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ICT in Business

Information System Architecture of Dairy Farming in the Netherlands

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MASTER'S THESIS

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Abstract

Dairy farms in the Netherlands adopt many information technologies to assist the operations on farms. Information systems on dairy farms have the potential to increase the efficiency and lower the cost of farming operations. And dairy farmers make business decisions according to the results provided by those information systems. However, the information system architecture on those farms is scarcely studied, which makes the structure of information systems is unclear. To address how dairy farmers in the Netherlands organize their information systems to support their business operations, this research studies three dairy farms in the Netherlands and constructs the reference information system architecture for those dairy farms from business, application and technology perspectives. Besides, this research relates the information systems with business operations and outlined how those information systems help dairy farmers make decisions.

Key words: *information systems reference architecture dairy farm Archi*

Contents

1. Introduction

The Netherlands is a dairy country. From a domestic perspective, dairy contributed to €7.4 billion (1.2%) of the national economy in 2014, and 14.7% of the total food and agriculture economy (ZuivelNL, 2015). According to NZO (The Dutch Dairy Association), "The Netherlands is home to approximately 18,000 dairy farms and 62 dairy factories. The dairy sector accounts for 60,000 jobs, and the country's 1.6 million cows produce 13 billion liters of milk. (ZuivelNL, 2015)." From an international perspective, the Netherlands was the fourth biggest country in the world in terms of milk production, only after New Zealand, Ireland and Denmark (ZuivelNL, 2015).

Dairy is a highly matured industry and has a completed production chain. Quality assurance, supply chain, food safety, climate and financial service are all considered in the dairy industry. Nevertheless, information technology is not yet highly emphasized.

This study aims to explain how dairy farmers in the Netherlands organize these information systems to support their business. Considering there is no existing architecture for dairy farms to reference, this research tries to develop a reference architecture on dairy farms. With this architecture, dairy farmers could get a well understand of dairy farming from an information system point of view. New incomers of dairy farming could get instructions to construct information systems and align them with business process. Furthermore, another intention of this research is providing a framework for information systems of dairy farms from areas that want to improve the dairy industry yet have no guidance. For example, China is an agricultural country, yet the dairy industry has a relatively low efficiency and quality.

This research starts with the literature and report review. After basic industry knowledge is well handed, a detailed case study is conducted to collect the first-hand information about dairy farm operations. An eighteen-day-long case study at Chestnut Dairy Farm is a good representation provided a structure of the dairy farm in the Netherlands. The information system architecture will be mainly described from business, application and technology perspectives.

1.1 Research questions

Main question: Considering the situation in dairy farming, the major research question is: What is the reference information systems architecture of dairy farming in the Netherlands?

Because the information systems support the business process of dairy farms, to address the reference architecture on dairy farms, the following sub-research questions are also necessary:

1) How do dairy farmers organize their business process?
2) What is the IT's role in those business process?
3) How do dairy farmers organize the information systems?
4) How to combine the business process and information systems into a reference architecture? And
5) What are the areas of improvement in the information systems currently used?

For easy understanding, each research question is labeled with an identification, represented in Table 1.

Table 1. The research question and research question label

Label	Research Question
MRQ	What is the reference information systems architecture of dairy farming in the Netherlands
SRQ1	How do dairy farmers organize their business process?
SRQ2	What is the IT's role in those business process?
SRQ3	How do dairy farmers organize the information systems?
SRQ4	How to combine the business process and information systems into a reference architecture?
SRQ5	What are the areas of improvement in the information systems currently used?

If those questions are well addressed, it will help owners of dairy farms know better about how to operate their farms with the assistance of information systems in a more efficient way. Besides, with the guidance of reference architecture, farmers could also know how to improve the existing information systems of their farms. Furthermore, the successful experience could be shared and applied to other areas more easily in a structured way with this reference architecture, which means it could increase the transferability of dairy operational knowledge.

1.2 Literature review

The intentions of literature review are:

1) Obtaining knowledge about the general situation of dairy farming in the Netherlands;
2) Obtaining knowledge about the essential roles and factors that will affect the dairy farming both in business and information system perspectives;
3) Finding existing architecture models that dairy farming could be referred.

To do so, the literature review focuses on four areas:

1) information system architecture theory and instance research;
2) dairy farming theory and instance;
3) business process and operations in dairy farming;
4) information technologies applied in dairy farming.

32 pieces of literatures are finally reviewed

1.2.1 Primary literature

[1] This study decides to use ArchiMate, which is one of the standards hosted by The Open Group (The Open Group, 2017) and aligned with TOGAF (The Open Group, 2017), to develop the architecture. And the basic structure of ArchiMate could be like what expressed in Figure 1 (Kruiswijk, 2017). This literature is related because it elaborates how three layers of architecture are connected. The existing literatures about the information system architecture in the agriculture sector are mainly focused on the crop farming or agriculture in general. There is no existing architecture in dairy farming. The contribution to the literature is: this research proposes a reference architecture in dairy farming and fills in the blank in this area. Considered that the different sub-industries in agriculture sector still share similarities, a matured reference architecture of a farm enterprise could be considered as the prototype of architecture for dairy farming.

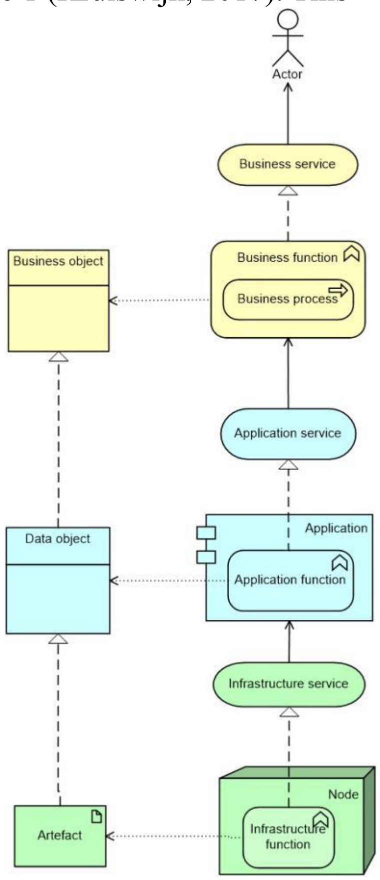

Figure 1. Basic architecture framework in ArchiMate

[2] In Figure 2, a reference architecture for farms is developed in ArchiMate (Kruize, et al., 2016). This literature is related because it provides a prototype for the reference architecture in this research. This architecture includes two major ICT components, FMIS and sensor, and covers three layers from business to application and then to technology. This architecture developed a basic model among end user, ICT components, software vendors, service vendors, infrastructure vendors, the software vendors developed FMIS and sensor, which contained several application functions. Even the architecture is not labeled with instance, it is still a complete reference architecture in agriculture sector constructed by ArchiMate. So, we set this as the framework to develop the reference architecture for dairy farming.

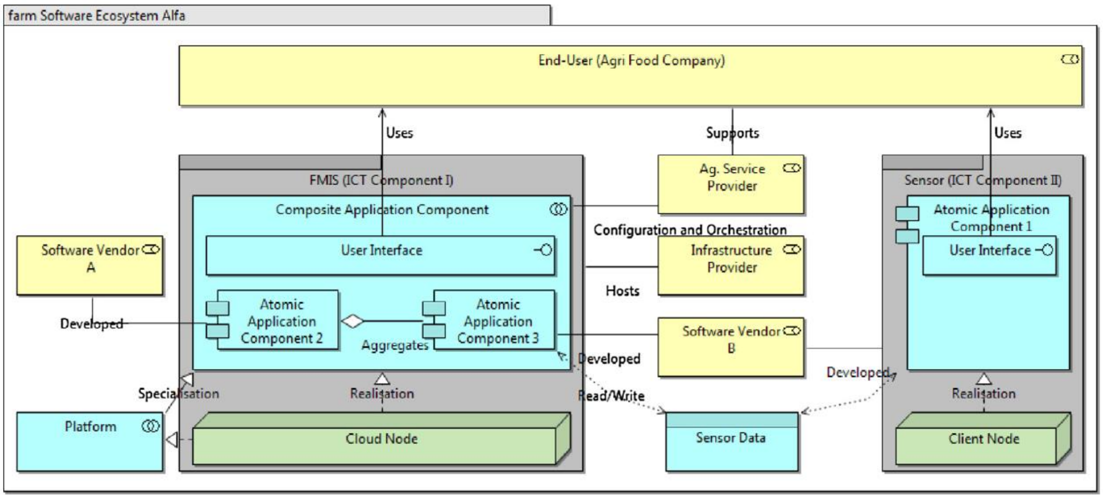

Figure 2. A reference farm information system architecture in ArchiMate

[3] To fill in more details, the reference architecture (Figure 3) could be referred when Fabian Aulkemeier study the e-commerce as a complementary case (Fabian Aulkemeier, 2016). It enriched the basic framework that is presented in the Figure 1. Different from the reference architecture in Figure 2, this architecture presents instance in each layer and makes the architecture more specific. For example, in Business layer, it enlists the business process according to different business units, such as marketing, selling, customer service and so on.

