenges and risks that need to be managed.

2.1.1 Types of predictive maintenance

Predictive maintenance can be described as a process to predict the failure of operational equipment and machines by determining possible defects through the use of condition-based monitoring tools. There are different types of predictive maintenance methods to determine the equipment condition e.g. vibration monitoring, oil analysis, ultrasonic leak detectors, shock pulse, infrared analysis and others. To implement the predictive maintenance, there exists necessary criteria, mainly access to data, preprocessing and fault detection [13].
Another form of predictive maintenance would be to conduct a manual analysis e.g. by using a Six Sigma team that use softwares such as Jmp or MATLAB to analyze the data. In this scenario, the proposed modifications are recorded and communicated to the company. This type of approach mainly depends on the team and require more investment in labor.

Another method, is using a software system that is operated by technicians e.g. CMMS (computerized maintenance management system) is used to monitor machines and notifies technicians when maintenance is required. Once the technicians have been informed, operators will be allocated to carry out the necessary maintenance. CMMS provide initial data from the maintenance cycle and notifies the operator if a machine is working outside of the pre-defined conditions.
Assisted learning systems is another method which focuses on identifying patterns in the data to detect risks and uncertainties. In this maintenance approach, mathematical models are custom-built for a specific industrial machine and are fed with real-time data. Assisted learning systems are often used by organizations that do not have enough analytical capabilities [14].

2.2 Background to Machine Learning

The term machine learning was first coined in the year 1952 by Arthur Samuel, who at the time worked for IBM and developed a computer software to play checkers [6]. The primary idea of machine learning is based on a model of brain cell interaction. The world is experiencing a new revolution, namely the digital revolution and the era of big data. This data is derived from the billions of web pages existing on the internet. This amount of data requires automated methods for processing and analyzing the data. This is solved by utilizing machine learning, which can be defined as various methods for identifying patterns in the data, and using uncovered patterns to predict and estimate future data, or to facilitate other types of decisions that are generally permeated by uncertainty [7].

Machine learning is categorized into two major sub-types, the predictive and descriptive learning approaches. The objective of the predictive approach is to learn to map from a particular input to an output, by providing a set of input-output pairs. In the descriptive learning approach, only inputs are provided. This results in a less defined problem, as there is no indicators or instructions regarding what kind of patterns to identify and there exists no error metric which can be utilized [8].

The capability of making accurate prognostics enables OEMS, customers and manufacturing companies to monitor the development of an equipment's health and can be used to conduct preventive activities. Consequently, it enables increased system safety and operations reliability by reducing the number of unnecessary maintenance actions and costs associated to the system life-cycle [9].

2.2.1 Challenges associated with AI-based system

Upon investigating, several challenges and risks associated with implementing a new system for maintenance management were identified, in particular machine learning systems. Poduval, Pramod and Raj discusses various barriers in implementing total productive maintenance [10]. They note that it is important to commence with establishing a team to identify objectives and create strategies to achieve them. Some of the risks and challenges in the organization are listed below.

- **Expectations exceeds reality**
  The expectations on the emerging machine learning-based technology are increasing in a rapid pace. From low expectations on the artificial intelligence in industrial and business applications, to surrealistic expectations following the prominence of AI. In today's society, the expectation of many people exceed the actual outcome from implementing these algorithms. This often results in a disappointment once an AI-system has been implemented, as it does not always correspond to expectations. [12].
- **Talent gap**
  Another challenge with machine learning is identifying and allocating the people that possess the correct competence and technical ability to utilize it i.e. experts. The downside of the high demand and low supply is that salaries are increasing for data technicians, resulting in increased labor costs. It is also difficult to find employees that are experienced in data science and programming [12].
- **Costs related to IT and computation**
  Large scale data processing projects often require expensive GPUs for analyses. However, not all companies have the necessary resources to provide GPUs to their employees. Another challenge lies within the processing time, as there can arise situations where several weeks are required to train a particular machine learning model. This is generally not an issue, as long as results are generated rapidly in a production environment. The major challenges emerge when there is a need to update the model continuously. For instance, acquiring and analyzing new data every day, but it takes a week to train the model. In this scenario the model cannot be in pace with the latest incoming data. This is a common problem, where the rate of incoming data is exceeding the rate of retraining the algorithm.
- **Black Box**
  Another challenge related to the interpretation of the actual results for managers and technicians i.e. the decisions and actions undertaken by a machine learning model. It is difficult to explain why particular algorithms and other software decided to undertake certain actions. This can generate a lot of

frustration as the algorithm makes the decision based on the received input, but its decisions cannot be explained.

- **Data hungry**
  Using machine learning algorithms requires an initial data as reference for different input parameters, in order to start making predictions of future outputs. The algorithm needs to be capable of evaluating and assessing its results i.e. comparing different solution alternatives. This requires some form of reference e.g. from historical data. Additionally, if failure occurs then it has to be able to identify the defective factors and operators, but also assign credit to the operators in successful outcomes. The availability of this type of data generally poses a significant business challenge for these kinds of projects. The core problem is that this labeled data is often non-existent and requires the company to extract this data in some way [11].
- **Expensive investment**
  Finally, tailoring an algorithm for a particular operation or activity consumes monetary resources. In addition to allocating time resources to train the algorithm, it is also expensive to acquire this technology. In general, the usage of machine learning is more prevalent in major organizations rather than smaller, due to the difference in resources [12].

As can be observed, the implementation of AI-systems are permeated by challenges. Poduval et al (2013) advocate that is is necessary that an organization standardize their processes and plans maintenance. Furthermore, they state that maintenance operations needs be conducted by operators to enable the maintenance personnel to plan for changes and maintenance programs [10].

2.3 Business Models

The current business landscape is characterized by complexity and turbulence, due to the influence of information technologies. There is a demand for tools that can manage this uncertainty. Existing business models emphasises increasing demand on the coordination of a large number of stakeholders, such as partners, strategists, business process designers and information systems staff. At the moment, only a few management tools exist that can facilitate the process of understanding, mapping and sharing the business logic of today's firms. After an initial stage consisting of major investments in business models, business planning for profitability has become indispensable due to the intense global competition. This means that all components of a business have to be optimized and reinforcing and that details in a business model make the difference [25].
Many managers possess a deep understanding of how their business work and how they generate value. However, the managers often have issues in communicating

the business model in a clear and transparent way. In this scenario, the machine learning based start-up is unsure of how it should conduct its business.
It is vital that the business model properly understood, as it otherwise becomes difficult to make decisions regarding changes and obstacles [25]. The introduction of information technology has had a major impact on business models, reducing transaction and coordination costs, facilitated collaborative relationships between partners and integrating customers in the company's processes and has also enabled new product and service offerings to be developed. There are various factors that must be considered when generating a business model.

2.3.1 Business model definition

There are various definitions to what a business model is. The generic definition would be that a business model is a strategic plan for operating the business, identifying revenue sources, customer base and finance. Another way to define it, is by describing a business and model separately [25].

- *Business*: A business can be defined as the process of purchasing and selling products and services.
- *Model*: A model can be described as a representation of something e.g. a physical object or a description of the object.

When combining the two definitions, a business model can be explained as a representation of how an organization purchases and sells products and services to acquire revenue. The purpose of the business model is to facilitate the interpretation, description and prediction of the external environment i.e. the business logic of a particular company. For instance, e.g. the process of purchasing and selling services and products and earning revenue. In other words, the business model is a conceptualization of the generating money logic in an organization and is often used to link the business strategy, business organization and information technology together [25], [27].

2.3.2 Generating a Business Model

There are several major aspects that must be considered when crafting a business model e.g. social environment, legal environment, competitive forces, customer demand and technological change. These factors are illustrated in figure 2.1.

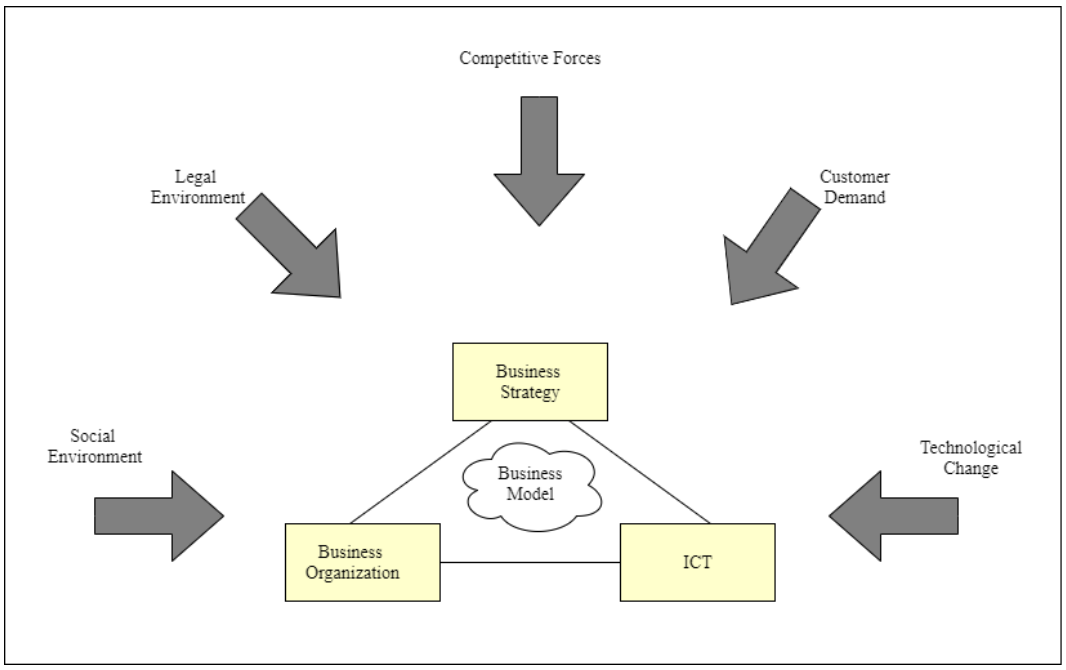

Figure 2.1: Factors that are essential to consider when generating a business model (Osterwalder, 2004)

- **Business strategy**
  The first component in the business model is the business strategy. It is a major area, where there is generally a lack of consensus. The business strategy and business model should both include similar challenges, but in different business layers. The organization's vision and strategy should be directly translated into the value propositions, customer relations and value networks [26], [27].

- **Organization**
  The business organization is the second element of the business model and focuses on the organizational structure. The business organization can be viewed as the physical manifestation of the business model in practice e.g. workflows, units, department, processes etc. Clarity in the business model regarding the organizational structure facilitates addressing issues related to business processes.

- **Information technology**
  The final element of the business model is the usage of information technology (ICT) to manage all the information and communication technology utilized in the company. This connection is more prevalent for online com-

panies. Costs related to communication and coordination are generally reduced as the cost of ICT increases i.e. it indirectly affects cost aspect in the business models. Furthermore, organizations are moving toward including value-adding services based on informational aspects.

A common tool for visualizing a business model, is by using a business model canvas. The canvas illustrates the key components of a company's business model. It mainly focuses on nine constituents e.g. revenue source, cost structure, key partners, distribution channels, value proposition, key activities, key resources, customer relationships and customer segments. A generic business model canvas template is illustrated in Figure 2.2 [25].

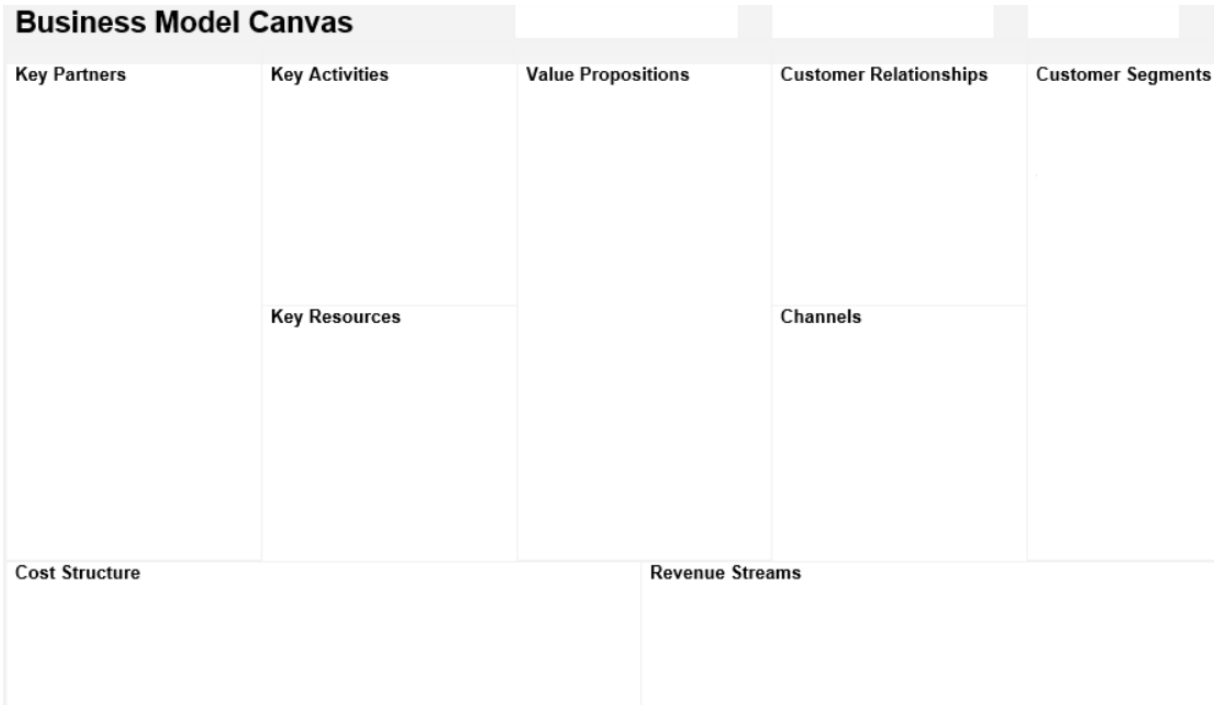

Figure 2.2: A standard business model canvas template.

2.4 Product planning and business strategy

It is essential to establish a product plan to position the product in relation to the market and identify development opportunities in the business model, which in turn will determine the business strategy. A product plan can be described as a portfolio of products that the organization will develop. For this particular project, the developed product is an AI-powered software that can be used to ana-

lyze energy data and predict when maintenance is required. The targeted market segment is the pulp and paper industry. The plan contains the timing for launching the products to the targeted market e.g. by using a technology roadmap. It identifies product development opportunities by using multiple sources e.g. suggestions from market research, patent research, customers, product development teams, SWOT, PEST, benchmarking of competitors etc. The information from the analyses will be used during the business model concept generation. The product plan is frequently revised after changes in the competitive environment and technological developments [15]. It is pivotal to outline a suitable business strategy to illustrate the organization's market and product approach, while also considering the market competition and customer needs.

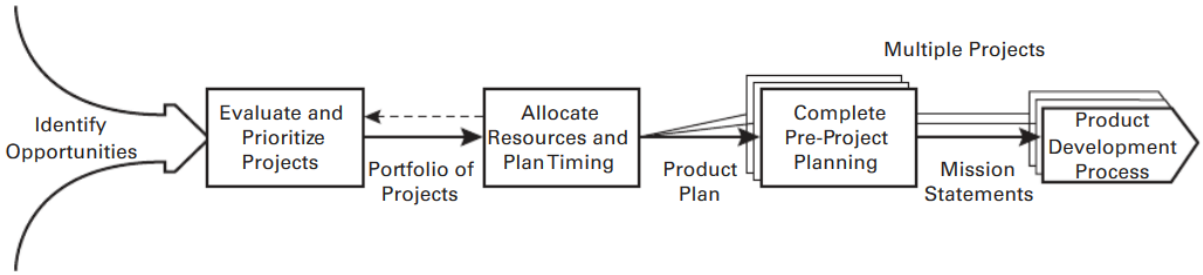

Figure 2.3: The product planning process. These activities address a portfolio of product development projects, resulting in a product plan and, for each selected project, a mission statement (Ulrich & Eppinger, 2012).

2.4.1 SWOT-analysis

As previously explained in the product planning, it is necessary to analyze the organization and its capabilities, while also examining external market factors. A common tool for examining and measuring a company, is the SWOT-analysis, where SWOT is an abbreviation for Strengths, Weaknesses, Opportunities and Threats [17]. The SWOT-analysis was first coined in the 1960's by Albert Humphrey at Stanford Research Institute [16]. The first two factors, Strengths and Weaknesses, identify and analyze internal contextual factors in the company. It relates to in what areas the organization exceeds, and where it needs to improve. For instance, motivating staff, access to certain resources or efficient production processes. Another example, would be a negatively perceived brand image, or restrictions on resources that can be allocated. The remaining factors, Opportunities and Threats, examine the external context e.g competitors and market development and how these influence the company. Opportunities generally arise from situations outside of the company, sometimes due to new development in the attitude of the targeted

market segment, or in the technology that is being utilized. Threats are generally identified by examining at competitors and substitutes [18].

