7/8/2022

The Impact of Product Y of Company X on Corporate Social Responsibility

Alex Kijk in de Vegte
INDUSTRIAL ENGINEERING AND MANAGEMENT

The Impact of Product Y of Company X on Corporate Social Responsibility

Bachelor project on investigating the effects of implementing a data-driven decision-making product within a company.

Final version
- PUBLIC –

Due to confidentiality reasons, the company name, as well as the names of the employees, partners, and business units has been made anonymous. Any information that can be traced back to the company, employees, partners, business unit, and competitors has been left out. Also, the data analysis results are factorized with an random unknown constant, which means that the data analysis results are fictitious.

Publication date: 8th of July 2022

Student
Alex Kijk in de Vegte
Industrial Engineering and Management
University of Twente

Supervisors
University of Twente

First supervisor
Dr. P.B. Rogetzer
Assistant professor
Faculty of Behavioral, Management and
Social Sciences (BMS),
Industrial Engineering & Business Information
Systems (IEBIS)

Second supervisor
Dr. rer. nat. D. Braun
Assistant professor
Faculty of Behavioral, Management and
Social Sciences,
Industrial Engineering & Business Information Systems

Preface

Dear reader,

In front of you lies the thesis ‘The impact of Product Y of Company X on Corporate Social Responsibility’. This research is conducted at a technology company based in the Netherlands between April 2022 and July 2022, to finish the bachelor Industrial Engineering & Management at the University of Twente.

First, I want to thank the company for the offering the challenging assignment. Foremost, I would like to thanks my colleagues of the business unit, especially my supervisors. Their support during the project was crucial to achieve the research results in time, I was able to ask any question at any time, which helped me a lot during the project.

Second, I want to thank my University of Twente supervisors, especially Patricia. The constructive and frequent feedback she provided contributed to the research quality, also the effective meetings were of great value.

Finally, I want to thank my friends and family for the constant interest and support in my research project.

Enjoy reading the report!

Alex Kijk in de Vegte

Glossary

Abbreviation	Definition or meaning
CSR	Corporate Social Responsibility
DIM	Days In Milk
FPCM	Fat and Protein Corrected Milk
GHG	Greenhouse gases
GPS	Global Positioning Systems
Kg	Kilogram
KPI	Key Performance Indicator
Lb	pound
PLF	Precision Livestock Farming
RFID	Radio Frequency Identification
UI	User Interface
VWP	Voluntary Waiting Period

Management summary

The aim of this thesis is to investigate the effects of implementing Product X related to CSR. This is done in a quantitative manner, based on pre- and post-implementation data that was gathered from two dairy farms.

Problem definition

The research is meant to analyse data to get quantified evidence about the effects of implementing Product Y. Company X, the problem owner, does not have any quantified evidence of the performance of their clients after they implemented Product Y. Product Y is a product that is worn by cows, Product Y movement data of individual cows. This data is subsequently converted into meaningful information that helps the farmer with decision making.

Increasing pressure from the society, that requires a more sustainable and responsible operation of the farmer is the main incentive to execute this research. Company X is interested in which way Product Y contributes to a more efficient, responsible, and sustainable operation of their clients. The following main research question is answered in this thesis.

What are the effects of implementing Product Y related to Corporate Social Responsibility (CSR)?

Research approach

Seven steps are executed to answer the main research question. We started with investigating which performance aspects of the farmer are influenceable by the Product Y implementation, which are subsequently related to the pillars or CSR. Based on that, Key Performance Indicators (KPIs) are formulated for every performance aspect. These are measured by analysing data, afterwards the significance of the results is calculated with the Welch's T-Test (significance level of 0.05). Lastly, an impact dashboard design is suggested and an extensive research report is delivered.

Data analysis results

Nine out of the 18 measured KPIs performed significantly better after the Product Y implementation. No single KPI performed significantly worse. Which means that the other KPI measurements did not have enough statistical power to show any effect.

The measured longevity, milk production, and labour KPIs showed strong improvements. We noticed that Company A used the abilities of Product Y to detect heat and time inseminations, which resulted in convincing reproduction improvements. Company B still applied hormone programs in the insemination of the lactation, which did not lead to any effects. The cow health KPI measurements did not show compelling results when comparing pre- and post-implementation data.

Conclusion

By associating the data analysis results to the three pillars of CSR, we concluded that implementing Product Y contributes to a more responsible operation related to the economic, environmental, and social pillar of CSR.

The economic performance of the analysed farms improved because of less youngstock investment is needed, less inseminations are needed to make cows pregnant, the milk production increased, and less labour is spent on detecting heats. The environmental performance of the farm improved because of less youngstock is needed, which reduces the emissions. Also, the emissions decrease because of less culling based on fertility and the milk production increases, which is beneficial for the efficiency of the farm. The Product Y implementation is beneficial for the social responsible operation of a farm, since the cows have a longer lifespan, which increases their welfare. Also, the Product Y implementation

contributes to the development of the employees, since a modern decision-making tool is applied.
The extent of the Product Y implementation effects are dependent on the management strategies. The management of a farm must be receptive to adjust their strategies to embrace the abilities of Product Y. Product Y itself will not show effects, implementing Product Y while the management adjusts strategies accordingly enforces the effects.
The fertility and cow health performance aspects are identified as important aspects when looking at the expectations of the Company X's clients. These performance aspects must be investigated more profoundly to identify the complete effects of the Product Y implementation. By collecting more (diverse) data, more evidence can be found of the Product Y implementation. These effects can be related to the management strategies, in which (potential) clients can learn.

Table of Contents

Reading guide

This thesis investigates the effects of implementing Product Y related to CSR. The report is structured in seven chapters, which are shortly discussed below.

Chapter 1: Introduction
The first chapter is the introduction of the research. The company and Product Y are introduced. The main research question is formulated and the research design is discussed, including a global approach to solve Company X's problem.

Chapter 2: Precision Livestock Farming
In the second chapter, Product Y is investigated more profoundly. Based on the features and technologies that are integrated in Product Y, different categories are defined. These categories indicate how the Product Y implementation eventually influence the performance of a farm. These different performance fields are then classified in performance aspects.

Chapter 3: Corporate Social Responsibility of farmers
In this chapter, the defined performance aspects are profoundly investigated. First, the importance of the aspects is examined. Second, the aspects are related to CSR, including a description how to influence a CSR pillar.

Chapter 4: Formulation of the KPIs
In Chapter 4, KPIs are formulated for every performance aspect. We identify the most important factors that influence the performance aspect, these factors are then formulated in a KPI.

Chapter 5: Data analysis
In this chapter, data is analysed to measure the formulated KPIs. First, the data preparation steps are discussed. Second, the KPIs are measured. Lastly, the data analysis results are associated to the pillars of CSR.

Chapter 6: Development and design of the impact dashboard
In this chapter, based on the investigation on the requirements of an effective dashboard, a design suggestion is provided and demonstrated.

Chapter 7: Conclusion
In the seventh chapter, the answer to the main research question is provided in the research summary. Also, the recommendations for further research, discussion, and research limitations are discussed.

1. Introduction

This chapter introduces this thesis research. Section 1.1 [LEFT OUT] introduces the company at which the research is conducted, also the product that is investigated in this research is introduced. Section 1.2 describes the problem that was faced by Company X. Section 1.3 explains some key construct that needs explanation to understand this report. In Section 1.4 the global problem-solving approach is declared subsequently, in Section 1.5 research questions are defined which are answered during this report. The research resources are discussed in Section 1.6. Some research methods topics are addressed in Section 1.7. The chapter is ends with Section 1.8, in which the structure of the report is addressed.

1.1. Company & product introduction

This section has been left out due to confidentiality agreements

1.2. Problem description

To describe the problem that is faced by Company X, the section starts with an explanation of the problem context in Sub-Section 1.2.1. Next in Sub-Section 1.2.2, the action problem and core problem are introduced.

1.2.1. Problem context

As mentioned in Sub-Section 1.1.1 [LEFT OUT], Products Y's target group are dairy farmers. In the beginning of 2021, the number of cattle worldwide was approximately 1 billion (Statista, 2021). The human population is growing, so dairy demand does. The expected world population in 2050 will be around 9.95 billion (Oxfam Novib, 2022), so 1.9 billion more consumers will demand milk products compared to the status quo. IFCN predicts an increase in milk consumption of +50 percent from 2020 to 2050 (IFCN Dairy, 2022). Figure 1 displays the expected milk production and consumption in the future. The horizontal axis is the year, while the vertical axis shows the expected tonnes of milk in millions.

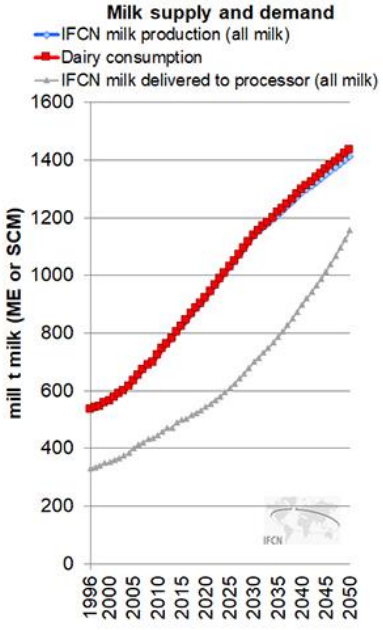


Figure 1: Expected milk supply and demand (Source: IFCN, 2022)

The growing dairy farming industry is not without danger. Increasing attention for climate change, meat consumption, and animal welfare causes more critical opinions from all over the world about the dairy farming industry. Dairy farming will play a major role in sustainable food system in the near future (Wordbank, 2022). There is urge for a more

efficient operation, where individual cows yield more milk, while ensuring lower emissions per kilogram (kg) produced milk (FAO, 2019).

1.2.2. Action problem and core problem

The idea of Product Y, is to be beneficial for the efficiency of the farmer, improve the health and well-being of the cow and to contribute to a more sustainable operation. These three topics are well-covered in the principle of CSR. CSR is a popular term with many different definitions. For this thesis we will use a combination for definitions derived from Deselnicu (2012) and Westerholz (2021), which is formulated as:

> *The voluntary activities of enterprises to eliminate their harmful effects on society, while maximizing economic performance.*

The dairy sector is facing considerable pressure to operate more responsibly, largely driven by consumers that prefer responsible and environmental friendly goods, which requires transparency (High, 2020). The concept of transparency is closely related to CSR, since transparency is a necessary condition for CSR (Dubbink et al., 2018). From the management of Company X, there is interest to know in which way Company X is operating responsibly and in which way Company X's products contribute to a responsible operation of their clients.

There are many different methods to separate CSR in different components. Nazzaro et al. (2020) did research on CSR related to the agriculture sector. In the paper CSR is separated in three dimensions, namely economic, environmental, and social. These three CSR dimensions will be called the pillars of CSR in this thesis. The economic pillar is related to the economical aspect of a farmer. The pillar has to do with the economic strength related to the traditional competitive factor, for example, costs, revenue, and market differentiation. The environmental pillar is associated with the sustainable performance and strategy of the farmer. By acting upon the CSR environmental pillar, the farmer tries to minimize its external impact. The social pillar is related to social relationships, both internal and external. It is the way farmers positively influence the growth of its employees and care about the health and well-being of the cows (Nazzaro et al., 2020).

By focusing on improving the performance of the CSR pillars, the farmer improves its market position, which will also express in a higher willingness to pay (WTP) for their products (Nazzaro et al., 2020).

Company X faces the problem that there is no quantifiable evidence if the implementation of Product Y contributes to a more responsible operation of the farmers. Company X has performed several qualitative data collections in the past. Through interviewing customers that have implemented Product Y at their farms, they collected qualitative data about the experience of their customers. The customers were asked why they invested in Product Y and if they recognize effects after the implementation, for example the milk production, amount of fevers, and insemination success rate. The main reasons of the companies to invest in Product Y is to improve the reproduction performance, decreased time spend on detecting heats, and to detect urgent diseases in early stage. Mainly to improve the economic performance of the farm (Company X, 2022b; Company X, 2022a).

However, operating data from Company X's customers have never been investigated profoundly, also the effects of implementing Product Y had never been expressed into clear KPIs that are related to CSR.

Now that the problem context and description are clear, we can define the action problem. The action problem for this thesis can be formulated as follows:

1.3. Key constructs

Performance aspect	Different performance aspects are identified in this research. A farmer has different performance aspects, for example fertility and cow health. The value of a performance aspect is influenced by multiple factors.
Factor	A factor is an influenceable number or quantity that contributes to a result (Cambridge Dictionary, 2022a). For every performance aspect, factors are analysed and formulated as KPIs.
KPI	A KPI is a measurement which evaluates how a company executes its strategic vision. The term strategic vision refers to how an interactive strategy is integrated into a company's strategy as a whole (Warren, 2011). In this thesis research, KPIs are formulated, analysed, and measured to see the difference of before and after the implementation of Product Y.
Lactation	Lactation is the period that the cow produces milk. One lactation is the time interval between one calving the subsequent dry period. A cow enters its first lactation after she calved for the first time, which is approximately after two years (Holstein Foundation, 2017). A visual representation of the cow's lactation curve can be seen in Appendix D.
Days in milk (DIM)	DIM is a term that is often used in the research. DIM refers to the amount of days a cow is in lactation. For example, if a cow calved on 19 October 2020 and has been culled on 30 October 2020. The cows have been culled at DIM 11.
Estrus	Estrus refers to the period in which a cow is sexually receptive and will stand to be bred. A cow shows symptoms, such as mounting other cows and mucus discharge. Estrus is also called 'heat', both terms will be used in this research and refers to the same definition.
Exit of cow	Exit of a cow means that the cows left the farm, which is also the end of its productive life. Exits can be distinguished in culled and mortality at farm. If a cow is culled, it means that the cow has been sold to the slaughterhouse. Mortality at farm means that the cow has died on the farm.
Farmer	In this thesis research, we define a farmer as an employee at a farm. In order to avoid confusion, all employees at the farm are called farmers, which decides to do certain activities.
Research stakeholders	Research stakeholders are people that have interest in this research. This are Company X, (potential) customers of Company X, and the staff of the business unit related to Product Y.

1.4. Global problem-solving approach

This figure has been left out due to confidentiality agreements

Figure 2: A visualized global problem-solving approach for this thesis assignment. [LEFT OUT]

The goal of this section is to declare the global problem-solving approach for this thesis. Figure 2 [LEFT OUT] visualizes the global journey for this thesis. We start off with Step 1, which is investigating the performance aspects that could possibly be influenced by Product Y. We declare the importance of the performance aspects and why they could possibly be influenced by Product Y. In Step 2, we relate these performance aspects to CSR and investigate which pillars can be influenced by the performance aspects. In Step 3, we formulate the KPIs that are measured in this thesis assignment. The KPIs are formulated based on the importance of the factor and keeping the available data in mind. The available data is discussed in Sub-Section 1.6.2.
Next, in Step 4, the KPIs will be measured by performing a data analysis based on pre- and post-implementation data. The data will be cleaned and prepared to make the measurements as reliable as possible. After the measurement of the KPIs, the reliability and validity of the results will be determined in Step 5. As deliverable, a sketch of an impact dashboard is made in Step 6. This dashboard displays the KPIs that show the effects of implementing Product Y. In Step 7, an extensive report about the research will be written. For most of the steps, a sub-research question is connected. The way in which we answer the sub-research question and so, execute the step will be discussed in Section 1.5.

1.5. Research question

To solve the selected core problem, a main research question needs to be determined. The main research question for this thesis research is formulated as follows:

What are the effects of implementing Product Y related to CSR?

The main research question is separated in sub-research questions. By answering the sub-research question, knowledge is obtained that is necessary to execute this research.

Sub-research question 1:

1. Which performance aspects can be influenced by the implementation of Product Y?

Understanding the abilities of Product Y is important to measure relevant KPIs. Via literature research we will obtain knowledge about performance aspects that could be influenced by Product Y. Next to the literature review, we obtain knowledge via semi-structured interviews with experienced people in the research field of this thesis.

Sub-research question 2:

2. How do the performance aspects influence the pillars of CSR?
    - 2.1. Which performance aspects influence the economic pillar of CSR?
    - 2.2. Which performance aspects influence the environmental pillar of CSR?
    - 2.3. Which performance aspects influence the social pillar of CSR?

It is essential to understand how every performance aspect influences the pillars of CSR. Through answering these questions, we understand the consequences of a change in the performance of an aspect.

Sub-research question 3:

3. How to formulate the most important KPIs of every performance aspect?
    - 3.1. How to assess the importance of a factor?

After we know how the CSR pillars are influenced, the most important KPIs for every performance aspect need to be defined. This knowledge is obtained via literature research and semi-structured interviews with experts in the research area.

Sub-research question 4:

4. How to measure the formulated KPIs?
    4.1. How to prepare the dataset to get reliable results?
    4.2. How to analyse the data to get measured KPIs?

The KPIs are measured by analysing the data. Several steps must be done to get the measured KPIs. The data must be prepared to obtain reliable data that can be analysed. Cleaning data consists of structuring, formatting, and combining data. The required knowledge and methods to clean and analyse the data are obtained via experienced data scientists at Company X and via tutorials and information websites acquired online.

Sub-research question 5:

5. How to quantify the significance of the results?

The reliability and significance of the results should be investigated. Conclusions can only be drawn if the results are verified. Literature research is performed, but also statistical tests are executed to assess the quality of the data and results.

Sub-research question 6:

6. How to visualize the KPIs in an impact dashboard?

It is important to select a user-friendly program, with high flexibility and customization. The developed dashboard should be accessible and understandable for future investigators, so they can further develop the dashboard. Further requirements and to which extend the dashboard is made is discussed in Chapter 6. Also, the best visualization methods should be investigated. There are a lot of different kinds of charts and other visualization tools. This knowledge is obtained via literature research and semi-structured interviews with experienced people.

1.6. Research resources

In this section, we describe the relevant research resources for this thesis. Firstly, the research aim & scope is described in Sub-Section 1.6.1. Secondly, the available data that has been collected by Company X is described in Sub-Section 1.6.2. Lastly, the research deliverables are addressed in Sub-Section 1.6.3.

1.6.1. Research aim & scope

The goal of this research is to investigate the effects of implementing Product Y. With effects we mean the consequences after implementing Product Y. For this thesis project, we are not interested in the return on investment for the farmer, the initial investment costs of implementing Product Y are left out for this research. Data from two big farms will be investigated to get quantified evidence of implementing Product Y. The quantified evidence is obtained via analysing data to measuring KPIs. We are only interested in the changes over time of the KPI value, not in the absolute values. For example, we are not interested in the amount of kg of milk that is produced after the Product Y implementation. Only the percentage change with respect to pre-implementation is relevant for this research.
This thesis project is part of a more comprehensive research project within the business unit of Company X. The final goal is to completely understand the effects of implementing Product Y. Getting full evidence of the effects of implementing Product Y is out of the scope for this thesis project, given the available data and timeframe we have. This research is too small to conclude all the effects of the implementation of Product Y. This research will have a much larger follow-up research. Therefore, it is important for Company X to be able to apply the acquired knowledge and reuse the code when more data is collected in the future. We have carefully documented and sourced the findings.

1.6.2. Available data

Company X gathered data for this thesis project, the data originates from two big farms from Country A and Country B, these companies are called Company A and Company B respectively in this report. The datasets consist of data that is collected via manual administration of the farmer, inseminator, or vet. Company A already had a Precision Livestock Farming (PLF) solution, they had the products called Product W and Product Z. Both products are ear tags and are placed in the cow's ear. The abilities of the products are the same compared to Product Y, namely heat detection, and monitoring cow health. During the implementation phase of Product Y, they dropped Product W and Product Z, to replace them with Product Y. Company B did not have a PLF solution before the implementation of Product Y.

Every row in the dataset consist of an activity that occurred on the farm, varying from calving moments, inseminations, disease detections, culling moments, to mortalities at farm. These rows consist of several columns, such as the registration number of the cow, birth date, activity name, DIM at the moment of the activity, and date of activity. In total we have access to approximately 150.000 rows of data. During the formulation phase of the KPIs, we are restricted to the data we have, we can only devise KPIs that can be measured with the available data.

Company X selected these companies, because of the large herd size, both companies have around 3.500 cows in its productive life stage. The size of the companies is beneficial for the reliability of this research, since the companies of this size work in standard protocols. This means that the company reacts equal in every situation with the same circumstances, contrary to assess every situation differently based on the performance of the cow.

1.6.3. Intended deliverables

As discussed in Sub-Section 1.6.1, the main aim of this research is to discover the effects of implementing Product Y including making this research replicable for further research when more data is collected. Therefore, the main deliverable for this thesis, is an extensive report with the well-documented findings. When the research project within the related business unit finished, research stakeholders should be able to see the quantified effects of implementing Product Y, an impact dashboard will be made to see the effects clearly in a user-friendly environment. A dashboard design suggestion is made in this thesis report, this non-interactive dashboard is a sketch in which the dashboard could be delivered to the research stakeholder, they can see the measured KPIs is a structured way to assess the effects effectively.

1.7. Research methods

In this section, several research methods characteristics are discussed. Starting off with the type of research in Sub-Section 1.7.1. Next, the research subjects are discussed in Sub-Section 1.7.2. The data gathering methods are discussed in Sub-Section 1.7.3.

1.7.1. Type of research

Cooper and Schindler (2014) defined four different types of research, which are reporting, descriptive, explanatory, and predictive. The research types can be distinguished based on the aim of the research. The research type that is applied in this thesis depends on the sub-research question. The sub-research questions for this research have a descriptive, explanatory, or a combination of both as character. A descriptive study tries to discover answers to the questions who, what, when where, and sometimes, how. While explanatory studies go beyond description and attempts to explain the reasons for the phenomenon that the descriptive study only observed (Cooper & Schiendler, 2014).