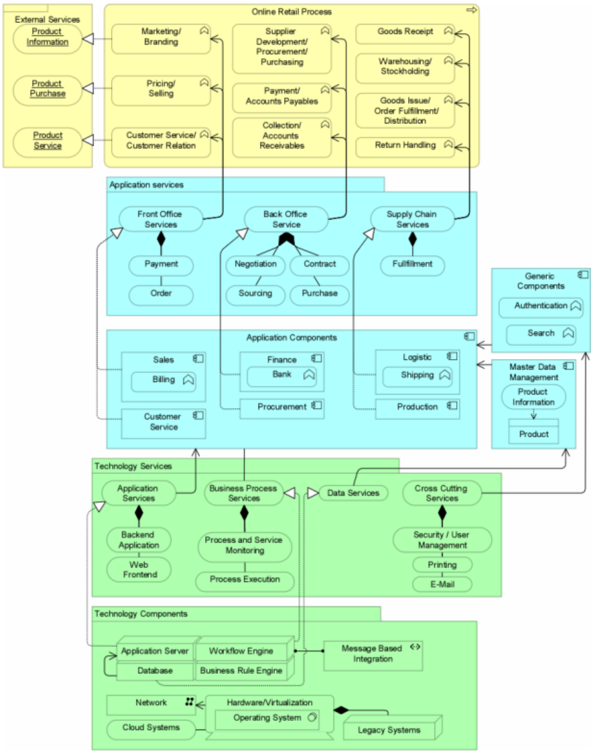

Figure 3. An reference architecture for E-commerce

[4] Back to the agriculture sector, Jones et al. discussed an integrated livestock modeling framework to address factors, such as farm size, concentrates offered, supplements, grazing and fertilizers use, that affect the input and output of the livestock information system (James W. Jones J. M., 2016). This literature is related because it provides the factors that influence

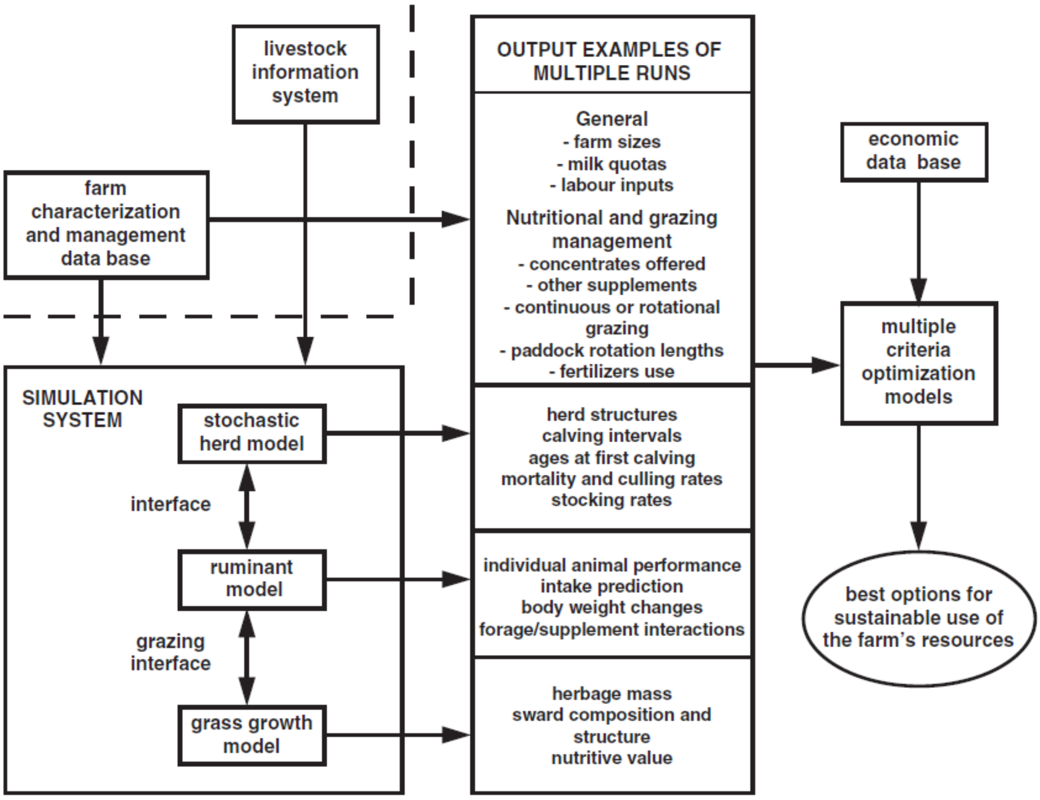

Figure 4. The integrate modeling framework for livestock farms

milk yield, which is the core of business process in dairy farming. Then it is related to SQR 1. So, these factors should be considered when conducting this research. In Figure 4, the integrate modeling framework represents whole livestock farms and related key components (Herrero, 1996). Dairy farming, which is one of livestock farms, could inherit those components as the key factors. And the factors could be divided into four categories: 1) farm related factors, including farm size, labor input, forage interactions and business partners; 2) livestock related factors, including bio-information (sex, body weight, fat, age and so on), activities, breeding, milk yield and healthy situations; 3) nutritional related factors on pasture, including concentrate offered, other supplements and fertilizers use; 4) nutritional related factors in milk. There is no reference about nutritional related factors in milk in this framework. Milk, as the main product on dairy farms, should be well considered into systems.

[5] Chakchai, Poolsanguan and Rujirakul developed a hybrid architecture involving the mobile phone management system. Besides, it mentioned four key environmental factors that affecting the poultry breeding, which are temperature, humidity, light intensity, and population density. (Chakchai So-In, 2014) The architecture for this system is represented in Figure 5. This literature is related because it is an instance that the information systems help the management of business operation (breeding process) in poultry farms. Then it is related to SRQ 2. Then, considering the breeding process is also important for dairy farms, those environmental factors should also be included into information systems on dairy farms. And this architecture with mobile phone management system could allowed farmers to monitor and control the environmental factors, such as light intensity, through mobile applications and wireless sensors located on the farms. Considering the similarity between poultry farms and dairy farms, where is the main location for livestock living indoor, it will be necessary to verify if dairy farms also adopts similar systems and where are their positions in the whole architecture.

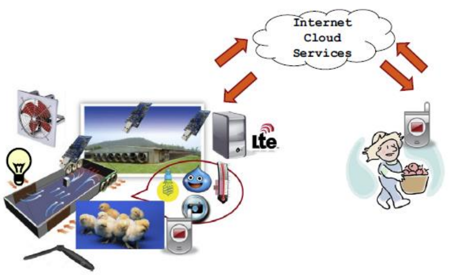

Figure 5. Poultry farms system architecture overview

[6] Simone Kraatz studied the energy flows in livestock operations and this research defined the system boundary, operational resources and business processes on dairy farms, showed in Figure 6 (Kraatz, 2012). This literature is related because it provides the business operations on dairy farms with the form of energy flows. Then it is related to SRQ 1. In this research, the system boundary includes five areas, which are replacement, feed-supply, buildings and storages, machines and technical facilities, milking. And the related processes in each area are also listed and discussed from an energy flow perspective. This system boundary could be referred when designing the business layer of the reference architecture for dairy farming.

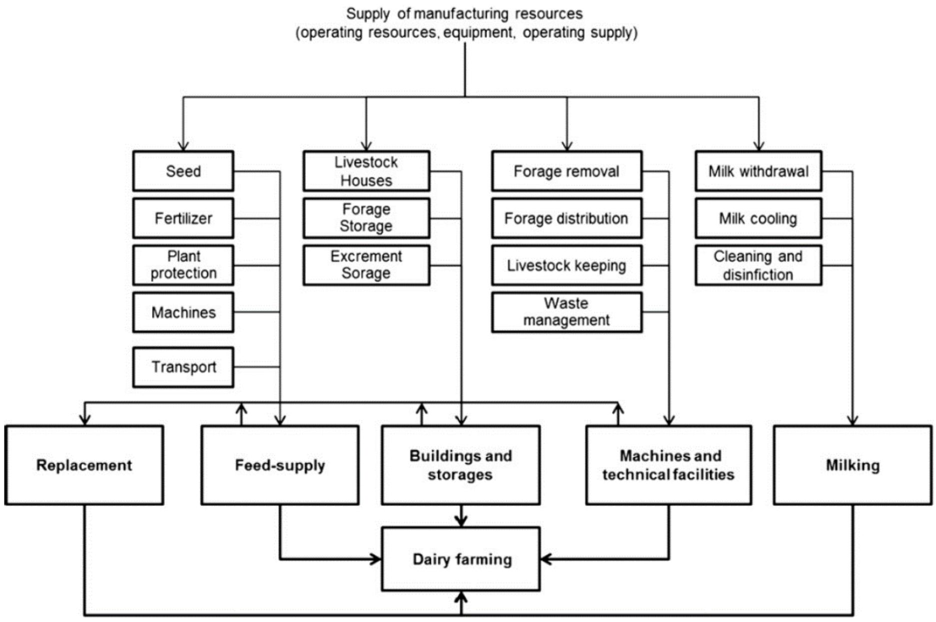

Figure 6. The system boundary and operating resources on dairy farms

[7] Kaloxylos et al. constructs a cloud-based farm management system, which is sophisticated and flexible (Alexandros Kaloxylos A. G., 2013). This literature is related because it used instance expressing the relationships between three layers. Combined with architecture in Figure 2, this literature helps the understanding of relationships between layers. Then it related to SRQ 3 and 4. The architecture of this cloud-based FMS is represented in Figure 7. This architecture adopts a structure guiding farms to organize their information systems. This structure is based on a cloud FMS to increase flexibility to tailor farmers' need and connected with multiple external service vendors and