2.4.2 PEST-analysis

A key tool for identifying external contextual factors and how they affect the company, is the PEST-analysis. The PEST-analysis was coined by Harvard professor Francis Aguilar in 1967 [19]. PEST denotes Political, Economical, Socio-cultural and Technology aspects that each affect the business and are important to consider when formulating a business strategy [20]. The political factors can include changes in domestic political arena, effects of collaboration, government change, tariffs, regulations or sanctions between different nations. Aspects regarding economic changes, can be related to currencies, commodity prices, labour markets, world trade and economic cycles etc. Socio-cultural factors consider the impact of the environment and sustainable development, demographic patterns and preferences, habits and cultural factors. The technology aspect include the effects that arise from technological changes regarding processes, products, distribution and operations etc. It is important to identify and search for new technologies that could be used or might radically affect the industry [21].

2.4.3 Technology roadmap

There exists various methods and models for coordinating technology development in new products and projects with product planning. A commonly used method in industry is the technology roadmap. It is perceived as a powerful technique for facilitating both the planning aspect and technology management. For instance, technology roadmaps are generally used as a product planning tool to enable and generate a strategy that combines both technology development and product development. A generic roadmap can be described as a time-based chart that considers both technological and commercial perspectives. These shape of these roadmaps often vary between technology push and market pull. Furthermore, it is used to support business strategy planning. There exists several types of product roadmaps, but the major emphasis, in this study, is on service and capability planning, since maintenance service is what characterizes the industrial partner's product. In this scenario, the roadmap will consider how the business is affected by technology development and, additionally, bridging the gap between the technology and the business by using the organizational capabilities [23]. The result of the roadmap should be a diagram that visualizes the product's crucial functional elements and a prediction of how the technologies that implement these elements will develop over time [15].

2.4.4 Benchmarking of competing products

Benchmarking is the investigation of existing competing products with similar functionality to the product that is being developed. The benchmarking can provide information regarding strengths and weaknesses of the competitors, as well as potentially revealing existing concept that are being utilized to solve a specific problem.
It is paramount to conduct a benchmarking to determine commercial success and acquire information on competitive products [24]. Additionally, it is important to position the product since it can contribute with ideas for the product process design and business model design. The information can also be utilized for future decisions regarding market position [15]. Identifying and analyzing different established solutions from competitors enable the ability to learn and sometimes mimic particular properties.

2.4.5 Patent Search

A patent is a monopoly, received from a government to an investor to prevent other from utilizing the invention. It is often limited to 20 years. A patent search is useful for examining existing sources of technical information, along with descriptions of how different product applications function. A search will be conducted in order to detect various patents related to either AI-based solutions or within the predictive maintenance industry. Patent analysis can provide a holistic view of the know-how of the used technology and might contribute to the concept generation stage [15].

Chapter 3

Methodology

The following chapter describes the Research Approach and the Proceeding Order of the Thesis. It further describes the used methods for gaining data and knowledge, making it possible to answer the research questions.

3.1 Research approach

To successfully answer the research questions, various methods were applied. Information was acquired through both an extensive literature review and several interviews. Using mixed study methods in the same project can increase the accuracy of the findings [44]. The mixed research approach is generally composed of both quantitative and qualitative methods to enable a clear holistic view [44]. A triangulation method was utilized in the thesis, combining the both interviews and articles. The order of the each stage in the project is visualized in figure 3.1.

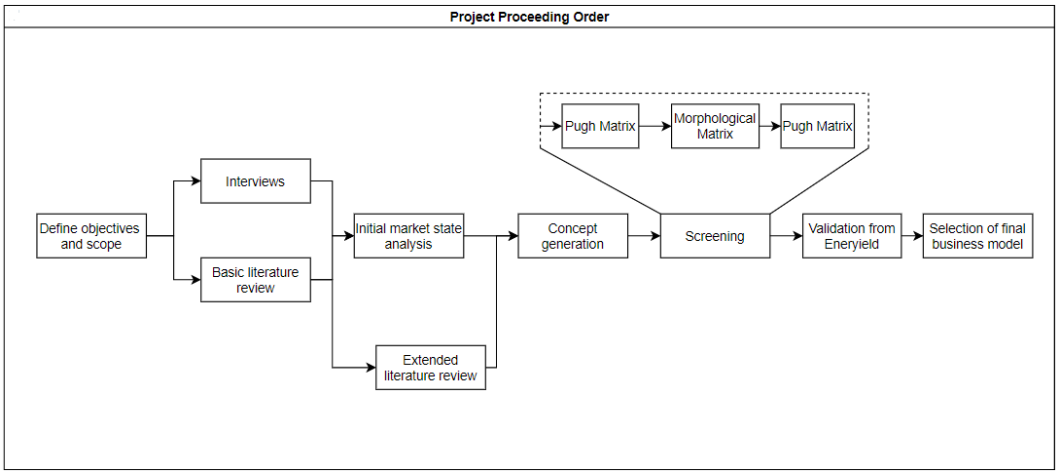

Figure 3.1: A diagram, illustrating the proceeding order of the project.

3.2 Execution

The study initiates with a brief background to the research topic i.e. maintenance management approaches along with various problems associated with it. A problem description was then provided in the form of several research questions, scope of the thesis and limitations.This was to set out the objectives of the study.

The literature review started with identifying important definitions and models related to machine learning and predictive maintenance, along with benefits and business challenges. It examined several published articles, books and patens, which is illustrated in Table 3.1. The definition of a product plan is presented and its importance for the launching of a new product. A product plan was viewed as essential for planning the new business model. The product plan contained several models e.g. SWOT-analysis, PEST-analysis, patent review, technology roadmap and benchmarking. In addition, a business model definition was presented along with how it can be generated.

Table 3.1: Illustration of the various data collection sources that were used during the study.

Data collection methods	*Books*	*Articles*	Patents	*Interviews*	*Workshop*	*Validation*
Number	8	37	Five patents	Seven different companies, including the industrial partner	One workshop	One validation meeting

Data was also collected through conducting several interviews. The interviews were carried out with seven different companies established in the maintenance industry, including the machine learning based start-up. The participants were

maintenance directors, machine learning application engineers, engineers responsible for prevention of failure and service technicians that were specialized in maintenance. Interviews were selected as a data collection method in order to acquire knowledge about existing solutions, needs and challenges that competitors had. Furthermore, a workshop was conducted with the industrial partner to elicit their current business model. This was facilitated through the usage of a standard business model canvas template, to visualize their existing business.

The interview process was divided into five steps.

1. **Objective**
   The purpose of the interview is established. Prior to the interviews, it was necessary to define what information was required.
2. **Preparation**
   A plan was defined to how the interviews should be structured in order to achieve the objective of the report. Ethical aspects e.g. anonymity of both interview subject and company were also considered.
3. **Execution**
   During the interview, the interaction between the interviewer and the participant went according to a predefined plan in stage two.
4. **Transcription**
   The conducted interviews were transcribed to facilitate the data processing.
5. **Analysis**
   The acquired data from the interviews was analyzed.
6. **Archiving**
   The obtained results were documented and made anonymous.

The different solutions to maintenance problems were then composed in a table, to facilitate comparison and evaluation of the solutions. This was done to acquire identify current methods being used, potential customer segments, customer needs.

A company analysis was then carried out, using a SWOT- and PEST-analysis. The SWOT was used to identify the organization's internal strengths and weaknesses, as well as external opportunities and threats. The purpose of the PEST was to obtain a more holistic view of the state of the market by analyzing political, economic, socio-cultural and technology factors. After the PEST-analysis, a benchmarking was conducted to compare the industrial partner with their competitors. The benchmarking focused on the key components of a business model i.e. product features, revenue stream, customer base and details of financing.

3.3 Concept generation and screening

The results from the analyses were used for the concept generation stage. A business model canvas was established for every concept. There was a mix between concept generation and the screening stage. Concepts that failed the screening, were combined using a morphological matrix to investigate if any *hybrid* concept would pass. The screening of potential companies i.e. customers was on the basis of their need and usage of energy analytics. These were then compared to industrial partner's current business model concept by utilizing a Pugh-matrix. Three concepts did not pass the first evaluation round. Instead of simply continuing with the remaining concepts, the morphological matrix was used to combine the concepts that failed. The motive for mixing concepts, was to not neglect competitive potential hybrid concepts that might arouse from concept combinations.
The second evaluation defined a different criteria, since all the concepts to this stage had already, hypothetically, exceeded the original business model. In this stage, concept 4 was set as the reference for the Pugh matrix comparisons. All remaining concepts were evaluated in relation to concept 4, resulting in only two concepts that passed. The morphological matrix process was iterated for the concepts that failed in the third stage, spawning two hybrid concepts. These were later evaluated in comparison to concept 4 and both passed the screening criteria. To select a suitable business model from the remaining concepts, other aspects were considered in order to choose a realistic and suitable model. A table was generated, listing the benefits, challenges and required resources needed for each of the concepts. This was in order to identify obstacles during a realistic implementation. After analyzing the data, several concepts were eliminated from the pool. Despite being, theoretically, superior to concept 4 in regards to the nine business model canvas components, they were deemed to require too much resource allocation from the start-up. This was considered a key factor, since the organization is a start-up and has limited access to resources. Additionally, the objective is to find a realistic concept that they could, *de facto*, use. All concepts that required extensive resources e.g. interpreting various types of data, which would require increased specialist workforce and increase salary costs. Only two concepts passed, namely concept 4 and 42.

3.3.1 Validation of business models

Since most of the validation of the screening was conducted by the Thesis group, using the previously carried out analyses, a meeting was scheduled with the industrial partner. The purpose was to validate the generated and selected business concepts. As they are the end-user of the concept, it is crucial that the business

model concept proposal is compatible with their business strategy. During the meeting, concept 4 was approved but not 42. Furthermore, a new business model concept was suggested, which was then integrated with concept 4, resulting in a new business model concept. After the validation, the new concept was exposed to the evaluation stages and passed.

3.4 Positioning of selected business model

After the business model selection concluded, a discussion is provided to discern the possible implications on the machine learning based start-up company's current business model by positioning it against current state-of-the-art practices in the predictive maintenance industry. This was to investigate how the recommended business concepts would perform. The study ends with a conclusion and recommendation for future research.

Chapter 4

Result and analysis

The chapter presents the results acquired from the selected methods i.e. patent review, interviews, workshop, SWOT-analysis, PEST-analysis etc. The information in this chapter is necessary in order to answer the research questions and to generate business model concepts.

4.1 Research questions

The research questions derived from the problem definition are stated again to emphasize what needs to be answered.

- **RQ1**: *What kind of maintenance solutions are currently being used in the predictive maintenance industry?*
- **RQ2**:*What is the machine learning based start-up company's current business model and what do its competitors' business models look like?*
- **RQ3**: *What are the challenges and benefits for competitors?*
- **RQ4**: *How could a new business model be designed and how could it affect the company's customer base, product features and revenue stream?*

4.2 Results from patent review

A patent review was carried out to investigate five different patents in order to identify existing sources of technical information. The five patents relates to either AI-based solutions or within the predictive maintenance industry and can be viewed in Table 4.1. Patent analysis can provide a holistic view of the know-how of the used technology and might contribute to the concept generation stage [15].

Table 4.1: Illustration of investigated patents during the patent search.

Patent1	Patent 2	Patent 3	Patent 4	Patent 5
The machine learning algorithms analyses sensor data to monitor the state of the vacuum pump and detects deficient oil levels.	The machine learning algorithms monitor process variation and critical dimension and make predictions	The machine learning system is connected to a computer database that host real time data, that helps to process the data.	The machine learning system is used to detect and remove non-complying metrics from the collection of propensity to failure metrics ans used as an application to rank the filtered propensity	The machine learning algorithm makes an assessment based on the real time data and informs about replacement for optimizing the battery.

4.2.1 Patent US 20190154032A1: Real time machine learning based predictive and preventive maintenance of vacuum pumps

Patent US 20190154032A1, is a method that uses machine learning systems for predictive and preventive maintenance of vacuum pumps, by using data extracted from a sensor that is attached to the motor and blower. The data acquired from the motor is used to monitor the state of the vacuum pump by analyzing the vacuum pump when it operates and emits a notification if a boundary-value, set *a priori*, is exceeded. Furthermore, the blower data is used to detect deficient oil level by analysing the data of operational range, the filters and the oil. In addition, the vibrational energy, is also evaluated. To summarize, the innovation analyses the sensor data from the motor and blower by applying machine learning algorithms to identify when maintenance is necessary [39].

4.2.2 Patent US 10430719B2: Process control technique for semiconductor manufacturing process

The technique in patent US 10430719B2 focuses on measuring process variation in a semiconductor in the manufacturing industry. Large sets of input data are pre-processed, organized and analyzed by the use of machine learning systems. The objective is to monitor critical dimension and make predictions of the quality in the semiconductor [40].

4.2.3 Patent US 20190310129A1: Detecting faults in rotor driven equipment

Patent US 20190310129A1 proposes a method and system of detecting faults in rotor driven equipment, by extracting data from vibration sensors that are attached to the equipment. The data acquired from the sensors is stored onto a mobile data device. The data is obtained over a limited time period and is transmitted to a

computer database hosting real time and historical data. The database is, in turn, connected to a machine learning system which analyzes the data. The real-time data is used for visualizing the rotor driven issue through a processor based on the analysis of big data. The method indicates rotor driven equipment issue through a user interface by setting an alarm through the processor [41].

4.2.4 Patent US 8751421B2: Machine learning for power grid

Patent US 8751421B2 is an innovation that utilizes an AI framework to rank the assortment of failure metrics in components within an electrical grid. Raw data is extracted by a sensor, and is later processed by a data processor into more uniform data that can be analyzed by machine learning algorithms. The processor is linked to a database, where the data is stored. The objective of the AI-framework is to detect and eliminate factors that are improbable, from the assortment of failure metrics. The information is used as a support application for decisions related to the propensity of failure measurements in the grid. [42].

4.2.5 Patent CN 106168799B: Machine learning to conduct predictive maintenance of batteries in an electric automobile

The idea of patent CN 106168799B is to conduct predictive maintenance of batteries of electric automobiles, by using machine learning algorithms to analyze big data. This method uses real-time battery data and operational data, extracted from sensors on the batteries in the electric cars. The data is used to predict when maintenance is required, and to establish a strategy for controlling and monitoring the batteries, as well as identifying when a replacement is necessary [43].

4.3 Results from interviews

Interviews were conducted with employees that possessed relevant positions regarding maintenance operations at various companies. The companies are active in the process industry. The interview subjects consisted of maintenance directors, machine learning application engineers, preventive engineer and service maintenance technician. Furthermore, several obstacles and needs were elicited during the interviews.
A summary of the most important information from the interviews and workshop is illustrated in the pains and gains in Table 4.2. The pains refer to the organization's fears, frustrations and obstacles, while the gains represent its wants, needs,

measures of success and obstacles [25]. The pains and gains were identified by listening to what the interview subjects said, how they perceived their environment, their attitude towards the company and towards customers.

Table 4.2: Illustration of elicited pains and gains, obtained from interviewed companies. The letters in the brackets represent which interviewed company that listed the particular pain.

Pains	Gains
Extract quality data (A)	Sensors that provide accurate quality data (A)
Unable to analyze the data (A)	Data analysis support (A)
Storing and sharing data (A, B, C)	A platform where data can be stored and shared (A, B, C)
Unsuitable suppliers (A)	Strategic partnerships (A)
Erroneous predictions, resulting in unnecessary costs (A)	Increased accuracy of predictions (A)
Difficult to detect which specific part requires maintenance (B)	Need for a system that not only alarms but also identifies the afflicted machine (B)
Difficult to identify what kind of error has occured (B)	Need for a system that not only alarms but defines the kind of failure or error (B)
Customers unable to comprehend how the data is processed (B)	Increase awareness regarding machine learning (B)
Variable reliability of predictions (C)	Increase reliability of predictions(B)
Too expensive or economical inefficient (D)	Identify where the cost of production losses exceeds the maintenance costs (D)

4.3.1 Company A

Interview with the maintenance director at company A, which is an organization within the paper and pulp industry and can be viewed as a potential customer. The company was selected to identify underlying and established customer needs. Company A utilizes AI based predictive maintenance, mainly conducting various analyses e.g. condition based maintenance. These analyses are categorized into different segments depending on the input parameter that is being evaluated e.g. vibration analysis, temperature monitoring, oil analysis and performance alignment using online systems. Company A stated that the selection of parameters is based on the equipment e.g. for rolling equipment, then vibration analysis are generally preferred, but they also monitor temperatures. The predictive maintenance analysis is dependant on each specific equipment to decide which strategy is suitable and what data is required. The data is collected through sensors that are placed on the objects and then transmit data online regarding the current state of the object to the AI software. Additionally, Company A also deploys employees to conduct physical inspections and manually collect data through different measurement instruments and then report it to the system. The maintenance director at company A stated that there are many aspects that must be carefully considered before any action is undertaken. For instance, the organization always conduct an economical profitability analysis prior to deciding whether they should implement any maintenance operations. The cause is that they do not believe it is necessarily economical efficient to measure everything, and it is important to narrow down the number of specific parameters that need to be analyzed. This is simply due to a correlation between the amount of analyses and costs, where more analyses increases the consumption of monetary resources. The company acquires

the software through external means, often outsourcing these activities to other suppliers or consultants. These external parties also do the interpretation of the analysis. Only the vibration analysis and temperature monitoring are conducted internally. Company A is also utilizing energy based AI analytics, primarily to evaluate electrical motors, fans and pumps.
In general, the organization attempts to narrow down what parameter is the most crucial that they need to measure.