Sub-research questions 1 and 2 are explanatory studies. Because of the importance of these questions, we do not only want to observe the results of the study but, we want to go beyond that and explain the reasons for the observed result. The importance will be

assessed for every parameter, which will help with finding the relationships between variables.
Sub-research questions 3, 4, 5, and 6 are classified as descriptive studies, the most important aspects of these studies are the observed results, not essentially the 'why' behind it.

1.7.2. Research subject

"The research population consists of the person(s), groups(s), or organization(s) that are the subject of the investigation" (Heerkens, 2017, p. 23). The research population is distinguished for every research question in Table 21 of Appendix B. Literature is the most important research population, since academic sources can provide the reliable information to answer the research question. The second research population are experts in the research area, which is for this thesis the dairy sector. This research subject will mainly consist of employees of Product Y's business unit of Company X. They can share their experience about relationships between variables and data analysis techniques. The company is the third research population, with company we mean Company X. We need to know their preferences regarding the research.

1.7.3. Data gathering methods.

Literature research and interviews will be the two main methods for data gathering. Mostly literature research will be performed to gather required data for answering the research questions. Data from literature research is better accessible, more reliable, and less sensitive to interpretation. Because of that, literature research will be the most valuable data gathering method for this thesis. However, interviews will be precious to get another perspective on the research and to obtain knowledge for people that are actually experienced in the field.
As mentioned in Sub-Section 1.6.2, we analyse a lot of data for this research. The collected data is an important source for this thesis, however, since this data is already gathered by Company X, it is not part of this research.

1.8. Structure of the report

In this section, the structure for the remainder of the report is explained. An overview of the research design can be found in Table 21 of Appendix B.
In Chapter 2, Product Y is extensively investigated. The PLF trend is shortly introduced and the abilities of Product Y are described extensively. The aim of Chapter 3 is to associate the identified performance aspects to the pillars of CSR. We want to obtain knowledge about how the performance aspects influence the pillars of CSR. Based on the knowledge obtained in Chapter 3, KPIs are formulated in Chapter 4, these KPIs are associated to a performance aspect. Next, in Chapter 5, the KPIs are measured by analysing pre- and post-implementation data. Also, the results of the data analysis are associated to the pillars of CSR in this chapter. A suggestion of an impact dashboard is delivered in Chapter 6, including substantiation of the design and structure choices. The report ends with Chapter 7. In this chapter, the conclusion of the research is given, in which the main research question is answered. Also, this chapter includes the discussion, recommendation for further research, and limitations.

2. Precision Livestock Farming

In this chapter, Product Y is extensively explained, also we investigate the abilities of Product Y, which means that we want to clarify the performance aspects that can be influenced by Product Y. This knowledge is obtained through answering the following sub-research question: Which performance aspects can be influenced by the implementation of Product Y?
Section 2.1 introduce the Precision Livestock Farming trend, which Product Y is part of. Section 2.2 starts with an extensive explanation of Product Y thereafter, by discussing the abilities of Product Y the possible performance aspects that could be influenced by Product Y are identified.

2.1. Precision Livestock Farming

The trend of an increasing number of sensors applied in the agriculture sector is called the Precision Agriculture trend. These sensors are used to gather data (e.g. cow activity or behaviour pattern data), which enables data-driven decision making. Next to an increase in efficiency, data-driven farming is also an opportunity for a more sustainable operation (Van Erp-Van der Kooij, 2021). Precision farming in the livestock industry is called PLF. PLF is meant to create a management system that continuously gathers real-time data about animals, which helps controlling the reproduction, animal welfare, animal health and environmental performance of a livestock farmer (Berckmans, 2014).
PLF is widely applicable across various animals and can be classified as wearable and non-wearable solutions (Caja et al., 2020). If the sensor, which gathers the data is placed at the cow, the solution is classified as a wearable solution. Non-wearable solutions are placed around the animals, at some strategic chosen places in the barn. So, a wearable solution touches the cows, non-wearable does not. Multiple technologies can be applied to gather the data, the best known are; radio frequency identification (RFID), global positioning systems (GPS) to determine animal position, accelerometers to measure certain movements in a direction, pedometers for step counts, microphones, thermistors, and cameras (Van Erp-Van der Kooij, 2021). Product Y, which is investigated in this research, is classified as a wearable solution, with an integrated accelerometer.

2.2. Product description: Product Y

In Section 1.1.2 [LEFT OUT] Product Y was shortly introduced. Product Y is a product that has built-in technologies that collect data. The collected data is the input for an algorithm, this algorithm converts the raw data into meaningful information. The first integrated technology is an accelerometer, this sensor measures proper accelerations in certain directions. The algorithm behind Product Y tries to find patterns in the data, in order to relate certain movements to a cow activity. Different cow activities can be distinguished, for example eating and ruminating (Company X, 2022c).
When a cow shows significant changes in cow activity or behaviour, a notification is shown on the dashboard of the farmer. Figure 3 displays the dashboard that is provided to the farmer. Based on the type of deviations and urgency the notification is placed in a certain section of the dashboard. The farmer can assess the notification and can act accordingly upon the it.
Overall, this data gathering technology helps the farmer with monitoring and tracking the herd. The raw data that is collected by the sensors are converted into meaningful information at the dashboard. The farmer can react and act upon this information, but he can also ignore it. Product Y by itself does not improve or affect any operations directly, to see affects, the farmer should act upon the information provided at the dashboard.

This figure has been left out due to confidentiality agreements

Figure 3: The dashboard used by the farmer to see the condition of the herd and check any notification. [LEFT OUT]

The algorithms behind Product Y have a limited set of abilities to assist the farmer. Four categories can be identified in which Product Y can support the farmer, namely accurate timing, early intervention, and feeding management. All categories are addressed below, including the discussion of factors that could be affected by Product Y.

Accurate timing

Farmers need to time certain activities accurately for example, calving moments and the optimal insemination moment. Based on certain behaviour and movements of a cows, the algorithm behind Product Y can detect heats, in order to advice a farmer for the optimal insemination moment. When the algorithm detects a potential heat, the specific cow is added to the top left cell of the dashboard, visualized in Figure 3[LEFT OUT].

Globally, the main reasons for a poor artificial insemination success rate are poor oestrus detection and insemination timing (Mohammed, 2018). First, the heat needs to be detected and second, the insemination needs to be timed correctly. Figure 4 visualized the best insemination moment. Detecting heats is a time-consuming activity and when the heat is detected by the farmer, the farmer needs to estimate the beginning of the heat, in order to determine the optimal insemination moment. Therefore, both activities could be difficult for the farmer, Product Y helps with detecting and advising the perfect insemination moment, according to the algorithm. The biggest advantage of using sensors over visual observations, is that the start of the oestrus is known. With oestrus detection via visual observations, it is always a guess when the oestrus period commenced, therefore, the optimal insemination moment can be determined more accurately using accelerometers compared to visual observations (Van Erp-Van der Kooij, 2021). Therefore, Product Y could possibly be beneficial for the pregnancy rate, and so improve the fertility of the farmers herd.

Detecting heats to advise an optimal insemination moment can improve the fertility performance. Also, if Product Y takes over the activity of detecting heats, the labour spend in detecting heats by the farmer can possibly be reduced. This results in the definition of the first two performance aspects namely, fertility and labour.

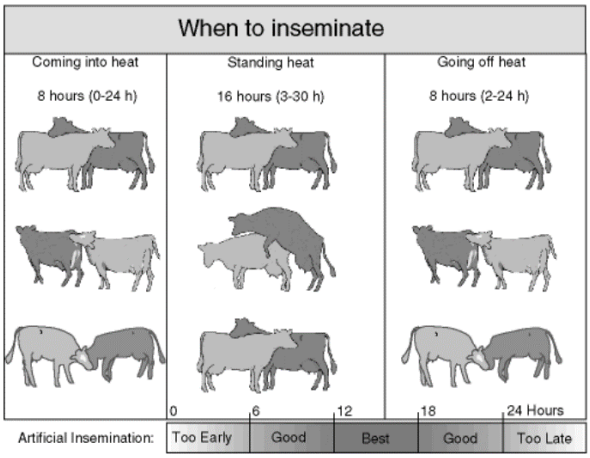


Figure 4 Timing of artificial insemination (Source: Mohammed, 2018)

Early interventions

Company X's algorithm can detect deviations from normal behaviour. Based on an increase or decrease in certain activities lameness, milk fevers and other diseases can be recognized (Van Erp-Van der Kooij, 2021). When a deviation is identified, the specific cow is added to the dashboard, and the attention is classified into two groups, based on urgency. Urgent attentions are included in the second cell of the left column, less urgent attentions are included in the third cell of the left column as visualized in Figure 3 [LEFT OUT]. By detecting deviation in early stage, Product Y can have beneficial effects on the fertility, efficiency, and health of the farmer's herd.

The advantage of applying a PLF solution is, that sensors can measure 24/7, even in harsh environments, something that is impossible for human beings. The goal is to detect deviations early stage, to prevent drastic consequences for example, mortality at the farm (Lokhorst, 2018). The transformations in activities related to the most occurring deviations are shown in Table 22 of Appendix C.
Farmers can react differently on deviations, which depends on their strategy and protocols. A farmer tries to heal the cow by treatments, in order to extend her productivity lifetime. Culling the cow in time is the second option. A cow must be able to walk before culling. Culling the cow before she is unable to walk, ensures that the farmer gets a financial compensation from the slaughterhouse (CompanyX, Interview with data analist, 2022c). With early interventions, the farmer can possibly improve the cow health of the herd, and so the lifespan of the cow, which can affect the longevity of the herd. The next identified performance aspects, which will be investigated profoundly in this chapter are called cow health and longevity.

Feeding management
Feeding management is one of the most important activities for a dairy farmer. Optimising feeding management requires careful choices to select the nutrition composition that converts feed to energy as much as possible (Krasniqi et al., 2018). The optimal diet of a cow requires a careful analysis of its condition (Da Rosa et al., 2020). Based on the data gathered by Product Y, the dashboard is able to display the daily behavioural pattern of a cow, and so the condition of the herd. The farmer can adjust the diet of individual cows when the condition of a cow deviates.

2.3. Conclusion
In this chapter, we investigated Product Y extensively, we obtained this knowledge by answering the following sub-research question: Which performance aspects can be influenced by the implementation of Product Y?
Product Y is part of the PLF trend, in which more sensors are used in the livestock sector. These sensors enable farmers to make data-driven decisions. Through an integrated accelerometer, we are able to identify cow activities. Because of the characteristics of the product, Product Y is classified as a wearable solution.
Four categories have been identified in which Product Y can help the farmer, namely accurate timing, early interventions, and feeding management. Product Y helps the farmer with identifying heats to advise the optimal insemination moment, which can improve the fertility of his herd and increase the labour efficiency. By early interventions, Product Y can eventually prevent drastic consequences of a disorder, which can be beneficial for efficiency and health of a cow and the longevity of the herd. By identifying the behaviour of individual cows, the farmer can adapt the diet of specific cows accurately, based on their condition and lactation stage.
We analysed the abilities of Product Y and we formulated the following four performance aspects that could directly be influenced by the implementation of Product Y namely, fertility, labour, cow health, and longevity.

3. Corporate Social Responsibility of farmers

In Chapter 2 we investigated which performance aspects can possibly be influenced by Product Y. In this chapter, these performance aspects are investigated profoundly. We examine the importance of the performance aspects, also we explain how Product Y can influence the performance aspects, and we relate these aspects to certain CSR pillars. To obtain this knowledge by doing a literature research and answering the following sub-research question: How do the performance aspects influence the pillars of CSR?

3.1. Influenceable performance aspects

In this section, every performance aspect is investigated separately in a sub-section. The sequence of the performance aspects is iterated for the rest of the report. This gives a clear structure for the report in which every performance aspect is measured separately.

3.1.1. Longevity

Longevity can be defined as the total lifespan of a cow (Vredenberg et al., 2021). This does not mean the productive life of a cow, but its entire life from birth to death. The productive life of a cow starts only when the cow produces milk, which is approximately around the age of two (Wathes et al., 2008). In the Netherlands, the average total lifespan of a dairy cow in 2018 was 5.5 years, while the natural total lifespan of a cow is approximately 20 years. Hence, it is common in the dairy sector, that cows are culled before the end of their natural lifespan. However, several studies show that an increasement of cow longevity improves the economic performance (Vredenberg et al, 2021). These culling decisions are mainly fostered by economic consideration by the farmer. The decision is mostly based on the level of milk production, reproduction performance, and health concerns. Most farmers have healthy youngstock available, with improved genetics. Also, older cows are more likely to get disorders, which makes some cull decisions logic (Vredenberg et al., 2021). An increasement in longevity has a negative association regarding technical efficiency. This means that old cows have a reduced productivity, which is caused by less milk production per unit of input (Huxley, 2013). However, the investment costs regarding youngstock will decrease when the longevity increases, since less youngstock should be available to replace cows (Ali, 2021).

Next to that cow longevity is recognized as one of the most important traits to improve the economic performance of dairy farmers concurrently, it can also decrease the environmental and social impacts. For example, increasing the cow longevity with 270 days results in a reduction of 210 kg of CO_2-equivalent greenhouse gases (GHG) emissions per cow (Van Middelaar et al., 2014). Putting in context, the average global emission per kg of milk is 2.4 kg of CO2-equivalent GHG (Vellinga & Gerber, 2010). Also, the social aspect of longevity has become an important public debate. The society requires a good animal welfare. An increasement in cow longevity is beneficial for the cow welfare (Vredenberg et al., 2021).

The importance of longevity has been declared, the effects of a change in longevity can be related to the pillars of CSR. As mentioned in this sub-section, when the longevity of the herd increases, less cows need to be replaced. This means that less youngstock must be held by the farmer, which requires less investment costs. This means that an increased longevity is beneficial for the economic performance of the farmer, and so, the longevity is related to the economical pillar of CSR. Since less youngstock must be reared, less animals bred at the farm, which reduce the emissions. As mentioned in this sub-section, an increasement of 270 days of a cow's longevity, results in a reduction 210 kg of CO_2-equivalent GHG emissions per cow. Therefore, an increase in the longevity of the herd is related to the environmental pillar of CSR. Since the society puts more pressure on animal welfare, the longevity is related to the social pillar of CSR. An increase in the longevity of a cow improves the animal welfare and so, the social pillar of CSR.

3.1.2. Fertility

Proper reproduction performance is essential for the successfulness of a dairy farmer. A cow needs to calve about every year to maintain sufficient milk production (Van Erp-Van der Kooij, 2021). A cow's daily milk production peaks after four to six weeks after calving. Thereafter, it declines until the subsequent calving moment (Hovey, 2018). This is called the lactation curve, a visual illustration for clarification of the lactation curve can found in Appendix D.

There are different methods to inseminate cows, most farmers in North-Western Europe try to make their cows pregnant via artificial insemination. For artificial insemination, the oestrus needs to be detected to determine the optimal insemination moment. To have an insemination success rate as high as possible, proper oestrus detection and determination of the optimal insemination moments is required. There are multiple methods available to detect the oestrus, in order to identify the optimal insemination moment (Van Erp-Van der Kooij, 2021).

Next to insemination moment, the success rate of inseminations is strongly dependent on the environmental and body conditions of the cow. When a cow gets inseminated, but not pregnant, the cow has reproduction issues. Poor fertility is identified when a cow has too much failed inseminations. Poor fertility accounts for more than one-third of all culling reasons and so, heavily affects the longevity of the herd (Wathes et al., 2008). These reproduction issues decrease the number of parities per cow's lifetime and reduces the longevity (Ali, 2021). Several studies show that the reproduction performance of the herd heavily influences the profitability (Walsh & Fahey, 2022). There are multiple costs associated to inseminating, for example sperm, technician costs, pregnancy test, and labour costs to detect the oestrus and determine the insemination moment (Cody, 2022). An increase in fertility requires less of these investment costs, which is beneficial for the economic performance of farm and so, fertility can be related to the economic pillar of CSR. Since poor reproduction performance accounts for more than one-third of all culling reasons, the fertility performance affects the longevity significant. Also, culling based on poor fertility is categorized as involuntary, as will be explained in Sub-Section 4.2.3. Therefore, the fertility performance is indirectly linked to the consequences of a change in the longevity and so, the performance aspect fertility can be associated to the same CSR pillars as longevity. A change in the fertility performance results therefore to the same consequences as a change in longevity, which were discussed in Sub-Section 3.1.1.

3.1.3. Cow health

Cow health has a big impact both on the quantity and the quality of milk, also they cause economic difficulties. The diseases cause a decline in milk production and an increase in costs, which leads to a loss of income (Põldaru & Luid-Lindsasar, 2020).

Different cow disorders can be identified. The two best-known and most common categories are lameness and milk fever, both categories are discussed separately.

Lameness is a notorious disease in the dairy sector. It has significant impact on the health and welfare of a cow. Several studies showed that lameness impacts the nutrition and feeding behaviour. To avoid standing and moving, the cow will spend more time laying to visit less often the food gate, which results in less eating time, and so the cow has less energy available to produce milk. This has a negative impact on milk production (Huxley, 2013). Lameness can be detected via visual observations, but also by the help of modern technologies such as Product Y, since cows with lameness adjust their daily activity and behaviour, which can be recognized by the algorithms behind Product Y. The disorder can be treated and prevented by hoof trimming (O'Leary et al., 2020). The treatment via hoof trimming is a time-consuming and costly activity, which is heavily dependent on skilled persons (Van Erp-Van der Kooij, 2021).

There are different kinds of milk fever recognized, for example, ketosis, metritis and mastitis, changes in behaviour and activity per disorder can be found in Appendix C. Milk

fevers affects the daily behaviour of a cow and eventually causes a decline in milk production. Also, the occurrence of milk fever decreases the reproduction performance (Bragança & Zangirolamo, 2018). Next to the decrease in milk production and fertility performance, milk fevers are associated with high treatment costs. Several diseases require dosing medicines, also threating milk fevers is a time-consuming activity (Liang et al., 2017).
For both the milk fevers and lameness, the quality of milk reduces. This conflicts with the demand from society, because of an increased customer awareness related to animal welfare and healthy food, farmers are required to deliver high quality milk (Põldaru & Luid-Lindsasar, 2020).
Intervening at an early stage and preventing cow disorders improves health condition, reduces costs for treatment, and prevents drastic production losses (Lovarelli et al., 2020). Modern technology can help dairy farmers with monitoring and enhancing animal welfare, through adequate reacting on critical diseases and individual attention (Põldaru & Luid-Lindsasar, 2020). However, much on-farm mortality is related to cow disorders. A cow can exits the farm in two ways, either she died on the farm which is called on-farm mortality or she has been sold to the slaughterhouse, which is called culling. On-farm mortality is a growing problem that has significant effect on the profitability of the farm. Also, an increase in mortality indicates suboptimal cow health and cow welfare.

We identified several drastic consequences of cow disorders. Both the quantity and quality of milk production are affected negatively by a cow disorder, this influences the economic and environmental performance of the farm, which is further declared in Sub-Section 3.1.5. The treatment of cow a disorder goes along with high costs, because of the medicines and labour associated to the treatment. This affects the economic performance of the farm. The reduction in the cow's condition and mobility reduces animal welfare. Also, an increase in on-farm mortality indicates bad cow welfare, this affects negatively the social pillar of CSR. Based on the identified consequences of cow disorders, which affects the cow health, the KPIs that will be measured related to cow health can be associated to all the pillars of CSR.

3.1.4. Feeding management

The profitability of a cattle farmer is heavily influenced by feeding of the cows. The feeding management of a farmer directly influences the health and the production a cow. Feed and the feeding management constitutes about 60-67 percent of the overall production performance of dairy cattle. Also, feed costs can contribute up to 60 percent of all costs of a dairy farm (Krasniqi et al., 2018).
Precision farming can help with getting the right nutrient to the right cow at the right time (EIP-AGRI, 2017). It is a promising feeding method to reduce the environmental footprint of dairy farmers. With precision feeding, cows can be fed individually based on the cow's condition and behaviour. Farmers can adjust the feed composition to increase feed efficiency and productivity, which improves the profitability and decreases the environmental impact (Van Erp-Van der Kooij, 2021).
Feed efficiency can be improved by individual based feeding, compositing feed to produce as much output based on the input. Therefore, the way the farmer copes with their resources, affects the feed efficiency heavily. Changes in efficiency can be related to the economic pillar of CSR, due to the costs associated to feed. Also, efficiency can be related to the environmental pillar of CSR, because of the high emissions during the development phases of the feed (Van de Haar & ST-Pierre, 2006). Since the feed of the cow influences its health and well-being, this performance aspect can also be related to the social pillar.

3.1.5. Milk production

The performance aspect "milk production" was not identified in Chapter 2 however, for dairy cattle farmers, milk production accounts for the biggest income. Although we couldn't

find a direct influence of the Product Y implementation related to the milk production, we are still interested if the main output of a farm changes after the Product Y implementation. Although cow health, fertility, and feeding management influence the milk production, many more aspects influence the milk production performance such as, for example, genetic background, breed, lactation length, and climate (M'hamdi et al., 2012). Since milk production is the biggest output of a dairy cattle farmer, we are of course interested if the implementation of Product Y influences the milk production.
If the milk production increases after the Product Y implementation, it means that the farmer is performing economically better. If the milk production increases, assuming the same input, the farm has lower emissions per kg produced milk, which is beneficial for the environmental performance of the farmer. Therefore, the KPI that are measured related to milk production can be related to the economic and environmental pillar of CSR.

3.1.6. Labour

Labour is an important resource on a farm, which should not be wasted. Systems that decrease the amount of work for a farmer makes the farm more efficient. Precision farming solutions that can indicate the location of a cow and can help with detecting disorders or the optimal insemination moment, can save time and energy for the farmer (Van Erp-Van der Kooij, 2021). Since the algorithm behind Product Y is able to detect heats and subsequently advice the farmer for the optimal insemination moment, Product Y is possibly able to take over the labour that is spend on detecting heats.
Product Y is a quite modern tool, which enables the farmer to perform data-driven decision making. Applying modern technologies that shapes the society is beneficial for the development of the farmer's employees, by balancing technological and social development, responsible advancements can be created (Potocan, 2021).
A change in the labour performance aspect can therefore be associated to the social pillar of CSR, since the social pillar of CSR is related to the development of employees. Also, the implementation of Product Y can be beneficial for labour efficiency of the farm, since Product Y can possibly take over the time spend by the farmer for detecting heats. Possible changes in labour efficiency can therefore also be related to the economic pillar of CSR.