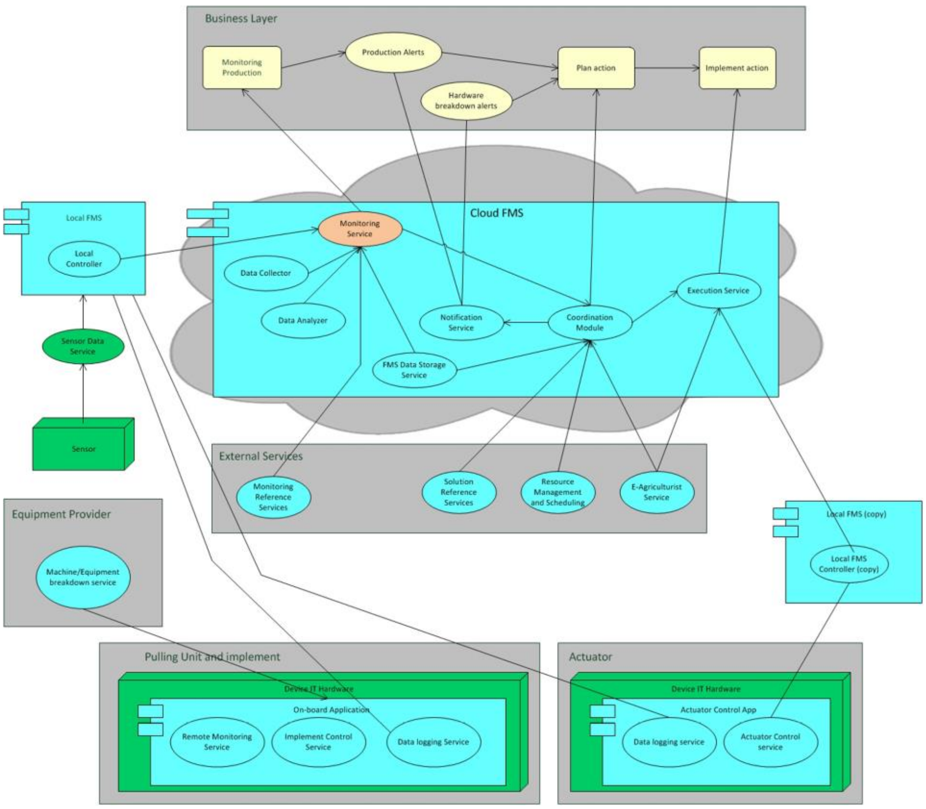

Figure 7. The architecture for a cloud-based farm management system

equipment vendors. Together with local FMS, this cloud-based FMS could serve business layer, which are farm operations and processes, with minimized cost and tailored services. Cloud might not be fully adopted by each dairy farm, yet this structure with external vendors could still be considered into the architecture for dairy farming.

[8] Kassahun mentioned the data flow in a meat transparency system with components. It defines the system components in a meat corporate, which is showed in Figure 8. (A. Kassahun R. H., 2014)In abstract, it is a system contains a corporate, an external trading partner, two applications, some interfaces and a data base. And the information connected each other are events. Those events including different types of business operations and activities in this context. And it generates some logical chain: first, an external partner could link the corporate through events by an interface; second, the application is driven by data generated from events. Based on this, Kassahun adopts a reference architecture in a meat sector, which is showed in Figure 9 (A. Kassahun R. H., 2016). This architecture describes a model that food operators (meet company) serves end users with the collaborations with third-party systems. This model is developed from the first logical chain generated from Figure 8. This literature confirmed the position of external partner in the architecture in agriculture sector.

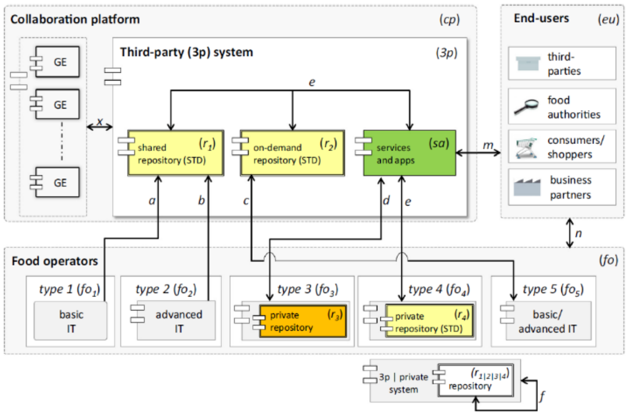

Figure 8. A data flow chart in a meat transparency system

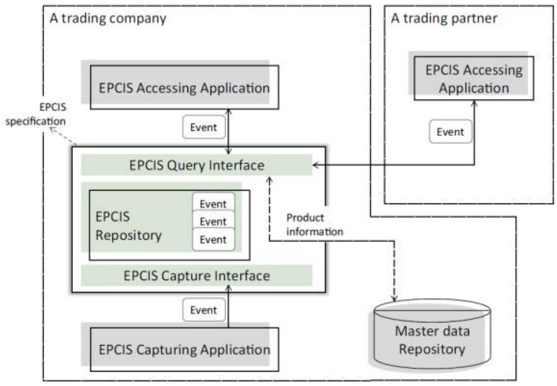

Figure 9. A reference architecture in the meat sector

[9] C.G. Sørensen designed an information flow chart showed in (Figure 10) when study the function requirements in the future FMIS (C.G. Sørensen, 2011). FMIS support the decision-making process of farms with the help of external assisting services. And those external services could be concluded into five categories: management, technology, market and legislation:

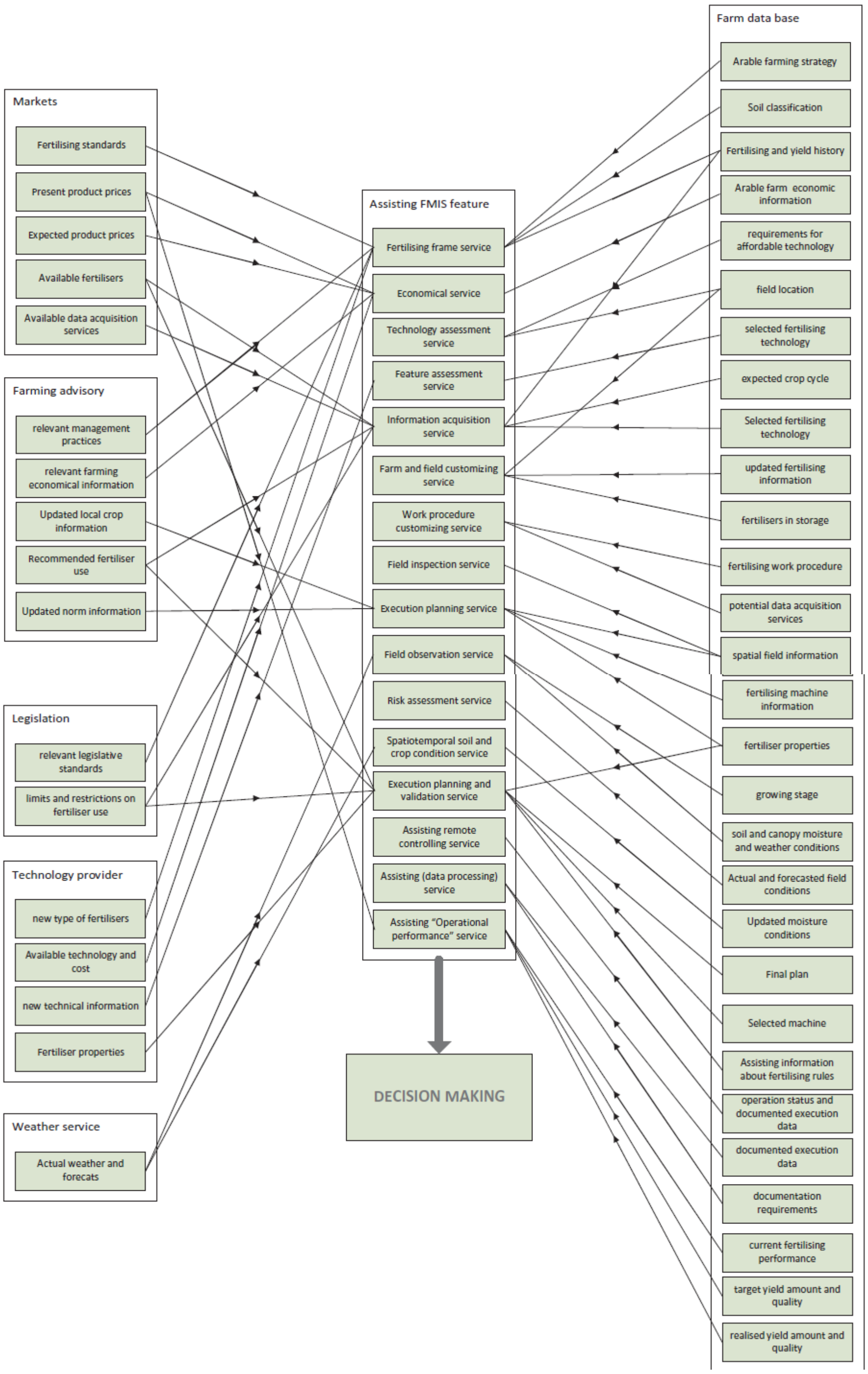

Figure 10. An information flow in the future FMIS

management service includes management practices, industry standards and so on; technology service includes fertilizer, available technologies cost, new technologies information and so on; market service includes production price information and so on; legislation service includes regulation and compliance standards from government. This literature concludes in which part could external service provider assist the farm. It helps to design the structure of external service providers in the architecture for dairy farming.

1.2.2 Supportive literature

Senthikumar and Chander did research in India and found that "dairy farmers with higher land holding size, bigger herd and good knowledge about dairy farm has a higher expectation to exposed to VICs more than the others with fewer holdings" (S. Senthilkumar, 2013). A reasonable hypothesis could be made that Netherlands farmers, most of whom have a large land holding size tends to rely more on information technologies. This literature reveals the potential relationship between business and IT (IT supports the business on dairy farms), and it is related to SRQ 2. Li Tan developed an extensible dataflow-driven software architecture when design the cloud-based decision support and automation system for precision agriculture in Orchard (Tan, 2016). This literature is related because it elaborates a process that data analyze support the decision-making. Then it is related to SRQ 2 and SRQ 3. Data from different source and sensors are integrated into a module to support the decision-making process. That software architecture mainly focused on the monitoring of environmental factors, such as water stress, soil and weather conditions. As for dairy farms, this architecture could be expanded to cover more data input, such as breeding, gender ratio, and healthy condition of the stocks.