"make sure we can predict what is going to happen and make the right decisions" "we try to measure them [different data types] simultaneously and overtime we try to combine them with some kind of algorithm for the future by using AI" - maintenance director at company A.

The objective is to prevent production losses as much as possible. Company A tries to measure different parameters e.g. current, vibration and oil simultaneously, the maintenance director stated that they need to monitor various output signals and how they develop together to make an adequate decision.
The key factor is to carefully balance the trade-off between how much can be saved on maintenance costs and how much it is possible to limit the production losses. The company stated that several areas that were in need of improvement.

- **Sensors**: Stable sensors that provide accurate data regarding the current state of a machine or equipment. The sensors at company A needs to be improved, since accurate data is crucial for the analysis.
- **Support for analysis**: Some form of support for facilitating the analysis and the interpretation of the results. This is due to the technical knowledge required to understand the algorithms and AI in order to evaluate the data.
- **Data sharing**: It is necessary to have a suitable digital platform for the machine learning system, where data can be shared between different instances and collaborators i.e. with who they want and when they want. Company A has issues with this and needs to *"be better on sharing the data with who they want and when they want"*. It also crucial for storing the extracted data from the sensors.
- **Strategic partnership**: The maintenance director at company A stated that they need to *"improve their current setup regarding strategic partnership"*. They desire to collaborate with companies that excel in their field and can support them.
- **Erroneous predictions**: The maintenance director also remarked that they have made erroneous analyses from the data due to incorrect predictions. These kind of mistakes generates unnecessary maintenance costs and potential costs associated to the object.

The output from the analysis is generally in the form of a curve that is being interpreted or, in more complex cases a recommendation to how they should act.

4.3.2 Company B

Interview with maintenance application engineers at company B, a competing company that is active in fabric automation, industry hydraulics and mobile applications and heavily relies on predictive maintenance. The application engineers stated that there are so called key gateways that enable them to upload data, analyze the data and make predictions. They refer to this as ODiN, an abbreviation for Online Diagnostics Network, where a machine health index is used to map the condition of the machine. To evaluate the state of the machines and equipment, company B uses Condition Monitoring in combination with Production Performance Management. In Condition Monitoring, different criteria have to be established by the organization and once a certain limit value has been surpassed, an alarm will set off. The Production Performance Management includes statistical and dynamical algorithms for detecting the machines current health. Another method is prescriptive analytics as well as performance benchmarking to identify different types of failure. The interviewed application engineers state they have some challenges.

- **Identify part**: Despite the alarm, it is difficult to obtain knowledge of what specific part of the machine that is malfunctioning and requires maintenance.
- **Identify type of error**: Identifying what kind of error or type of failure on the machine was also stated as difficult.
- **Increasing awareness**: The customers need to understand and learn more about AI and machine learning. It is a breaking point, where the market is divided between those who wants to utilize this technology and those that actually implement it.

Company B also uses other measurements e.g. remaining useful life regression analysis which indicates the product life cycle and can be used to determine when the machine is deteriorating and needs to be replaced. These described methods are used for predicting when the devices require maintenance or needs to be replaced, often several months ahead, due to long lead times. As previously mentioned, there are certain limits that have to be defined i.e. what is a critical value regarding temperature, vibration and acceleration. The organization does not conduct energy analyzes and was surprised to learn of the product offered by the machine learning based start-up. By using collected data from drives, company B is able to use a machine learning system to detect what kind of values are necessary to maintain within particular limits, to ensure that the machines function. In contrast to company A, company B tailors their own software to their needs, in-house. Sensors are often placed on devices and machines to extract data

regarding temperature, vibration and other properties, depending on what is desired. Company B has been collecting data for the past 25 years and has recently started to integrate it with AI-based applications.

4.3.3 Company C

Company C is a global manufacturing company in the paper and pulp industry, and can be viewed as a potential customer. The interview was conducted with the preventive engineer, responsible for preventing failures and production losses. The organization also produces other forest products.
The preventive engineer stated that company C uses different methods for predictive maintenance such as valve monitoring. Their motive is to reduce and avoid breakdowns and repairs which are more expensive than planned maintenance operations. They use diagnostics based on vibration, temperature, flow pressure, consistency and voltage using their machine learning algorithms. The data is collected by placing sensors on the machines and equipment. The extracted data is then uploaded to servers and stored online. As with the other companies, company C conducts calculations to determine if it economically beneficial to carry out predictive maintenance on certain machines. Company C is plagued by a few problems that they would prefer to be enhanced significantly.

- **Reliability of prognosis**: The preventive engineer explained that they have variable reliability of their forecasts and would like to perform a statistical analysis to estimate how the reliability differs.
- **Communication**: There is a need for an adequate software communication with the enterprise resource planning (ERP) and Production systems so that data can be automatically uploaded. It is critical that the data is transferred correctly as the data is then processed and analyzed.

4.3.4 Company D

Company D is a medium size business that specialize in industrial maintenance and wear. They can be viewed as a competing business since they offer maintenance solutions for the process industry. Company D works with preventive and predictive maintenance, however they do not deploy AI-based software. The service maintenance technician stated that they focus on wear as they often work within short time frames. They also observe production rate and fatigue, but do not conduct any calculations on the fatigue. Furthermore, shafts and tolerances are also investigated by using fiber optic technology. The organization specializes in heavy rotating machines e.g. paper machines, centrifugal pump, vacuum pump etc. and targets the paper and pulp, steel and mining industries. This is due to the prevalence of large rotating machines and equipment in these process indus-

tries. The major reason for not using sensors and machine learning systems are that they are viewed as too costly.

"Too expensive for now and not reliable. We monitor different measures such as vibration and other parameters to make a statement but it has nothing to do with AI" - Service maintenance technician

Company D uses fibre optics to monitor tolerances and compare them with the original tolerances and measure how much they have changed over time. This deviation is measured under a specific time period e.g. annually. This information is then used to generate predictions and estimations regarding how it will develop and how it affects availability and capacity. The service technician noted that most customers they conduct business with, generally already have large maintenance departments to control and monitor how the condition of the stock is changing by using online monitoring on e.g. a paper machine. However, for the surrounding machines and equipment there is no online monitoring.

4.3.5 Workshop with industrial partner to elicit current business model

At the moment, the machine learning based start-up is developing power electronics and different devices that can be placed on a power grid. Furthermore, the organization is also developing an product that can manage active power quality filters and conducts root-cause analyzes for disturbances in the power quality. The problem is that power quality filters generally have some form of delay.
The company is currently developing a prototype for their main product offering, where the objective is to connect the device to other power electronics to control and manage them more effectively. The product is similar to a box, and the idea is that it will model a power system and, based on the extracted data from the power system, can send a predefined signal to regulate it more efficiently. This signal can also be used to acquire a more holistic overview of the state of the power system. The co-founder mentioned that, despite being primarily focused on controlling electronics, there exists a customer segment that could have use for only one part of the solution, which is the health status. Obtaining information regarding the health status of the power system but not being able to manage it, is a potential business opportunity that the start-up wants to explore and research. The existing business model, elicited from the workshop, is illustrated in figure 4.1.

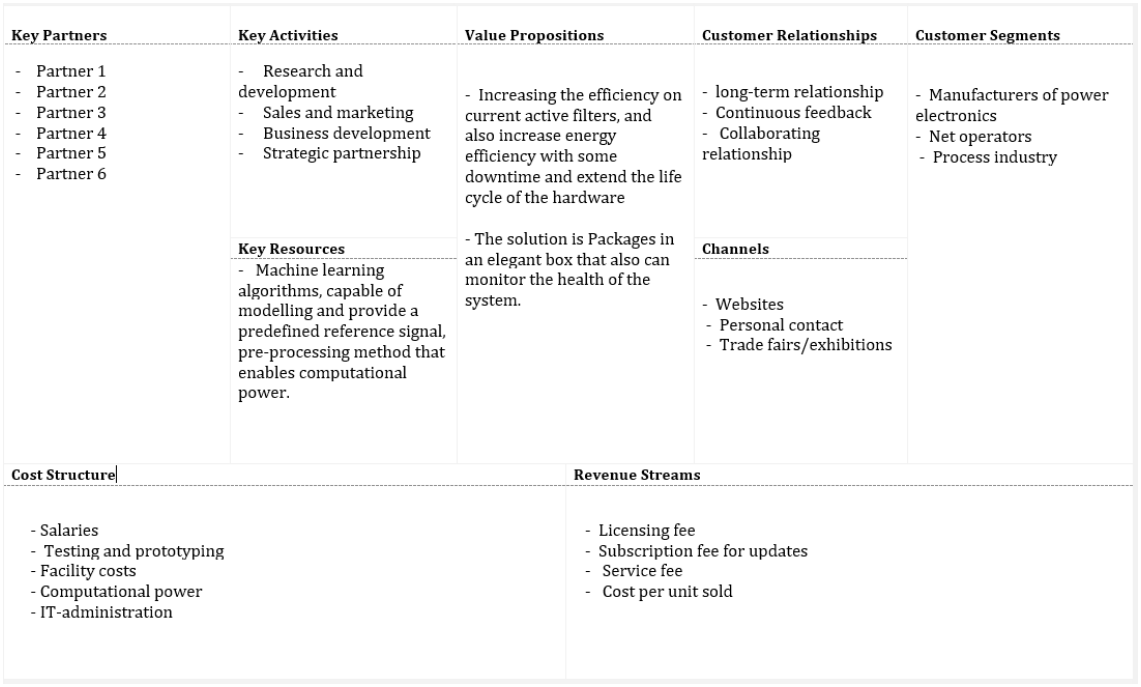

Figure 4.1: Illustration of the current business model canvas of the machine learning based start-up.

The value proposition for the product offering is to increase the efficiency on existing power quality filters, minimize downtime and increase the product life cycle. The customers are mainly companies in the processing industry, generally manufacturers of power electronics but also net operators. The company is addressing the problem that some machines operate with a delay, resulting in unnecessary energy consumption, resulting in energy losses in some electronic devices.
The pricing model for the product is preliminary set to a fixed unit price, along with a subscription fee for keeping the software and algorithms updated. The unit price will not be presented, due to secrecy. To conclude, the pricing model depends on the customers preferences and needs. The revenue stream is thus derived from the unit price for the measurement device, the software and an annual subscription fee.

One of the major issues for the company is the collection of qualitative data to build and train the algorithms. The product has to learn in an offline mode prior to being applied, and needs access to data to continuously train itself. This affects the customer base and the co-founder stated that they mainly target companies that already possess devices for extracting and storing the necessary data.
"It is ideal if the company already has a device for measuring voltage and current."
- Co-founder

To promote their product, another co-founder explained that their marketing strategy mainly consists of personal contact. This is due to the long sell cycles that characterize predictive maintenance industry. As there is complex technology involved, it is essential that customers understand the benefits of the solution, which facilitated through personal interaction. The start-up carefully manages their customer relationships through cooperation and having a continuous feedback with the customers, while also encouraging a long-term relation. Another factor is that due to being a start-up, it has not established its brand reputation, resulting in the need of directly interacting with customers to increase awareness.
"The more established the company becomes, the less is the need for personal contact since the company could host fairs, online advertisement or other gatherings." - Co-founder

There are currently no plans to construct a factory for their main product offering and different production processes are outsourced by collaboration partners. As the company views itself as a software business, it is perceived as excessive to focus on hardware processes as they increase the system complexity. They are currently collaborating with several major energy organizations.
The dominating costs of the start-up is related to salary, facility and for developing the prototype. The cost for training the algorithm translates directly to the salary. In addition, there are also IT related costs e.g. testing computational power, servers and costs associated to patents and IP. The company is also searching for alternative revenue sources.

"There are many usages of data. We have sensors that can extract particular data that can be used to monitor devices, not only to predict failure but also to acquire a more effective control. It is hard to obtain data today, and those that have it can take a fee for it. If we have the opportunity, we can collect data that we analyze and make profit for the customer but also have some form of ownership of data. This could be just as profitable and can be sold to other organizations that require the data for their functions. At the moment there exists a lack of data and companies are willing to pay to access it." - Co-founder

4.4 Competitor analysis

In this section, the company's capabilities will be evaluated by using a SWOT-analysis to identify its strengths, weaknesses, threats and opportunities. This is to

achieve a holistic view of the organization, while examining several critical internal and external aspects.

4.5 Result of SWOT-analysis

The purpose of the SWOT-analysis is to facilitate the understanding of company's current market position, relationship with customers and competitors. This is illustrated in the information below, where the companies strengths, weaknesses are assessed, as well as potential opportunities and threats. Some of the identified factors can be viewed in Table 4.3.

Table 4.3: SWOT-analysis of the machine learning based start-up.

Strengths	Weaknesses	Opportunities	Threats
Specialized in energy analytics	Has to build their customer base	Predictive maintenance industry expected to grow	Difficult to compete with major competitors
Expert competence	Needs to establish their brand image	Several competitors are slow to adopt AI, and rely on other methods	Competitive products with more integrated technology
	Limited resources	Integrate AI with other technologies	Confidentiality limiting access to necessary data
		Joint venture	Data leakage

4.5.1 Strengths

The start-up has developed a product that can facilitate maintenance operations and reduce costs and downtime by producing accurate predictions based on available data. The product offering enables more efficient solutions towards maintenance management than other non-data powered methods. The demand and usage of this emerging application is increasing at a quick pace. The company differentiates itself from the market by providing AI-powered services that focus specifically on energy measurements i.e. power output [5]. The analyses are conducted by machine learning algorithms and demand high technical competence from the employees that train them. The expert knowledge that the company's employees have, is one of the company's key strengths.

4.5.2 Weaknesses

The company is a recently founded start-up and has little market presence and brand reputation. This means that the organization does not have any prior reputation, customer base and needs to establish themselves on the market. Consequently, the company is not prevalent on several global markets, but rather focuses on local segments. There exists an evident need of developing their customer base and enhance their brand. They have a small staff, with an expertise knowledge

in machine learning and is vulnerable if vital staff becomes sick or leaves. At the moment, there is a pandemic, Covid-19, which threatens the health of the employees and, in turn, the rate of production if someone becomes sick. Furthermore, the company has less resources than several of their competitors, which also limits options to acquire market shares. Cash flow is generally unreliable in the early stages of a start-up. This in turn affects the business model as the company may have difficulties in knowing their sources of revenue as they are entering a new market. The organization may have difficulties in knowing their intended customer base, since many start-ups have issues in knowing how they should operate their business.

4.5.3 Opportunities

There exists several opportunities within the predictive maintenance industry as the business sector is expanding. The maintenance market is expected to grow by more than 30 percent annually until 2026, and thus the demand for maintenance solutions will increase. The usage of machine learning systems are becoming more prevalent in different industries and markets. Several companies already have AI's incorporated in their operations and activities, and companies that are yet to embrace use of AI risk becoming obsolete. However, many competitors rely on traditional methods that do not require as much data processing and are slow to adopt the new technologies. This approach towards maintenance management are characteristics of Industry 4.0 environments. Some companies are viewing the potential of integrating predictive maintenance with industrial IoT and AI to monitor machines and equipment in real-time [4]. By continuing to train staff and algorithms, the organizations that are applying the latest state-of-the-art technology has a competitive advantage in the form of technical superiority. There are, however, many other factors that need to be accounted for e.g. brand reputation. As a start-up, it has the technological capability but lacks the resources required to undertake major product development projects. This obstacle can be eliminated by entering a partnership with an organization, e.g. technological hubs, educational institutions or competitors, to conduct product development processes i.e. a joint venture.

4.5.4 Threats

The developments in technology risks changing the market beyond the organization's ability to adapt. The predictive maintenance industry is growing and many organizations want to acquire as much of the market as possible. The main driving forces behind the expansion of predictive maintenance industry are the need of improving the uptime of equipment, reducing maintenance costs and increase

investment in predictive maintenance. These needs are being satisfied by other actors that offer solutions based on machine learning or other substitutes.