3.2. Conclusion

In this chapter, we investigated several performance aspects namely, longevity, fertility, cow health, feed management, milk production, and labour. For every aspect, we declared the importance of proper performance and we related the aspects to certain CSR pillars. Through answering the sub-research question: "How do the performance aspects influence the pillars of CSR?" we obtained this knowledge.
The longevity directly influences all the pillars of CSR. An increase in longevity reduces the amount of needed youngstock and so, the emissions and investments related to the youngstock. This influence the economic and environmental pillar. Also, we identified that an increase in the longevity is beneficial for the welfare of the cow and so, affects the social pillar of CSR. Because of the large costs that are associated to inseminating cows, changes in the reproduction performance can directly be related to the economic performance of the farm. We also identified that poor fertility accounts for more than one-third of all culling reasons. A change in the fertility performance affects the longevity, therefore the fertility can be related to the same pillars of CSR as longevity. For the cow health performance aspect, we profoundly discussed lameness and milk fevers. These cow disorders reduce the quantity and the quality of the milk production, a change in the milk production affects the economic performance of the farm and so, the environmental performance, since less output is produced with the same input. When a disorder is identified for in a cow, the condition and the mobility of the animal reduces, which affects the welfare of the cow and so, the social pillar of CSR. The feeding management of a farmer directly influences the production performance and the cow health. There is need to give the right diet to individual

cows at the right time. Since feed constitutes to a big part of the expenses of a farmer, a change in the feed efficiency affects the economic pillar. A change in the amount of feed that is needed for the same input affects the environmental pillar, since the production of feed is associated with a lot of emissions. The feeding management pillar is also related to the social pillar, since the feed of the cow affects the cow health and welfare.
The milk production is most important output and revenue stream of a dairy farm. A change in the milk production affects the economic pillar, and so in the environmental pillar, since the amount of emissions per kg produced milk changes. The labour pillar influences the economic and social pillar. By implementing Product Y, the amount of labour that is spend on detecting heats can possibly be reduced, which affects the economic pillar of CSR. Also, the implementation of Product Y is beneficial for the development of the employees, which influences the social pillar.

4. Formulation of the KPIs

In Chapter 3 we investigated the performance aspects that are possibly influenced by Product Y. We discussed their importance, how they can be influenced, and we associated the aspects to the pillars of CSR.
In this chapter we formulate the KPIs, which will subsequently be measured in Chapter 5. For every performance aspect, based on literature, we identify the most important factors. We obtain this knowledge by answering the following research question: How to formulate the most important KPIs of every performance aspect?

4.1. Requirements for an effective KPI

Measuring performance and tracing the performance movements over time is important for dairy farms. Measuring the performance is generally done by KPIs (De Vos, 2014).
To ensure de reader of proper understanding of the research topic, the key construct KPI was shortly introduced in Section 1.3. In this section, KPIs will be explained more extensively, also the requirements for an effective KPI will discussed.

The selected KPIs will be measured to show the performance of certain performance aspects that could be possible influenceable by Product Y eventually, these KPIs will be displayed on a dashboard. The measurement of the KPIs enables research stakeholders to trace the performance over time. Furthermore, the KPI measurement is also accessible for future data, goals can be set, to aim for these performances over time.
KPIs need to match with certain requirements in order to be an effective KPI. Several methods can be applied in order to formulate effective KPIs. The well-known conceptual framework SMART is often applied in practice for this (Podgórski, 2015). SMART means; Specific, Measurable, Achievable, Relevant, and Time-bound. All KPIs should comply to these criteria, because of that, each will be elaborated separately.

Specific
Both Doran (1981) and Chamberlin (2011) agreed on the importance of the specific aspect of a KPI to be effective. The KPIs should be aimed to the objective of the research. Detailed, focused, and well-defined formulation will help during the measurement of the KPI. A KPI complies to the specific aspect if you measure what you intend to measure with the KPI (Podgórski, 2015).

Measurable
The measurement of the KPI is hugely important, if a KPI is measurable, it enables you to find out if you achieved the aimed objective. So, it should be possible to measure the KPI (Podgórski, 2015). To quantify and find out the effects of implementing Product Y, the performance should be measurable, which means that the KPI should be a percentage, fraction, frequency, or rate.

Achievable
MacLeod (2012) discusses the achievability in terms of the resources that are available to measure the KPI. We should be able to measure the KPI with the resources we have at our disposal, which are the data, knowledge, and time.

Relevant
A KPI complies to the relevant aspect if the KPI is align with the research goal. We should only measure KPIs that are relevant for this research and that adds value to this thesis.

Time-bound

You should be able to measure the KPI throughout the time. The idea behind the measurement of the KPIs is to find the effects of implementing Product Y. These effects will not show up immediately after the implementation, but the effects, if there are any, will be notifiable throughout the time. This requires the ability to measure the KPI over a time period.

4.2. Formulating the KPIs

In this section, KPIs are formulated for every performance aspect.
To help with understanding several terms of the lifetime of a cow, an illustration of a cow's lifetime is visualized in Appendix E.

4.2.1. Longevity

Measuring longevity is recognized as an important trait that influences the profitability, environmental impact of cattle farms as well as the welfare of the cows. It heavily influences the replacement and amount of older cows (Essl, 1998).
The longevity is mostly determined by the farmer, since the farmer decides to cull a cow or not. Longevity can be measured in lifetime trait and stayability trait. Lifetime trait is the length of the productive life of a cow or the lifespan of a cow, these can only be measured after the death or culling of the cow. The stayability trait measures if a cow is alive after a certain number of months from birth. This can be measured at any point in time (Van Pelt, 2017).
To measure the lifetime trait of the herd, we will use the lifespan of a cow. Due to data related reasons, the lifespan of a cow is chosen over the length of productive life. The timeframe of the dataset is too short to have enough data of a reliable quantification, since we do not have the productive life starting dates of cows that already calved at least once at the starting date of the dataset. However, we have the birth dates of these cows, which enables us to measure the lifespan.
This brings us to the formulation of the first KPI in this report:

KPI 1 $The\ average\ age\ of\ exit.$

The exit of a cow is the day of culling or mortality.

We also measure a stayability KPI of the herd, KPI 2 is formulated to ensure this.

KPI 2 $The\ percentage\ of\ cows\ that\ finishes\ lactation\ 2.$

This KPI is a variant on the description of stayability by Van Plet (2017). During a meeting with the research stakeholders within Company X, we discussed the formulation of relevant longevity KPIs. We concluded that the given formulation of KPI 2 is more relevant compared to description provided by Van Plet (2017), which measure the stayability trait via measuring the percentage of cows that are alive at a certain point in time after birth. The reason behind this formulation is based on the payback period of a cow, which is normally measured in lactations numbers. The payback period of a cow is dependent on the region of the farm and management decisions, however two lactations as break-even is known as an average in the dairy sector (Company X , 2022e; Company X , 2022i).

4.2.2. Fertility

Several factors influences the reproduction performance of a herd. A lot of studies for example, De Vos (2015), Hanks (2018), and McDougall (2016) uses the pregnancy rate as an important factor to assess the reproduction performance of a herd. The pregnancy rate can be calculated by multiplying the conception rate with the insemination rate.
The conception rate is the percentage of cows pregnant divided by the number of cows inseminated during a given time period (Poock et al., 2009). This can be calculated by dividing the amount of successful inseminations by the total number of inseminations. For

example, if ten cows get inseminated and four become pregnant, the conception rate is 40 percent.
The insemination rate is the percentage of cows inseminated over a given period divided by the number of cows eligible to be bred in this period (Poock et al., 2009). For example, if ten cows are eligible to be bred and five of them get actually inseminated, the insemination rate is 50 percent. Multiplying the conception rate and insemination rate of the above examples ends up in a pregnancy rate of 20 percent over the specific time period.
As mentioned in Section 2.2, for inseminating a cow, first the heat needs to be detected and second the optimal insemination moment needs to be determined. The pregnancy rate is a powerful KPI to combine these activities. However, the conception rate and insemination rate are also valuable KPIs on their own. The insemination rate indicates the heat detection performance of a farm, while the conception rate refers to the performance of determining the optimal insemination moment (De Vos, 2014).
To assess the effects of implementing Product Y related to the reproduction performance, we measure and discuss the conception rate, insemination rate, and pregnancy rate separately in a KPI.

KPI 3 $Conception\ rate = \frac{\#\ of\ cows\ pregnant}{\#\ of\ cows\ inseminated}$

KPI 4 $Insemination\ rate = \frac{\#\ of\ cows\ inseminated\ over\ time\ period}{\#\ of\ cows\ elegible\ to\ be\ bred\ over\ time\ period}$

KPI 5 $Pregnancy\ rate = \text{Conception rate} \times \text{Insemination rate}$

4.2.3. Cow health

In Section 3.1 we discussed the most common culling reasons namely, low milk production, bad reproduction performance, lameness, and milk fevers. Culling can also be distinguished between voluntary and involuntary culling. Culling for low milk production can be referred to voluntary culling, while culling for a disorder and low fertility can be referred to involuntary culling. Voluntary culling reasons are mostly based on economic reasons, where it is no longer profitable to keep the cow compared to replacing the animal with a heifer. With involuntary culling, the cow exists the herd for biological reasons, for example lameness, milk fever, or infertility (Fetrow et al., 2006; Van Arendonk, 1985).
In the beginning of the lactation the farmer assesses the condition and performance of the cow, based on that the farmer decides to inseminate the cow or not. If the farmer inseminates the cow, it means that he wants to have another lactation with the specific cow. He invests in the insemination, so the cow gets another calve, in order to start a new lactation. Therefore, voluntary culling in early lactation rarely occurs because of the production potential for the remainder of lactation. However, since most of the cow disorders occur in the transition period, the probability of culling is greatest in early lactation (Dechow & Goodling, 2008). Therefore, culling in early lactation is likely an indicator of poor cow health (Fertrow et al., 2006). Next to the economic consequences of culling in early lactation, cow health is increasingly important because of increased customer focus on dairy welfare (NDAWB, 2008). Therefore, the KPIs related to this performance aspect are even more relevant. Cow health can also be measured in the amount of disorders in total. However, since disorders that results in early lactation exits has the biggest economic impact on the farm, we decided to formulate the KPI in this way:

KPI 6 $Percentage\ of\ cows\ that\ exit\ in\ DIM \leq 60.$

As shortly discussed in 3.1, farmers cope differently with identifications of cow disorders. Farmers can treat the cow, helping the cow to recover, so she proceeds with her productive

life. The other contrary strategy is to cull the cow as soon as possible to prevent on-farm mortality. Also, several in between strategies are applied. Since Product Y helps the farmer with detecting disorder in early stage, we are interested if the mortality rate is influenced by implementing Product Y.

KPI 7 *Mortality rate*

4.2.4. Milk production

For dairy farms, milk production is the most important factor of income (Armengol & Fraile, 2018). Therefore, we are interested if the implementation of Product Y influences the milk yield of a farmer. For measuring a milk production KPI, several methods are available and milk production can be expressed in litres or kgs. The methods varies in the way of quantification, the most common methods are; the production over lifetime (Hanks, 2018), the Fat and Protein Corrected Milk (FPCM) (CVB, 2017), and production in 305 days, which a normalized number of days of one lactation (De Vos, 2014; Hanks, 2018; Rougoor, 1999). For this research, we will use the average production of cows in 305 days, since this fits the best to the available data. The way in which this KPI is measured with the available data and the formulation of this KPI will be more extensively explained in Sub-Section 5.3.4.

KPI 8 *Average milk yield over 305*

4.1.1. Labour

Accelerometers could increase the labour efficiency on a farm. Labour is one of the most important resources on a farm and should be assigned carefully. Introducing sensors which detect heats and assists with determining the optimal insemination moment could make farming more efficient. Good calibration between the sensitivity and the expectations of the farmer is needed. For this research, we are interested if the amount of inseminations, whereof the heat is detected by visual observations has changed.

KPI 9 *The percentage of inseminations whereof the heat is detected by visual observations.*

The measurement of this KPI is very interesting, because if the percentage decreases over time, it means that the farmer has spent less time observing heats, which increases the labour efficiency.

4.2. Conclusion

In this chapter, KPIs are formulated for every performance aspect. We applied the principle of SMART KPI formulation, to ensure we formulate KPIs that complies to the requirement of an effective KPI. For the longevity, we discovered that the longevity performance can be measured in two ways namely, the lifetime trait or stayability trait. We formulated a KPI for both manners. The fertility performance will be measured by the pregnancy rate, which can be found by multiplying the successfulness rate of inseminating with the percentage of detected heats. The cow health performance is measured by two KPIs, an increase in the percentage of on-farm mortalities is an indication of poor cow health. Therefore, the mortality rate is formulated as a cow health KPI. Also, early lactation exits are an indication of poor cow health and has drastic economic consequences, therefore percentage of cows that exits in DIM $\leq$ 60 is the second cow health KPI. The milk production performance will be measured by the average expected milk yield in a lactation. If the percentage of inseminations whereof the heat is detected by visual observation decreases, the labour efficiency will improve. Therefore, we will measure if the percentages of heats that is detected by visual observation changes.

5. Data analysis

The main aim of this chapter is to measure the formulated KPIs. The following research question is answered in this chapter: How to measure the formulated KPIs? We start with the discussion of the most important preparation steps to execute the data analysis, in which the data cleaning steps are addressed. In Section 5.2, the following research question is answered: How to quantify the significance of the results? We find the most suitable significance test by executing a literature research. Then is Section 5.3, the KPIs are measured for every performance aspect separately. After the data analysis, the KPI measurement results are associated to the pillars of CSR. In Section 5.5, the practical contribution of the insight after the data analysis are discussed for the research stakeholders. The chapter ends with a conclusion in Section 5.6

5.1. KPI measurement preparation

In this section, the KPI measurement preparation steps are discussed. The section starts with an explanation why data preparation is needed which kind of preparation steps were executed. Next the data preparation steps for every companies are discussed separately.

5.1.1. Data preparation

To ensure proper data quality, data preparation is one of the most important research tasks. In practice, data scientists spend more than 50 percent of their engineering effort in preparation tasks (Zang et al., 2003). The datasets that will be used for this research must be complete, accurate and consistent in notation. Data that does not meet these criteria can cause unreliable research results, which could cause poor decision making.
Data cleaning is an essential part of data preparation and is the activity to correct or delete inaccurate records from the database (Dilmegani, 2022). The most important cleaning steps for this research were, the removal of irrelevant, invalid, incomplete, conflicting, and duplicate data.
Next to data cleaning steps, several other data preparation steps were executed for example, merging data files, adjusting datatypes, separating columns, and concatenating data files. These activities do not influence the results. Consequently, they will not be discussed in the main body of this chapter.

The data available for this research was extensively discussed in Sub-Section 1.6.2. We mentioned that the data from Company A and Company B are not identical regarding the format and content, which required different data preparation steps. The preparation steps that were required for every KPI will be discussed in this section. KPI specific data preparation is included in the section that corresponds to the measurement of that specific KPI.

Data preparation Company A

The data from Company A was extracted on 11 January 2022, so the data included all events from the first day of 2019 until the data extraction date. To ensure consistency, we only want to measure a KPI value of a year if the years include the same months. Therefore, we decided to delete the data originated from 2022.
The dataset contains a unique cow-code, which is called the “REG1” code in the dataset of Company A. The “sold and died” dataset which has information about the exits of cows, had ten (out of 3029) duplicates, which is of course not possible in practice. Therefore, this data has been excluded.
At Company A, Product Y is implemented in October 2019, which means nine months of pre-implementation data and two years and three months of post-implementation data is available. To take seasonal effects into account, we will compare the pre-implementation data with the first nine months of 2020 and 2021.

Data preparation Company B

Company B also provided administration data from youngstock. Dairy youngstock are cows that do not have calved yet, see Appendix E for an illustration. Cows mostly calve for the first time at an age of approximately two years, which is also the start of their productive life (Mohd Nor et al., 2013). Youngstock performances should be quantified separately. Because of time limitations of this project, this research is focussed on the performance of the cows that are in their productive life stage. Therefore, we excluded the youngstock data in the KPI measurements.

At Company B, Product Y is adopted in February 2020. This means we have one year and one month of pre-implementation data and one year and 10 months of post-implementation data. To stay consistent and consider the seasonal as well, we will compare the last ten months of 2019 with the last ten months of 2020 and 2021, respectively.

After these steps were made, we could identify a research delimitation. The KPIs will only be measured based on the data of cows that are in their productive life stage in the calendar years 2019, 2020, and 2021.

5.1.2. Quantification decisions

The KPIs will be measured for every month and the KPIs entail a percentage representing a rate that indicates the performance in the specific month. The changes over time in the KPI values indicate the effects of implementing Product Y.

During the measurements of the KPIs, we need to take seasonal effects into account. Cows show significant differences in milk production over different seasons (Ray et al., 1992). The heat stress negatively affects the feed intake, feed efficiency, milk quality, milk yield, reproduction performance, cow behaviour, and disease incidence (Zeinhom et al., 2016; Cook et al., 2007; Tucker et al., 2007; Rhoads et al., 2007). To make the results as reliable as possible, we will only compare performances that include the same seasons.

5.2. Statistical significance test

The significance of the research results is evaluated by a statistical test. Numerous statistical tests are available to apply, each with their own characteristics. The Welch's T-Test is selected as the most suitable test for this research. Welch's T-Test does not assume equal variances and accepts different sample sizes (Ruxton, 2006). This is extremely relevant for our research, since we have more post-implementation data compared to pre-implementation. While the test does not assume equal variances over the samples, the test does assume normality.

$$t' = \frac{\mu_{post} - \mu_{pre}}{\sqrt{\frac{s_{post}^2}{n_{post}} + \frac{s_{pre}^2}{n_{pre}}}}$$

Formula 1: Welch's T-Test (derived from: Ruxton, 2006)

Formula 1 denotes the formula of the Welch's T-test. μ (Mu) denotes the mean of the sample, s denotes the standard deviation of the sample and n denotes the sample size. The subscript *pre* stands for the pre-implementation data, while *post* stand for the post-implementation data. The outcome of the formula, t' denotes the t-value.

We want to test if implementing Product Y has effect on certain performance indicators. We set the alternative hypothesis to state that, the value of the KPI is not equal between pre- and post-implementation. The null hypothesis is that the performance is equal. We perform a two-sided test, since effects can occur positively and negatively. The tests are executed at an alpha of 5 percent (95 percent of confidence level).

For both companies all KPIs are measured separately. Also, we will apply the statistical test for every KPI and company individually. Appendix F shows a worked out example of the Welch's T-Test.

The measured KPIs can be distinguished in three groups. The first group is applicable for KPI 1 & 8, these are continuous numbers and could be any number. Given the characteristics of the Welch's T-Test, it is selected as the most suitable. The second group consist of KPI 5, this is a continuous variable derived from the multiplication of the conception rate and the insemination rate. The binomial test is not suitable for this KPI, since we do not have a specific sample size or population. The third group is applicable for the other KPIs, the value of these KPIs is a fraction, so a continuous number between 0 and 1. Again, we selected Welch's T-Test as the most suitable for calculating the significance of the results, in which we compare the month averages of pre-implementation against the month-averages of post-implementation. We selected the Welch's T-Test above the binomial test. With the binomial test, a sample size is tested against the population for a binary variable (University of Taxes, 2015). However, the binomial test assumes that the population is significantly greater compared to the sample size (Glen, 2014). This is not the case for our pre- and post-implementation data, because of that we selected the Welch's T-Test. However, we were interested if the results were different if we selected the binomial test because of that, we worked out the binomial test for the relevant KPIs. One worked out example can be reviewed in Appendix G and the differences between the binomial test and the Welch's T-Test can be seen in Appendix H.

5.3. KPI measurement

Confidentiality measurement:

The data analysis results that are shown in the tables and graphs in this section are factorized with an unknown constant. Which means that the changes does not represent the actual changes.

The KPIs are measured in this section. Every performance aspect has an own sub-section, in which the corresponding KPIs are measured and discussed. The results of the KPI measurements are indicated in a table and a graph, these figures are discussed below separately.
The tables indicate the KPI values for every measured year. See Table 1 for illustration, 2019 is the pre-implementation period, while 2020 and 2021 are post-implementation. The first row indicates the average of the KPI value of the specific year, while the second row indicates the percentage change with respect to pre-implementation average (which is 2019 in this case). The KPI values and percentage changes of the post-implementation years are coloured green or red. Green indicates a positive change, which means that the farm is performing better in that KPI, while red means a negative change.
The graphs indicate the KPI changes over time, see Figure 5 for example. The x-axis are the months for which the KPI is measured, the y-axis indicates the percentage change with respect to pre-implementation. The graph shows two different lines. The red line indicates the pre-implementation phase average, which is then of course 0 percent. The orange line indicates the difference with respect to pre-implementation average. The blue bars are the monthly-adjusted KPI values, which indicates the specific monthly KPI change with respect to the same month in pre-implementation.

5.3.1. Longevity

In this sub-section the longevity KPIs are measured, which are the average age of exit and the percentage of cows that finishes lactation two.

5.3.1.1. Average age of exit

In Chapter 4 we formulated the first KPI as: the average age of exit. During the data preparation phase, we added a column that subtracted the date of exit from the birth date of the cow. Based on that, the age of the cows is calculated.

KPI 1 $$The\ average\ age\ of\ exit = \frac{\sum \text{Age of cow at day of exit}}{\#\ Exits}$$

The calculated value represents the average age of all exits in a specific month.