2. Research approach and Method

2.1 Research design

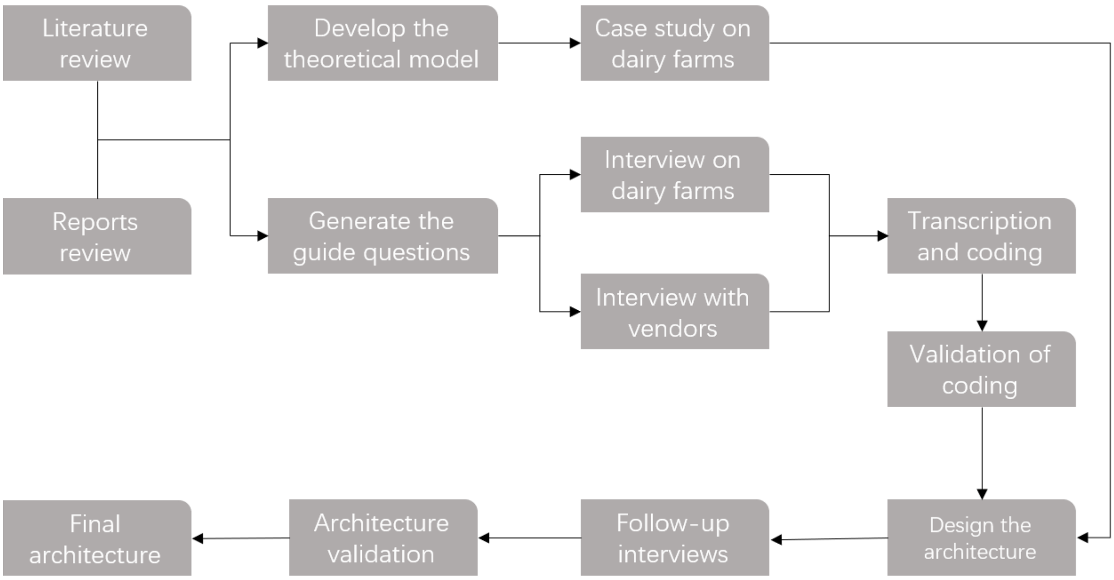

Figure11. The research steps and methods

To answer the research questions, this research adopts a qualitative designed science approach. And the detailed research steps are presented in the figure 11.

The research starts from the literature review and reports review to acquire the background knowledge about dairy farming in architecture perspective and the business context in dairy industry, Besides, a list of factors related to the dairy farming should be concluded for the future reference to architecture. It is important to outline what dairy farming cares about (the list of related factors) before conduct the future studies. With this list of factors and background knowledge concluded from literature review, a theoretical model about the architecture for dairy farming is constructed as the initial starting point for the following steps. As a qualitative approach, it is essential to induct findings during the research. This research adopts interview as a method to collect first-hand information on dairy farms. Those information is the resource to induct findings and refine the theoretical model. To make sure the interviews covers all areas to be studied and have moderate flexibility, the semi-structured interview is finally adopted. At the same time for theoretical model to be constructed, the guide questions for interviews are also generated according to the list of factors. The interview covers both dairy farms and vendors of dairy farms to obtain thorough information on dairy farms from business perspective to information architecture perspective. After interviews, the transcription and coding process are conducted to transform raw materials into valuable information related to the architecture. The validation process is the designed to test the reliability of coding results. Considering the fund limitation, the validation process conducts a test-retest method. On the other hand, a case study is conduct on dairy farms to refine the theoretical model. Together with coding results, an initial architecture on dairy farms could be developed based on the theoretical model. The follow-up interviews with dairy farmers and vendors are complementary step to collect extra information to fill the blanks in the initial architecture, if there exists any. Then we contact again with dairy farmers to validate this initial architecture. After necessary modification, the final architecture for dairy farming could be finally constructed.

In following session 2.2 - 2.5, detailed elaborations on each step will be introduced.

2.2 Theoretical model

According to the system description from ISO/IEC/IEEE Standard 42010, “a software architecture describes the components of the system, the interactions among the components, and the interaction of the system as a whole with its environment”. Components and interactions between them should be developed before the define of an architecture. A theoretical model is developed in a logical way from above literature to defines the types of components in an architecture and the interactions between them.

In the above session, the literature is reviewed with an order, it is also the order to develop the theoretical model, in the following table 2, the contribution of each literature is listed.

Table 2. Contribution of literature to the theoretical model

ID	Type	Contribution to the theoretical model	Related research Question
[1]	Layer	This literature confirmed the layers of reference architecture in this research: Business layer, Application layer and Infrastructure.	SRQ 4
[2]	Components	This literature pointed the objects of business layer is end-user and the application layer are mainly realized by separate ICT components. Besides, the ICT components tend to be supplied by external vendors.	SRQ 4

<table>
<tr><td>[3]</td><td>Components</td><td>This literature continued in business layer and addressed that the business layer should be constructed by business units and the functions they provide.</td><td>SRQ 4</td></tr>
<tr><td>[4]</td><td>Components</td><td rowspan="3">These three pieces of literature enlisted all possible components (factors) in agriculture sector that could have influences to business units and functions. And it could be concluded into five categories: Feeding, Milking, Barn and storages, Technologies and Machine, others. More details are elaborated in the following part in this session.</td><td>SRQ 1</td></tr>
<tr><td>[5]</td><td>Components</td><td>SRQ 2</td></tr>
<tr><td>[6]</td><td>Components</td><td>SRQ 1</td></tr>
<tr><td>[7]</td><td>Interactions</td><td>From this literature, the review addressed the interaction between components. In this literature, some interactions between layers are listed. For example, ‘Coordination module’ in the application layer serves the ‘Plan action’ in the business layer and the ‘Execution service’ in the application layer serves the ‘Implement action’ in the business layer.</td><td>SRQ 3 and 4</td></tr>
<tr><td>[8]</td><td>Interactions</td><td>This literature introduced the external vendors and address the possible method of interactions between external vendors with internal information systems.</td><td>SRQ 4</td></tr>
<tr><td>[9]</td><td>Interactions</td><td>This literature farther addressed which parts in the FMIS (the internal information systems) could be interacted with external vendors. For example, the external ‘technology provider’ interacts with the ‘fertilizing frame service’ of FMIS.</td><td>SRQ 4</td></tr>
</table>

A complete architecture should include three layers: Business layer, application layer and technology and each layer represent different process or components from different perspective (as represented in Figure 1). In this research, business layer represents the business process on dairy farms; application layer represents the functions provided by ICT components adopted by dairy farmers; and technologies layer represented the hardware, software and units that compose the ICT components. The basic logic should be ICT supports Business. And the basic relationships between layers are: Technologies layer services application layer and application layer served business layer.

The top-down method is adopted when developing this theoretical model, which means the boundaries of each layer should be defined from the top layer to the bottom layer. In the following steps, the research will address the mechanism in each layer and the relationship between layers based on this model.

Business layer

Simone Kraatz described the system boundary and related resources on dairy farms from five different areas in Figure 6. In each area, the related business processes are listed and connected. Those business process are divided into corresponding sectors, which are feeding, milking process, barn and storages, technologies and machine (as presented in Figure 12: Business processes). All those four sectors flow energy to the replacement, which is not a business sector. In this step, the replacement is temporarily included in item “Other”. However, it could be picked out and defined in the following research if it refers a business process.

To include the other miscellaneous processes except from those four major business sectors, the item “Others” is introduced (same for the item “Others” in application layer and technology layer).

Application layer

The application layer represents the functions provided by ICT components. In the theoretical model, the boundary of application should be defined. Kruize mentioned user interface as one application and represented the others with “Atomic application component”. Alexandros Kaloxylos descibed the monitoring service, data processing service (data logging, data collector, data analyzer, data storage service), execution service, solution reference service and implemention control service. Chakchai, Poolsanguan and Rujirakul also mention monitoring and control in the architecture for the mobile management system. Different service aims to different object. To conclude, the application services are archived into related sectors. The detailed inforamtion is concluded in Table 3.

Table 3. The application service and related objects on dairy farms

Application service	Service Object	Archive
User Interface	Farmers	UI
Atomic Application component	Unknown	Others
Monitoring service	Farms, livestock, milk	Monitoring and control
Data processing service	Data	Others
Execution service	Plans	Others
Solution reference service	Plans	Others
Implementation control service	Machine and equipment	Automation
Monitoring and control service	Barns and environment	Monitoring and control

From this table, the most of application layer are archived into four sectors: UI, Monitoring and control and, Automation, and Others

Technology layer

Technology layer in charge of the realization, and it focuses on those components empowered the ICT components. In this step, the particular mechanism in the technology layer could not be depicted because the lack of information. However, the objects of technology are explicit. From the Table 3, the application serves data, farmers(users), farms, livestock, milk, machine, equipment, barns environments and plans. Those objects should also be the objects of technology layer and we archived them into four sectors: Data, Infrastructure (includes farm, barns and so on), Machine (including equipment) and Others (includes milk, farmers, environment, plans and so on). In the following research, the detailed technologies, the object of each technology and the relationship between them should be identified.

External vendors

Both Kruize and Kaloxylos mentioned external service vendor in their architecture. Kruize mentioned software vendors, service vendors and infrastructure vendors, while the Kaloxylos mentioned external service vendors. Hence, the external vendors are defined and included into the theoretical model as a supportive third part to complement the architecture of dairy farming.

To enrich this theoretical model and address the mechanism in each layer, other research method, such as interview and case study should be adopted to collecting information. The literature review and theoretical model provide a guidance of the direction of interview and case study. Table 4 will elaborate the guidance for the following research. It includes the research objects, belonging layer, related considering factors and research method intend to be used.