Several companies are investigating the potential of integrating predictive maintenance with industrial IoT and AI to monitor machines and equipment in real-time. As the start-up is specialized in pure machine learning, this type of new integrated solution could threaten their product. Small changes in the competitors' products might be detrimental to the company's market position. As the technology advances, it is essential to adapt in order to prevent launching products that are inferior in terms of technical capacity. Furthermore, another threat is the accessibility to data, which is vital for the algorithms to function. Some information, that might be necessary, could be limited by industry policy regarding data confidentiality and security, which restricts what data the algorithms are allowed to process. Since the start-up is a software based company, it is also exposed to the risk of data leakage e.g. due to someone breaching their security and gaining access to sensitive information regarding the company or their customers [4]. This type of breach, if not directly harmful to the company, might damage their customers and could in turn have a negative impact on the perceived brand image.

4.5.5 Conclusion of SWOT

There are many weaknesses, opportunities and threats that needs to be addressed. The company is specialized within energy analytics and possess expert competence, however, it needs to establish its brand image and improve the customer base. Furthermore, they need to monitor competing products that might be technologically superior, while managing the risk of both access to data and data leakage. There exists several opportunities as the predictive maintenance industry is expected to grow, while many of the competitors are reacting slowly to technological developments. This allows for specialized companies to differentiate themselves with their algorithms. The organization should also consider the possibility of integrating their product with other technologies. While a start-up company might not be able to allocate the required resources to undertake a major projects, it would be possible to conduct a collaborative product development with an external party.

4.6 Market analysis

This chapter contains a discussion and analysis of the targeted market segments and how they are identified. Characteristics for the predictive maintenance market will be defined in relation to political, economical, social and technology aspects i.e. a PEST-analysis.

4.7 PEST-analysis of the machine learning based start-up

A PEST-analysis enables a broader and more holistic perspective of the current state of the market. It analyzes four different factors that are political, economic, social and technology. In contrast to the SWOT-analysis, which evaluates a particular company, the PEST-analysis views a market in its entirety. The PEST-analysis relies more on external information while SWOT is based on internal information. The PEST-factors are illustrated in Table 4.4.

Table 4.4: PEST-analysis of maintenance industry.

Political	Economic	Socio-cultural	Technology
Government stability	Economic growth and stability	Awareness about environment	Collaboration partners
Data regulation	Weak currency	Customer and employee expectations	Integrated maintenance solutions
Stricter environment legislation	Expensive to outsource	Brand profiling	Limited availability to data
	Cheaper to hire experts due to higher unemployment rate		

4.7.1 Political

Political factors that could affect the company's business would be upcoming policies regarding data collection and the usage of data. As previously mentioned, there is a lot of legislation toward protecting and limiting the access and use of certain data that could be considered sensitive. The emergence of Industry 4.0 is influencing legislation, liability and privacy of industrial data which poses a risk to companies that rely on data [45]. This trend is most prevalent in Europe, where the implemented GDPR enforces data integrity and prohibits free use of all available data [4]. However, GDPR targets the data of private persons, and not industry data. The start-up utilizes data from the customer to conduct its analyzes, but some of the data can still be difficult to access. The cause could be due to secrecy and confidentiality related to certain business activities and process that the customer company may be reluctant to provide e.g. it could be hard to separate particular information regarding energy measures for just the machines. Restricting the availability and accessibility to various kinds of data limits, the amount of information that can be processed by the AI. Another important aspect to consider is government stability, which is important for the employees. The company is stationed in Gothenburg in Sweden, and a change of government could impact regulations regarding taxes and expenses. At the moment, no major changes has occurred. In addition, machine learning algorithms requires a lot of

computer power and consume a lot energy, which impacts the environment. This could become a potential threat in the future if access to electricity is limited, either by political legislation related to sustainability, or due to political crises e.g. war. At the moment, there are no current political threats to the company.

4.7.2 Economic

Economic growth is important, since a stable economy is a prerequisite for increased employment which result in more resources for the companies that can be spent on acquiring machines and equipment. These machines, in turn, would eventually require suitable maintenance management to function properly, resulting in an increasing demand and more business opportunities. Additionally, it would also allow the start-up to establish their brand reputation on the market. In the current situation, the Swedish currency is quite weak, which would make it more expensive for outsourcing activities or conducting business with foreign businesses. However, it might also be an incitement for foreign customers since it would be cheaper to purchase the company's product. The organization wants to enter the global market, but at the moment they are mainly operating in a local region. Another issue related to currency is commodity prices, as when these prices increase the costs related to the production of the product could increase. Another economic factor is the salary for labor costs, where salaries vary depending on where the company is located. At the moment, the economy is stagnating due to several reason e.g. the current pandemic, which negatively impacts the market and increases unemployment rate is increasing and it is more difficult to access credit. The number of possible expert within machine learning that can be employed might have increased, and as the supply increases, the labour costs could decrease i.e. it could be cheaper to hire due to increased competition . However, the production might decrease since many companies are attempting to reducing their costs and could postpone their scheduled maintenance activities. Furthermore, it might be more difficult for the company to access credit for product development projects. Additionally, it also affects customers that might require credit to invest in machines and, also, maintenance services.

4.7.3 Socio-cultural

Socio-cultural factors such as cultural opinion of data management and public opinion regarding sustainability are important aspects that need to be considered. One of the emerging attitudes in Europe is toward protecting sensitive information for private persons, which manifests through stricter data legislation and regulation. It is important to monitor the development of data and if the industry will adopt similar changes. Another aspect to consider is the increasing awareness

regarding the environment, where companies that tend to neglect their influence on the surroundings and sustainability receive a negative brand reputation. As the reputation can affect the customer base, and also possible future employees, it is important to develop and maintain a good profile. Consequently, since the start-up operates within predictive maintenance management and focuses on increasing efficiency and life-expectancy for machines, this could result in a positive brand image. The company's vision could be used to promote their work with sustainability and profile them as a green company. It is, however, important to investigate differences between the input and output i.e. how much energy is needed to power the algorithm and the amount that is saved by using this method instead of another maintenance solution. In the future, it is possible that maintenance organizations will be influenced by stricter environmental legislation and standards, and could be expected to guarantee that machines and equipment meets environmental requirements.

4.7.4 Technology

New technological changes may result in positive and negative effects for the company e.g. reducing the amount of resources required to perform a particular task. It can also be a threat to the business, as new technology may render existing business solutions and services obsolete and inefficient. It is important to continuously identify and search for new technologies that could harm or help the company. In addition, the company needs to analyze if any of its competitors use the new technology. Another thing to consider would be to identify potential collaboration partners e.g. technological hubs, educational institutions etc.
As the start-up uses machine learning to manage maintenance problems, they also need to consider the development of alternative maintenance solutions e.g. solutions that are not powered by AI, or AI-solutions that require other data, focus on different parameters when creating the prediction or uses a different method. For instance, an application that merges IoT with AI to monitor machines in real-time. Another aspect is that not all companies have the technological capability required to extract and store their data, which is a prerequisite that the start-up expects from its customers.

Despite how much the business landscape changes, the company needs to adapt and identify potential business opportunities that may arise. Furthermore, there are several actors on the predictive maintenance market that must be monitored [4]. These can be approached as either potential business partners or competitors. Data sharing is common during industrial collaboration, however due to competitiveness between the parties the exchange may be limited. Another issue is the worry for data security from the customer [45].

4.7.5 Conclusion of PEST

To conclude, there are several aspects in regards to each of the PEST-factors that needs to be considered. It is crucial to monitor the political development of government stability, data regulation and environmental legislation. Furthermore, it is necessary to monitor how the current state of the economy affects their resources and activities e.g. staff and outsourcing activities. Due to the increasing awareness regarding the environment, amongst both customers and employees, it is important that the company communicates their vision. This can be used to profile their brand. Furthermore, it is important that the organization examines possible partners e.g. for collaborative product development. It is also vital that they monitor technological changes that could enable new maintenance applications. Finally, it is necessary to consider that some customers do not possess the technological capability that is necessary to extract and store their data.

4.8 Benchmarking analysis

As the technology advances, it is essential to adapt in order to prevent launching products that are inferior in terms of technical capacity. It is difficult to implement machine learning algorithms that are limited by existing regulations regarding data privacy and industry security, which restricts what kind of data the algorithm are legally allowed to process. There are several main actors on the predictive maintenance market and a benchmarking was conducted with these companies to identify how their revenue sources, intended customer base, the finance and product offerings differed from the start-up. The objective of the benchmarking analysis is not to merely examine products of existing companies, but to instead reflect the companies' way of doing business. In other words, the benchmarking is not restricted to the product aspect, but should include all parts of the business model in order to acquire a holistic picture of the market competition.

4.8.1 Result of benchmarking

The benchmarking was carried out with six other companies that provide similar solutions as the industrial start-up partner. The benchmarking focused on revenue source, customer base, product offering and details of financing. The key insights from the benchmarking are illustrated in a Table 4.5. The selected companies were given anonymity, as they compete for the same customer segment and the start-up also asked to remove the companies' names since it was sensitive information.

Table 4.5: Benchmarking analysis of maintenance industry.

Benchmarking	*Product*	*Revenue source*	*Customer base*	*Details of financing*
Industrial partner	Increasing efficiency, minimize downtime, and monitor the health status of machines by using main product	Licensing fee, cost per sold unit and subscription fee for updates.	Manufacturers of power electronics, net operators and process industry.	Is funded by six different investors.
Competitor 1	Self-service analytics software that is capable of analyzing large amounts of data and conduct maintenance predictions.	Revenues are derived from the software analytics.	Process industry, vehicle industry, heavy industry, smart cities.	Funded by three different investors.
Competitor 2	Real-time predictions by monitoring machines with sensors. Additionally, the product automate time consuming and repetitive tasks.	Revenue is derived from the predictive maintenance analyses.	Companies that are active in the process industry or manufacturing industry.	Was recently acquired by a major Swedish company and has a funding of two million SEK.
Competitor 3	Determines asset failures, predict maintenance analyses,.	As it is a major company, revenues are derived from multiple software services	Companies that require software support in AI, blockchain, IT, and cyber security.	Self-funding company with an annual turnover of 12.5 billion US dollars.
Competitor 4	Improved asset management, maintenance efficiency through a combination of data analytics, IoT and AI in a single solution.	Revenue source is derived from predictive and prescriptive analytics.	Energy market, manufacturing industry, retail industry, information and telecommunication industry and maintenance industry.	Self-funding company with many subsidaries and an annual turnover of 81 billion U.S. dollars.
Competitor 5	Asset performance monitoring, condition-based maintenance with predictive insights, wireless temperature monitoring system, partial discharge monitoring.	The major revenue sources are related to the predictive industry.	Energy market, process industry, manufacturing industry.	Competitor 5 is a public organization with 109 investors and an estimated 27 billion euros in turnover.
Competitor 6	Predict sudden machine breakdowns, unplanned, costly maintenance work and pre-defined maintenance cycles by using machine learning algorithms to monitor the health.	The main revenue sources are derived from the predictive maintenance industry.	Mobile applications, industrial hydraulics, fabric automation and predictive maintenance industry.	Competitors 6 is self-funding, with an annual turnover of approximately 77.9 billion euros.

- **Competitor 1**
  Competitor 1 is an AI company based in Gothenburg that are active in the predictive maintenance market and automatisation and optimization. The customers generally have huge amounts of data. The revenue source is derived from their main product, which can analyze multiple data inputs from customers. The customer base consists of companies that operate in the process industry, vehicle industry, heavy industry and smart cities, where large amounts of Big Data is managed. The product itself is a self-service analytics software used to prepare, analyze and organize large sensor data without advanced data-analytics skills. For example, a predictive model for the health of the electrolyzers was developed and the energy consumption was optimized based on mathematical and data driven models. Further a mathematical optimization was performed to account for fluctuations in energy prices, customer orders and storage. They presently collaborate with an IoT-company to integrate the technology with their algorithms. Competitor 1 is funded by three different investors [30].

- **Competitor 2**

Competitor 2 is an organization that offers AI-powered predictive maintenance solutions. These solutions enable real-time predictions of machine failure by monitoring data that is extracted from sensors. The targeted customer base is composed by companies that are active in the process industry and manufacturing industry. The revenue is generated from the company's product offering which consists of predictive maintenance analyses to predict machine failures. Their product is used to automate several time consuming and repetitive machine learning tasks such as big data preprocessing, feature engineering and model selection and validation. It provides a software as a service AI solution that requires no interaction with data scientist to perform the application engineering tasks. Competitor 2 was recently acquired by a major Swedish company that provide bearing products, and has a funding of approximately 2 million dollars and an annual turnover estimated to 3.2 million U.S. dollars [31].

- **Competitor 3**
  Competitor 3 is a major company that offers several software based technologies within artificial intelligence, blockchain, IT and cyber security. Consequently, their entire customer base includes companies that are active in industries that require software based solutions. The company offers predictive maintenance services and the revenue source is derived from improved asset management, information and inventory, extending the life of assets and improving work processes. Competitor 3's product is used for predictive maintenance insights, helps maintenance managers predict the likelihood of future failures and determine asset failure factors that could impact plant or business operations. They have developed an AI called for identifying patterns in asset data, usage and the environment, and correlates with any known issues to help predict failures. They are a well established company and are self-funding from the annual turnover or the revenues they are generating, for the year 2019 their total income of 12.5 billion U.S. dollars [32].

- **Competitor 4**
  Competitor 4 has a huge customer base since they provide solutions to the energy market, the manufacturing industry, retail industry, information and telecommunication systems industry and the maintenance industry. Within the maintenance industry, the revenue source is derived from the product offering which enables predictive maintenance by conducting predictive and prescriptive analytics. Competitor 4 significantly enhances asset and maintenance efficiency, along with more efficient production by implementing an asset monitoring and AI-based predictive maintenance solution. Their prod-

uct combines data analytics, IoT technologies and operations consulting in a single solution. They are also an established brand over different segments and have acquired many subsidiaries and have a turnover of 81 billion U.S. dollars [33].

- **Competitor 5**
  Competitor 5 offer products for powering data centers, software solutions, lifecycle services, smart homes, real-time automation, reliable power, efficient grid, smart manufacturing. Their product for maintenance operations, is the main revenue source in the predictive maintenance market. The company's predictive maintenance solutions help reduce downtime as well as improve workplace safety, and monitor the condition of equipment provides trending data to help anticipate and plan maintenance activities. The products they offer are asset performance monitoring, condition-based maintenance with predictive insights, wireless temperature monitoring system, partial discharge monitoring. Competitor 5 is a public organization with 109 investors and an estimated 27 billion euros in turnover [34].

- **Competitor 6**
  Competitor 6 is a company that have four main business areas, the mobile applications, industrial hydraulics, fabric automation and predictive maintenance and thus covers a large customer base. Their main product within predictive maintenance, product 6, is the company's major revenue source in the predictive maintenance market. The company provides product 6 to predict sudden machine breakdowns, unplanned, costly maintenance work and pre-defined maintenance cycles. It initially collects data on all monitored components over a training phase which lasts several months. Based on these signals, a machine learning algorithm determines a normal health condition for the system. The health index not only indicates the condition of the unit being monitored, it also identifies subtle changes in the upstream and downstream components. If movements start to take longer or require more power over time, it is perceived as a sign of wear in the mechanical or hydraulic system. Competitor 6 had a turnover of approximately 77.9 billion euros in 2019 [35].

4.9 Conclusion of results

The information regarding the start-up, its competitors and the market situation, acquired through the various analyses and data collection, are pivotal for constructing a business model. The key insights obtained from each of these will be

listed, as well as how the information will be utilized.

1. **Information from interviews and workshop**
   The identified pains and gains from the interviews will be used for the business model concept generation. The cause is that they emphasize existing needs and issues that are prevalent in the industry, and may provide vital information to acquire a competitive advantage to the company. The workshop with the start-up provided a lot of information regarding their existing business model, as well as potential areas of improvements. The business model will be used as a reference during the concept generation stage.

2. **Information from PEST- and SWOT-analyses**
   The PEST-analysis provided information regarding external opportunities and threats that the new business model should consider. The SWOT illustrated internal areas of improvement for the company. It would be beneficial if the new business model would eliminate or reduce the weaknesses and enhance the company's strengths.

3. **Information from benchmarking**
   One of the most important analyses was the benchmarking, which yielded information regarding competitors. Comparing their businesses, mainly through focusing on products, revenue sources, customer base and details of financing between the start-up and its rivals facilitated the understanding of the company's market situation.

The next part of the study will focus on examining the elicited business model, and develop it by utilizing the findings in the results chapter.

Chapter 5

Designing a business model for machine learning based predictive maintenance

The chapter presents the business model concepts that were generated from the results and analyses. The generation stage, screening stage and final selection stage are presented, along with a discussion regarding the possible implications of the selected business model.