Company A:

Year	2019	2020	2021
Average age (in years)	4.29	4.41	4.32
Relative change	0%	+2.8%	+0.7%

Table 1: KPI 1 results of Company A

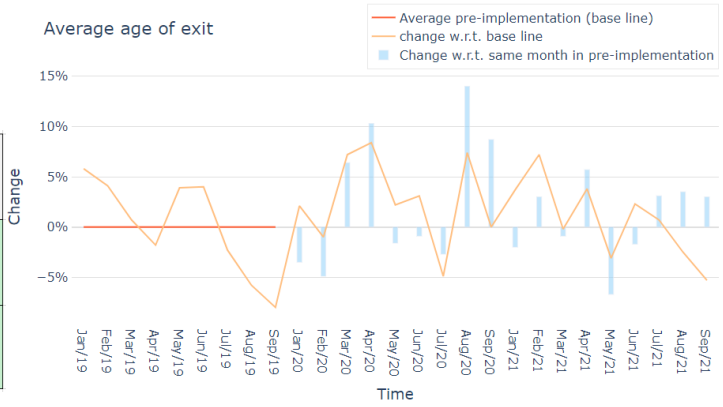


Figure 5: KPI 1 measurement of Company A

Table 1 indicates the yearly values of KPI 1 for Company A. The average age of exits increased slightly after the Product Y implementation, which means that the herd lives on average slightly longer, compared to pre-implementation. We can notice from Figure 5 that there is less variation in the KPI value over time. Due to these small changes, we failed to reject the null hypothesis (p-value of 0.3965). This means that the average age of exit at Company A does not differ statistically significant when comparing pre- and post-implementation data.

Company B:

Year	2019	2020	2021
Average age (in years)	3.42	3.8	3.75
Relative change	0%	+11.1%	+9.7%

Table 2: KPI 1 results of Company B

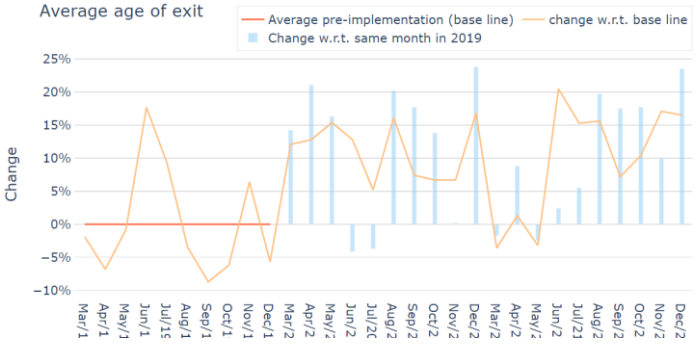


Figure 6: KPI 1 measurement of Company B

By comparing pre- and post-implementation data, the p-value turns out to be 0.004, which is lower than 0.05, hence we could reject the null hypothesis of the test and conclude that the difference in average age of exit at Company B is significant. Table 2 and Figure 6 displays that the average age at exit increased for both years significantly. The increased longevity enables the farmer to keep less youngstock, which reduces the investment costs for replacing the cows. Also, less youngstock means less emissions.
In the KPI measurements of KPI 1, KPI2, and KPI6 we see bad performances in March, April, and May of 2021, after a meeting with the contact person of Company X with Company B, we found out that these were caused because they sold a lot fresh cows to another farms (Company X, 2022d), fresh cows are cows that are in an early stage of the

lactation. This caused a bad performance for the KPI measurements, which affected the performance negatively.

5.3.1.2. Percentage that finishes lactation two

The second KPI measurement related to longevity is the percentage of cows that finish two lactation periods. To measure this KPI, a cow has finished lactation two, if either she has calved at least three times or she has calved twice and has DIM of 305 or higher at the day of exit.

$$\textbf{KPI 2} \quad The\ percentage\ of\ cows\ that\ finishes\ lactation\ two = \frac{\#Exits\ calved \geq 3 + \ \#Exits\ calved\ two\ times\ and\ DIM \geq 305}{\#\ Exits}$$

Company A:

Year	2019	2020	2021
% finished LACT 2	51.4%	55.1%	56.5%
Relative change	0%	+7.2%	+10.1%

Table 3: KPI 2 results of Company A

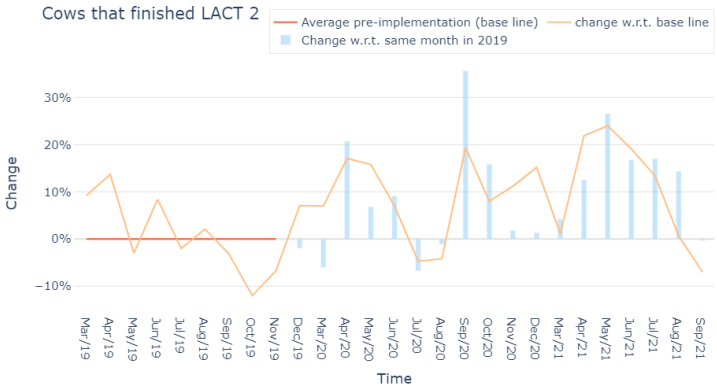


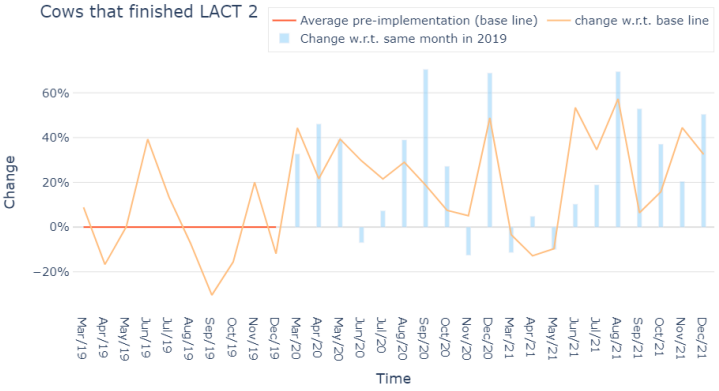
Figure 7: KPI 2 measurement of Company A

Table 3 showed that the percentage of cows that finishes at least lactation two increased for both year after the Product Y implementation. Also Figure 7 shows that almost all month (approximately 90 exits per month) perform better compared to pre-implementation. The statistical test enabled us to reject the null hypothesis (p-value of 0.024). Which means that the percentage of cows that finished lactation two at Company A increased significantly. This is beneficial for the longevity of the farm. As mentioned in Section 4.2, this stayability KPI is formulated based on the payback period of a cow, which means that Company A is able to reach the break-even point with more cows.

Company B:

Year	2019	2020	2021
% finished LACT 2	36.7%	46.4%	44.7%
Relative change	0%	+26.4%	+21.8%

Table 4: KPI 2 results of Company B



` 8: KPI 2 measurement of Company B

On average there were 120 exits per month at Company B. We can see in Table 4 and ` 8 that more cows that exits the farm has finish lactation two. Next to KPI 1, Company B also performed significantly better (p-value of 0.007) on KPI 2. The longevity of the herd increases and the farmer is able to reach the break-even point with more cows.

5.3.1.3. Intermediate conclusion

We identified longevity as an important performance aspect. All longevity KPIs performed better after the Product Y implementation, whereof three out of four significant. The increased performance of the lifetime trait KPI (KPI 1) meant that cows that a longer lifespan. The stayability KPI (KPI 2) showed that more cows finish lactation two, which means that the farmer reaches more often the break-even point with a cow.
This significant increase of longevity enables the companies to have less youngstock, this means that the farmer has less investments costs to replace cows. Also, less cows are at the farm, which means that less feed and other resources are needed at the farm, which reduces the emissions of the company. In Section 3.1, we mentioned that an increase of longevity with 270 days results in a reduction of 210 kg of CO_2-equivalent GHG emissions per cow. The increase of longevity after implementing Product Y is beneficial for the environmental performance of the companies, also it enhances the cow welfare, which is related to the social pillar of CSR.
We can conclude that the Product Y implementation increases the longevity of the herd, and therefore improves the performance of the economic, environmental, and social pillar of CSR.

5.3.2. Fertility

As mentioned in Section 1.3, cows show estrus around every 21 days. Calculating the insemination rate for every month is a complex task, because of the different estrus cycles of very cow. Writing code for this is out of the scope for this thesis project. Therefore, we decided to only include the first insemination of the lactation that is found in the dataset. Calculating the insemination rate for the first insemination of the lactation is a less comprehensive task, since this is the voluntary waiting period (VWP) plus 21 days. The VWP is a management choice and is defined as the time between parturition and the time at with the cow is first eligible for insemination (Inchaisri et al, 2011). The VWP is a number of days and could be inferred from the available data. For example, the VWP of Company A was around 50 days until June 2020, afterwards they increased it to 60 days (see Appendix I for the code and visualization).
The first three months of data are left out for measurement of these KPIs. The data of the first three months became unreliable because of cows that started the lactation before the starting date of the dataset. We only want to use the first insemination of the cow's lactation. Therefore, we selected all the first insemination in a cow's lactation that could be recognized in the dataset. However, some of the first recognized inseminations in the dataset were not the first insemination of the cow, the actual first insemination originated before the stating date of the dataset. After three months, these cows became pregnant or had been inseminated once, which made the data reliable again. So, while interpreting and assessing the fertility KPIs, we need to keep these data constraints in mind, since a lot of data has been excluded in the measurement of the KPIs.

5.3.2.1. Conception rate

To calculate the conception rate we will divide the successful inseminations by the amount of inseminations. Both defined from the first insemination of a lactation.

KPI 3 $$Conception\ rate = \frac{\#\ Successfull\ inseminations}{\#\ Inseminations}$$

To check the results of the insemination, farmers execute a pregnancy test around five weeks after the breeding (Fricke, 2016). Because of the pregnancy test, all insemination results of December 2021 were not yet available at the data extraction date. We recognized a lot of missing values in December 2021 (75.2 percent), while the average is 4.83 percent. The percentage of missing values in November 2021 is lower than average, so we marked that as reliable data. Therefore, we decided to delete the data of December 2021. The same

method was applied to the data of Company B (code and output can be seen in Appendix J). November 2021 (22.4 percent) and December 2021 (88.8 percent) had a significant amount of missing values, because of that we removed the data from both months from the dataset.

Both datasets have some missing values that are caused by cows that have exit between the insemination date and the pregnancy test date. These data records do not have an insemination result, because of that we decided to delete this data.

Company A

Year	2019	2020	2021
Conception rate	39.2%	48.8%	44.7%
Relative change	0%	+24.4%	+14.2%

Table 5: KPI 3 results of Company A

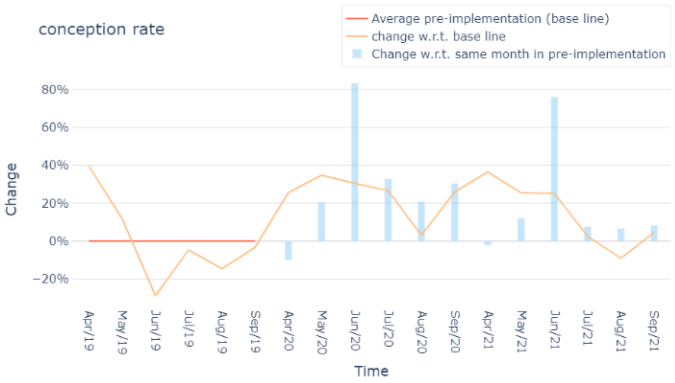


Figure 9: KPI 3 measurement of Company A

The conception rate of Company A in post-implementation overperformed consistently compared to pre-implementation. Table 5 shows the yearly performance, we can see that both post-implementation years perform better compared to pre-implementation. Figure 9 shows spikes in the July months of post-implementation. This is the performance compared to July pre-implementation, which significantly underperformed. Because of that we see two spikes in the July months of post-implementation.
The farmer became more successful in inseminating, however the effects are not statistically significant (p-value of 0.1041), which is caused by the high variance between the performance of the months, on average there were 240 first inseminations per month. The increased conception rate made the farmer more successful in inseminating, less insemination moments, and so less labour and sperm is needed to make the cows pregnant, which is beneficial for the economic performance of the farmer.

Company B:

After the general data cleaning steps that were discussed in Section 5.1.1 and the KPI specific data cleaning steps that were addressed earlier in this sub-section, the data from Company B still had 242 missing values. After some discussions and research, we could not find, next to administration errors a specific reason for this missing data. The amount of missing data accounts for 1.2 percent of all recorded data. We decided to delete the rows that had no insemination result.

Year	2019	2020	2021
Conception rate	45.8%	45.3%	45.3%
Relative change	0%	-1.2%	1.2%

Table 6: KPI 3 results of Company B

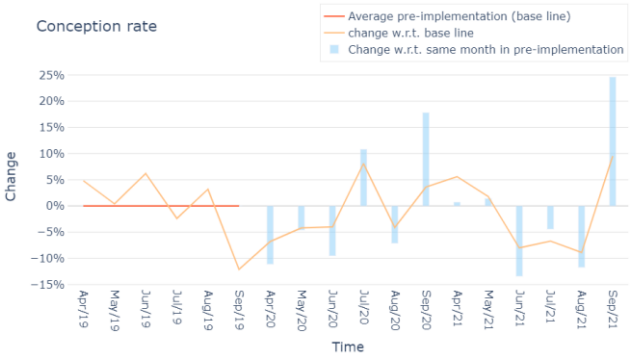


Figure 10: KPI 3 measurement of Company B

As assumed, the conception rate effects for Company B are not statistically significant (p-value of 0.7302), out of on average 290 first inseminations per month.
We have to note that Company B is mostly applying a hormone program to force the first heat of the cow, 88.5 percent of the cases versus 67.1 percent in the whole dataset of Company B. As mentioned in Section 2.2, Product Y can recognize the heat of a cow and helps the farmer with determining the optimal insemination moment. While applying a hormone program, the farmer inseminates the cow a fixed number of days after the injection of the hormones. Therefore, the measured KPIs of Company B are not directly relevant to assess the effects of implementing Product Y related to reproduction performance. However, having the knowledge that Company B is not adapting their reproduction strategy after implementing Product Y is interesting. After the KPI measurements of Company B we were interested why Company B still applies hormone programs for the first insemination in a lactation. We talked with the person within Company X that has contact with Company B and gathered the data. That person mentioned that Company B still relies on a strategy that says that applying hormone programs for the first insemination in a lactation is beneficial for the overall reproduction performance. However, Company B is using Product Y to detect heats and determine the optimal insemination moments for the other inseminations (Company X, 2022d).

5.3.2.2. Insemination rate

The insemination rate is calculated by dividing the amount of cows that has been inseminated within a DIM that is lower or equal to the VWP plus 21 days with the total amount of cows that has been inseminated, again only for the first heat of the cow's lactation for the first time in the lactation.

KPI 4 $$Insemination\ rate = \frac{\#\ Inseminations\ with\ DIM \leq VWP + 21}{\#\ First\ inseminations\ of\ lactation}$$

Company A:

Year	2019	2020	2021
Insemination rate	43.1%	53.5%	58.7%
Relative change	0%	+24%	+36.1%

Table 7: KPI 4 results of Company A

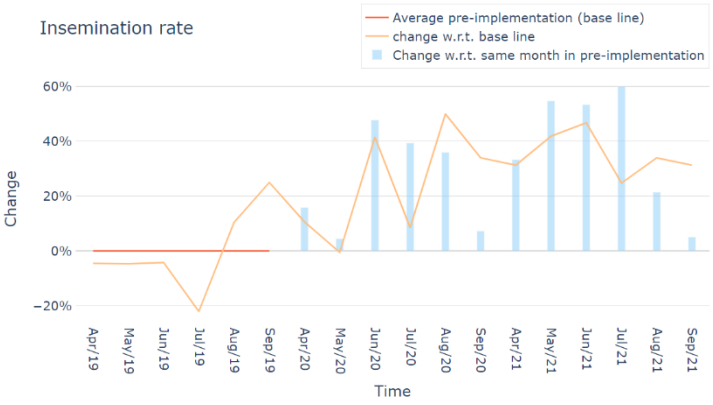


Figure 11: KPI 4 measurement of Company A

The insemination rate increased positively in post-implementation period. We are able to reject the null hypothesis and accept the alternative hypothesis, with an p-value of 0.0046. In the data we discovered that Company A inseminates the first heat based on labour heat detection or heat detection via a PLF solution. If the first heat in a lactation is not detected, the farmer applies a hormone program afterwards. Figure 38 in Appendix L displays the categorized heat detection method over time, Figure 39 [LEFT OUT] and Figure 40 [LEFT OUT] in Appendix L are two example months of pre- and post-implementation. Based on these figures and the measurement of the KPI, we can identify that the farmer was able to inseminate more cows in their first heat, which is beneficial for the insemination rate, and so for the reproduction performance of the herd. Also, the farmer applied less hormone programs, which means that the cows are inseminated in a more natural manner.

Company B:

Year	2019	2020	2021
Insemination rate	99.5%	99.1%	97.7%
Relative change	0%	-0.4%	-1.8%

Table 8: KPI 4 results of Company B

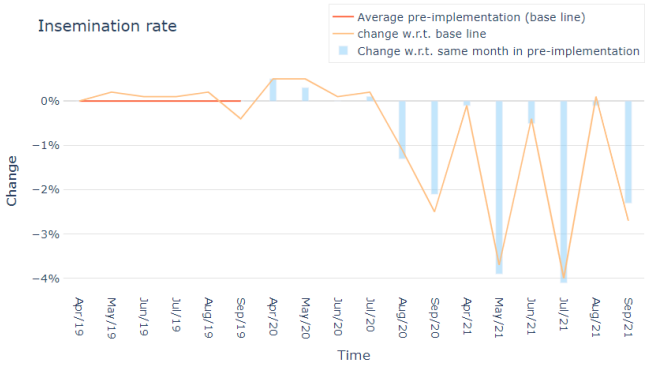


Figure 12: KPI 4 measurement of Company B

We failed in rejecting the null hypothesis (p-value of 0.0843). As mentioned in Sub-Section 5.3.2.1, Company B relies on a strategy to use a protocol for applying hormone program to all cows for the first insemination in the lactation. Because of that, (almost) all cows get inseminated within VWP and VWP plus 21 days. Therefore, this KPI value is not relevant for our research, however the fact that they are still using this protocol after the implementation of Product Y is useful information.

5.3.2.3. Pregnancy rate

The pregnancy rate is calculated by multiplying the conception rate with the insemination rate.

KPI 5 $Pregnancy\ rate = Conception\ rate \times Insemination\ rate$

Company A:

Year	2019	2020	2021
Pregnancy rate	17%	22.8%	25.7%
Relative change	0%	+34.1%	+50.1%

Table 9: KPI 5 results of Company A

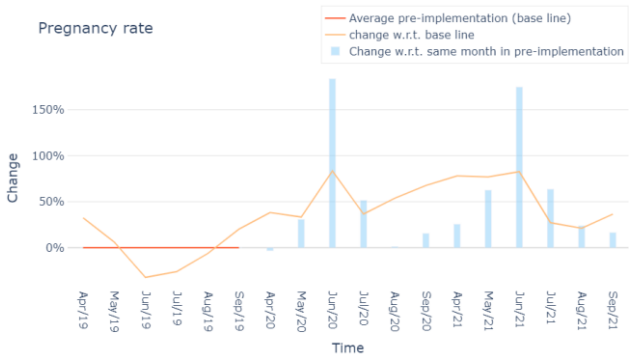


Figure 13: KPI 5 measurement of Company A

Both the conception rate as the insemination rate improved significantly for Company A, we are also able to reject the null hypothesis and accept the alternative hypothesis for the insemination rate, with a p-value of 0.0112. The post-implementation months performed consistently better compared to pre-implementation. This means that more cows got pregnant after the first insemination at Company B.

Company B:

Year	2019	2020	2021
Pregnancy rate	45.6%	44.8%	44.2%
Relative change	0%	-1.7%	-3%

Table 10: KPI 5 results of Company B

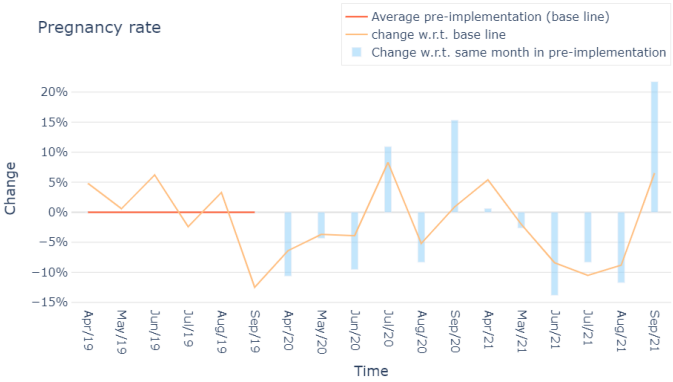


Figure 14: KPI 5 measurement of Company B

Figure 14 and Table 10 shows that the reproduction performance of Company B did not change constantly over time. Also, the effects are not statistically significant (p-value of 0.5023).

5.3.2.4. Intermediate conclusion

We found several interesting results in the measurement of the fertility KPIs, since both companies have quite different results, we will discuss them separately.
After implementing Product Y, the reproduction performance of Company A improved significantly, compared to pre-implementation. Company A also had a PLF solution before the implementation of Product Y, we can see that Product Y performs better compared to Product W and Product Z. Both the conception rate and the insemination rate increased. Product Y performed better at detecting heats, on which the farmer reacted, this has to do with the insemination rate. Also, with determining the optimal insemination moment, which as to do with the conception rate, Product Y performed better compared to the predecessors. Product Y outperformed his predecessors on reproduction performance, which is quite valuable information to have, since an expected reproduction performance is one of the main reasons the clients to invest in Product Y, as mentioned in Section 2.2. The increase of reproduction performance is beneficial for the economic performance of company A, the farmer needs less inseminations to make the cow pregnant, which reduces the labour and sperm costs. Also, since a lot of culling are related to poor reproduction performance, the increase fertility is beneficial for the longevity.
The reproduction performance of Company B did not change for the first inseminations in a lactation. Company B a good example of dependence of Product Y related to the management choices and strategies. Company B did not change their insemination strategy for the first insemination in a lactation. Instead of using the abilities of Product Y, they kept trusting on the performance of applying hormone programs for the first insemination in a lactation.