Table 4. Elaboration of the research guidance based on the theoretical model

ID	Research objects	Architecture Layer	Factors	Research method
1	Farmland	Business	· Location · Owner · Business partner · Operation History	Case Study Interview
2	Pasture	Business Application	· Size · Concentrate used · Fertilizer used · Monitoring condition	Case Study
3	Barn	Business Application	· Composition · Environment control, includes ·Humidity ·Light intensity ·Temperature ·Population density ·… · Fodder storage	Case Study
4	Cows	Business	· Bio-information, includes · Sex · Body weight · Fat · Age · ... · Activity · Breeding · Milk yield · Healthy situation	Case Study
5	Farmer	Business	· Business partner · Technology vendor · Service vendor	Interview
6	Milk	Business	· Nutritional Factor · Monitoring condition · Milking process · Milk processing · Milk storage	Case Study
7	Application	Application	· Vendor · Function · Service object · Relationship · Related application context	Case Study
8	Equipment	Technology	· Vendor · Type · Function · Service object	Case Study
9	Machine	Technology	· Vendor · Type · Function · Related application	Case Study

10	Data	Application Technology	· Data source · Data type · Data collecting · Data analyzing · Data usage · Data storage · Data sharing	Case Study

Based on the literature review (in session 1.1), and the analysis of those literature in the previous part of this session, a theoretical model for the construction of reference architecture for dairy farming is developed (presented in Figure 12).

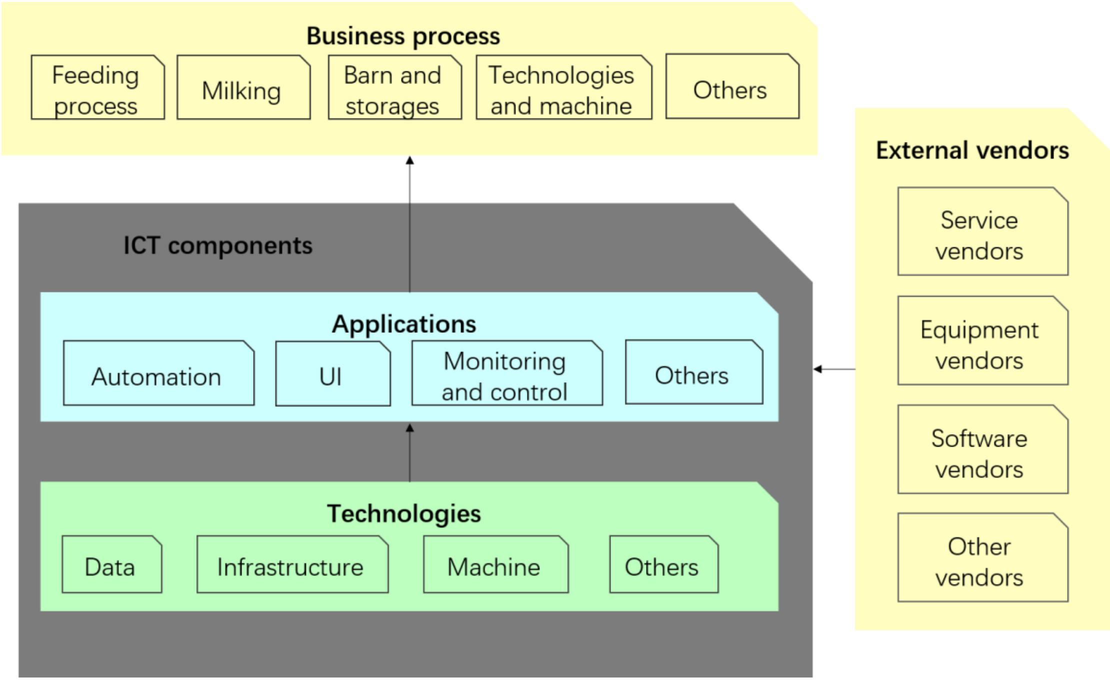

Figure 12. The theoretical model of reference architecture for dairy farming

2.3 Guide questions and interview questions.

To make sure the freedom as well as the structure of the interview, the semi-structured interview dominates the whole interview process. Before the interview, the questions could not be fully anticipated and forecasted. So, the guide questions are set to make sure the interview will be well structured and cover every aspect of dairy farming that this research needed. The guide questions could be found in Appendix 6.5.

In session 6.5.1, 6 guide questions are set for different intentions. And in session 6.5.2, 8 guide questions are set. The guide questions are asked to lead the interviewees to certain area (such as business process or the information system they use). The possible related questions are continued in the following interview process, guiding interviewees to reveal more information in this area. The possible related questions are set before the interviews were conducted. During the interview process, the questions asked are modified according to the answers of interviewees. The detailed designing of guide questions is elaborated in the following table 5 and 6. “ID” is the number of guide question in Appendix 6.5.1 and 6.5.2. “Intentions” is why this guide question is asked. “Possible related questions” is what questions could be asked in this area after this guide question. “Basis” is the foundation of this guide questions.

Table 5. The elaboration of the guide questions in Appendix 6.5.1

ID	Intentions	Possible related questions	Basis
1	Understand the interviewees' situation in the farms; Establish the bond with interviewees	What kind of jobs are you doing? What do these job meanings to the farms? How will you help the farms?	Interview preparation.
2	Understand and draw a job portfolio for interviewees; Establish the bond with interviewees.	Do you like your job? What do you think about your job?	Interview preparation.
3	Collect the information technologies applied on dairy farms; Address the mechanism in application layer and technology layer; Answer the SRQ 2 and 3.	How will you operate them? What are the interactions between you and machines? Who are their vendors? What functions will they provide? What information will they provide for you? How will these information systems help you doing your job? How will they connect each other? Is there exist information system cooperation?	Theoretical model: Application layer and technology layer; SRQ 2; SQR 3.
4	Address the core of application layer and technology that serves the business layer; Help the answer to SRQ 4.	Why these information technologies contribute most? What relationship does those technologies have with the business process?	Theoretical model: Business layer and application layer; SQR 4.
5	Collect potential points of improvement of information system applied on dairy farms; Answer the SRQ 5.	What do you think about these information technologies? Have you met any problem when you interact with those information systems? Have you solved the problem? Do you think the existing information technologies have overlaps or gaps between functions?	SRQ 5.
6	Collect potential points of improvement of information system applied on dairy farms; Answer the SRQ 5.	What information system are you expecting in the future that could be adopted on dairy farms?	SQR 5.

Table 6. The elaboration of the guide questions in Appendix 6.5.2

ID	Intentions	Possible related questions	Basis

1	Understand the farm's history; Establish the bond with interviewees.	How do you develop your farms in those years? What have been changed in those years?	Interview preparations.
2	Understand the farm's situation; Establish the bond with interviewees.	Are you satisfied with your farms? Have you expanded your farms? If not, why not?	Interview preparations.
3	Understand the farm's situation; Establish the bond with interviewees.	What does this yield mean to your farms? Is that enough to cover the cost and make the profit? Does it vary in a year? Has it improved in the past?	Theoretical model: Business layer; SRQ 1.
4	Collect information about business process; Address the mechanism in business layer; Answer the SRQ 1;	How will you spend the day when you work in the farms? What business process will you operate? How will you interact with these business processes? Who are your business partners? What business service will they provide for you? How will you organize these business processes? How will you manage these business processes?	Theoretical model: Business layer; SRQ 1.
5	Same as Table 5, ID 3.		
6	Same as Table 5, ID 4.		
7	Same as Table 5, ID 5.		
8	Same as Table 5, ID 6.		

Besides, general questions, such as the scale, infrastructure, business environment, about the industry context are also covered in these interviews. Some industry knowledge that are not covered by literature and reports, are also be revealed. Such as what are cooperated organizations in dairy farming and who are leading technology vendors in this industry. These complementary information helps the development of the architecture.

2.4 Interview

During the case study, interviewing is a good way to anchor the field of data to be collected and concrete the idea and topics to be covered in the case study. During the whole research, four of them are conducted in three different dairy farms. After practice, the knowledge about the information system infrastructure of dairy farms is transformed from the theoretical stage into the practical stage.

Meanwhile, due to the importance of the supplier in the dairy industry, some interviews to the suppliers for dairy farms are also conducted. Suppliers for dairy farms include equipment supplier and technology supplier. Equipment supplier could provide robots and tractors for dairy farmers and some famous suppliers, such as Lely, also collect data from dairy farms to support farmer operations. And

Technology suppliers, such as Agrifirm and Eurofins provides professional testing service about cows, pasture and milk for dairy farmers. Their reports also contribute a lot to the farm's operation. So, this research also conducts one interview with the information officer from Lely company to enrich the context of information. The briefing introduction of those companies are also listed in the Appendix 6.4.

2.4.1 Interview settings

To ensure interviews could obtain quality information, server factors should be considered when designing these interviews

1) The objection of interviewees. Dairy farms are normally a family-run business. One family could run a dairy farm contained 100 cows. When selecting the interviewees, the function and position should be taken into consideration. The ideal interviewees should be those who know the business context on farms and how to interact with information systems. And the head of the household normally take these responsibilities. Normally speaking, they will also be the owners of those dairy farms. Therefore, the interviewees are normally the owners of the dairy farms, who in charge of the major business on farms. It provides interviews with more detailed information and quantified data.
2) The duration of interviews. In this research, the duration of interviews varies from 30 mins to several hours. Short interviews could cover the general information of dairy farms, and the long interviews are able to provide detailed information about system operation and business context. During the research process, the interviews are designed with moderated duration, not too short so that the interviews are unable to obtained meaningful information; nor too long that make the interviewees losing focus. 90 minutes to 120 minutes is a moderated interval to have a quality interview. And the interviews are tried to controlled within this time interval.
3) The location of interviews. Similar with duration of interview, the location of interview can also affect the answers. The location should be familiar to interviewees so that it can make them maintained in a comfortable zone and willing to share. To do that, the interviews are normally conducted in the farms or the houses of interviewees.
4) The settings of interviews. The settings of interviews will affect the reaction of interviewees and the answers they provide. More importantly, it will affect the quality of transcription and coding. In this research, the settings of interviews are one computer for media play, one pen for drawing charts and table, and notepad for recording the information and answers. And this combination has advantages and disadvantages. The advantages are: firstly, the pen and paper could help interviewees express their ideas while drawing charts, which provides interviewees more freedom to express; second, no filming device nor recording device provides a more comfortable environment for interviewees. The disadvantage is: the absence of filming and recording device will not records the interview completely, which might cause information missing in the following transcription process.