5.1 Business model components

Information extracted from the interviews and data collected through other methods will be used to generate a suitable business model for the machine learning based start-up. The existing business model was examined to identify possible areas of improvement for sub-optimizations, using the obstacles that were elicited during the interviews. The entire business model selection process can be observed in Figure 5.1.
The business model concepts are derived from the information acquired from the results and analysis chapter, which can be viewed in Figure 5.2. Once a suitable concept has been identified and passed the screening criteria, a meeting will be held with the start-up where they will provide feedback. This is to validate the findings but also to identify possible concepts that have not been considered.
Before initializing the concept generation stage, the current business model will be examined.

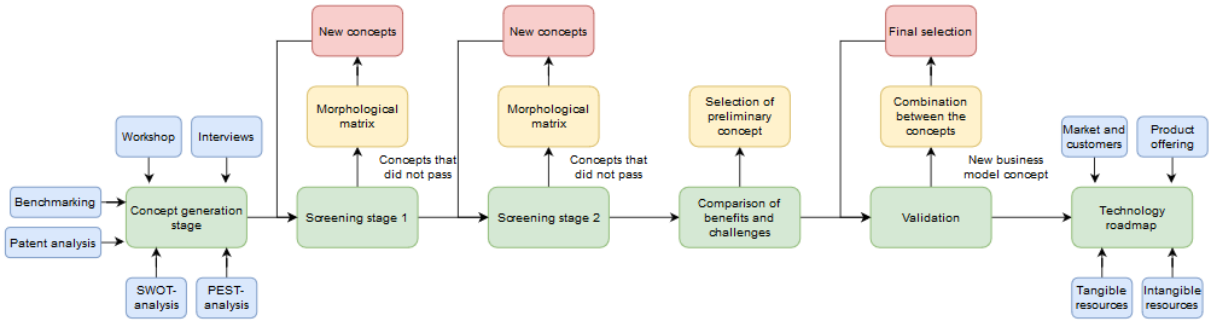

Figure 5.1: Visual image that represents the business model selection process.

5.2 Current business model

In this section, the company's current business model canvas will be presented with a description of all components. Furthermore, possible development opportunities will be examined.

5.2.1 Customer relationships

The workshop with the start-up emphasized how they interact with their customers. At the moment, they believe it is important have continuous feedback from the customers to detect how they perceive the product and identify possible ways of improving the product. The company appears to focus on establishing long-term relationships with their customers, which is reflected in the annual subscription fees for the software. However, there are also several prerequisites that is expected from its customers regarding the access to data. Customers that lack the capabilities to extract and monitor their data are, at the moment, not considered as a part of the targeted market segment.

To ensure good customer relationship, the start-up could have continuous feedback sessions, which could both enhance customer satisfaction and brand image through word of mouth publicity.

An approach to expand their customer segments, would be to maintain good communication in order to identify issues. Additionally, the customer relationship could be developed if the company offered a solution that removes the limitations imposed on the customers i.e. a product that can address the data problem. For instance, by facilitating the data extraction process for customers by deploying sensors or similar solutions.

5.2.2 Value proposition aspect

At the moment, the organization is focusing on generating value to the customers by increasing the efficiency on existing powergrid filters, minimizing downtime and extending the product life. Another value-adding activity is by packaging the solution in a box that provides a holistic overview of the state of the power system. The product offering can be used to both monitor the health index and plan for maintenance operations.
From the interviews it was observed that potential customers are having difficulties in analyzing the data. Sometimes it is due to an absence of qualitative data. This unreliable data creates a ripple effect, since the analysis is based on this information, resulting in inadequate predictions. Several companies that already had tools for analyzing information, noted that they needed reliable data that indicated the state of their machines and equipment. These kind of companies are not currently part of the targeted market segment, but can potentially become customers if the product is fragmented into subsolutions. These subsolutions could address the *pains* of a larger market segment.

As previously mentioned, there is a demand for reliable data, both from customers and companies that perform analyzes. The start-up could offer sensors to customers that do not possess the necessary data as a potential value-adding service. In other words, enabling customers to extract data which can then either be used in combination with the product or separately. Consequently, once the business transaction with the customer has concluded, the company could profit from the accumulated data by selling it to other external parties. As of now, companies that do not possess a suitable data format, are not viewed as customer. Thus, providing the opportunity to collect data and analyze it can be a potential expansion of the current business model. It could be offered as a package solution or independently, depending on the customers. The same reasoning can be applied to the analysis process, which can be split into analyzing the state of the machines and planning for future maintenance activities.

To conclude, it would be suitable to add services that can satisfy sub-demands from the market e.g. extracting data, or only determining the health status of machines rather than only focusing on a package solution for the entire maintenance process. The reason is that it can enable a broader customer base, increased revenue sources and a higher market share. A larger customer base also contributes to establishing the brand, increasing its reputation on the market and raising awareness. This business strategy can be manifested by incorporating sensors into the product package and also offer services for different needs e.g. providing data, information regarding state of machines, maintenance planning tools and analyzes

and more.

5.2.3 Revenue source

The current revenue stream model is based on a licensing fee, a price per unit cost and a subscription fee for software updates.
A new revenue model could be established, derived from the new suggested value proposition where additional services can be offered to customers. This has several implications for the organization's existing pricing model. Changing the product offering from hardware to incorporating algorithms i.e. leasing the service, will shift the pricing model to a licensing fee.

5.2.4 Key Activities

There are several activities that the company undertakes in order to sustain their business model. These activities relate to the need to satisfy the demand with a suitable technology, have a strategy for sales and marketing and process development.

1. **Research and development**
   A necessary activity for maintaining the business is continuously research and develop new and existing solutions to increase the efficiency. A method to achieve this could be through researching competitor's products and benchmarking them, or to examine algorithms in similar business areas and attempt to apply them in a new context. Software reverse engineering, without infringing on immaterial properties and patents, can be used to develop existing software or algorithm structures and enhance certain processes.

2. **Sales and marketing**
   Another key activity is to market the product and conduct sales. It is important to facilitate this process for the customers as much as possible. The marketing is carried out through the organization's distribution channels, primarily by personal contact, fairs, exhibitions and their website. As the company grows and enters new business collaborations, it could also start with joint advertisement.

3. **Business development**
   This refers to the expansion or development of the current business. An example of this would be to identify business opportunities in the existing activities e.g. a sensor could be offered in combination with the product to the customer. This sensor would generate data that the machine learning

system could analyze, however there are hidden opportunities here. One of them would be to extract additional data, in addition to the one required for the product. The start-up could then profit from this data by selling it to other companies i.e. the sensor would provide data for the algorithms but also be a revenue source if the data can be legally sold. Other business opportunities would be to enter a strategic partnership with companies e.g. instead of producing a sensor in-house, another external company could provide the necessary sensors.

5.2.5 Key Resources

In order, for the company to sustain and develop its business model, it needs to improvise its key resources. These resources are the building blocks for a business model to function, generate revenues and achieve business objectives.

1. **Machine learning algorithm**
   The machine learning system is one of the major key resources, as the company's expertise lies within machine learning algorithm for energy analytics. The algorithms are capable of modelling networks and then send a predicated reference signal, in this case they can further improve the algorithm to monitor the data continuously and record the health status of the system.

2. **Pre-processing method**
   This is another key resource and is a crucial step in machine learning to enhance the quality of the data, in order to make it suitable for training the machine learning algorithm. It also enables the computational power, to process the data with utmost speed. The process will be faster if refined data that is fed to the machine learning algorithm, than the raw data.

5.2.6 Key Partners

The start-up is collaborating with several key partners. Due to issues related to confidentiality, these business partners have been anonymous. Instead, these companies will be described and listed as partners 1 to 6.

- **Partner 1**: The first partner is an incubator who invests in early start-ups and help to develop ideas. They start, develop and finance research- and knowledge-based companies. Partner 1 has worked with over 600 start-ups and invested in approximately 200 start-up companies. Furthermore, they also offer unique programs to coach approximately 80 companies annually, and invests in 10-15 of them.

- **Partner 2**: The second partner aspires to incite innovation in various industries e.g. automation, robotics, smart cities and transportation technologies. Partner 2 helps start-ups accelerate and expand by offering mentorship, investments and access to various networks, clients and technology.

- **Partner 3**: Partner 3 can be described as an innovation community, with the aim of facilitating the transition to a zero-carbon, electrified society. They support and identify technologies that helps society to adapt to the climatic change.

- **Partner 4**: The fourth partner focuses on providing power quality solutions to the industry, with the objective of increasing productivity while simultaneously reducing carbon footprint. Their vision is to support customers in all industries through enhanced power quality.

- **Partner 5:**: Partner 5 focus on energy efficiency and high quality to increase their customers' competitiveness and be an attractive business partner. They help companies that are active within energy efficiency.

- **Partner 6**: The sixth partner is a company that focuses on the transitioning to a more sustainable and productive society by using engineering sciences. Partner 6 works with integrating software in electrification, automation and robotics.

Depending on how the business model changes, there are several potential partnerships that could emerge. The implications of the suggested business model will be discussed at the end of the chapter.

5.2.7 Customer segments

It can be observed that the targeted customer segment consists of manufacturers of power electronics, net operators and companies that are active in the process industry. This information was acquired from the workshop.
From the interviews, it is prevalent that there exists a need for data and companies are prepared to pay for it. Furthermore, it can be noted that another segment emerges if the company decides to profit from extracted customer data. This segment would be software analysis companies that need the data to conduct evaluations and measurements.
To conclude, an additional customer segment could be included in company's market strategy. This customer segment would be derived from the changes in the value proposition and result in a business development.

5.2.8 Distribution channels

Distribution channels play an important role in an organisation, from raising awareness among customers about their products and services to helping them to evaluate company's value proposition and to provide service to customer after purchasing. These are some of the distribution channels used by the start-up to reach out to their customers.

- **Website**
  The company uses their website as a distribution channel, where customers can view the offered products offered. The customers can also contact them through mail.
- **Face-to-face interaction**
  The start-up interacts directly with their customers, as of now they are a startup and need to establish their brand recognition. The technology is difficult to understand at times and there is a chance people can misunderstand it. So, they need to clearly explain the benefits and it working structure. To improve, they need to have good communication with the customer to increase trust and also can be a free publicity for brand recognition.

- **Trade fairs and exhibitions**
  Another distribution channel is participating in trade fairs. These kinds of fair help the company to interact with other companies and to know about their work structure or methods. Several companies attempt to find possible collaborators in these kinds of fair, which can be helpful for future business opportunities.

5.2.9 Cost structure

The cost structure is one of the most important components in a business. It relates to the costs that are incurred when the company operates their business. The dominating cost factor is the salary, which is paid to all employees. The salary is what drives the business, as it can be indirectly linked to their product i.e. algorithms. These algorithms must be trained by an expert specialist, who is paid a salary in exchange. Another cost related to employees is facility costs, where the company has their office. The company also has costs related to testing and prototyping of the product. It is a necessary cost since the product is tested to evaluate both its efficiency and safety. Other costs related to the product would be computational power, which can be described as the processing power that is necessary for running the algorithms. As the start-up is software-based, IT-administration is also a cost. It is necessary to maintain servers, networks,

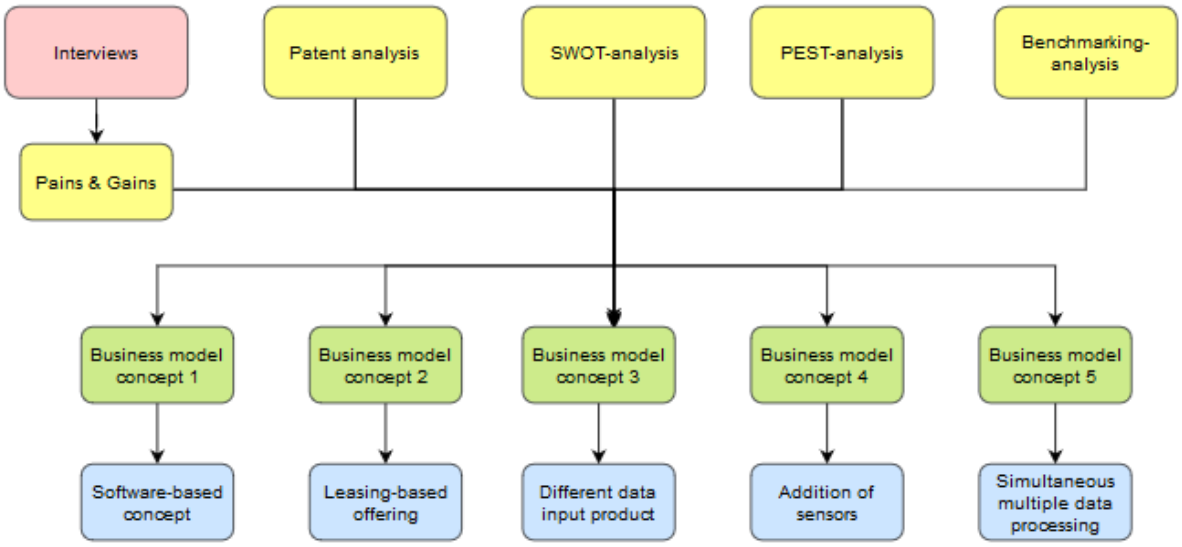

Figure 5.2: The five concepts were created by using the information that was acquired from the interviews, patent-, SWOT-, PEST- and benchmarking analyses.

security programs and systems and protect them from cyber attacks.

5.3 Concept generation stage

This section emphasizes the business model concept generation stage. Five different business model ideas will be presented and explained, by using a business model canvas model. The concepts are derived from the information acquired from the results and analysis chapter, which can be viewed in Figure 5.2.

An overview of the five concepts can be viewed in Table 5.1. Their focus vary between developing the software, to improving the hardware.

Table 5.1: Table illustrating the five different business model concepts.

Concept	Differentiation
1	Pure software-based solution
2	Leasing of box
3	Different single data input to analyze
4	Adding of sensors
5	Multiple data processing

1. **Business model concept 1 (pure software services)**

This business model constitutes of only providing software based services to monitor the status of machines and equipment, and to plan for maintenance operations both as a package and separately. The benefits of this business model are that is will not require physical manufacturing which will facilitate the system complexity related to logistics and production processes. It will reduce costs as there will not exist a need for a storage. The disadvantages are that certain functions and solutions could disappear.

2. **Business model concept 2 (leasing of the product)**
   Business model concept 2 embraces a more sustainable approach and explores the possibility of leasing the box rather than selling it and shifting the ownership permanently i.e. a form of leasing. In this scenario, the product will be reset once it has finished the predictive maintenance analysis and fulfilled its objective. Once it has been reset, the idea is that it can be reused. Even if the algorithms may need to be retrained, the hardware itself can continuously be reused. The product will not be sold in the regard that the ownership shifts completely, but rather provided to the customer until the maintenance analysis has been successfully conducted. In other words, the essence of this concept is similar to leasing the product, where once the predictive maintenance report has been generated, it will be returned to the company. The motive is that activities related to manufacturing and logistics will be reduced, resulting in a decreased system complexity. The organization could have several quantities in storage, but it would not be required to manufacture a new box for each customer but rather reset and reuse the same ones. This could also help to profile the start-up as a company that focus on sustainability, since the environmental impact would be significantly reduced. However, the perceived value from the customer may be affected. The product remains, however the ownership does not shift and this could reduce costs. In addition, the price for the services could decrease i.e. the customer pays less, which could have a positive impact on the perceived value.

3. **Business model concept 3 (different single data input)**
   This business model concept examines the possibility of modifying the machine learning algorithm to be congruent with the elicited customer needs. At the moment, the company only focuses on power quality measurements, but in this scenario they could train their machine learning algorithm to analyze any singular data type. This could increase the customer base, since the prerequisites are reduced.

4. **Business model concept 4 (adding of sensors)**
   The aim of concept 4 is to extract and analyse the data. It enables a full-system solution where the necessary data can be extracted through sensors and monitor them and analyze the current state of machines. By including both sensor and analysing service, risks related to insufficient data quality are mitigated . In addition, this concept will also increase their brand value as well as the customer base. The customer base would consist of companies that need predictive maintenance solutions, wants to monitor their equipment and machines, and companies that demand data for various processes. The revenue source is derived from the sales of the product that analyzes the need for maintenance, monitors the health status of the system and from the selling of data.

5. **Business model concept 5 (multiple data processing)**
   The start-up is developing their machine learning algorithms so that they can interpret and analyze other kinds of data, in addition to only energy measurements, e.g. vibration monitoring, oil analysis, ultrasonic leak detectors, shock pulse, infrared, and others. In order to offer a full-system solution, this kind of approach allows the company to predict when maintenance is required by considering a multitude of factors. As of now, the company's maintenance analytics has to be set in a context e.g. in combination with other analytics in order to generate an accurate prediction and planning schedule.