5.3.3. Cow health

5.3.3.1. Percentage of early lactation exit

To measure this KPI, we need to have the DIM at the exit date, this could be ensured by subtracting the exit date of the cow with the calving date, which is the start of its lactation.

KPI 6 $$Percentage\ of\ cows\ exit\ in\ DIM \leq 60 = \frac{\#\ Cows\ which\ exits\ within\ DIM \leq 60}{\#\ Exits}$$

This KPI can be measured in different manners. For example, the KPI value for January 2019 means: the percentage of cows that calved in January 2019 and subsequently exits in DIM <= 60. This means that we can measure the KPI for a month 60 days after the month is finished. To ensure reliable research results and consistency, we deleted the data from November 2021 and December 2021, since the data from these months is not reliable at the data extraction date.

Company A:

Year	2019	2020	2021
% of exit DIM <= 60	11.3%	12.3%	10.9%
Relative change	0%	+8.9%	-3.7%

Table 11: KPI 6 results of Company

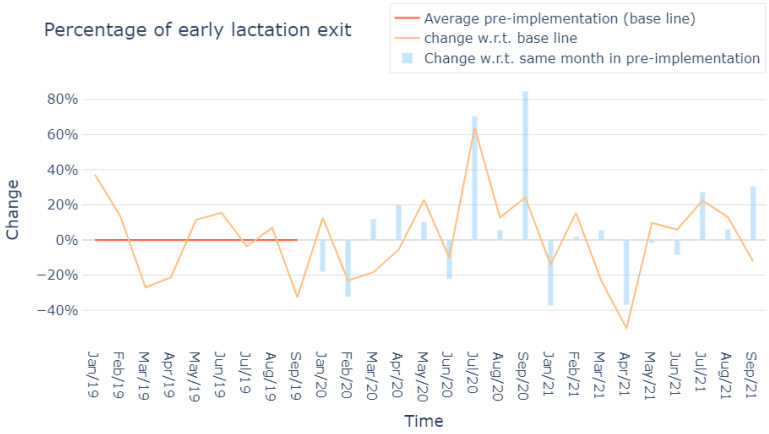


Figure 15: KPI 6 measurement of Company A

On average, 260 cows start a new lactation in a month. As shown in Table 11, in the first nine months of 2019, 11.3 percent of the cows had an early lactation exit (DIM <= 60). The year averages of early lactation exit at Company A did not differ a lot and also not consistently. We failed to reject the null hypothesis (p-value of 0.7924), which means that the farmer was not able to prevent more drastic cow disorders. Several reasons can be devised why there are no affects in this KPI performance. While the urgent attentions of Product Y are one of the main reasons why farmer invest in Product Y, Company A did not benefit from that aspect.

Company B:

Year	2019	2020	2021
% of exit DIM <= 60	14.6%	8.9%	10.7%
Relative change	0%	-39.1%	-26.3%

Table 12: KPI 6 results of Company B

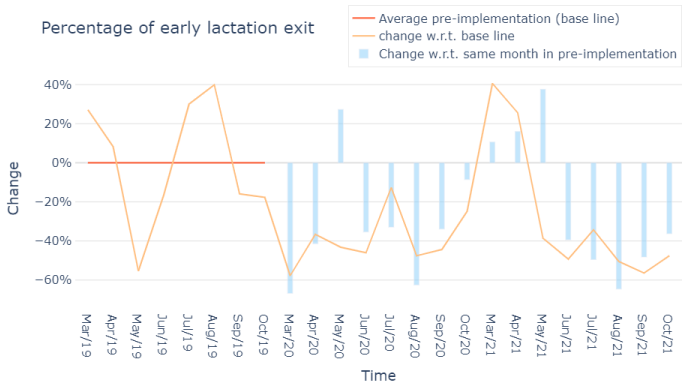


Figure 16: KPI 6 measurement of Company B

On average, 320 cows start a new lactation in a month at Company B. As shown in Table Table 12, both post-implementation years performed significantly better compared to pre-implementation. In Figure 16, we can see that most months performs better. The effect can be marked as significant (p-value of 0.0103). As mentioned in Sub Section 5.3.1.1, the relatively bad performance in March, April, and May were caused by selling fresh cows to another farm. We are able to reject the null hypothesis, which means that the percentage of cows that has an early lactation exit at Company B decreases significantly.

5.3.3.2. Percentage of on-farm mortality

Because of the economic consequences of mortality at farm, farmers try to minimize the amount of the mortality rate as much as possible. The mortality rate is the amount of mortalities at farm compared to all exits.

KPI 7 $Mortality\ rate = \frac{\#\ Mortalities\ on\ farm}{\#\ Exits}$

Company A:

Year	2019	2020	2021
Mortality rate	12.2%	12.9%	10.4%
Relative change	0%	+5.4%	-15%

Table 13: KPI 7 results of Company A

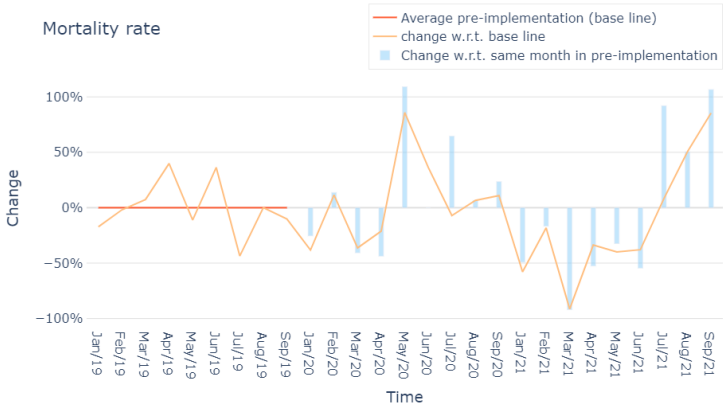


Figure 17: KPI 7 measurement of Company A

On average, there are 80 exists per month at Company A, so approximately 9 mortalities at farm. This makes the KPI quantification sensitive for high variations in the KPI value, which can be noticed from Figure 17. However, the mortality rate did not perform consistently better or worse, with the statistical test, we failed in rejecting the null hypothesis (p-value of 0.7389).

Company B:

Year	2019	2020	2021
Mortality rate	6.6%	6.7%	10.1%
Relative change	0%	+1.4%	+53.5%

Table 14: KPI 7 results of Company B

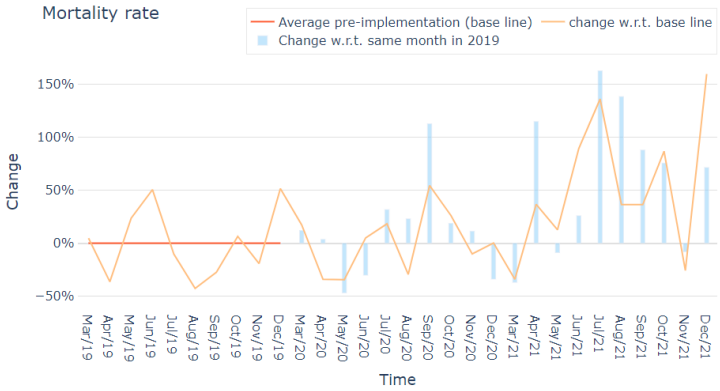


Figure 18: KPI 7 measurement of Company B

On average, 135 exits occur per month at Company B, so around 11 mortalities at farm. We can observe big changes in 2021, compared to pre-implementation, however we are still unable to reject the null hypothesis (p-value of 0.1061). At first glance we might think the effects are significant, however because of the high variances of the KPI value, the alternative hypothesis cannot be accepted. Sometimes big changes can be seen, but because of the high variance, the data has inadequate statistical power to reject the null hypothesis (Frost, 2020). As mentioned earlier in this section, the KPI value is sensitive for high variations, because of the low absolute values. For further research, it could be useful to measure the KPI values for every quartile instead of every month. This makes the absolute values higher, and so, less sensitive for high variances.
However, Table 14 and Figure 18 indicates that the mortality rate increased after implementing Product Y. After an interview with Company X's contact person of Company B we found out that it was caused by a series of wrong implemented embryos in cows in 2021. Some embryos became too big which resulted in several mortalities (Company X, 2022d).

5.3.3.3. Conclusion performance aspect

While interpreting these results, we have to understand that the results are dependent on the way the farmer acts after identifying a disorder. As mentioned in Section 3.1, the farmer can treat the cow, to trying to heal her. The farmer can also choose to cull the cows, which gives the farmer a financial compensation for the meat.

For Company A, both cow health KPIs did not change significantly after the Product Y implementation. The farmer was not able to prevent or timely intervene on disorders on cows in early lactation. Also, the mortality rate did not change after the implementation. It could be that the disorders where not detected in time by Product Y. It is interesting for further investigators to further examine why these cow health KPIs did not perform better, since this is one of the main reasons of Company X's clients to invest in Product Y, as mentioned in Section 2.2.
Both KPI measurements of Company B showed results. The amount of early lactation exits decreased, which is positive, while the amount of mortalities increased. The two KPI results are contradicting each other. However, the reason that caused the increased mortalities, the wrong embryo implementations, as mentioned in Sub-Section 5.3.3.2, makes the contradiction clear. The wrong implemented embryos do not influence the early lactation exits, since the embryos are not placed in the beginning of a lactation.
Because of the decreased percentage of early lactation exits, the economic performance of the farmer increases, since more cows can pay out the invested money for another lactation.
The increased percentage of mortalities after the Product Y implementation caused negative economic consequences, because of draining costs and missed meat revenue. Also, the increased mortality negatively affects the longevity of the herd.

5.3.4. Milk production

5.3.4.1. Average expected milk production

Both datasets include a column which indicates the 305-day milk yield, in kgs for Company A and pounds (lbs) for Company B. This value is the expected milk yield over the current lactation of the cow. This parameter is based on a certain amount of test days and is an important basis for the selection decision of a farmer (Kong, et al., 2018). The expected value is based on the amount of milk the cow gives on the specific test moments, which is then converted to the expected amount of milk the cow will give in that lactation.
The method predicts the milk yield more accurately when the amount of test days increase (Kong, et al., 2018). We aim to have a reliable research as possible to ensure this, we only use predicted milk yield values that are based on at least three test moments. Some records in the datasets are based on one or two test moments, which meant that the cow has been culled or died before the third test moment.

KPI 8 $$Milkproduction = \frac{\sum Expected\ milkproduction}{\#\ Calved\ cows}$$

The KPI will be measured for every month and the number indicates the expected milk yield for the cows that has calved in this month. This means that the KPI value for a month is finished after the cows had at least three test moments.

To measure the milk production KPI we will use the median instead of the mean. Figure 34 in Appendix K displays the distribution of the expected milk yield of Company A in 2020, the distribution looks like a well-fitting normal distribution. Figure 33 in Appendix K displays the distribution of the expected milk yield of Company A in 2020, the distribution looks less like a good-fitting normal distribution. Since there are relatively more outliers, the mean of the expected milk yield varies more over time. The number of lower tail outliers significantly affect the mean, which gives a spiky graph Figure 35 Appendix K. The relatively small sample size of the measured milk yield of a month is sensitive for outliers. The median is less sensitive for outliers (Leys et al., 2013), this results in a less fluctuating graph. Therefore, we decided to use the median of every month as KPI value.

Company A:

Figure 36 of Appendix K indicates that around 77 percent of the cows have their third test day before DIM 95. This means that there is a delay of three months before the KPI of a month gets reliable, because of that, we will exclude the last three months in this research.

Year	2019	2020	2021
Expected milk production (kg)	9670	10216	10795
Relative change	0%	+5.6%	+11.6%

Table 15: KPI 8 results of Company A

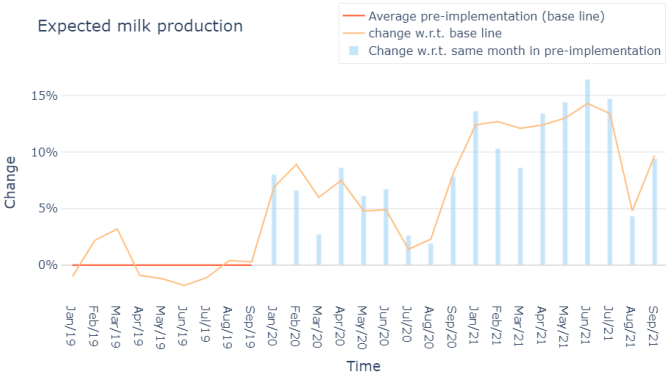


Figure 19: KPI 8 measurement of Company A

As Figure 19 displays, the expected milk production increases steadily overtime. By performing the Welch's T-Test, we are able to reject the null hypothesis confidently (p-value less than 0.0001). Table 15 indicates that the expected milk production increased in both years after implementing Product Y. This means that the farmer reached a higher productivity in a cow's lactation.

Company B:

The dataset of Company B had a lot of missing values in the third test day column. In contrast to the data of Company A, we do not have the test day dates. However, Figure 37 of Appendix K shows us that the cows that were culled after 220 of DIM all had at least three test days. This means that we need to remove the last seven months to retain consistent measurement, which will result in three valid months of reliable data for each year. We decided to remove 2021 of this KPI measurement to compare the last ten months of 2019 with the corresponding months of 2020.

Year	2019	2020
Expected milk production (lb)	26301	27086
Relative change	0%	+3%

Table 16: KPI 8 results of Company B

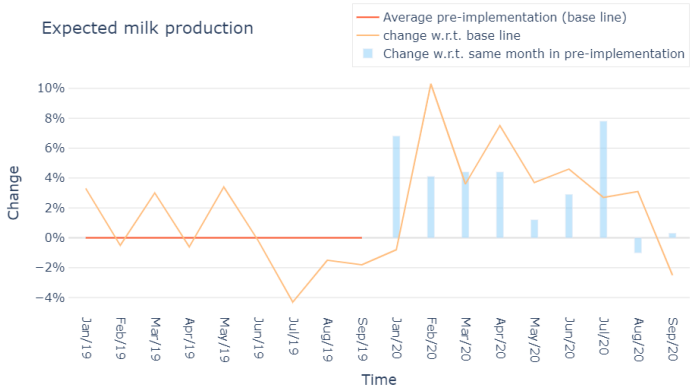


Figure 20: KPI 8 measurement of Company B

The post-implementation expected milk production increased on average 3 percent compared to pre-implementation. However, we failed to reject the null hypothesis (p-value of 0.0673).

5.3.4.2. Conclusion performance aspect

Both companies showed an increase in the expected milk production. We can wonder to what extent the increased milk production is due to the implementation of Product Y, but for now we assume that the circumstances and other management strategies did not change. This means that we can conclude that the implementation of Product Y has a positive influence on the productivity of the companies. This is beneficial for the economic

performance but also for the environmental impact, since the cows has produced more milk, while the emissions kept the same.

5.3.5. Labour

5.3.5.1. Percentage heat detection based on labour

As mentioned in Sub-Section 5.3.2.2, the datasets indicates the heat detection method for every insemination. Table 24 and Figure 41 for Company A, Table 25 and Figure 42 for Company B in Appendix L indicate the codes of the dataset and how they are categorized. Based on these codes we can distinguish heat detection method between labour and non-labour. Heat detection based on labour means that the farmer spends time in detection of verifying the heat of a cow.

KPI 9 $$Percentages\ of\ insemanations\ based\ on\ labour\ heat\ detection\ = \frac{\#\ Insemination\ based\ on\ labour\ heat\ detection}{\#\ Inseminations}$$

Company A:

Year	2019	2020	2021
Inseminations based on labour	10.4%	0.5%	0.2%
Relative change	0%	-95.1%	-98%

Table 17: KPI 9 results of Company A

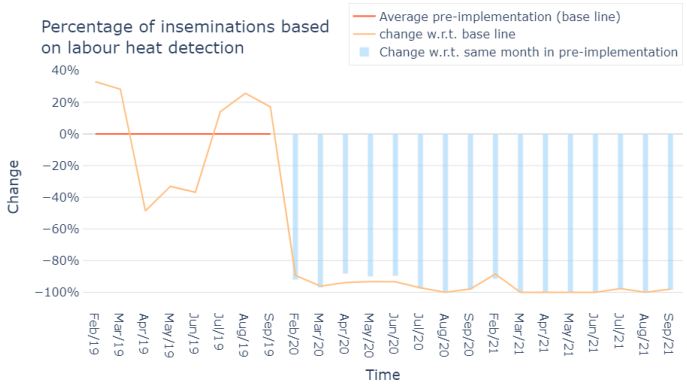


Figure 21: KPI 9 measurement of Company A

On average, 450 insemination are executed at Company A per month. The percentage of inseminations based on labour heat detection decreases statistically significant with an p-value of less than 0.00007. Company A already applied a PLF solution before the Product Y implementation, however after the Product Y implementation the amount of inseminations based on labour heat detection decreases significantly. Company A trusted on the abilities of Product Y, which resulted in a lower percentage of labour heat detection, while the reproduction performance increased significantly, as shown in Sub-Section 5.3.2.

Company B:

The heat detection column in the dataset of Company B includes some values that indicates the insemination method (e.g. embryo transfer) instead of the heat detection method. The heat detection method of these inseminations is unknown. The data record accounts for 7.5 percent of the dataset. We decided to remove the data that did not specify the heat detection method.

Year	2019	2020	2021
Inseminations based on labour	12.7%	0.7%	0%
Relative change	0%	-94.6%	-100%

Table 18: KPI 9 results of Company B

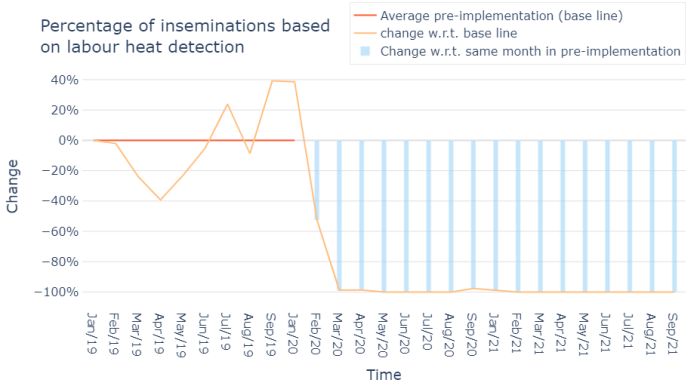


Figure 22: KPI 9 measurement of Company B

On average 620 inseminations are executed per month at Company B. As can be seen in Table 18 and Figure 22, the amount of insemination based on labour heat detection decreased significantly (p-value of considerably less than 0.05) after the Product Y implementation. The farmer spend way less time in detecting heats, this saved time can be invested in executing other activities at the farm.

5.3.5.2. *Conclusion performance aspect*

Labour was identified as one of the most important resources of a farm. The implementation of Product Y at Company A and Company B resulted in a significant decrease of labour time that is invested in detecting heats.
Company A already used a PLF solution before the Product Y implementation. However, the amount of inseminations based on labour has significantly decreased when Product Y is applied. Either the farmer trusted more on the abilities of Product Y or Product Y detected the heat faster than the farmer. The same holds for Company B, which did not have a PLF solution before the Product Y implementation. Company B only applies hormone programs at the first insemination of a lactation, which do not require heat detection, however after the first insemination they apply more natural heat detection. We can also conclude for Company B that the amount of time spend on detecting heats has decreased significantly. These reductions are beneficial for the efficiency of the farmer and so, for the economic performance of the companies. Less time is spend on detecting heats, which enables the farmer to apply the saved time on other activities. Also, the application of Product Y is beneficial for the development of the employees, which contributes to the social pillar of CSR.

5.4. Associated results to CSR

In this section, we associate the results of the data analysis with the pillars of CSR. We have defined and explained the performance aspects in Chapter 3, based on the most important factors for every performance aspect we formulated KPIs in Chapter 4, these KPIs are measured in Chapter 5.

5.4.1. Economical pillar

The performance of the economical pillar of CSR is influenced by the following performance aspects; longevity, fertility, cow health, milk production & labour. The longevity increased significant by three out of the four KPI measurements, which means that the implementation of Product Y has positive effects on the longevity of the herd of Company A & Company B. This is beneficial for the economic performance of the companies. As mentioned in Section 3.1, an increased longevity requires less youngstock, and so less replacement costs. When using the abilities of Product Y to detect heats and inseminate cows on the suggested insemination moment, the fertility performance improves, as we can see for Company A. When the reproduction performance improves, less inseminations are needed in order to make cows pregnant. This results in less insemination labour and sperm costs, which is beneficial for the economic performance of the company. Also, an improved reproduction performance results in less culling based on fertility, which is beneficial for the longevity. Moreover, for both companies, these inseminations are based on less labour detected heats. KPI 9 indicates that after the Product Y implementation the farmer hardly inseminated a cow based on labour heat detection. The farmers trust on the ability of Product Y to detect the heat, which enable the farmers to spend their time to other activities, which is beneficial for the efficiency of the employees and so, for the economic performance of the companies. The cow health KPIs did not perform constantly better or worse. We identified that Company B had more mortalities on farm, which resulted in negative economic consequences although, less cows were culled in early lactation, which is beneficial for the return on the cows. While Company B showed interesting results for the cow health KPIs, Company A did not perform different on these KPIs. The milk production increased for both companies after implementing Product Y, whereof Company A

significantly. This means that the companies are producing more of its primary output, which improves the economic performance.
When implementing and applying the abilities of Product Y, we can conclude that the economic performance of the farm improves for the most aspects.