2.4.2 Interview coding process

As the supportive research method of the case study, the purpose of interviewing is collecting the first-hand information from the farmers' point of view, what kind of information systems do they use and how will they organize these information systems. After the interview, the transcription of the interview is made and the answers are coded. According to Gorden and Raymond (Gorden, 1992), the coding process should have 6 steps:

1) Define the coding categories.
2) Assign code labels to the categories.
3) Classify relevant information into the categories.
4) Test the reliability of the coding.
5) Measure the reliability of the coding.
6) Locate the sources of unreliability in the coding.

According to the size of interviews and the purpose of research, some steps in the coding process are simplified. For example, we combine the step 1 and 2 in one single step, and we omitted the step 5 for the most of workload had already been done in step 4. In Appendix 6.3, the workload and results of these coding steps are recorded.

1) Define the coding categories and assign code labels to the categories

In the interview process, the information could be divided into seven different categories and the related definition are listed in the following Table 7.

Table 7. Definition of coding categories

No.	Name	Label	Definition
1	The condition of dairy farms	context	Including the information about the size, the location, the history, the composition, the turnover, the revenue and anything related to this dairy farm.
2	The name of information systems	name	The brand, the type, the name and any identification could represent the information systems.
3	The functions of information systems	function	The mechanism of information systems and the functions they will provide for dairy farmers.
4	The interactions between information systems and dairy farms	interaction	Including the information they get from other systems, the information they provide to other systems and reactions to this information.
5	The relationship between different information systems	relationship	Including the affiliation, causality, cooperation and so on.
6	The vendors of information systems	vendor	The vendor who provide systems and maintaining service.
7	The other useful information	other	Including any information that will help the understanding of the information architectures, such as third-parties, government regulations and so on.

2) Classify relevant information into the categories

After classifying, the relevant information is divided into different categories. And the results are listed in the Appendix 6.3. All information comes from the transcription of interviews.

3) Test the reliability of the coding

In the step, the test-retest method is adopted to test the reliability of the coding. After comparing the results of two coding process, over 95 percent of coding items are homogeneous. The coding process in step 2 is reliable.

4) Locate the sources of the unreliability in the coding

There are three sources or cause for the unreliability of coding, and in this step, we test these three sources one by one.

First, the coding categories may be at fault. In this coding process, seven different categories including their definitions are clearly listed in Table 7, and they do not have possible overlap with each other. To be clear, the label 'interaction' and 'relationship' might be similar and confused, but they referred to different concepts and areas. Label 'interaction' refers to the internal interactions of this information systems with other roles, such as cows, barns and farmers. Label 'relationship' refers to the external relationship with other information systems or roles, such as cooperation, including, and affiliation. So, there is no unreliability factor in coding categories.

Second, the information being coded may be ambiguous, vague, unclear, contradictory, or confusing. During the coding process, the sectors are selected as small as possible to avoid the possibility of ambiguous and vague. After the selection of each information from the transcription, there will be a re-test of this piece of information to make sure it only contains exactly one information being coded. So, there is no unreliability factor in information selection.

Third, the coders may be at fault because of the unclear or unfamiliar of concept. To avoid this, the interviewer read many pieces of literature and checked related knowledge before conducting the interview. Before the interview, the guide questions are sent to the interviewees in advance so that they could fully prepared. During the interview, the interviewer will double-check each concept to avoid any unfamiliarity. Some follow up questions are asked and answered by interviewees to make extra elaborations. After these measures, the unreliability factors in these processes are minimized.

2.5 Case study

The case study is a good way to collect the first-hand information about the technologies context on dairy farms. To fully represent the dairy farms in the Netherlands, the selection of dairy farm should take the scale, location into consideration. After representative dairy has been chosen, the case study could cover the owner, employees, and related business context. After selection, the Chestnut Dairy Farm is an ideal representation and is selected to conduct the future case study. The detailed information about this farm could be found in Appendix 6.4.7.

The case study is conducted with following orders:

1) Preparation

   Before the case study, some preparations should be done. In this step, the basic information (the size, the location, the composition) about the dairy farm is collected from email and website and the guide questions are initiated. These guide questions are necessary when conducting the semi-structured interview during the case study. Furthermore, interview equipment is well prepared, including the recording device, laptop, camera, research proposal and questionnaire.

2) Interview with farm owners

   When doing the case study inside the farm, some interviews with farm owners are necessary and helpful. During the interview, some depth questions could be answered, for example, the business process of the dairy farm operation, the business partnerships with this dairy farm, the information systems management model the farm is using, and some extra information added up the research. This step is critical for the case study because the relationship built with the farm owner will help the following steps moving fluently.

3) Farm environment study

After the interview, a study of the farm environment is conducted. During this process, an entire trip from the barn to pasture, from breeding room to milking areas, from operation room to milk tank, leading to a dive into the farm, is guided by the farm owner. The farm owner also showed how he operates the machines, what is the schedule of the farm daily operations, what kind of information systems are using in these operations and what will he do to assistant these operations during the farm trip. The farm environment study use practice to concrete those ideas developed in the interview step. After this study, the whole business process and the interaction between information systems and business process are more clear and vivid.

4) Data collection and analysis

After the farm environment study, the farm owner showed some reports and data to explain how he uses information systems to manage the farm and how can this information support his decision-making process. The reports include the testing reports on milk, pasture, cows and fodders from technologies supplier and bio-information of cows that he is feeding. The usage of these reports will be elaborated in the following session 3.3 and 3.4.

5) Follow up interview

After the case study ended, there came up some new questions. A follow-up interview is conducted through emails. The follow-up interview is a complementary process to complete the study process.

2.6 The relationship between the case study and interview.

The interview and the case study are correlated with each other. However, they are not identical. The object of interview is people, and the objects of case study are farms, environment and reports. Interview with farmers helps the following steps of case study in three ways: firstly, a friendly connection between researcher and farmers would let farmers willing to share more and deeper information about their farms; secondly, interview will provide points on which the case study should focus, such as the practical operations of information systems or the layout of farms that helps the process of business; thirdly, the interview provides theories while the case study provides practices. For example, during the interview, interviewees express what kind of information will they get from the system. And during the case study, farmers will present how they get that information and how to use it.

The interview induces the ideas and theories. And the case study concretes the ideas and put them into practice. The results of interview are listed in Appendix 6.3. And the result after the whole case study are presented in session 3.1.

2.7 Modeling and verification

After case study and interview, a draft version of information system architecture could be modeled. Then this model should be tested and verified. There exist two ways to verify the model: feedback from farm owners and compliance with the information system architecture. And the modeling process might need iterated improvement. After each improvement, another round of verification is needed for the new version of the architecture. The modeling process could be done after the architecture are verified to be valid.

3. Results

3.1 Interview and case study results

The interview transcription could be found in Appendix 6.3. From the interview and case study, seven results are inducted. And they are correlated to the research question. The corresponding relationship between those seven results and research questions are presented in Table 8.

Table 8. The corresponding relationship between interview results and research questions

Research question label	Interview and case study result number
SRQ3	3.1.1
	3.1.2
SRQ1	3.1.3
SRQ2	3.1.4
	3.1.5
SRQ5	3.1.6
	3.1.7

3.1.1 The information systems adopted in dairy farms can be divided into two parts: internal information system and information system from external service vendors.

Dairy farms adopt many information systems and those information systems could be divided into two parts. One is internal information system, which is used inside the farms and take charge of business operations, such as breeding, feeding and milking. The farmers operate these information systems to facilitate the business process. The other is information systems from external service vendors, which is provided and operated by external technology vendors, such as Agrifirm and Eurofins. Those external services are not highly related to the producing process of milk. However, they are essential to the quality assurance of production. Those external services include pasture monitoring, milk quality testing, health care of cows and so on. Dairy farmers care the results of those services and make decisions based on them. The relationship between business process and these information systems could be found in Table 12.

3.1.2 The dairy farmers organized internal information systems according to different business processes.

Dairy farmers in the Netherlands adopt different information systems to support their business processes. And information systems are organized into different sectors to support them respectively. In Figure 20, the deployment of information systems mainly serves three business processes: breeding, feeding and milking. From a business-IT alignment perspective, the business process leads the IT deployment on dairy farms.

3.1.3 Dairy farmers organize business process according to the natural process of milk producing.

The business process of dairy farms is related to the natural process of milk producing. Dairy farmers add appropriate business process to manage this natural

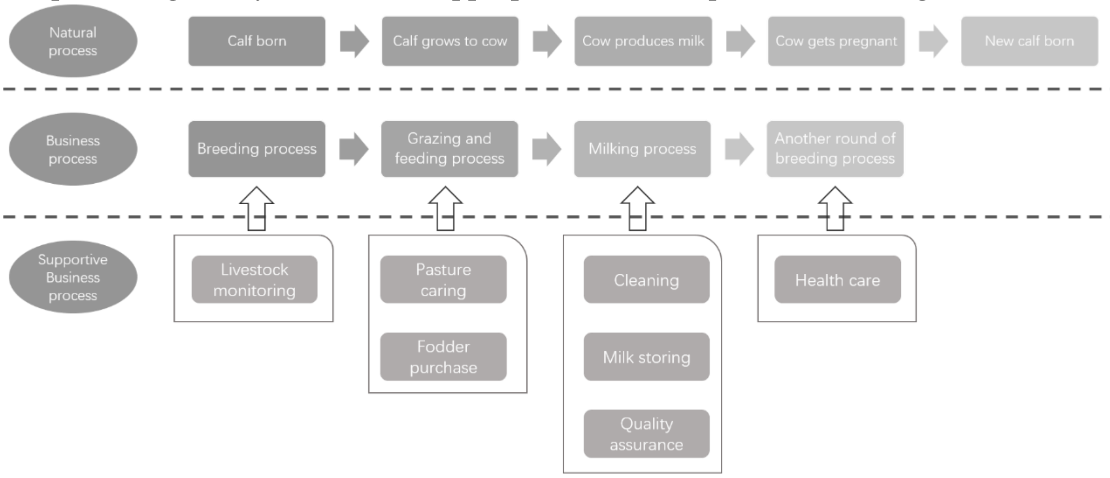

Figure 13. The congruent relationship between natural process of milk produce and business process of dairy farming

process of milk produce and get the final product, which is milk. And the congruent relationship between natural process and business process is presented in Figure 13.