5.3.1 Business model canvas for concept 1 (pure software services)

Business model concept 1 differs from the existing business model since it only focuses on software solutions. The service of analyzing data is maintained. Only software based services are offered and the objective is to reduce system complexity by reducing operations regarding manufacturing process and logistics for the product. This concept presumes that it is still possible to model and conduct the predictive maintenance services without the presence of a physical hardware.
The value for the company lies in the reduced system complexity and eliminated costs related to manufacturing and logistics. For the customer however, the perceived value may decrease since the supply of services is reduced. In addition, this approach would also force the company to revise their product offering, since it is a physical resource, and transform their offerings to a pure software based solution. Several functions will however disappear due to absence of the physical components e.g. the company has to rely on existing data and can not utilize sensors to acquire

more data. This type of approach, demands that the company has the capability to conduct the analyses by using only the available data to monitor the machines and equipment.

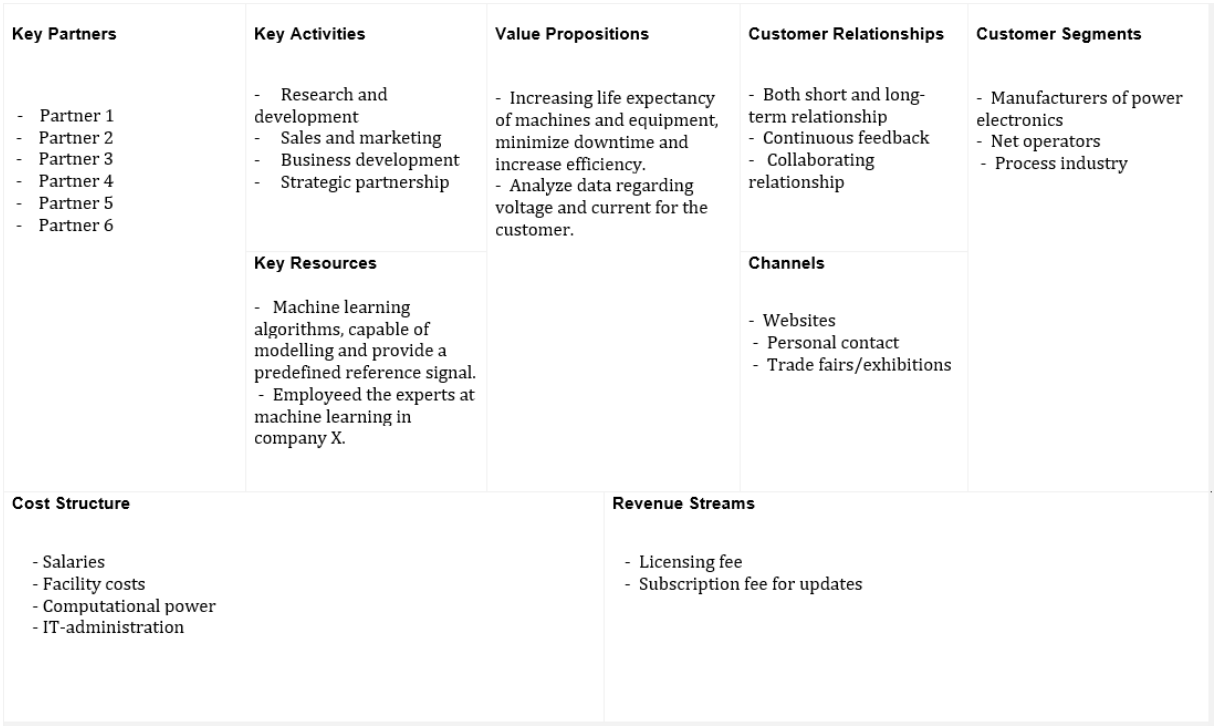

Figure 5.3: Illustration of business model canvas 1, which focuses on a pure software-solution.

This business model would require the machine learning based start-up to transform their current solution package and reevaluate existing partners. The factors that are affected the most are the value proposition, cost structure, revenue source and customer segment.

5.3.2 Business model canvas for concept 2 (leasing of the product)

The product will not be sold in the regard that the ownership shifts completely, but is rather provided to the customer until the maintenance analysis has been successfully conducted. In other words, the essence of this concept is similar to leasing, where once the predictive maintenance report has been generated it will return to the company. The motive is that activities related to manufacturing and logistics will be reduced, resulting in a decrease of system complexity. In

addition, it would reduce the environmental impact from the product's lifecycle. The organization could have several articles of the product in storage, but it would not be required to manufacture a new box for each customer but rather reset and reuse the same ones. As previously mentioned, this approach could contribute to profile the start-up as a company that focus on sustainability, as the environmental impact would be significantly reduced. However, the perceived value from the customer may be affected. This especially important since the company is still establishing its brand and can shape the customers opinions. The product remains the same, however the ownership does not shift and this could reduce costs. To only have a few boxes in a storage, would facilitate the both the delivery time and the system complexity. In addition, the price for the services could decrease as it is no longer sold but leased. In other words, the price and the delivery time would be reduced which in turn increases the customers perceived value. Business model concept 2 is illustrated in figure 5.4.

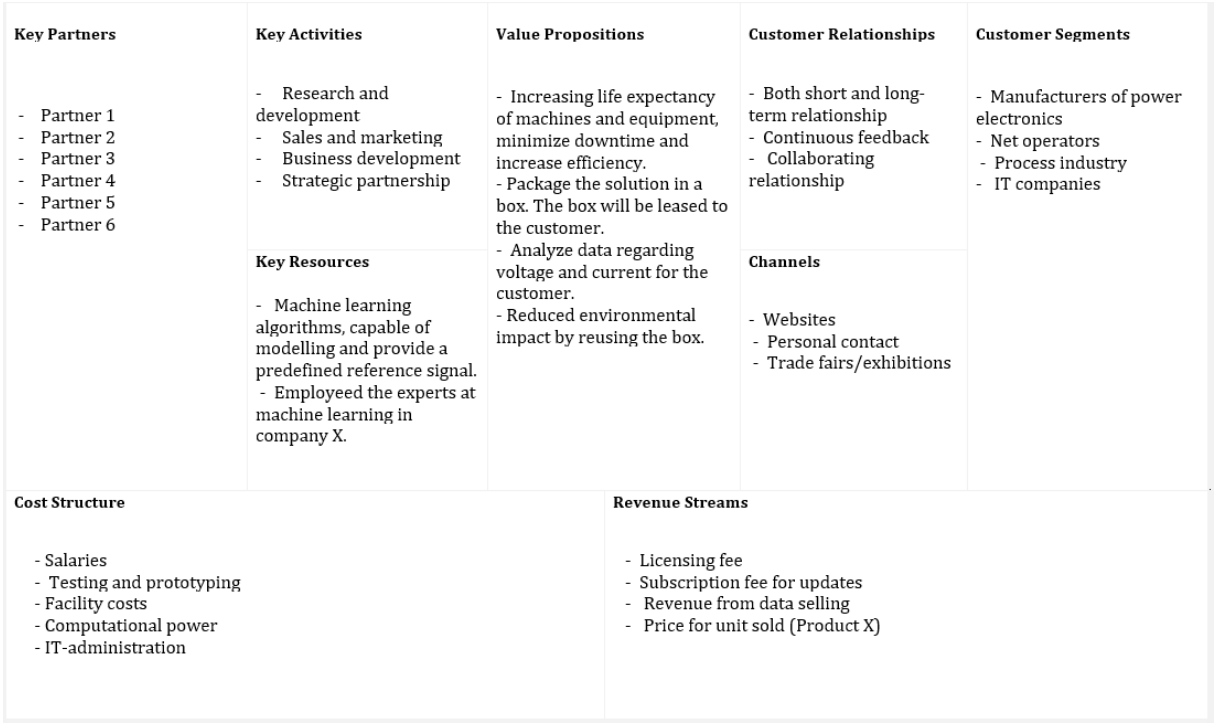

Figure 5.4: Illustration of business model concept 2, which focuses on a leasing aspect.

5.3.3 Business model canvas for concept 3 (different single data input)

The main difference between business model concept 3 and the existing business model is that in concept 3, the algorithms are trained to analyze any singular type of data. This enables a more tailored solution to the customer and also for a wider customer segment as energy data is no longer a prerequisite. Concept 3 would, hypothetically, increase the customers' perceived value as the maintenance solution would not be limited by the type of accessible data. Business model concept 3 is illustrated in figure 5.5.

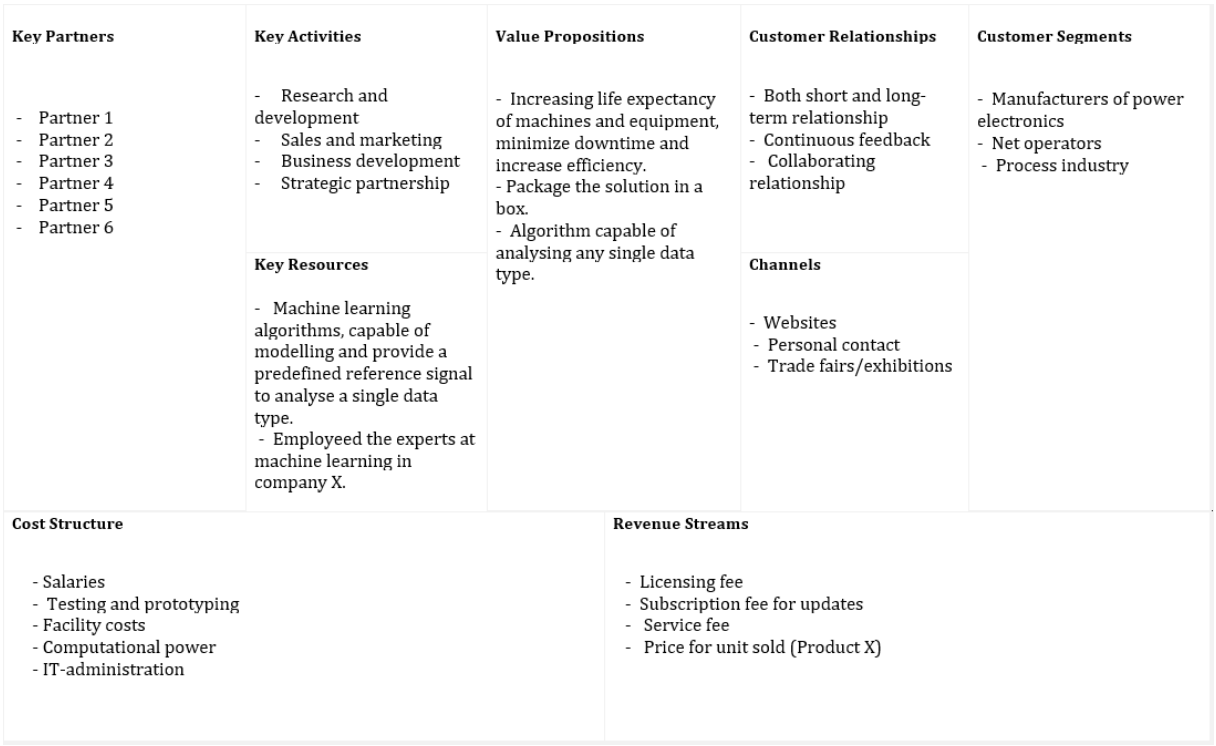

Figure 5.5: Illustration of Business model 3, which focuses on analyzing any single data input.

5.3.4 Business model canvas for concept 4 (adding of sensors)

The main difference between concept 4 and the original business model can be found in the value proposition. For this concept the company will, in addition to analyzing the data, also extract data regarding voltage and current for the customer. In other words, the company offers the customers the opportunity to

to analyse the data and make predictions and the other is to extract the data for the customers that lack the necessary data. It is a combination of both, where the necessary data is collected through sensors and can then be used to monitor and analyse the current state of machines. By including both sensors and analysing services, the customers are provided with full-system solutions i.e. the customer does not need to fulfill certain prerequisites regarding available data. The extracted data can also be of value to other IT-companies and can be sold to these actors, thus affecting the customer segment and the revenue stream in the business model. The change in the value proposition also leads to an additional key resource, which is the sensor. The costs increase since the sensors need to be prototyped and tested. Business model concept 4 is illustrated in figure 5.6.

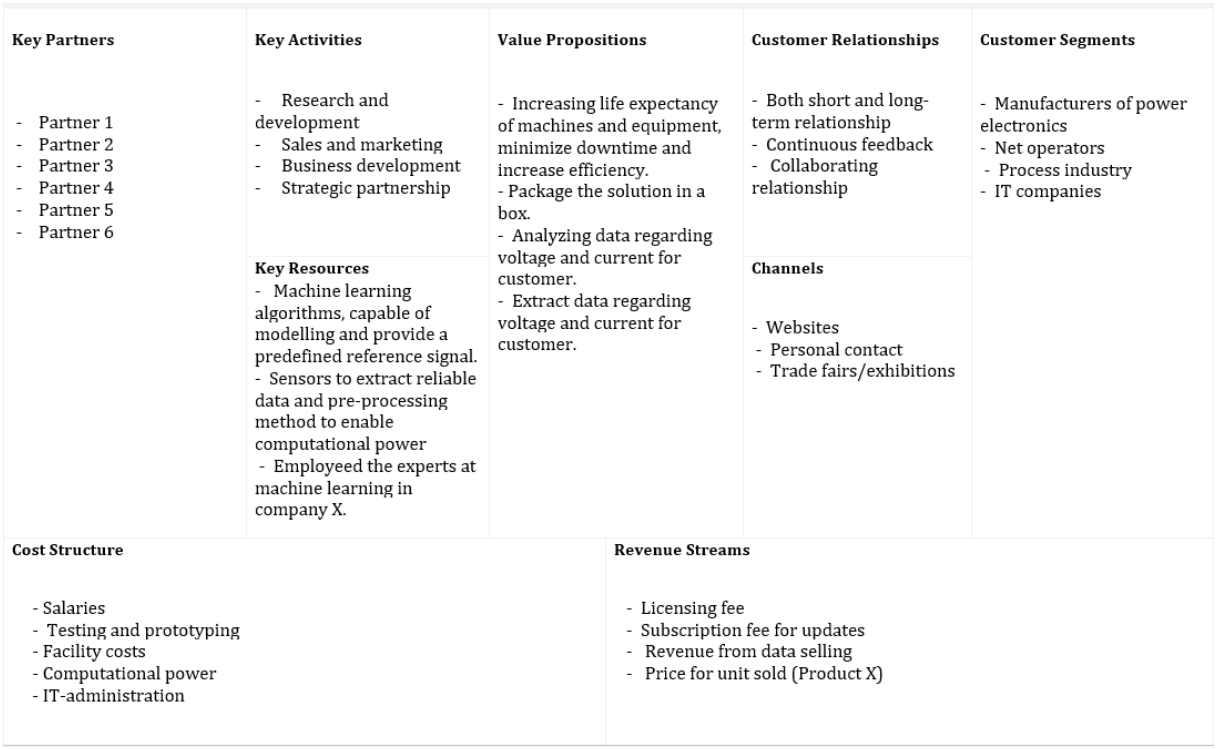

Figure 5.6: Illustration of business model 4, which focuses on extracting data through the use of sensors.

5.3.5 Business model canvas for concept 5 (multiple data processing)

Increasing life expectancy of machines and equipment, minimize downtime and increase efficiency. Package the solution in a box. To offer a full-system solution

by developing their machine learning algorithm to analyse all kinds of data simultaneously, in addition to energy measurement. This would allow the organization to predict when maintenance is required by considering different factors, and also will broaden their customer base. To analyse more kinds of data will enable them to increase their revenues but at the same time will increase the complexity of their machine learning algorithm. Business model concept 5 is illustrated in figure 5.7.