5.4.2. Environmental pillar

The environmental pillar is affected by the longevity, cow health, fertility, and milk production. The increased longevity positively affects the environmental performance of the companies. When cows has a longer lifespan and so, has a longer productive life stage, less youngstock is needed on the farm to replace cows. This requires less feeding, manure disposal, and other resources, which results in a lower emission. These affects are applicable for both analysed companies. By using the abilities of Product Y to inseminate cows, Company A managed to improve the fertility performance. This will result in less involuntary culling, which improves the longevity and so, the environmental performance of the company. The milk production improved for both companies, while in inputs kept the same the output increased. This is beneficial for the environmental performance of the farms, since there are less emissions per kg produced milk. No significant differences were found in the cow health performance of the analysed companies. While we recognized that cow disorders has drastic consequences, the companies did not manage to performance constantly better compared to pre-implementation. Huge potential for environmental improvements can made when cow health improves, since we identified that cow disorders drastically reduced the condition and productivity of a cow. Which results in lower milk production and poor reproduction performance. However, the other performance aspect related to the environmental pillar performed better, which made the operations of the analysed companies more environmental responsible.

5.4.3. Social pillar

The responsible operation of the companies related to the social pillar of CSR is influenced by the longevity, fertility, cow health, and the labour aspect.
As mentioned in Section 3.1.1, an increasement in cow longevity is beneficial for the cow welfare. Also, the cow welfare became more important in public debate when the society puts pressure on the importance of cow welfare. The significant changes in longevity is beneficial for the cow welfare and helps the companies with complying to the needs of society, this means that the increasement in longevity is beneficial for the social pillar of CSR. The improved longevity performance is influenced by the fertility of the herd, the increased reproduction performance of Company A causes less culling related to fertility. This is beneficial for the welfare of the cow and so, for the responsible operation of the company related to the social pillar. In Section 3.1, we mentioned that PLF solutions can help dairy farmer with monitoring animal health and welfare, through timely reacting on critical diseases. However, we did not see significant changes in the KPI performance of the cow health KPIs.
In Sub-Section 1.2.2, we identified that that social pillar of CSR is also related to development of the employees on a farm. That fact that both companies are applying Product Y to detect heats and so, trying to inseminate the cows on the optimal insemination moment with the help of a modern PLF solution, is beneficial for the development of the employees on a farm. Which makes the company's operation more responsible to the social pillar of CSR.
We can conclude, based on the performance of the related aspects that the Product Y implementation is beneficial for the social performance of the companies.

5.5. Practical contribution

In this section, the practical contribution of the KPI measurements are discussed for the two research stakeholders namely, Company X and Company X's clients.

5.5.1. Company X

The measured KPIs, that were associated to a certain profoundly investigated performance aspect, resulted in some interesting research insights. These research insights brings some valuable knowledge that can be applied in practice. The main takeaway from the data analysis is, that the implementation of Product Y improves the environmental, economic, and social performance of a farm and so, Product Y is contributes to a more responsible operation of a farm. However, there are some more interesting research findings that are notifiable.

The qualitative evidence, that Company X already had is supplemented with quantified evidence. As mentioned in Section 1.2.2, clients expected an improved reproduction performance, less time spend on detecting heats, and a proper detection of urgent disorders, which could consequently lead to a better cow health. While the reproduction performance improved at the company that embraced the abilities of Product Y, cow health did not show significant better results at the analysed companies. Company X can use this knowledge to either inform the client to reshape their expectations, investigate the cow health effects more profoundly, or improve the product. Company X can also use the other research results namely, the increased longevity and milk production.

Product Y on itself does not have any influence on the operation of a farm, but the implementation and application of the abilities of Product Y does. Company X can inform the clients how to use Product Y effectively. The dependence of the effects of implementing Product Y related to the management strategy is clear. By quantifying effects of more companies, expected improvements can be showed, categorized on management strategies. Which could inform the client on how to apply Product Y most effectively.

5.5.2. Company X's clients

Company X's (potential) clients expects a return on investment. They mainly invest in Product Y to improve the reproduction performance, reduce the time spend on detecting heats, and to detect disorders in early stage. Mainly forested by economic incentives. The measured KPIs, that were related to the CSR pillars showed that not only the economic performance improved, but the Product Y implementation also contributes to a more responsible operation related to the environmental and social pillars of CSR.

On a widespread of factors, the two analysed companies performed better after the Product Y implementation. The expected ability of Product Y to detect disorders in early stage did not lead to a better cow health performance. However, the companies performed better in milk production and longevity, which are not included in the main reasons to invest in Product Y. This could also be caused by the interrelation between the effects. An improved cow health and reproduction performance can eventually result in an increased longevity and milk production, as mentioned in Section 3.1

Just implementing Product Y without adapting management strategies might not lead to the highest return on investment. Farms that implement Product Y should be receptive to adjust management strategies that complies with the abilities of Product Y. Not applying proper management strategies might not lead to any effect, as we have seen for the fertility performance of Company B. This does not mean that Company B is missing something, their strategy might be more efficient. We just want to make (potential) clients aware that implementing Product Y, while applying certain management strategies might not lead to any effect at all.

5.6. Conclusion

The main aim of this chapter was to measure the formulated KPIs. We started with the description of the most important data preparation steps. A lot of data has been excluded from the KPI measurements, because of one of the following reasons: the data was originated from 2022, derived from youngstock, or the data was unreliable because of a transition period. The Welch's T-Test was identified as the most suitable statistical test for

the calculation of the significance of the results. Next, in Section 5.3 we measured the KPIs for every performance aspect. We identified interesting results from the measurements, no KPI performed post-implementation statistically worse, compared to pre-implementation. The implementation of Product Y had a positive effect on all the performance aspect, except from the cow health aspect. We didn't find consistent significant differences in the performance of the cow health KPIs. Notifiable effects were found in fertility aspect performance, Company A used the abilities of Product Y to detect heats and inseminate the cows on the suggested insemination moment. This resulted in a significant positive increase of the reproduction performance. However, Company B kept applying hormone programs in the first insemination of the lactation because of that, no effects were identifying in the fertility performance of Company B. By associating the KPI measurements to the pillars of CSR, we found out that the implementation of Product Y contributes to a more responsible operation to all the pillars of CSR.

6. Development and design of the impact dashboard

In this chapter, the development and the design of the suggested impact dashboard is shown. This knowledge is obtained by answering the following research question: How to visualize the measured KPIs in an impact dashboard? The chapter is divided into four section. First, based on literature we investigate the way to provide an user-friendly dashboard. Second, the requirements of the suggested dashboard are discussed. Third, the suggested dashboard design is shown, including explanation of the dashboard parts. Last, the chapter ends with a conclusion.

6.1. User-friendly impact dashboard

The goal of the dashboard is to show the effects of implementing Product Y to the user. The users of the dashboard are the research stakeholders, which are discussed in Section 1.3. To provide an effective dashboard, it is essential to understand the users of the dashboard. We must know the purposes of the users and involve the user in the development process of the dashboard to ensure we achieve the intended purpose (Laurent et al., 2021). We aim at developing an effective dashboard, which means that the user should be able to directly see the useful KPIs of certain performance aspects. Furthermore, the impact dashboard should look attractive, which means that the dashboard layout and design is chosen accordingly. Both user-friendly requirements will be discussed separately below.

First, a user-friendly dashboard must be effective, which means for our impact dashboard that the user can directly see the performance of certain KPIs. It must be clear what every part of the dashboard indicates. Selecting the right data is important to obtain this. Right data can be chosen by studying which data and data visualization is the most relevant for the specific part or topic in the dashboard (Janes et al., 2013). Therefore, the front page must be non-detailed and straightforward. Other pages behind the front page can be more specific, where we can zoom into the details of the performance aspects.

Second, a user-friendly dashboard must look attractive. The attractiveness of a dashboard has to do with the user interface (UI). The UI is recognized as an important part of the design process, in which for instance layout, colours, navigation, and icons into account (Pastushenko et al., 2018).
Malik (2005) states some useful guidelines for colour picking on a dashboard. Banners, navigation, tabs, and borders should have a light or neutral colour. Visualization and other key messages should have their own colour scheme to differentiate from the other functional elements and background. Furthermore, big graphics such as company logos must be avoided. During the development of the dashboard we take the guidelines of Malik (2005) into account.
Different layout guidelines can be found on the information page of Microsoft (2022), the most applicable and relevant ones for our dashboard are mentioned: we must categorize the layout of the dashboard on subjects to ensure we keep related visualizations and KPIs near each other. No variation in data visualization is done, also the axes scales and graph colours are kept consistent. Lastly, the axes are scaled as clearly as possible.

6.2. Impact dashboard requirements

The dashboard must include various objects to give the user the ability to assess the performance of the KPI as effective as possible. The requirements including motivation are summarized in Table 19 below.

Requirement	Motive
Display all performance aspects separately	The user must be able to assess all performance aspects separately. The front page must include at least one object of every aspect.
Ability to open detailed performance aspect overview	The user must be able to evaluate every performance aspect in detail. This detailed overview should indicate the performance of the aspect extensively.
Ability to adjust timeframe	The dashboard should have a high degree of flexibility. The ability to adjust the timeframe ensures that the use can assess the aspects for a certain self-chosen time period.
Relation of the performance aspects to the CSR pillars(s)	The dashboard must indicate the relation between the performance aspects and the CSR pillars.
Showing the general and seasonally adjusted performance	The user must be able to assess the KPI compared to the general performance and the seasonal adjusted performance. General performance means the performance of the KPI related to the average of pre-implementation.

Table 19: Requirements for Company X's impact dashboard

6.3. Impact dashboard demonstration

Figure 23 [LEFT OUT] shows the front page of the impact dashboard, Company A is used for illustration.

The front page is divided in sevens part, starting off with the header; which includes Company X's logo on the left, the impact dashboard title in the middle of the page and the name of the specific company on the right. Company X's branding colour, which can be recognized multiple times in the dashboard, is used as header colour. Next, all five performance aspects get a spot on at the front page. We have chosen to include the most interesting KPI for every performance aspect at the front page. Every performance aspect element includes a graph. These graphs have the same design and purposes as the KPI visualizations depicted in Chapter 5. The graph design is explained in the introduction of Section 5.3. Furthermore, every performance aspect element features the related CSR icons: a green square with the average percentage change and a green plus icon. These components are more extensively discussed in Table 20. The last elements of the front page consist of three parts: (1) a graph legend, (2) a CSR pillars legend, and (3) a time range indicator. The graph legend includes the meaning of the blue bars and the orange line in the graph. When the user hovers over the information icon next to the green square, the dashboard shows the explanation of the green box. The second element is the CSR pillars legend, which is explained in detail in Table 20. In the last part, the user is able to adjust the time range of the displayed items on the dashboard. Via an integrated "range slider" the user can set the desired time range.

When clicking on a green plus icon, the dashboard user gets directed to the specific performance aspect page, which is illustrated for the fertility performance aspect in Figure 24 [LEFT OUT]. The fertility performance page consists of five elements: The header which follows the same design as in the front page, plus added CSR icons, which are displayed in the header for the specific performance aspects pages. Next, three KPI-specific graphs are

shown, including the KPI performance value. The last element on the page consists of the same content as at the front page, namely the graph legend, CSR pillars legend, and the time range setting.

Icon/shape	Description
+0.9%	This square shape indicates the average change of the seasonal adjusted performance of the KPI. The box turns green when the change is positive, meaning that the KPI performed better. The box turns red when the change is negative, meaning that the KPI performed worse. Example: The +0.9 percent for the longevity KPI at the front page means that the selected months in 2021 performed on average +0.9 percent better compared to the same months in pre-implementation.
	When the dashboard user clicks on the green circle, the user gets directed to the specific performance aspect page, in which the performance aspect in shown in detail.
CSR pillars	If this yellow money-icon is indicated at a figure, or at a performance aspect specific page, it indicates that the performance of the aspects can be related to the economic pillar of CSR.
	If this brown cow-icon is indicated at a figure, or at a performance aspect specific page, it indicates that the performance of the aspect can be related to the social pillar of CSR.
	If this green leaf-icon is indicated at a figure, or at a performance aspect specific page, it indicates that the performance of the aspect can be related to the sustainability pillar of CSR.
	This information icon is displayed several times in the dashboard. When the user hovers over this icon, extra information pops up, for example extra information about a CSR pillar icon.

Table 20: Explanation of the icons and features of Company X's impact dashboard

This figure has been left out due to confidentiality agreements

Figure 23: Front page of the suggested impact dashboard of Company X, for Company A as example. [LEFT OUT]

This figure has been left out due to confidentiality agreements

Figure 24: Specific performance aspect page of the suggest impact dashboard of Company X. The fertility page of Company A used as example. [LEFT OUT]

6.4. Conclusion

In this chapter, we delivered a design of the impact dashboard. We started with discussing which design requirements are necessary to comply to the expectations of the users. We found out the importance of the relation between the front page and the specific performance aspect pages. The front page must be clear, non-detailed, and straightforward.

The specific performance aspect pages must indicate the detailed performance of the performance aspects. To ensure flexibility for the user, the time range for which the KPIs are shown on the dashboard can be adjusted. The related pillars of every performance aspect are shown in the dashboard, so the user can assess what the effects indicate as contribution for the responsible operation of the farmer.

7. Conclusion

This this chapter, we will conclude the research. First, in Section 7.1, a summary of the research is given. Next, the recommendations for Company X's further investigators are given in Section 7.2. The discussion points of this research are addressed in Section 7.3 and the limitations in 7.4.

7.1. Summary

Company X did not have any quantified evidence related to the pillars of CSR about the implementation of Product Y. Company X did not had quantified evidence, because of the challenging activity of collecting data and the complexity of the many different aspects that influences the performance of a farmer. Hence, the main research question was:

What are the effects of implementing Product Y related to Corporate Social Responsibility (CSR)?

We started with describing the abilities of Product Y. Four different categories were identified. The category accurate timing is originated via de ability of Product Y to assist the farmer with detecting heats, based on the detection moment the optimal insemination moment can be determined. Other identified categories were, early interventions and feeding management. Based on these categories and literature study, we introduced five performance aspects namely, longevity, fertility, cow health, milk production, labour, and feeding management. The KPI formulation, measurement, and evaluation of these aspects are discussed separately. Because of data limitations, no KPIs are formulated for the feeding management aspect, therefore this aspect is excluded.

Longevity

Longevity is identified as an important aspect, less youngstock is needed when the longevity increases. Less youngstock means less investment costs and emissions. Also, increasing longevity is beneficial for the welfare of the cow because of that, this aspect is related to all the pillars of CSR. We formulated a lifetime trait and stayability trait KPI for this performance aspect. All measured longevity KPIs performed better after the Product Y implementation.

Fertility

We discovered the importance of proper reproduction performance, which is the next performance aspect called fertility. Poor reproduction performance is one of the main culling reasons, which affects the longevity. Also, an improved fertility is economic beneficial since less inseminations are needed, which required less investment costs. The main performance indicator of fertility is the pregnancy rate, which is derived from multiplying the insemination rate with the conception rate. Because of the importance of all these factors, we formulated separate a KPI for the conception rate, insemination rate, and the pregnancy rate. Company A embraced the abilities of Product Y, the reproduction performance of Company A increased significantly. Company B still relies on a strategy to apply hormone programs for the first insemination of a lactation. Therefore, their fertility performance did not change after the Product Y implementation.

Cow health

Lameness and milk fevers corresponds to the cow health aspect. These cow deviations heavily affect the reproduction performance and milk production negatively. Also, diseases entail huge costs of treatment and labour. Because of these costs, the cow health aspect is related to the economic pillar of CSR. The disorders cause involuntary culling and affects the health of the cow, which is negative for the welfare of a cow. Therefore, the cow health aspect is also related to the environmental and social pillar.

The measured cow health KPIs did not perform significantly different compared to pre-implementation. While time detection of disorders is one of the main reasons of farmer to invest in Product Y, no significant effects were found in the two analysed farms.

Milk production
Milk production accounts for the biggest income of a dairy farmer. Although the milk production is influenced by a lot of factors, we are interested if the milk production changes after implementing Product Y. An improved milk production results in less emissions per produced kg of milk. Moreover, an increased milk production results in more revenue for the farmer. Therefore, the milk production aspect is related to the economic and environmental pillar of CSR. We compared the pre- and post-implementation data to see any affects. For both analysed companies, the expected milk production increased. This means that the farmers increased their primary output, also the efficiency increased, which decreases the amount of emissions per kg produced milk.

Labour
We identified labour as a valuable resource of a farm, if Product Y affects the time that is spend on the activities of a farmer, the economical pillar of CSR is affected positively. Product Y could possibly take over the time of the farmer to detect heats, we formulated a KPI to compare the percentage of inseminations that is based on human heat detection. For both companies the amount of inseminations based on labour heat detection decreased significantly. At both companies, the employees spent less time detecting heats, this saved time can be invested in other activities, which increases the efficiency of a farm. Also, the application of Product Y is beneficial for the development of the employees therefore, the implementation of the data-driven decision-making tool is beneficial for the social pillar of CSR.

Association to CSR pillars
Except from the cow health aspect, all performance aspects improved after the Product Y implementation. The economic performance of the farms improved because of less youngstock investment is needed, less inseminations are needed to make cows pregnant, the milk production increased, and less labour is spent on detecting heats. The environmental performance of the farm improved because of less youngstock is needed, which reduces the emissions. Also, the emissions decrease because of less culling based on fertility and the milk production increases, which is beneficial for the efficiency of the farm. The Product Y implementation is beneficial for the social responsible operation of a farm, since the cows have a longer lifespan, which increases their welfare. Also, the Product Y implementation contributes to the development of the employees, since a modern decision making tool is applied.

Conclusion
By analysing pre- and post-implementation data, we identified that the Product Y implementation contributes to a more responsible operation of the farm, related to the economic, environmental, and social pillars of CSR. Mainly the increased longevity and fertility are the biggest gains for the farmer. However, the extent to which the effects of implementing Product Y are visible is dependent on the management strategies. The management should be receptive to adjust their strategies to embrace the abilities of Product Y. For example, we identified that the fertility performance of a farm can increase significantly by implementing Product Y. The reproduction performance of Company A increased after the Product Y implementation, while Company B did not embrace the abilities of Product Y, which resulted in no effects after the Product Y implementation related to the fertility performance for the first insemination in a lactation.

7.2. Recommendations for further research

As a most logic and common advice for further research is to collect more data, which is continually advocated for further research in data analysis research (Canessa et al., 2015). However, there are more interesting points for further researchers, next to data related advice, advice regarding the KPI formulation, enhancement of research reliability, and enrichments for the research will be addressed.

Data quantity

A lot of data has been excluded because of several reasons. To ensure seasonal adjusted results, we were enforced to exclude several months of data. Also, some KPI results are delayed with several months, for example the milk production, conception rate, pregnancy rate, and the percentage of early lactation exit. To compare full years of performance the time frame of the data needs to be extended. The collected data has a time range of three year, the KPI quantifications are based on average on 23.6 months of data. It is advised, to for example, extend the time range of the data to five years, most KPI measurements can then be based on four full years of data. Increasing the amount of data will lead to more reliable research results. Also, it will enable to formulate certain KPI different.

KPI formulation

Some KPIs are formulated differently than preferred, certain performance aspect can appended with extra KPIs or the KPIs can be formulated different.
It is preferable to replace KPI 1, the average age of exit, with the average length of the productive life stage of a cow. The length of productive life stage indicates the amount of time the cow generates output, which is more relevant to assess the efficiency of a farm.

In this research, we only investigated the successfulness of heat detection and inseminations. As mentioned in Sub-Section 1.2.2, an expected increase in reproduction performance is one of the main reasons of the farmers to invest in Product Y. An addition to measure the reproduction performance of a farm would be to include a KPI that indicates the number of days open. The number of days open is the time interval between calving and a successful insemination. It is one of the most important indicators of fertility and is influenced by the VWP, conception rate, and insemination rate (Bousquet et al., 2004). This KPI is interesting since the costs of one extra day of calving interval ranges between $0.08 and $4.04 per cow (Groenendaal et al., 2004; Inchaisri et al., 2011; Veerkamp et al., 2002).

In this research, we only measured the amount of milk that is expected in the lactation, we did not measure the frequency of the lactations. To complement the milk production measurements, the calving interval can be measured as KPI. The calving interval is defined as the interval between two calving moments. The calving interval is also related to the reproduction performance of the herd.

The cow health performance aspect can be complemented with the following KPI: the percentage of cows that dies at farm within 30 days after a disorder is detected. This KPI formulation fit to the abilities of Product Y, since one of the aims of implementing Product Y is to detect disorders in early stage to prevent drastic consequences. Regardless of the management strategy, the farmer tries to avoid mortality on farm, which makes this KPI valuable.

Research reliability

As mentioned earlier in this section, the research reliability will increase when more data is collected that can be used for this research. By the collection of more diverse data, in terms management strategies and countries, the research results will be more reliable and applicable for more farmers around the world.

At the moment, the research results are not sector adjusted. Sector adjusted means that the results are corrected by the performance of the whole sector. For example, the average age of exit at Company B increased with 11.1 percent in 2020 compared to 2019. Maybe average age of exit increased in the whole sector. By normalizing the results against the sector, the research reliability will increase and so, the quantified evidence of implementing Product Y.

Research enrichment
In this research, the fertility KPIs are only quantified for the first insemination in a lactation. An expected increase in reproduction performance is one of the main reasons of Company X's (potential) clients to invest in Product Y. A valuable addition to this research is to measure the reproduction performance for all inseminations.

It will be valuable for further investigators to associate the data analysis results to the management strategy of the specific farm. At the end of this research, we had contact with Company X's contact person of Company B, in which we found out why they made certain decisions, also some striking changes in KPI values were explained. It will be valuable for further researchers to associate the results to the practice. By collecting data why certain KPIs performed different compared to pre-implementation, current clients can adapt their strategies to achieve more effect of the Product Y implementation. Also, potential customers can get better insights in the expected effects of the Product Y implementation when certain management strategies are applied.

During the data analysis, only data that is derived from cows that are in their productive life stage is included. KPI measurements of youngstock need to be done separately. In the future, it will be a valuable research addition to identify the performance of youngstock for the relevant KPIs.

7.3. Discussion

In this section, the discussion points of the research are addressed. The discussion is separated in three subjects namely, research scope, assumptions, and results.