3.1.4 The adoption of information systems has three main purposes: for better management, for monitoring and for automation.

From the management perspective, the information systems on dairy farms will provide data for farmers to support them making better decisions in business operations, such as buying suitable fodders, taking care of specific cows, grazing on the pasture or feeding in the barn and so on. For example, the milking robots find some cows haven't been milked for over sixteen hours and this could be a signal of illness, the milking robots will send this alert to the farm owner so that the farm owner could check the identified cow and decide whether it needs further medical care. Another example could be the CRV system, which could provide the live and future weather condition around farms, so the owners could decide whether to graze the cows on the pasture.

From the monitoring perspective, the information systems will monitor all possibly useful data inside and outside the farm, such as the movement track, the milk amount, the milk time, the weight, the fat of the cows; the nutrition condition, the temperature, the color, the fat, and the protein of the milk; the hygiene condition of milk tank and so on. Some of data would be presented to farm owner with periodic reports and the others could be directly accessed from information system. By reading this data, the farm owners would get a well understand about whether their farms (including the cows and milk) are in good conditions. And the milk companies could also know from these reports that whether their suppliers could provide qualified milk.

From the automation perspective, the information systems will automatically control the most of daily operations inside the farm: from feeding, cleaning, to milking. The controls system will directly control robots (feeding robots, cleaning robots, milking robots and so on) to conduct operations in instructions. In the meantime, the labor could be free from repetitive activities and focus on the strategy thinks.

3.1.5 The information systems are mainly focused on the operation process.

A complete business process should include three parts: supply, operation and sell. However, in the dairy industry, the information systems are mainly focused on the operation process, for the supply and sell are relatively simple and straightforward. Normally, a dairy farm will have fixed suppliers to buy fodders and clients to sell the milk. And the contracts will also be over years. So, the supply and selling process is stable and relatively fixed. A farm owner will make the order of the fodders and the supplier will deliver them directly to the farm. Each three to four days, the milk company will come to the farm and fetch milk from milk tanks. And how to manage those processes belongs to the suppliers and milk company, which is out of the discussion of this study. The dairy farmers' job is managing cows and products the qualified milk. So, the information systems studied so far are all contributing to the operation purpose.

3.1.6 It is meaningless to integrate the information systems on dairy farms.

There are dozens of vendors that could provide machines and technologies for dairy farming according to the Dairy Report 2017 (IFCN, 2017). But each vendor has its own market segment and none of them could provide the whole set of information systems that the dairy farmers need. For example, the equipment vendor Lely provides milking robots and feeding robots, but it could not provide the monitor or test service on milk or cows. It is hard for dairy farm owners to find a vendor providing one-stop service of information systems. Because of the different standards and interfaces between information systems from different vendors, it is hard to integrate those information systems in a farm. And it is also not necessary. From the case study in Chestnut Dairy Farm, the owner adopts four different information systems inside his farm: the milking system, the CRV management system, the GD health system and the Eurofins test system. The four different systems are operating synchronously and concordantly. Because four systems take charge in four different areas and they have the low coupling with each other, it is more efficient for them to operate separately.

3.1.7 There is function overlap between systems from different vendors.

For example, the milking system will make sure the milk quality stored in the milk tank, while the outsourced testing system also provides the milk quality assurance service. Nevertheless, they provide some function using different methods. The milking system will test the quality of milk from the physical perspective, such as color, temperature. While the outsourced testing system assures it from a chemistry perspective, such as the nutrition composition and the condition of germs. The small function overlap between different systems is not necessarily a waste of resources. From a farmer's view, it would be a double insurance during the business.

3.2 Business process architecture

3.2.1 Business Canvas (Osterwalder, 2008)

Before the elaboration of the business process architecture, a general business context analysis should be conducted. Based on the Business Canvas Framework developed by Alexander Osterwalder (see Figure 14) (Osterwalder, 2008), the business model of the dairy farm has been architected as Figure 16. In Figure 16, the key elements of the business process in a typical dairy farm in the Netherlands are listed and connected.

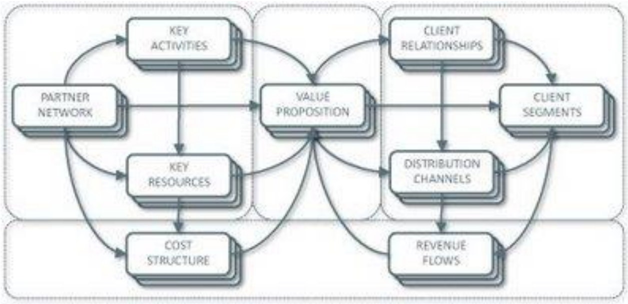

Figure 14. Business Canvas framework

The business canvas should start from Value Propositions, which is the center of the Business Canvas and where the dairy farm makes the money. According to the cash flow statement provided by Chestnut Dairy farms, (see Figure 15), there are three main revenue parts "Melkgeld (Milk)", "Overige (Other)" "Over bedrijfsontvangsten (Other company receipts)". And these three revenue parts divide dairy farm into three business units: 1) Milk and milk products; 2) Hospitality activities; 3) Knowledge and patent.

(Rollend) jaarresultaat	**Uw bedrijf**	**Gemiddelde bedrijf**	**Gemiddelde 25%-beste*)**	**Uw bedrijf**
	rollend jaar	**rollend jaar**	**rollend jaar**	**laatste boekjr**
	01-07-2016	01-07-2016	01-07-2016	01-01-2016
Bedragen in euro's	30-06-2017	30-06-2017	30-06-2017	31-12-2016
Resultaten bedrijfsniveau				
Kg afgeleverde melk	923.574	924.000	924.000	900.783
% Vet	4,26	4,42	4,46	4,42
% Eiwit	3,55	3,56	3,59	3,69
Ontvangsten:				
Melkgeld	296.300	295.800	300.300	264.400
Weidegangtoeslag	-	2.900	3.500	-
Inhoudingen/toeslagen op de melk	-	900	1.000	-
Nabetaling melkgeld	33.300	25.500	30.500	28.100
Verkopen vee	25.300	28.900	30.500	14.200
Aankopen vee	-	3.500-	4.000-	-
Verkoop ruwvoer	5.000	1.300	1.200	1.300
Overige	-	300	200	-
Totale ontvangsten	359.900	352.100	363.200	308.000

(Rollend) jaarresultaat	**Uw bedrijf**	**Gemiddelde bedrijf**	**Gemiddelde 25%-beste*)**	**Uw bedrijf**
	rollend jaar	**rollend jaar**	**rollend jaar**	**laatste boekjr**
	01-07-2016	01-07-2016	01-07-2016	01-01-2016
Bedragen in euro's	30-06-2017	30-06-2017	30-06-2017	31-12-2016
Saldo overige takken	2.800	600	600	3.700
Landbouwbeleid - beheersvergoeding	1.100	700	600	-
Landbouwbeleid - bedrijfstoeslag	21.300	22.700	23.600	21.300
Landbouwbeleid - overig	-	100	100	1.300
Verlease melkquotum	1.200	-	-	-
GVE regeling bonus	-	100	100	-
GVE regeling boete	-	600-	600-	-
Overige bedrijfsontvangsten	34.900	7.900	7.200	43.500
Saldo bedrijf	285.600	235.900	265.700	241.500

The first one, milk and milk products, is undoubtedly the most important business unit for dairy farm and it dominates the major part of cash flow. If possible, some dairy farm may even sell new calves for extra revenues, because the limited area of pasture could only raise a limited amount of cows according to Netherlands law, see also Appendix 6.4.6.

The second business unit, hospitality activities, is known as a sideline business of the farm. According to owner of Chestnut Dairy Farm, the farm will host gathering activities for families and organizations. Families will come to the

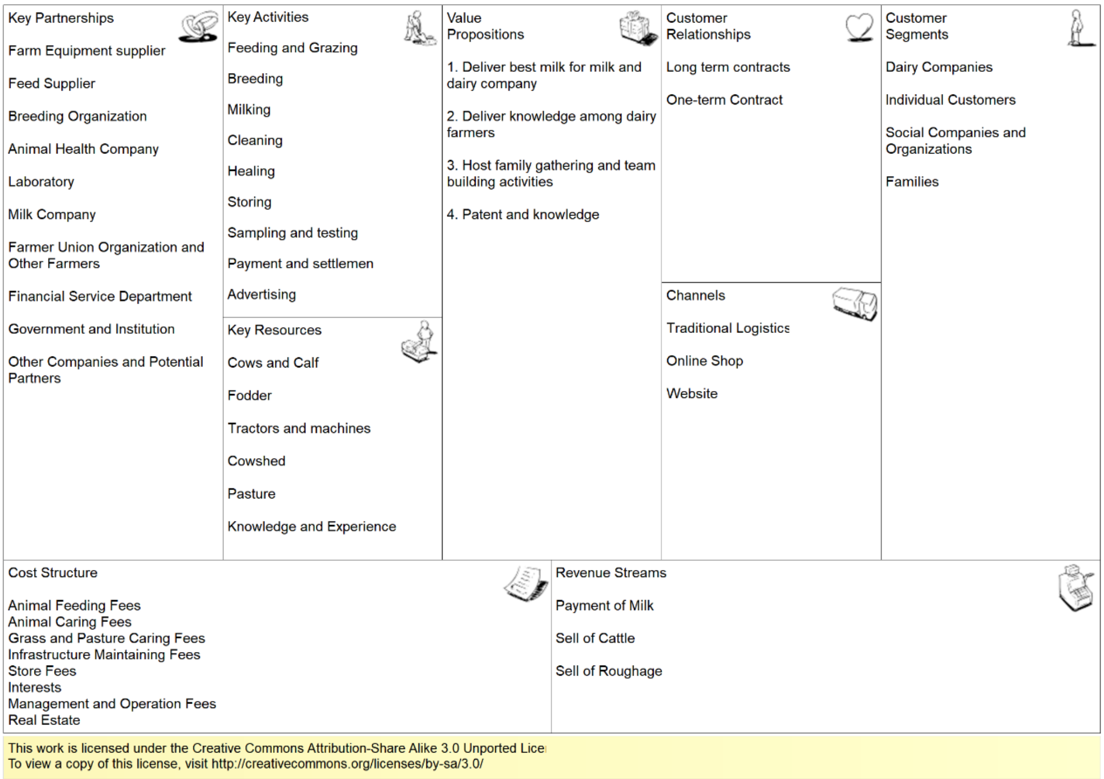

Figure 15. The part of the accounting statements

dairy farm for a holiday or weekend, play with cows and calves, make their own milk or cake and enjoy the countryside view for relaxation. Organization and company will sometimes contact with farm to provide place and tools for some team building activities. According to some farm owners, host such activities has already been part of their lifestyle and they enjoy it as well.