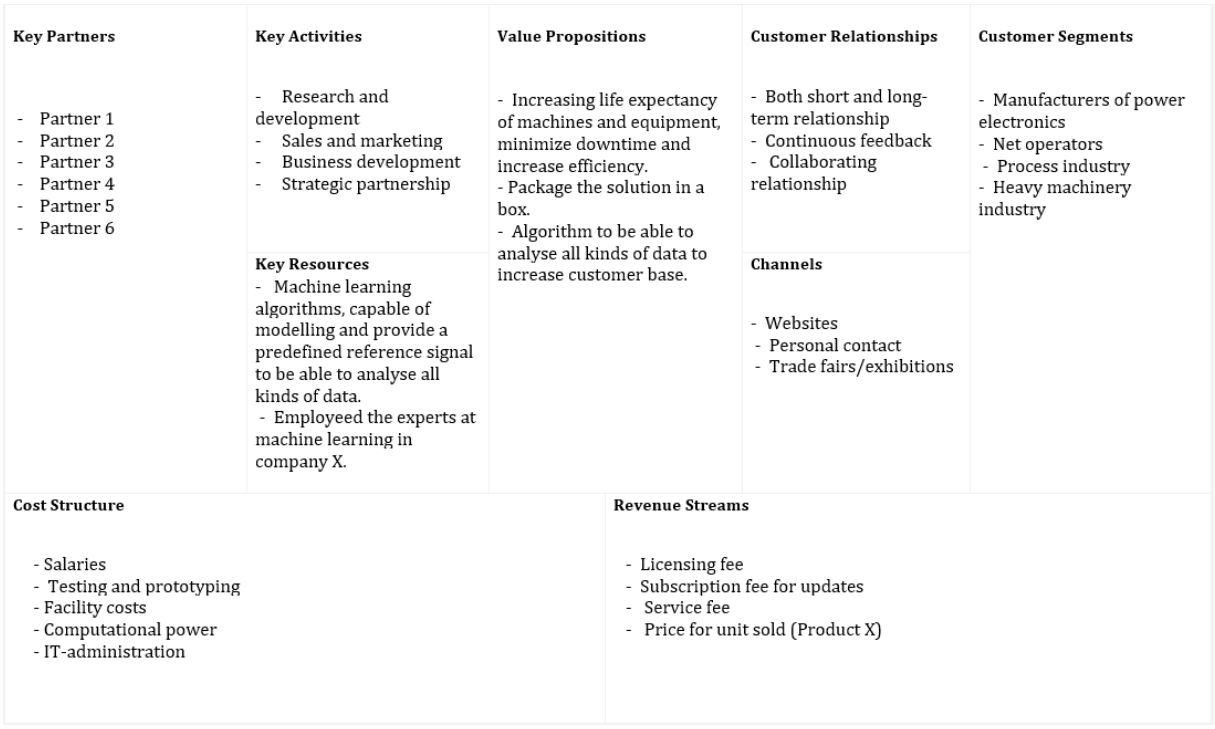

Figure 5.7: Illustration of business model 5, which focuses on conducting processing multiple data inputs simultaneously.

5.4 Screening stage of generated business model concepts

In this part of the chapter, an evaluation and comparison of the new business model and current business model will be conducted. In this evaluation, the business model concepts will be evaluated by utilizing a Pugh-matrix. The matrix compares the nine components of the business models with the company's existing business model. If a concept receives a score higher than the existing one, that concept will be kept for further evaluation. If it scores equal or less, that specific concept

is no longer considered. Points are received in relation to each concepts relative performance to the reference i.e. better (+), similar (0) or worse (-). However, the concepts that do not pass the screening stage will be combined, by using a morphological matrix, in order to identify compatible hybrid solutions that have a better performance.

Table 5.2: The generated concepts were compared to the current business model by using a Pugh-matrix, where each element of the business model canvas was considered.

Business Model Concept	**Original**	**1**	**2**	**3**	**4**	**5**
Key Partners	0	0	0	0	0	0
Value proposition	0	-	+	+	+	+
Key Resources	0	+	-	+	-	+
Key Activities	0	+	-	-	-	-
Revenue source	0	-	+	+	+	0
Cost structure	0	+	-	-	-	-
Distribution channels	0	0	0	0	0	0
Customer segments	0	-	+	+	+	+
Customer Relationships	0	0	0	0	+	+
Net Sum	**0**	**0**	**0**	**2**	**1**	**2**

As illustrated in table 5.2 concepts 1, 2 and 3 did not rank higher than existing business model. It will no longer be considered in the selection process. As it did not pass, it was deemed excessive to elaborate on the concept. Concepts 4 and 5 passed the criteria and will remain for additional evaluation. Their differences lie in that concept 4 also includes the aspect of generating and profiting of data, while concept 5 enables the machine learning algorithms to analyze other input than voltage and current e.g. vibration, oil, leakage and infrared in order to increase the accuracy of the predictions. In addition, using concept 5 results in the software becoming a full-system solution instead of a complement-service.

5.5 Concept combination

The concepts that did not pass the first evaluation, will be combined and mixed using a morphological matrix. The objective is to identify and generate a hybrid concept that performs better than the current business model.

Table 5.3: Illustration of concept 1, 2 and 3 in a morphological matrix. The matrix was used to generate new hybrid concepts.

Morphological matrix			
	Concept 1	**Concept 2**	**Concept 3**
Concept 1	-	Incompatible	+
Concept 2	Incompatible	-	+
Concept 3	+	+	-

As can be viewed in Table (5.3), a combination of concept 1 and 2 is incompatible as concept 1 focus on software while concept 2 focus on the box. It was detected that a merge between concept 2 and 3 was possible. The hybrid solution 23 maintains the leasing aspect of the box, however the algorithms are trained to analyze a specific type of data as in concept 3 e.g. only in vibration, electrical, oil, ultrasonic, infrared etc. In other words, the product will be reused and the algorithms will be adapted comply with the customer specifications and requirements, resulting in a product that is tailored for each customer. Once the analysis has been completed, the box can be reset, reused and retrained for the next customer. Concept 1 and 3 also worked, resulting in hybrid concept 13 that is software-based and can analyze a specific type of data input.

5.5.1 Evaluation of hybrid concepts

In this evaluation, the business model concept 13 and 23 will be evaluated by utilizing a Pugh-matrix. The matrix compares the nine components of the business models with the company's existing business model. If the new concept ranks higher than the existing one, further evaluation will be conducted. If it scores equal or less, the concept is terminated and no longer considered.

Table 5.4: Pugh-matrix comparison between current business model and hybrid concepts 23 and 13.

Business Model Concept	Original	13	23
Key Partners	0	0	0
Value proposition	0	+	+
Key Resources	0	+	-
Key Activities	0	-	-
Revenue source	0	-	+
Cost structure	0	+	+
Distribution channels	0	0	0
Customer segments	0	+	+
Customer Relationships	0	-	0
Net Sum	**0**	**1**	**2**

The hybrid concepts 23 and 13 exceeds the original business model and will be advanced to the next evaluation stage see table 5.4.

5.6 Screening of remaining concepts

In this stage, concepts 5, 13 and 23 will be evaluated in relation to a new reference, concept 4. If the new concept ranks higher than the existing one, further evaluation will be conducted. If it scores equal or less, the concept is terminated and no longer considered.

Table 5.5: Visual table of how concept 5, 13 and 23 perform in relation to concept 4.

Business Model Concept	4	13	23	5
Key Partners	0	0	0	0
Value proposition	0	-	-	+
Key Resources	0	+	+	+
Key Activities	0	+	+	-
Revenue source	0	-	-	-
Cost structure	0	-	+	-
Distribution channels	0	0	0	0
Customer segments	0	+	+	+
Customer Relationships	0	-	-	+
Net Sum	**0**	**-1**	**1**	**1**

In the third evaluation, concepts 5 and 23 ranked higher than concept 4, which is shown in Table 5.5.

5.7 Combination of concepts

In this evaluation, a morphological matrix will be used for concept 2,3 and 4 to identify hybrid concepts.

Table 5.6: Visualization of concept 2,3 and 4 in morphological matrix used to generate hybrid concepts.

Morphological Matrix			
	Concept 2	**Concept 3**	**Concept 4**
Concept 2	-	23	42
Concept 3	23	-	34
Concept 4	42	34	-

The figure illustrates a hybrid concept 42, which is a business model where the company offers sensors to extract data, but also leases the product. In other words, it is a combination of concept 4 and 2 and can be viewed as a more sustainable and environmental friendly approach. Concept 34 focuses on analyzing any specific type of data, while also providing sensors to extract that data. It is similar to concept 23 and 5 as it covers other data types, but the main difference lies in the ability to extract the necessary data. It enables tailored solutions, depending on the customer's situation.

5.7.1 Evaluation of hybrid concepts

The hybrid concepts will be compared to business model concept 4 by utilizing a Pugh-matrix. The matrix compares the nine components of the business models with business model concept 4. If the new concept ranks higher than the existing one, further evaluation will be conducted. If it scores equal or less, the concept is terminated and no longer considered.

Table 5.7: Illustration of how hybrid concepts 34 and 42 perform in comparison to concept 4.

Business Model Concept	**4**	**34**	**42**
Key Partners	0	0	0
Value proposition	0	+	+
Key Resources	0	0	0
Key Activities	0	-	+
Revenue source	0	0	0
Cost structure	0	-	+
Distribution channels	0	0	0
Customer segments	0	+	0
Customer Relationships	0	+	0
Net Sum	**0**	**1**	**3**

From the second hybrid screening, two additional hybrid concepts, concept 34 and 42, were generated. These concepts passed the screening criteria i.e. ranked higher than concept 4 in a Pugh-matrix analysis.

5.8 Selection of final Business Model Proposal

Several concepts passed the screening phase and have advantages and challenges. The main challenge with concept 5, 23 and is that they requires advanced specialist knowledge and increase the complexity for both the staff and the company. In addition, the start-up deviates from their main goal of specializing in energy analytics if it develops algorithms that can manage any type of data. The consequences of implementing concept 5 and 23 could also impact their other business areas. To mitigate risks and the challenge, it is essential to consider a realistic implementation, concept 4 and 42 were selected for further elaboration instead.

Table 5.8: Comparison of benefits, required resources and challenges related with each concept.

Comparison	*Benefits*	*Required resources*	*Challenges*
Concept 4	Capable of extracting data.	Sensors that generate the required data.	Develop a sensor that can measure power output, or identify a sensor from an external party that is compatible.
Concept 5	Analyzes several different types of data simultaneously.	Specialized experts that can train algorithms to analyze several data inputs.	Hiring experts that can adequately train the algorithms.
Concept 23	Analyzes a specific type of data. Box can be reused.	Specialized experts that train the algorithms to analyze a specific data input. Design engineer to redesign box.	Hiring experts in machine learning that can train the algorithms. Design the box in such a way that it can be reused.
Concept 42	Capable of extracting data. Box can be reused.	Manufacture sensors and boxes.	Develop a sensor that can measure power output. Design the box in such a way that it can be reused.
Concept 34	Can extract data. Can analyze any singular data input.	Sensors and specialized experts that train algorithms to analyze a specific data inputs.	Develop a sensor that can measure power output. Hire experts that can adequately train the algorithms.

The motive for selecting concept 4 is that the only difference between it and the original concept is that it requires hardware sensors to extract data, that can either be produced in-house or acquired from an external supplier. This could increase the complexity, but enables a larger customer segment that includes companies that do not have stored data and allows for an additional revenue source from the selling of data. The same reasoning applies to concept 42, but in addition the product will also have to be revised to allow it to be reused.

5.9 Validation with the industrial partner

A meeting was scheduled with the industrial partner to obtain their feedback on the generated business model concepts. The company approved of the suggestions and also discussed a potential business concept. They were unsure of the practicality of having a reusable product at this time, as they believed that the box would remain with the customer for a long time period, but stated that the concept was interesting. The addition of sensors was approved and they also suggested an additional change.

5.9.1 Strategic collaboration with external party

The start-up stated that it would be possible to change their current algorithms to fit into other companies digital platforms. Instead of building their algorithms and customizing their software services for each customer, the company could enter a strategic collaboration with an external party and adapt their algorithms to an existing platform. In other words, shifting their current business of developing a platform for every customer, to relying on an existing platform provided by another organization i.e. similar to licensing their product to another company.

The new concept will be integrated with the concept 4, resulting in a business model concept that focuses on both strategic partnerships and extracting data from customers. This is illustrated in figure 5.8.

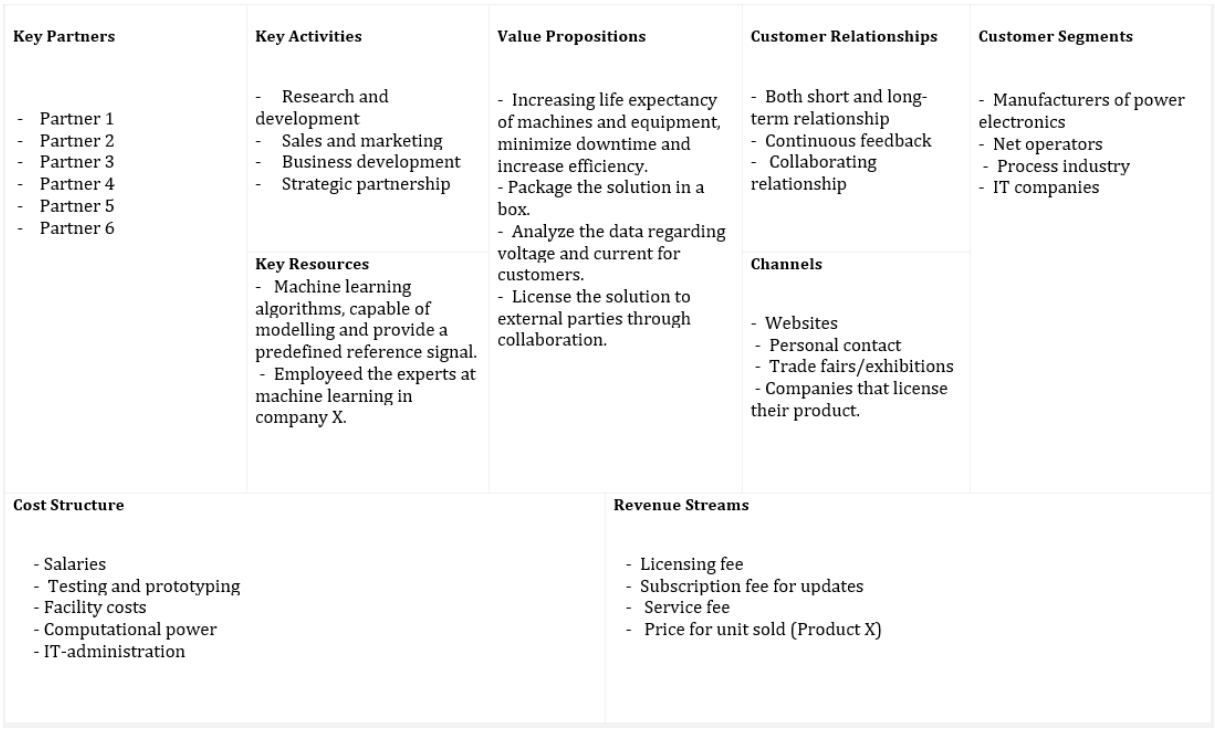

Figure 5.8: Business model canvas of the new business model concept.

5.9.2 Evaluation of new concept

As can be observed in the table, the new concept affects several constituents of the business model. It would reduce system complexity and costs as the software would only be used for a single platform when it is leased rather than several. The company's offering would shift from only being directly provided to customers to also using a middleman i.e. a company that leases their product to their customers. This could probably have had a positive impact on the customer segment, since company can focus on both licensing to partners and their customers, and due to the existence of sensors, the start-up can increase their customer base. In other words, they expand their customer base and develop their partnerships, resulting in a positive effect on key partners, but also on customer segments in the business model. It is postulated that the value proposition will increase from the customers' perspective and from the company's view.

Table 5.9: Comparison between the new business model concept and current business model.

Industrial partner	Existing business model	New business model concept
Key Partners	0	+
Value proposition	0	+
Key Resources	0	-
Key Activities	0	-
Revenue source	0	+
Cost structure	0	-
Distribution channels	0	+
Customer segments	0	+
Customer Relationships	0	+
Net Sum	0	3

5.10 Technology roadmap for implementing suggested business model concept

From the selection process, it is recommended that the company expands their business idea by providing sensors and license their product to external parties. It is recommended that they offer sensors, but its not necessary that they produce them in-house. The sensors could be derived through outsourcing, or through a joint venture, where another organization produces the hardware for the start-up. Additionally, as the sensors are not required to be customized, standardized generic sensors could be acquired from low-cost organizations, provided that the data is accurate. This would ensure that the organization would remain a pure software company, while also not increasing their system complexity by including logistics and manufacturing processes. There are several steps that are necessary to implement the suggested business model.

1. **Define business objective**
   The strategic objective is to identify revenue sources, customer base, enhance product features and, if possible, increase the brand reputation. This could be achieved by providing sensors to customers and a licensing option for specific companies.

2. **Plan to remain competitive in the future**
   To prevent decreasing profitability and losing their market position, it is important to establish a plan for future development. The sensors could result in additional revenue sources from data selling and expand the customer base by enabling companies that do not have stored data to extract it. Ad-

ditionally, this could be carried out without necessarily increasing the costs of the start-up, since customers could be demanded to pay for the addition of sensors. There exists different models, for instance just-in-time, to limit the costs related to physical products e.g. storage and facility costs. The licensing could enable another revenue, affect the brand reputation through the collaboration of different enterprises and, possibly, enable a joint product development process with an external party. The last aspect, conducting the product development process with another company, could be a pivotal factor as the start-up, in this scenario, might also be allowed to allocate the resources of a major company. As a start-up, this would be an important step to increase competitiveness.
The business model can be expanded by allowing various data types to be analyzed. Furthermore, the company actively monitors technological developments to identify technologies that could be integrated with their solutions. It may also be more beneficial to only have one digital platform for the algorithms i.e. only focusing on the licensing aspect completely. There are also other risks that must be considered e.g. risk of increased confidential industry data, regulations regarding energy usage, cyber security and data leakage. It is impossible to plan for all outcomes, but it is important to monitor changes that could impact the business model immediately.