Research Scope
We had to take some decisions to limit the scope of the research. Firstly, the results are not sector adjusted, most KPI measurements showed an (significant) improvement of performance, when comparing pre- and post-implementation data. It could be that the whole dairy sector is performing better over time. Secondly, the KPIs are only measured for cows that are in their productive life stage. This means that no data is analysed for the performance of youngstock and so, the results are based on only the events of matured cows. So, when interpreting the results, there must be understood that the measured KPIs do not include all the performances of the farm. Thirdly, as discussed in Section 1.6.1, we did not take the investment costs for Product Y into account. The results showed that the implementation of Product Y is beneficial for the economic performance of the farmer, however the costs are not included into that conclusion. Lastly, as mentioned in the recommendations for further research, Section 7.2, not all relevant KPIs for the fertility and milk production performance aspects has been quantified. Therefore, when interpreting the results, it must be known that the performance aspect can be quantified more extensively.

Assumptions
When interpreting the research results, the following assumption must be understood. We assumed that the main activities and management strategies stayed the same during the

time range of data at Company A and Company B. Therefore, we relate the changes over time to the implementation of Product Y.

Results

As we have seen in the differences of results between Company A and Company B the effects of implementing Product Y is heavily dependent on the way the farmer uses the abilities of Product Y. The effects are not universal for every company, so we cannot conclude that the same effects will occur at a company that implements Product Y in the future. It must be emphasized that the farmer should embrace the abilities of Product Y to see the implementation effects.

We have to notice the interrelation between some performance aspects. In Section 3.1, we mentioned that the longevity of a herd is dependent on the culling decisions of a farmer, these decisions are mostly based on poor fertility, cow health, or milk production. For example, when the fertility increases, less culling occur based on poor reproduction performance, which will be beneficial for the longevity. This is also applicable for the cow health and milk production. We have to understand that the performance of some performance aspects are dependent of each other.

The identification of differences in performance over seasons, in Section 5.1.2, resulted in a seasonal adjusted quantification, in which we only compare data that is derived from the same time period. However, the seasonal effects are not the same in every year, some years has more extreme circumstances than the other, which could influence the result.

During this research, we did not take any transitional period into account. In practice, it can take a while before the effects of the implementation are visible. However, we could not afford to exclude more data out of the data analysis.

7.4. Limitations

An important limitation for the research execution is time. The time span for this research was ten weeks. Due to this limitation, some performance aspects could not be quantified in-depth. As discussed in the recommendations for further research section (Section 7.2) and the discussions section (Section 7.3) the fertility performance aspect can be investigated more profoundly. However, writing code for this was not able with the given time frame. When more time was available, investigating the fertility more extensively was the high-test priority. Also, the results are not sector adjusted, which could have been done when the time period of the research permits.

Another notifiable research limitation is the available data. This research was restricted to the available data that has been gathered. The data has been gathered from two companies over a time range of three years, which withhold the research to scale up the data analysis. Also, we needed to restrict to the features that has been gathered. Company X has gathered the data for this research in advance, this disabled the measurement of certain KPIs, either because the dataset did not include certain data, or the time range of the data was too short.

Bibliography

Ali, B. M. (2021). The effect of cow longevity on dynamic productivity growth of dairy farming. *Livestock Science*. doi:https://doi.org/10.1016/j.livsci.2021.104582

Armengol, R., & Fraile, L. (2018). Descriptive study for culling and mortality in five high-producing Spanish dairy cattle farms (2006–2016). *Acta Veterinaria Scandinavica*.

Berckmans, D. (2014). Precision livestock farming technologies for welfare management in intensive livestock systems. *Rev Sci Tech*, 189-196. doi:doi: 10.20506/rst.33.1.2273

Bhosale, M. (2017). Development of Lifetime Milk Yield Equation Using Artificial Neural Network in Holstein Friesian Cross Breddairy Cattle and Comparison with Multiple Linear Regression Model. *Current Science*.

Bousquet, D., Bouchard, E., & D., D. (2004). *Decreasing fertility in dairy cows: Myth or reality?* Quebec: IVIS.

Bragança, L., & Zangirolamo, A. F. (2018). Strategies for increasing fertility in high productivity dairy herds. *Animal Reproduction*, 256-260. doi:doi:10.21451/1984-3143-AR2018-0079

Caja, G., Costa, A., Salama, A., & Oliver, J. (2020). Sensing solutions for improving the performance, health, and wellbeing of smal ruminants. *Journal of Dairy Research*, 34-46.

Cambridge Dictionary. (2022a). *Factor*. Retrieved from Cambridge dictionary: https://dictionary.cambridge.org/dictionary/english/factor

Canessa, S., Guillera-Arroita, G., Lahoz-Monfort, J., & Southwell, D. (2015). When do we need more data? A primer on calculating thevalue of information for applied ecologists. *Methods in Ecology and Evolution*, 1219-1228.

Chamberlin, J. (2011). Who put the 'ART' in SMART goals. In *Management Services* (pp. 22-27).

Cody, R. (2022). *Economic impact of beef cattle best management practices in Sourth Taxes: Artificial insemination*. Retrieved from Texam A&M Agrilife extension: https://agrilifeextension.tamu.edu/library/ranching/economic-impact-of-beef-cattle-best-management-practices-in-south-texas-artificial-insemination/

Company X. (2022b). *Customer stories from Company X technology solutions*. Retrieved from Company X.

CompanyX. (2022a). Interview with a Sales & Account Manager of Company X. (A. K. Vegte, Interviewer)

CompanyX. (2022c). Interview with data analist.

CompanyX. (2022d, 6 20). Interview with Business development manager. (A. K. Vegte, Interviewer)

Cook, N., Mentink, R., Bennent, T., & Burgi, K. (2007). The effect of heat stress and lameness on time budgets of lactating dairy cows. *Journal of Dairy Science*, 1674-1682.

Cooper, D. R., & Schiendler, P. S. (2014). *Busniess Research Methods.* Singapore: MCGraw-Hill Education.

CVB. (2017). *CVB Tabellenboekje.* CVB.

Da Rosa Righi, R., Goldschmidt, G., Kunst, R., & Deon, C. (2020). *Towards combining data prediction and internet of things to manage milk production of dairy cows.* Computers and Electronics in Agriculture.

De Vos, A. (2014). *Association between operational KPIs and milk revenue on dairy farms.* WAgeningen: Wageningen Unversity - Department of Social Sciences.

Dechow, C., & Goodling, R. (2008). Mortality, Culling by Sixty Days in Milk, and Production Profiles in High- and Low-Survival Pennsylvania Herds. *Journal of Dairy Science*, 4639-4639.

Dilmegani, C. (2022, 5 9). *AI Multiple*. Retrieved from Data Cleaning in 2022: Steps to Clean Data & Tools: https://research.aimultiple.com/data-cleaning/

Doran, G. (1981). There's a S.M.A.R.T. way to write management's goals and objectives. In *Management review* (pp. 35-36).

Dubbink, W., Graafland, J., & van Liedekerke, L. (2018). CSR, transparency and the role of intermediate organizations. *Journal of Business ethics*.

EIP-AGRI. (2017). *EIP-AGRI Focus Group.* European Commission.

Essl, A. (1998). Longevity in dairy cattle breeding. *Livestock production science*, 79-89.

FAO. (2019). *Climte change and the global diary sector.* Rome: the Food and Agriculture Organization of the United Nations. Retrieved from https://www.fao.org/3/CA2929EN/ca2929en.pdf

Fetrow, J., Nordlund, K. V., & Norman, H. (2006). Invited review: Culling: Nomenclature, definitions, and recommendations. *Journal of Dairy Science*, 1896-1905.

Fricke, P. (2016, 8 16). *Dairy-Cattle*. Retrieved from When to Pregnancy Check Dairy Cattle and Why: https://dairy-cattle.extension.org/when-to-pregnancy-check-dairy-cattle-and-

why/#:~:text=Because%20many%20experienced%20bovine%20practitioners,by%207%20to%209%20days.
Frost, J. (2020). *Failing to Reject the Null Hypothesis*. Retrieved from Statisticsbyjim: https://statisticsbyjim.com/hypothesis-testing/failing-reject-null-hypothesis/
Glen, S. (2014, December 9). *Statisticshowto*. Retrieved from Binomial test / Exact Binomial Test: https://www.statisticshowto.com/binomial-test/
Groenendaal, H., Galligan, D. T., & Mulder, H. A. (2004). An Ecnonomic Spreadsheet Model to Determine Optimal Breeding and Replacement Decisions for Dairy Cattle. *Journal for Dairy Science*, 2146-2157.
Grummer, R., Wiltbank, C., Fricke, M., Watters, R., & Silva-Del-Rio, N. (2010). Management of dry and transition cows to improve energy balance and reproduction. *Journal of Reproduction and Development*, 22-28.
Gulay, M., Hayen, M., Bachman, K., & Belloso, T. (2003). Milk Production and Feed Intake of Holstein Cows Given Short (30-d) or Normal (60-d) Dry Periods. *Journal of Dairy Science*, 2030-2038.
Hanks, J., & Kossaibati, M. (2018). *Key Performance Indicators for the UK national dairy herd.* Reading: University of Reading.
High, M. (2020). *How technoogy can enable a more sustainable agriculture industry*. Retrieved from Sustainabilitymag: https://sustainabilitymag.com/esg/how-technology-can-enable-more-sustainable-agriculture-industry
Holstein Foundation. (2017). *Milking and Lacation.* Holstein Foundation.
Hovey, C. (2018). The Marvels of Milk and Lactation. In *Encyclopedia of Reproduction* (pp. 793-797). Biomedical Sciences.
Huxley, J. (2013). Impact of lameness and claw lesions in cows on health and production. *Livestock Science*, 64-70. doi:https://doi.org/10.1016/j.livsci.2013.06.012
IFCN Dairy. (2022). *IFCN Annual Dairy Sector Data with Dairy Outlook*. Retrieved from IFCN Dairy: https://ifcndairy.org/ifcn-products-services/ifcn-dairy-data/ifcn-annual-dairy-sector-data-and-dairy-outlook/
Inchaisri, C., Jorritsma, R., Vos, P., Van der Weijden, G., & Hogeveen, G. (2011). Analysis of the economically optimal voluntary waiting period for first insemination. *Journal of Dairy Science*, 3811-3823.
Janes, A., Sillitti, A., & Succi., G. (2013). *Effective Dashboard Design.* Cutter IT Journal.
Kok, A., Chen, J., Kemp, B., & Van Knegsel, A. (2019). Review: Dry period length in dairy cows and consequences for metabolism and welfare and customised management strategies. *Cambridge University Press*, 42-51.
Kong, L., Li, J., Li, R., Zhao, X., Ma, Y., Sun, S., . . . Zhong, J. (2018). Estimation of 305-day milk yield from test-day records of Chinese Holstein cattle. *Journal of applied animal research*, 791-797.
Krasniqi, F., Kamberi, M. A., Kastrati, R., Emiri-Sallaku, E., & Tafaj, M. (2018). Investigation on feeding level and milk production of holstein dairy cows under farm conditions in kosovo. *Bulgarian Journal of Agricultural Science*, 450-459.
Laurent, G., Moussa, M. D., Cirenei, C., Tavernier, B., Marcilly, R., & Lamer, A. (2021). Development, implementation and preliminary evaluation of clinical dashboards in a department of a nesthesia. *Journal of Clinical Monitoring and Computing*, 617-626.
Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *Journal of Experimental Social Psychology*, 764-766.
Liang, M., Arnold, M., Stowe, J., Harmon, J., & Bewley, M. (2017). Estimating US dairy clinical disease costs with a stochastic simulation model. *Journal or Dairy Science*, 1472-1486.
Lokhorst, K. (2018). *An introduction to Smart Dairy Farming.* Leeuwarden: Van Hall Larenstein University of Applied Sciences.
Lovarelli, D., Bacenetti, J., & Guarino, M. (2020). A review on dairy cattle farming: Is precision livestock farming the compromise for an environmental, economic and social sustainable production?
MackLeod, L. (2021). Making SMART goals smarter. *Physician Executive Journal*, 69-72.
Malik, S. (2005). Enterprise Dashboards: Design and Best Practices for IT.
Mayo, L., Silvia, W., & Ray, D. (2019). Automated estrous detection using multiple commercial precision dairy monitoring technologies in synchronized dairy cows. *American Dairy Science Association*.
McDougall, S. (2006). Reproduction Performance and Management of Dairy Cattle. *Journal of Reproduction and Development* , 185-194.

M'hamdi, N., Bouallegue, M., & Frouja, S. (2012). Effects of Environmental Factors on Milk Yield, Lactation Length and Dry Period in Tunisian Holstein Cows. In N. Chaiyabutr, *Milk Production.*

Microsoft. (2022). *Power BI documentation*. Retrieved from Microsoft: https://docs.microsoft.com/en-us/power-bi/

Mohammed, A. (2018). Artificial Insemination and its Economical Significancy in Dairy. *International Journal of Research Studies in Microbiology and Biotechnology*, 30-43.

Mohd Nor, N., Steeneveld, W., Van Werven, T., Mourits, M., & Hogeveen, H. (2013). First-calving age and first-lactation milk production on Dutch dairy farms. *Journal of Dairy Science*, 981-992.

Nazzaro, C., Stanco, M., & Marotta, G. (2020). The Life Cycle of Corporate Social Responsibility in Agri-Food: Value Creation Models. *MDPI*. doi:https://doi.org/10.3390/su12041287

NDAWB. (2008, May 6). *National Dairy Animal Well-Being Initiative*. Retrieved from http://www.dairywellbeing.org/guidelines.php

O' Leary, N., Byrne, D., O' Connor, A., & Shallow, L. (2020). Invited review: cattle lamness detection with acceloerometers. *Journal of Dairy Science*, 3895-3911.

Oxfam Novib. (2022). *Het overbevolkingsprobleem*. Retrieved from Oxfam Novib: https://www.oxfamnovib.nl/blogs/dilemmas-en-oplossingen/het-overbevolkingsprobleem

Pastushenko, O., Hynek, J., & Hruska, T. (2018). Generation of Test Samples for Construction of Dashboard Design Guidelines: Impact of Color on Layout Balance. In: Rocha, Á., Adeli, H., Reis, L., Costanzo, S. (eds) Trends and Advances in Information Systems and Technologies. In *Trends and Advances in Information Systems and Technologies* (pp. 980-990). Springer.

Podgórski, D. (2015). Measuring operational performance of OSH management system – A demonstration of AHP-based selection of leading key performance indicators. In G. Boustras, *Safety Science* (pp. 146-166). Lefkosia.

Põldaru, R., & Luid-Lindsasar, H. (2020). The impact of herd health on the efficiency of dairy farms. *Agronomy Research*, 1404-1417. doi:doi:10.15159/AR.20.031

Poock, S., Horner, J., & Milhollin, R. (2009). *Missouri dairy Growth Council: Dairy cattle reproductive manual.* Missouri: University of Missouri: University of.

Potocan, V. (2021). Technology and Corporate Social Responsibility. *Sustainability*, 1-16.

Ray, D., Halbach, T., & Armstrong, D. (1992). Season and lactation number effects on milk production and reproduction of dairy cattle in Arizona. *PubMed*, 2976-2983.

Rendel, J. M., & Robertson, A. (1950). Some aspects of longevity in dairy cows. *Empire Journal of experimental Agriculture*, 49-56.

Rhoads, M., Rhoads, R., M.J., V. B., Collier, R., Sanders, S., Weber, W., . . . Baumgard, L. (2009). Effects of heat stress and plane of nutrition on lactating Holstein cows: I. Production, metabolism, and aspects of circulating somatotropin. *Journal of Dairy Science*, 1986-1997.

Rougoor, C. (1999). *Management, milk production level and economic performance.* Wageningen: Grafisch Bedrijf Ponsen & Looijen B.V.

Rutten, C., Steeneveld, W., Inchaisri, C., & Hogeveen, H. (2014). An ex ante analysis on the use of activity meter for automated estrus detection. *Journal of Dairy Science*, 6869-6887.

Ruxton, D. (2006). The unequal variance t-test is an underused alternative to Student's t-test and the Mann–Whitney U test. *Behavioral Ecology*, 688-690.

Stengeferro, M. L., Wijma, R., & Maselli, M. (2018). Extending the duration of the voluntary waiting period from 60 to 88 days in cows that received timed artificial insemination after the Double-Ovsynch protocol affected the reproductive performance, herd exit dynamics, and lactation performance of dairy c. *Journal of Dairy Science*, 717-735.

T., Y., Takeda, H., Hagiya, K., Yamaguchi, S., & Sasaki, O. (2018). Prediction of random-regression coefficient for daily milk yield after 305 days in milk by using the regression-coefficient estimates from the first 305 days. *National library of Medicine*, 1542-1549.

Tucker, C., Rogers, A., & Shutz, K. (2007). Effect of solar radiation on dairy cattle behavior, use of shade and body temperature in a pasture-based system. *Applied Animal Science*, 141-154.

University of Taxes. (2015). *SOS*. Retrieved from Binomial Test: http://sites.utexas.edu/sos/guided/inferential/categorical/univariate/binomial/#:~:text=A%20binomial%20test%20uses%20sample,equals%20a%20specific%20claimed%20value.

Van Arendonk, J. A. (1985). Studies on the replacement policies in dairy cattle. II. Optimum policy and influence of changes in production and prices. *Livest. Prod. Sci.*, 101-121.

Van de Haar, M., & ST-Pierre, N. (2006). Major Advances in Nutrition: Relevance to the Sustainability of the Dairy Industry. *Journal of Dairy Science*, 1280-1291.

Van Erp-Van der Kooij. (2021). *Precision technology and sensor aplications.* Wageningen: Wageningen Academic Publishers.

Van Middelaar, C., Berentsen, P., Dijkstra, J., Van Arendonk, J., & De Boer, I. (2014). Methods to determine the relative value of genetic traits in dairy cows to reduce greenhouse gas emissions along the chain. *American Dairy Science Association*.

Van Pelt, M. (2017). *Genetic improvement of longevity in dairy cows.* Wageningen: Wageningen University.

Veerkamp, R. F., Dillon, P., Kelly, E., Cromie, A. R., & Groen, A. F. (2002). Dairy cattle breeding objectives combining yield, survival and calving interval for pasture-based systems in Ireland under different milk quota scenarios. *Livestock production science*, 137-151.

Vellinga, V., & Gerber, J. (2010). Greenhouse Gas Emissions from the Global Livestock Sector - Methodology for a life Cycle Assessment. *Wageningen University and Research Centre*.

Vredenberg, I., Han, R., Mourits, M., Hogeveen, H., & & Steeneveld, W. (2021). An empirical analysis on the longevity of dairy cows in relation to economic herd performance. *Frontier in Veterinary Science*. doi:doi:10.3389/fvets.2021.646672

Walsh, P., & Fahey, G. (2022). Economics of timed artificial insemination with unsorted or sexed semen in a high-producing, pasture-based dairy production system. *Journal of Dairy Science*, 3192-3208.

Warren, J. (2011). *Itegrating KPIs into your company's strategy.* atinternet.

Wathes, D. C., Brickell, J. S., Bourne, N. E., Swali, A., & Cheng, Z. (2008). Factors influencing heifer survival and fertility on commercial dairy farms. *Animal*, 1135-1143. doi:doi:10.1017/S1751731108002322

Wordbank. (2022). *Moving Towards Sustainability*. Retrieved from Wordbank: https://www.worldbank.org/en/topic/agriculture/brief/moving-towards-sustainability-the-livestock-sector-and-the-world-bank

WUR. (2022). *Precision agriculture - Smart Farming*. Retrieved from WUR: https://www.wur.nl/en/Dossiers/file/dossier-precision-agriculture.htm

Zang, S., Zang, C., & Yang, Q. (2003). Data preparation for data mining. *Applied artifician intelligence*, 375-381.

Zeinhom, M., Absel Aziz, L., Mohammed, N., & Bernabucci, U. (2016). Impact of Seasonal Conditions on Quality and Pathogens Content of Milk in Friesian Cows. *Asian-Australas J Anim Sci*, 1207-1213.

Appendices

A. Company X's problem cluster

This appendix has been left out due to confidentiality agreements

Figure 25: Visualization of Company X's problem cluster [LEFT OUT]

B. Research overview

Chapter	Research Questions	Type of research	Research subjects	Data gathering methods	Results
2. Precision Livestock Farming	1. Which performance aspects can be influenced by the implementation of Product Y?	Explanatory	Literature & experts in research area	Literature & semi-structured interviews	Explanation of how the performance aspects can be influenced by Product Y, including the importance of the aspects.
3. Corporate Social Responsibility of farmers	2. How do the performance aspects influence the pillars of CSR?	Explanatory	Literature	Literature	CSR pillars are assigned to the performance aspects. Every performance aspect is investigated separately and substantiated why it influences the assigned CSR pillars
4. Formulation of the KPIs	3. How to formulate the most important KPIs of every performance aspect?	Descriptive	Literature, experts in research area & company	Literature & semi-structured interviews	By investigating the most important factors for every performance aspect, the most meaningful KPIs are formulated for every aspect.
5. Data analysis	4. How to measure the formulated KPIs? 5. How to quantify the significance of the results?	Descriptive	Literature & experts in research area	Literature & semi-structured interviews	By executing a statistical test, we investigate if the results of the data analysis are significant.
6. Development and the design impact dashboard	6. How to visualize the measured KPIs in an impact dashboard?	Descriptive	Literature, experts in research area & company	Literature & semi-structured interviews	A sketch of the impact dashboard is made. The dashboard aims at visualizing the effect of the Product Y implementation as effective as possible.