3. **Identify functional needs**
   There exist some inefficiencies that could be improved e.g. data input, cyber security, brand reputation. In order to overcome this potential problem, it is important to analyze the possibility of employing additional labour force for training the algorithms. However, the first priority is ensuring financial stability and a stable revenue source before developing the business model. It is important that the organization reviews their available resources and costs prior to deciding which approach to undertake.

4. **Cost estimation**
   Technology initiative can be expensive e.g. acquisition of sensors, salary for machine learning experts, costs for energy consumption for the machine learning and IT-administration. The new business model, was selected by considering the limited organizational capabilities of a start-up company, along with the budget to undertake new projects. For instance, the sensors could be obtained after a customer specification has been ordered, by outsourcing the process to a general supplier. This means that no cost would arise until after the customer has paid for the acquisition of the sensors. A licensing will not incur any costs, meaning that the proposed changes will

not require any major monetary investments from the start-up.

5. **Define timelines**
   The machine learning based start-up is currently developing their software to comply with customers' specifications and rely on customers to have access to stored quality data. Licensing the software to an existing is already technically feasible, as well as contacting possible suppliers for sensors. As the suggested modifications do not require any major resource consumption, it is, therefore, recommended that the company implement the changes immediately. In other words, contact various external parties that could be interested in a strategic collaboration and might desire to use the system solution. Additionally, sensors for extracting energy data can be obtained through outsourcing and it is suggested that the start-up examines the industry for suitable suppliers. Note, however, that it is also suggested that the organization starts with using existing sensors instead of developing their unique sensors, as their forte lies within software rather than hardware.

Once the roadmap elements have been defined, it should be possible to implement the proposal. The steps can be viewed in figure 5.9. As previously mentioned, it is advised that the company immediately incorporates the addition of sensors and search for possible actors that are interested in licensing the software. As the suggestions do not necessarily require a lot of resources to be allocated, it is recommended to identify a suitable supplier that can provide with sensors, that are either congruent to customer specifications e.g. for the customers that do not have any stored data, or depending on stock levels if the organization desires to have an available quantity that they can access without delay.

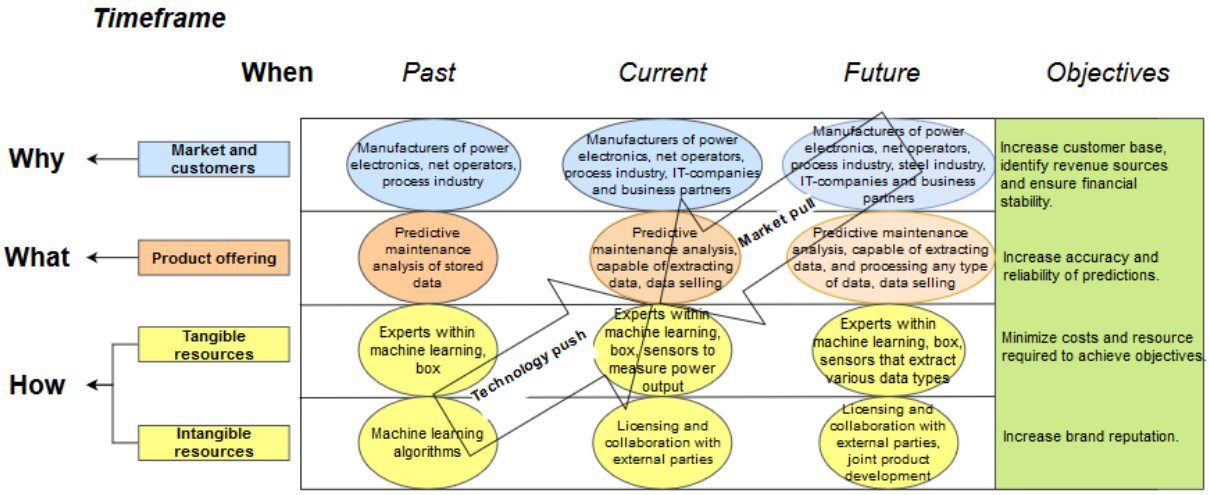

Figure 5.9: Technology roadmap that illustrates the company's development. Past refers to the business they conducted prior to this project, while current relates to the proposed changes that were investigated in this study. The future aspect, focuses on possible changes that could occur if the start-up decides to expand their business.

5.10.1 What impact could the selected business model have on the company

The new business model concept will affect all major constituents of the existing business model, i.e. revenue, customer base, product and financing, see Table 5.10. There are also several future implications. The new business model comprises of extracting and analysing data through the application of hardware sensor, and on strategic business collaborations. This kind of approach expands their customer base from power electronics, process industry to IT companies that require data. This in turn affects the revenue as customers that do not have access to data, are now able to access it and store it. To acquire the sensors, the customers has to purchase them, which results in additional revenue for the start-up. Once the data has been extracted and used, it can also be sold to external parties. An additional revenue source is derived from the selling of data, as other companies may need it. In addition, the licensing of their product to business partners also results in an additional source of revenue. Cooperating with external parties and using their digital platforms also has a positive influence on the revenue. The additional service, enables a wider customer base and allows for the opportunity of new revenue sources.

Table 5.10: The impacts of the new business model on the product, customer base, revenue source and finance.

	Business model implications
Product	Increased product independency
Customer base	Increased customer segment
Revenue source	Additional revenue sources
Finance	Potential increase of investors

The criteria required for the product to function properly has changed, since it no longer relies on input that is stored by the customer, but rather becomes more self-reliant and extracts the data that is necessary to carry out analyses.
The suggestion does not immediately affect the company's current financial position and funding. However, as their business expands and collaborations increase there might emerge more investors that want to invest in their company.

Chapter 6

Discussion

The chapter discusses how the elicited business model would position itself in comparison to existing state-of-the-art practice in the predictive maintenance industry.

6.1 Positioning of new business model

The new business model concept suggested by the start-up is to collaborate with other companies and license their product by modifying the algorithms to be compatible with their platform, in addition to offering sensors. The business model will be set in reference to the companies that were used in the benchmarking, which is illustrated in Table 6.1.

As was mentioned in the benchmarking, one of the main competitor is Competitor 1, who offer a self-service analytics software used to prepare, analyze and organize large sensor data without advanced data-analytics skills. In addition to offering sensors, competitor 1 also collaborate with an external IT-company within the IoT-industry to improve their algorithm with the use of IoT. It appears to be a common practice in the industry to collaborate with external parties to facilitate different processes, or to enhance particular product features. Both companies utilize partnerships, but competitor 1 uses another actor to enable IoT integrated services, while the start-up focuses on sharing a platform. The company license their product to their partner, thus acquiring revenue from the business collaboration. It can be viewed as more beneficial from an economical perspective. Another company is competitor 2 that provides AI-based software solutions to automate machine learning tasks. Competitor 2 is subsidiary company of a major organization, which differs a bit from the partnership collaboration that was suggested to the start-up. The new business model promotes partnership, but still allows the company to remain self-reliant and able to undertake independent actions. This

could be viewed as an advantage, since the company can decide how they want to change their business without being limited by the interests of a major stakeholder.

Competitor 3 has a software used to determine future failures by searching for patterns in asset data and correlates with known issues to predict failures. It is one of the leading companies in predictive maintenance industry, they build their own algorithms and focus on predicting future failures. Competitor 3 mainly conducts their processes internal and purchases a lot of companies. This is not an option since it is a start-up with limited resources, however it can collaborate with major corporations without losing its independence.

Competitor 4 is a well established company and combines innovative data analytics with IoT technologies in a single solution for predictive maintenance. The company's algorithms adapt to the partner's digital platform and is used for predicting system health and future failures.

Competitor 5 offers asset performance monitoring, condition-based maintenance with predictive insights to reduce downtime and improve workplace safety. The company provides lots of service related to maintenance using different methods, whereas the start-up uses only machine learning algorithm to predict system failure

Competitor 6 provides software to predict sudden machine breakdowns, unplanned, costly maintenance work and pre-defined maintenance cycles. Instead of predicting future failures or system health they focus on predicting sudden breakdown of machines. Since competitor 6 is part of a major corporation, they conduct many processes in-house and are not dependent of external parties. Due to a lack of resources, which is a characteristic of many start-up companies, it can not carry out all activities internally. It is beneficial to collaborate with major companies, as they can be used as a revenue source and also to increase brand reputation.

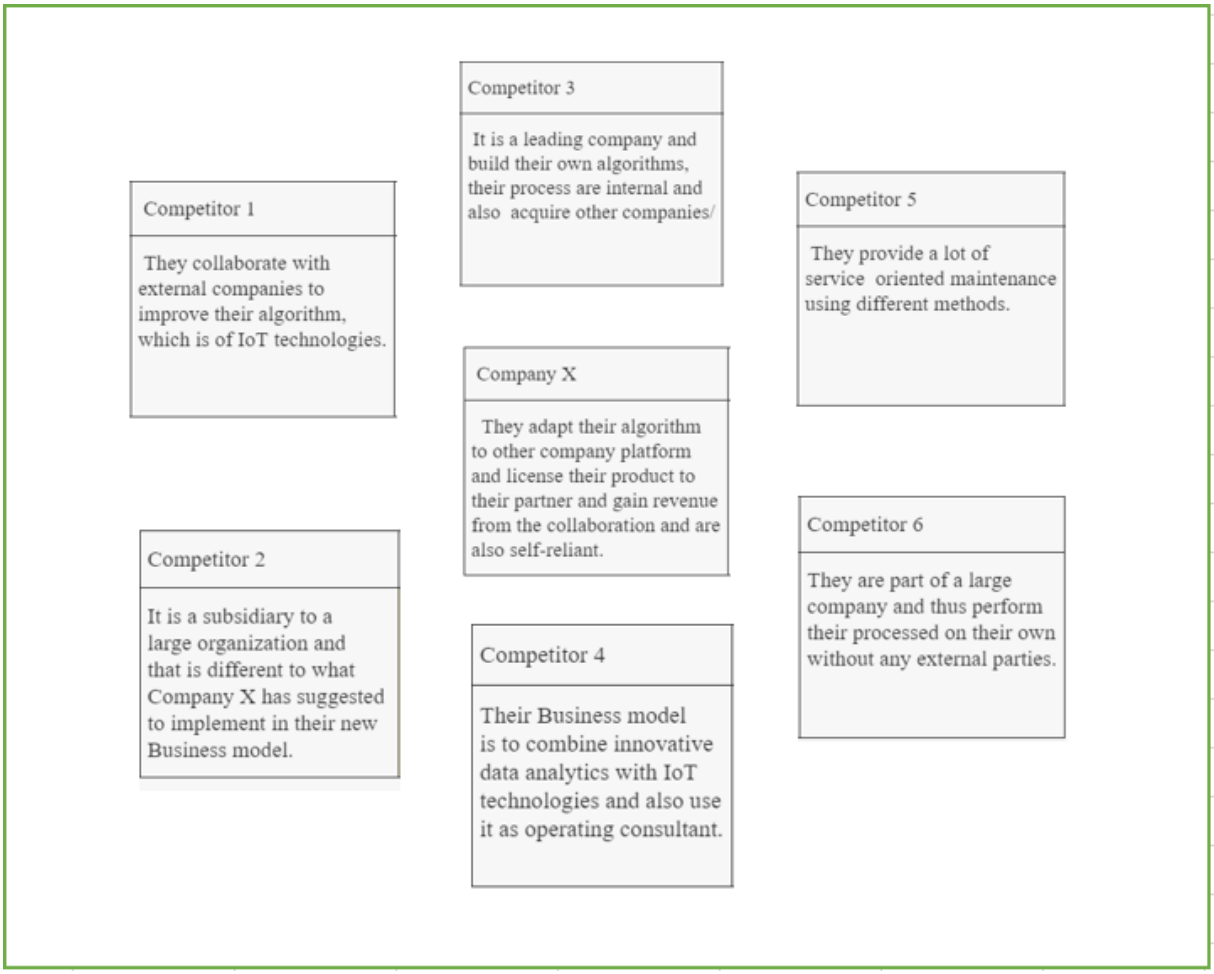

Figure 6.1: Illustration of positioning with the new business model.

6.2 Implication of positioning

To summarize, some competing companies utilize strategic partnerships to improve their algorithms and product offerings. Several of these companies are acquired by a major organization and becomes a subsidiary company to improve their funding. Major companies tend to conduct all main processes internal without utilizing external parties. Compared to the lesser companies, the new business model enables flexibility on the market, it can enter into various business collaborations, while simultaneously expanding the customer segment and promoting its reputation on the market. These strategic business partnerships are not restricted to only licensing their product and sharing a platform, but also joint product development e.g. collaborating with an IoT-company to integrate the product with IoT, or other

additional functions.

Chapter 7

Conclusion

The initial research questions, outlined in the start of the report were the kind of maintenance solutions being used in maintenance management, how the start-up compares to competitors, what kind of opportunities and threats exist and what could be an alternative business model. The stated research questions were answered in the results and analyses chapter.

- **RQ1**: *What kind of maintenance solutions are currently being used in the predictive maintenance industry?*
  There are different kinds of solutions offered by the competitors which can be viewed in the benchmarking and in the interviews. These are all software based solution used to predict failures and monitor the system performance. The main driver behind these solutions are machine learning algorithms that are often connected to a cloud server, or another digital platform. Some predictive maintenance solutions also integrate machine learning with IoT technology.

- **RQ2**: *What is the machine learning based start-up company's current business model and what do its competitors business models look like?*
  The current business model focuses on increasing the efficiency on existing powergrid filters, minimizing downtime and extending the product life. This is done by packaging the solution in a box, and it was observed that the main focus is primarily on the product. The competitors' business models were generally characterized by a software based approach, often providing sensors and having different kinds of business collaborations. Many of the companies had been acquired by major corporations, enabling more financial support and resources. They offered similar values but did not focus on energy efficiency, but rather focused on other measurements to conduct their predictions.

- **RQ3**: *What type of challenges and benefits exist for competitors?*
  The predictive maintenance industry is expected to grow a lot and there exists possible business opportunities to obtain a favourable market position for the company and to establish their brand. As the market is expanding and companies are adapting, machine learning is becoming increasingly widely used. Several challenges and benefits were elicited from the interviewed companies e.g. inaccurate data, which makes it difficult to analyze and share the data and can result in a erroneous analysis. Other challenges, or *pains*, related to predicting which specific part that would require maintenance. Some companies produced their own sensors to extract accurate data, while others used standard sensors from an external supplier to enable the analyses. Another issue was how the data could be stored e.g. a digital platform where data sharing would be possible. Many of they investigated companies had also formed strategic partnership to improve their market position.

- **RQ4**: *How could a new business model be designed and how could it affect the company's customer base, product features and revenue stream?*
  The new business model focuses on identifying new revenue sources by offering sensors and collaborating with external parties by modifying the algorithms to adapt to an external platform. It is important that the start-up monitors how their customer base and revenue is affected by the implementation of the suggested sensors and increased collaboration. The aim of the collaboration is to increase the revenue, expand the customer base and to establish their brand. It also affects the product features, as they are tying up with other company and they should adapt their algorithm to the needs of the other companies' customers and might reduce the product feature and can become limited. There will be a increase in the revenue source from collaborating and also from the licensing of the product and also from the product sales in comparison to the previous business model.

Since the initial objective was to design a suitable business model and identify revenue sources, customer segment and existing products, the study achieved its original purpose. The business model concept has also been validated by the machine learning based start-up.

Chapter 8

Future research

For further studies, it is recommended that the company examines the possibility of integrating the other generated business model concepts into their new one e.g. having multiple data inputs and leasing the product. In addition, it would also be interesting to evaluate if their product could be combined with other emerging technologies e.g. IoT.

There is also the economic aspect that needs to be considered i.e. whether it is economically efficient to use this new product for all types of machines and equipment. Calculations relating to maintenance costs and loss of production costs have to be conducted. An increase of the product cost, would result in an increase of price and that might negatively impact the customer segment or perceived customer value. This could lead to reduced revenue since the customer segment might be narrowed down due to the increased maintenance costs.

There are many areas where the start-up can conduct further research. As they are now entering the pulp and paper market, they can monitor the progress of their product and possibly consider using predictive maintenance in other processing industries e.g. the food processing industry.

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Appendix A

Appendix 1

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Figure A.1: Product roadmap