Table 21: Overview of the research design and the report overview

C. Change in the cow's activities

	Hypocalcaemia	Ketosis	Metritis	Mastitis	Lameness
Standing	↑	=	=	↑	=
Lying	↑	=	↑	=	↑
Feeding	↓	↓	↓	↓	↓
Ruminating	=	↓	↓	↓	↓
Physical activity	=	↓	↓	=	↓

Table 22: Change in behavioural patterns for different health issues. ↑ means increase in duration found in research; ↓ means decrease in duration found in research; = means no change found in research (Based on: Van Erp-Van der Kooij, 2021)

D. Lactation curve

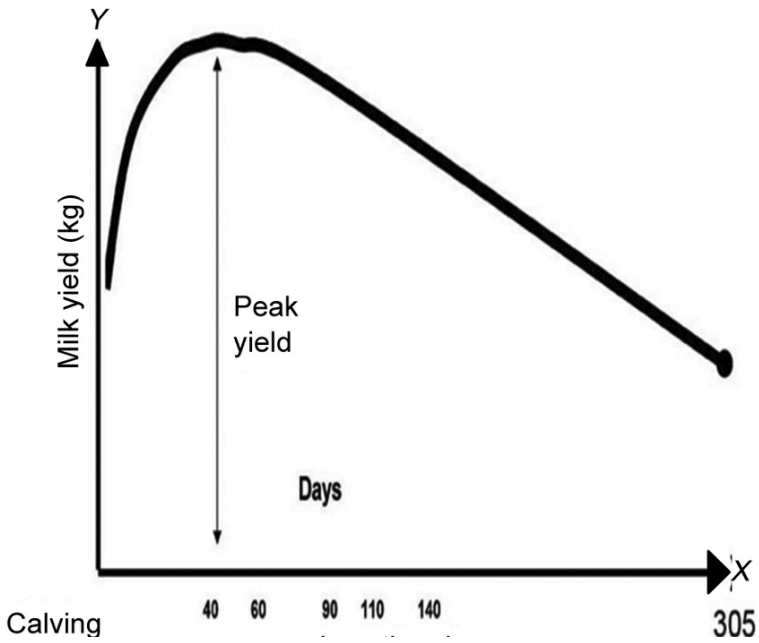


Figure 26 Visualization of a cow's lactation curve. (Source: (Bhosale, 2017))

Figure 26 displays the cow's lactation curve. Representing the daily milk yield in kg on the y-axis and the lactation days on the x-axis.

E. Example of the lifetime of a cow

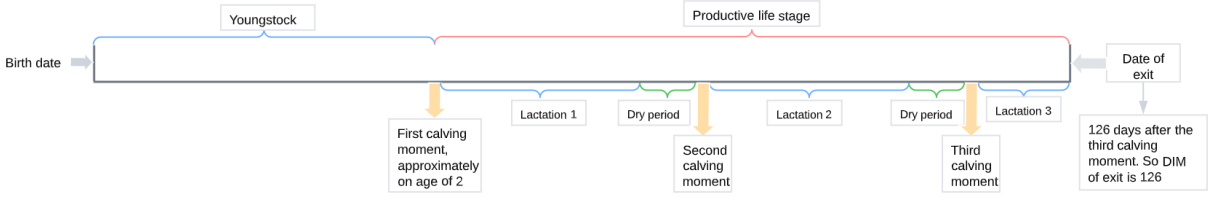


Figure 27: Example of the lifetime of a cow

Figure 27 illustrates an example of the lifetime of a cow. A dry period is the period of a cow before calving, the length of the dry period is a management decision, but is often about 6 to 8 weeks (Kok et al., 2019). This cow exit in lactation three at a DIM of 126.

F. Example worked out Welch's T-Test

One worked out example of how all statistical test were performed after the measurement of the KPIs, this is the statistical test for KPI 1 (average age of exit) of Company A.

Hypothesis:
H_0: average age of exit pre-implementation = average age of exit post-implementation
H_A: average age of exit pre-implementation ≠ average age of exit post-implementation

This figure has been left out due to confidentiality agreements

Figure 28: Code for calculating the Welch's T-Test p-value [LEFT OUT]

We are able to reject the null hypothesis if the p-value < 0.05, as can be seen in Figure 28, this is not the case for this statistical test. We are unable to reject the null hypothesis, which means that we cannot statistically prove that the average age of exits at Company A differs when comparing pre- and post-implementation, with a significance level of 95 percent.

G. Example worked out binomial test

One worked out example of the binomial test, this is the statistical test for KPI 7 (mortality rate) of Company A

Hypothesis:
H_0: the mortality rate pre-implementation = average age of exit post-implementation
H_A: the mortality rate pre-implementation ≠ average age of exit post-implementation

This figure has been left out due to confidentiality agreements

Figure 29: Code for calculating the p-value of the binomial test [LEFT OUT]

We used the pre-implementation data as the sample size, in order to use the post-implementation data as the population. To ensure we have a as big as possible difference between the sample size and the population.

We are able to reject the null hypothesis if the p-value < 0.05, as can be seen in Figure 29, this is not the case for this statistical test (p-value of 0.5396). We are unable to reject the null hypothesis, which means that we cannot statistically prove that the mortality rate at Company A differs when comparing pre- and post-implementation, with a significance level of 95 percent.

H. Welch's T-Test versus binomial test

Company	Company A (p-value)	
KPI	Welch's T-Test	Binomial test
KPI 2	0.024	0.0124
KPI 3	0.1041	0.0001
KPI 4	0.0046	9.6284e-14
KPI 6	0.7924	0.5583
KPI 7	0.7389	0.5396
KPI 9	4.39-e08	0.0036

Table 23: P-values of both tests for the relevant KPIs

Table 23 indicates the p-values for both statistical tests. We can identify that we need less statistical power to reject the null hypothesis with applying the binomial test. All p-values of the binomial test are lower compared to the Welch's T-Test. Also, the null hypothesis of KPI 3 (conception rate) is convincingly rejected with the binomial test, while we were unable to reject the null hypothesis with the Welch's T-Test. As mentioned several times in Chapter 5, the variance in the KPI values made is harder to reject the null hypothesis with the Welch's T-Test. The variance over the months are not taken into account while applying the binomial test, since all the values of pre- and post-implementation compared together.
We can identify that the conclusions we draw from the data analysis is dependent on the statistical test we choose.

I. Calculating voluntary waiting period

This figure has been left out due to confidentiality agreements

Figure 30: Python code of calculating the voluntary waiting period of a company. [LEFT OUT]

Output:

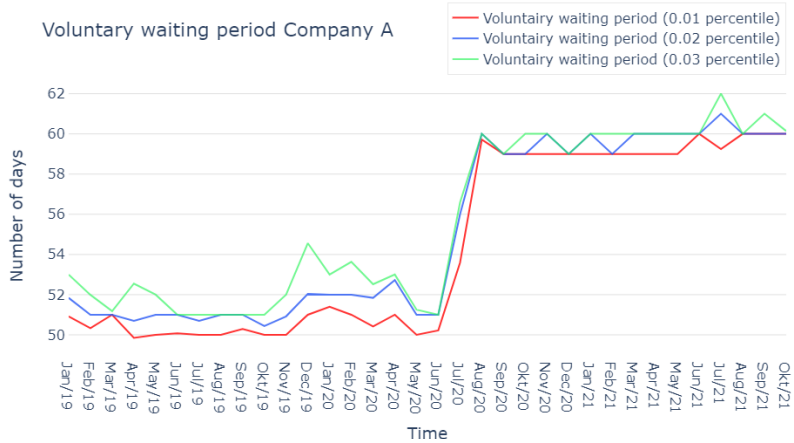


Figure 31: Visualization of the voluntary waiting period of Company A. The x-axis indicates the month, while the y-axis is the number of days of the first insemination in a lactation.

The aim of this code, was to get the VWP of the company, the VWP is a management decision and is the time interval between the calving moment and the date the farmer starts with detecting the heats. Determining the VWP is an important management decision, it is a decision that affects the profitability of the farmer heavily and is a trade-off between the rest of a cow and the lactation length (Stengeferro et al., 2018).
Figure 31 displays the lines with the first insemination of a cow in a lactation. For this visualization, we selected all first insemination of a cow in a lactation, we calculated the difference between the calving date and the date of the first insemination. By looking at the

amount of days the farmer start with inseminating, we can find the VWP. Every line indicates a different percentile of the amount of days between the calving and the insemination moment. We use the 0.01 percentile value as the applied VWP of the farmer.

J. Missing values in insemination result month

This figure has been left out due to confidentiality agreements

Figure 32: Code and output of the amount of missing values in the insemination results column. [LEFT OUT]

Figure 32 [LEFT OUT] indicates the code and the output of the percentage of missing values of the insemination results column. We can identify that the data of November and December 2021 have significant more missing values.

K. Distribution of expected milk yield

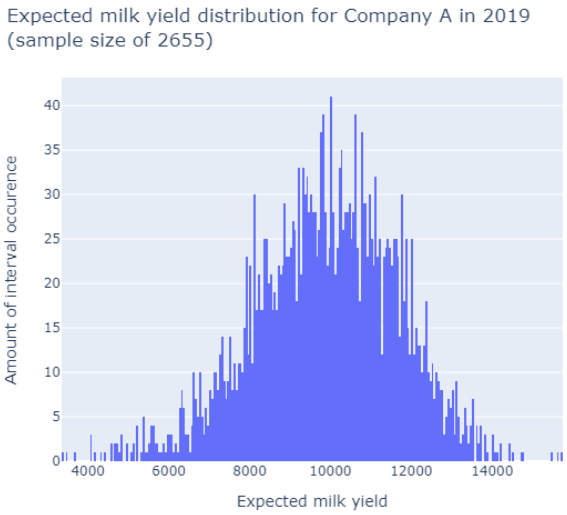


Figure 34: Distribution of the expected milk production of Company A in 2020 (n = 2655). X-axis indicates the expected milk yield in kg.

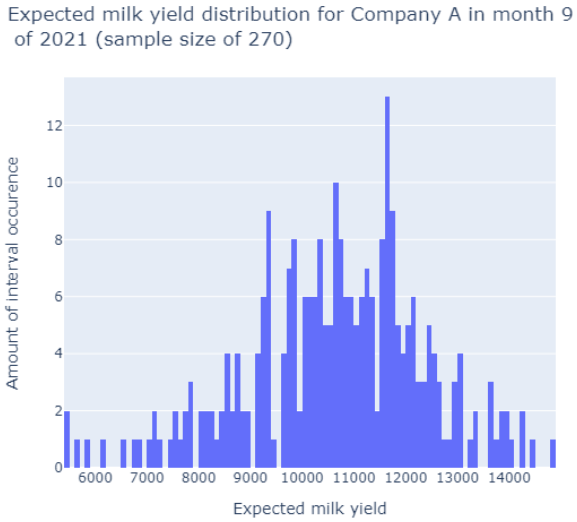


Figure 33: Distribution of the expected milk production of Company A in September 2020 (n = 270). X-axis indicates the expected milk yield in kg.

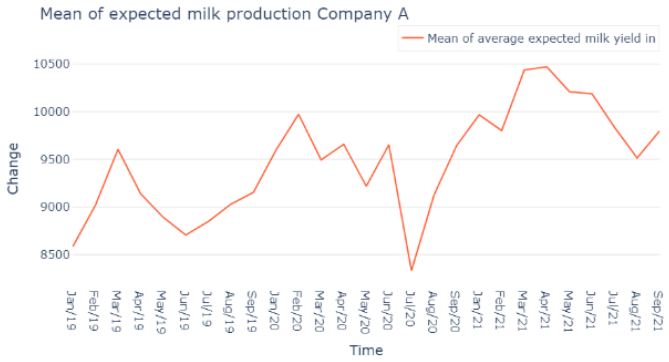


Figure 35: The mean expected milk production of Company A from 2019 until 2021.

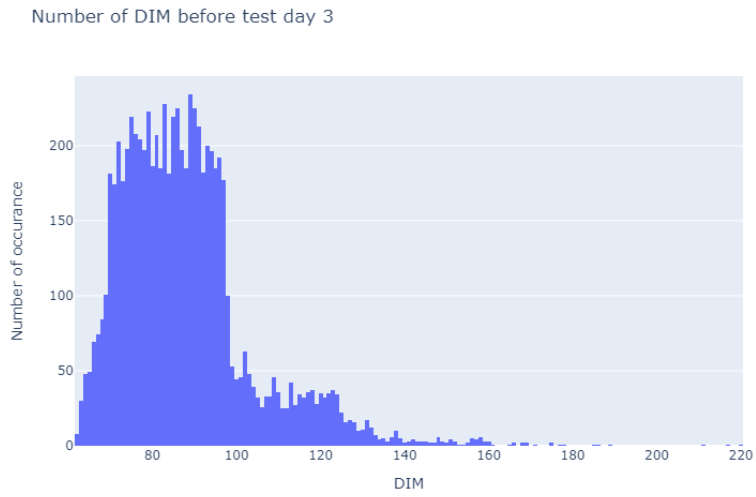


Figure 36: Number of DIM before a cow has 3 test days.

Figure 36 indicates the amount of DIM before a cow has three test moments. We calculated that before DIM 95, 77% of the cows had at least three test moments.

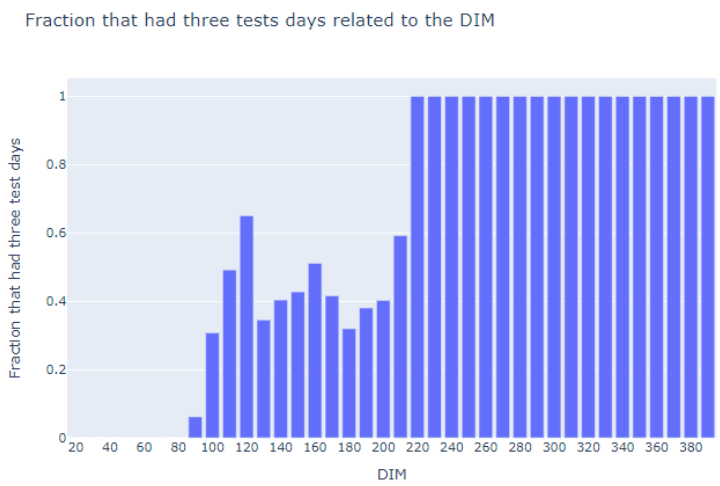


Figure 37: Fraction of cows that had at least three test moments.

Figure 37 indicates the fraction of cows that had at least three test moments. The y-axis indicates the fraction. The x-axis is the DIM. Every bar indicates the following: the fraction of cows that had exit in the particular DIM interval and that at least three test moments. For example, the second bar from the left side indicates: 31% of the cows that were culled between DIM [100, 109] had at least three test moments.

L. Heat detection method

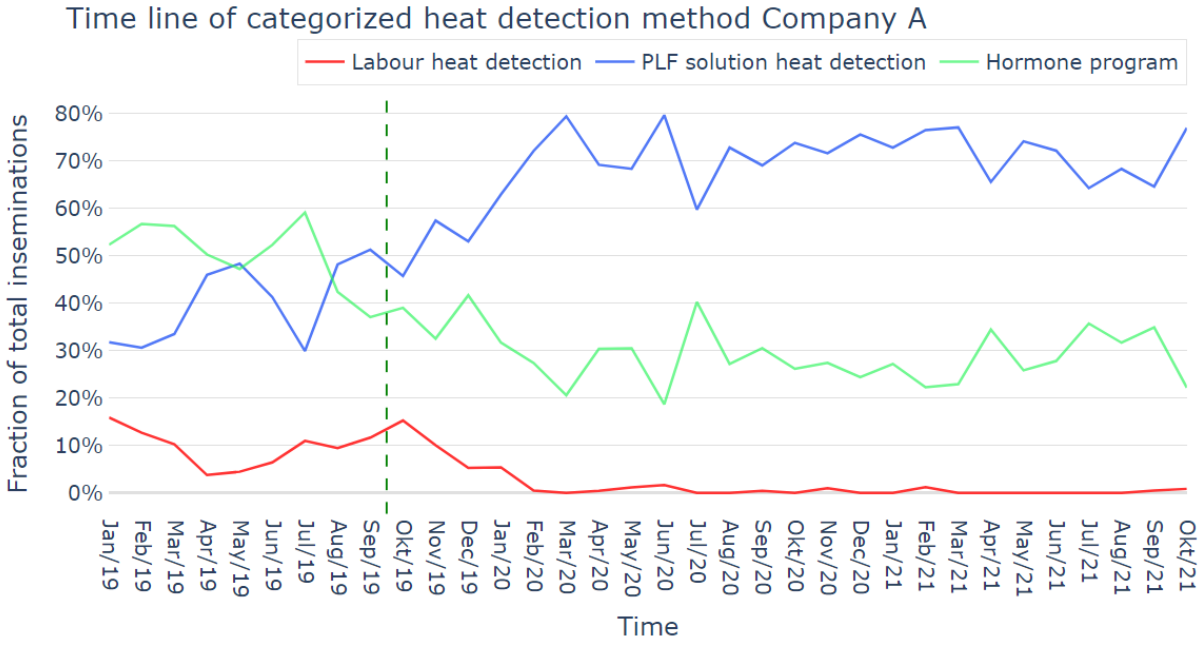


Figure 38: Categorized heat detection method for Company A of the first insemination in the cow's lactation. The x-axis is the month and the y-axis are the percentage of occurrence. The dotted line is the moment of the Product Y implementation.

Figure 38 shows that the percentage of insemination that are based on a category. The percentage of insemination based on labour heat detection or hormone program decreases a lot, while the inseminations based on a PLF solution increases.

This figure has been left out due to confidentiality agreements

Figure 39: The amount of occurrence of every heat detection methods in August 2019 of Company A [LEFT OUT]

Figure 39 [LEFT OUT] displays the amount of occurrence of every heat detection method in August 2019 of Company A. The meaning of the labels can be found in Table 24.

This figure has been left out due to confidentiality agreements

Figure 40: The amount of occurrence of every heat detection methods in August 2021 of Company A [LEFT OUT]

Figure 40 [LEFT OUT] displays the amount of occurrence of every heat detection method in August 2021 of Company A. The meaning of the labels can be found in Table 24.

By analysing Figure 39 [LEFT OUT] and Figure 40 [LEFT OUT] we can see that the farmer was able to inseminate cows more during their first heat. The first heat period can be seen in the figures as the day of the first insemination plus 21. The increase of inseminations in the first heat is beneficial for the insemination rate, and so for the reproduction performance of the herd.

Company A		
Classification	Code	Explanation
Labour	S	Standing heat; heat detected by the farmer

	B	Product W + human help: Product W recognized heat, subsequently this heat is checked by the farmer
PLF solution	G	Heat detected by Product Y
	M	Heat detected by Product W. Product W is a competitor of Company X and is the predecessor of Product Y at Company A.
	E	Heat detected by Product W + Product Z. Product Z is another competitor of Company X and was active at Company A before Product Y was introduced
	W	Product Z; heat detected by Product Z
Injection of hormones	V	Ovulation synchronisation; the farmer forced the heat by applying a hormone program

T

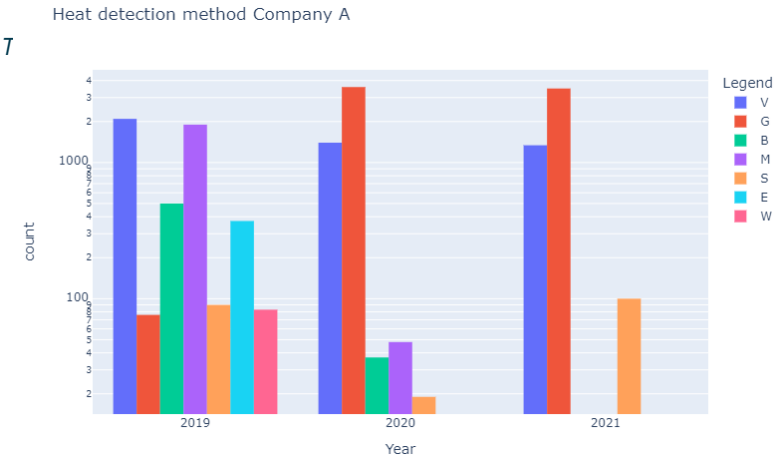


Figure 41: Amount of yearly heat detection for Company A for every heat detection method. The x-axis indicates the heat detection method and is categorized per year. The y-axis is the amount of occurrence.

Company B		
Classification	Code	Explanation
Labour	H	Standing heat; heat detected by the farmer
PLF solution	A	Heat detection by Product Y
	P	Heat detection by Product Y
Injection of hormones	F	Ovulation synchronisation first; the farmer forced the heat by applying a hormone program. This program is used in the first heat of the cow's lactation.
	O	Ovulation synchronisation; the farmer forced the heat by applying a hormone program. This program is used after the first heat of the cow's lactation

Table 25: Categorized heat detection methods of Company B.

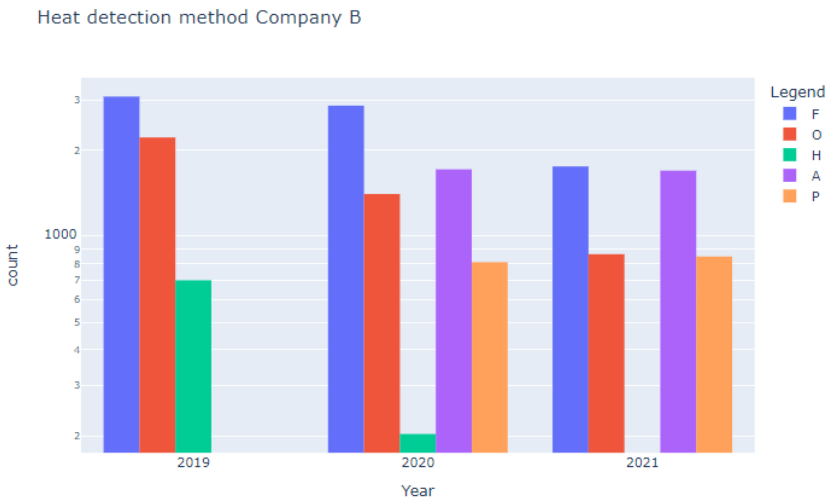


Figure 42: Amount of yearly heat detection for Company B for every heat detection method. The x-axis indicates the heat detection method and is categorized per year. The y-axis is the amount of occurrence.