The third business unit, Patent and knowledge, is not an obligatory part of every dairy farm, because not every farmer could develop knowledge and transform it into revenue. During the case study, the farm owner showed me the prototype machine that invented by himself. This machine is specially developed for the cleaning of the cowshed. It could evacuate the feces from cowshed with an enhancement of efficiency compared with finishing this work manually. A farm equipment supplier had bought this technique from him and put it on market (Appendix 6.4.7). The patent does contribute a lot to this dairy farm, see Figure 15, item “overige bedrijfsontvangsten” (other company receipts).

Other segments of Business Canvas are all derived from the Value Propositions and could be easily understood.

3.2.2 Business Process Architecture

The business process is organized according to the natural process of milk producing (session 3.1.3). With the assistant of logistic service (Table 18, No. 6,7,8) and testing on milk, pasture and cow (session 3.1.3), the business layer is developed in Figure 17. Furthermore, some farm may conduct side business, such as hospitality (Appendix 6.4.7). So, there are 6 business functions: “Breeding”, “Feeding”, “Milking”, “Testing”, “Logistics”, and “Side business”. Each business functions are achieved by several business processes and the have the following relationships in Table 9.

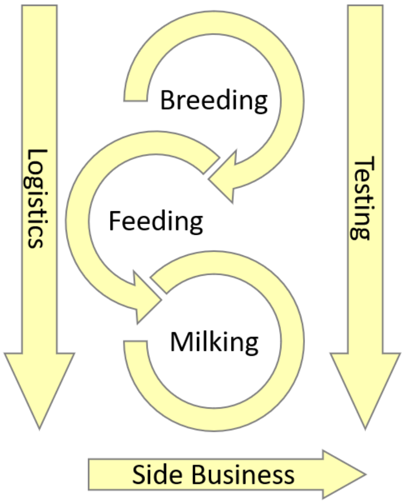

Figure 17. The developed business layer in the architecture

Table 9. Relationship between Business functions and business processes

Business function	Business process	Relationship	Source
Testing	Monitoring	Monitoring flows to Sampling	Table 18, No. 12, 13.
	Sampling	Sampling serves Testing	Table 18, No. 17, 33.
	Testing	N/A	Table 18, No. 14, 17, 35.
Breeding	Breeding	Breeding flows to Health care	Table 20, No. 86.
	Health care	N/A	Table 18, No. 30.
Feeding	N/A	N/A	Table 18, No. 19, 23; Table 19, No. 45.
Milking	Milking	Milking flows to Storing	Table 18, No. 20, 21;
	Storing	Storing flows to Selling	Table 18, No7, 8.
	Selling	N/A	Table 18, No. 6.
Logistics	Ordering	Ordering serves Allocating	Session 3.1.5.
	Allocating	Allocating serves Transporting	
	Transporting	N/A	
Side business	Hosting	N/A	Appendix 6.4.7
	Advertising	N/A	
	Business	N/A	

	cooperating		

Besides, there are two business services, three business actors, two business products and two resources are related to those business functions and processes. Those components' relationships and resources are elaborated in the following Table 10.

Table 10. Relationships of other components in the business layer

Type	Label	Relationship	Source
Business service	Reproduction	Breeding realizes Reproduction	Session 3.1.3
	Hospitality	Hosting realizes Hospitality	Appendix 6.4.7
Business actor	Technology supplier	Technology supplier serves Testing	Table 19, No. 14, 16
		Technology supplier serves Health care	Table 20, No. 83
	Equipment supplier	Equipment supplier serves Feeding	Table 20, No.82
		Equipment supplier serves Milking	Table 20, No.82
	Customer (Farm Owner)	Milking serves Customer	Table 20, No. 92
		Logistics serves Customer	Table 18, No.6
		Side business serves Customer	Appendix 6.4.7
Business product	Cattle	Cattle serves Breeding	Session 3.1.3
		Cattle serves Milking	Session 3.1.3
	Milk	Milk serves Testing	Table 18, No. 33
		Milk serves Milking	Table 20, No. 92, 93
Resource	Pasture	Pasture is associated to Testing;	Table 18, No. 14, 17
	Patent	Patent is associated to Business cooperating.	Appendix 6.4.7

With the information from Table 9, 10 and Figure 17, the business layer architecture is visualized in Archimate as Figure 18.

Breeding is the trigger function for Feeding and Milking. Logistics function supports the whole process of dairy farm operations from initial procurement to the final delivery. Side business function has integrated all other business processes such as hosting and business cooperation with other company, which have already discussed in the above sector.

The dairy farm normally has four business products that could bring income cash flow: milk, dairy products, cattle and roughage (See Figure 16. Business Canvas: Revenue Streams). However, roughage is sold only if it is redundant after feeding. And dairy product is not obligatory for every dairy farm. So, roughage and dairy products could not be "real" business products and they are not shown in the architecture. Cattle is not obligatory as one of revenue streams, though, it is essential for the breeding and milking function. So, "cattle" is included in the architecture.

Pasture and Patent are two special resources for dairy farms in the architecture, it is listed because they are essential and different from traditional resources, such as equipment and materials, in producing. The condition and quality of pasture will affect the health of cows so as the final products, which is milk. It is vulnerable because it will be affected by many factors, such as weather, climate, fertilizer, excrement, soil, and so on. On the other hand, it also has resistance and

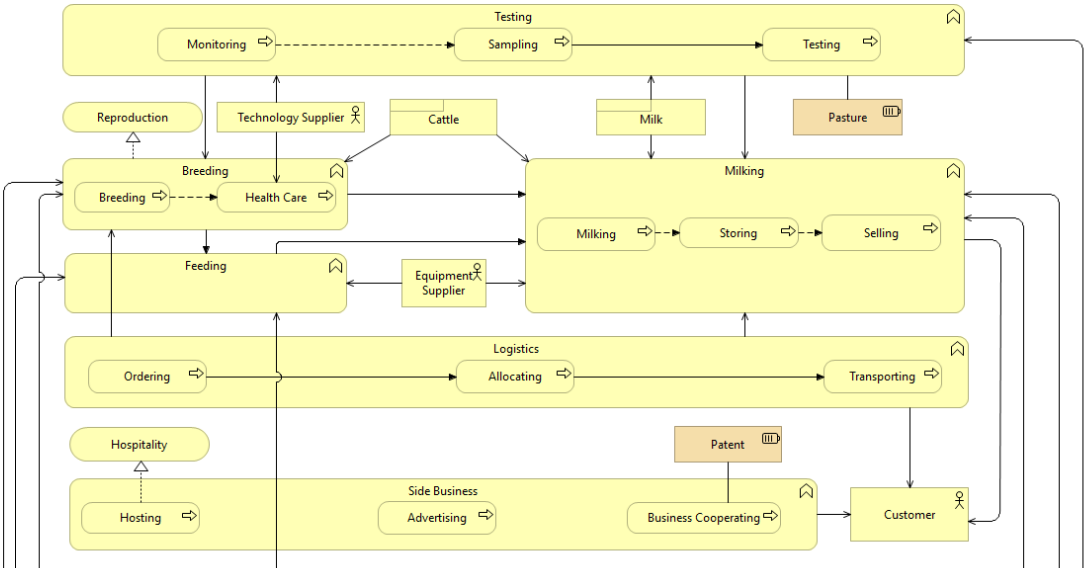

Figure 18. Architecture of business layer for dairy farms in the Netherlands

resilience stability for it also part of the ecological cycle. There is plenty of literature about the pasture (Kerkhof, Persie, Noorbergen, Schouten, & Ghauharali, 2015) (Mohammad Mehdi Matinzadeh A. K.-L., 2017). What matters about pasture with this topic is that lots of technologies are used to monitor and test the quality of pasture for dairy farms. With the feedback information and data, farm owners will decide what kind of concentrate and fertilizer are needed in the next period and for how much amount should they buy them. The information flow between technology suppliers and dairy farms assists the decision-making process on dairy farms and makes the management and operation more efficient and accurate.

The patent is another essential resource for dairy farms. What behind patents is knowledge, which is not well managed in the existing architecture. The process of knowledge formation and concretion is random and messy in the existing dairy farms. The occasional idea and inspiration are not yet well captured and transformed into concrete knowledge. Let alone to transform the knowledge into productivity. The conducted case study has proven that the dairy industry is relatively traditional, so innovation process barely happens inside the farm. Even there is emerging some idea and inspiration, the sharing process is only loosely connected with limited members and organizations, leading the innovation rate and actual conversion rate of knowledge are relatively low in the dairy farm industry. The industry has a model of one-way knowledge flow, which is from technology companies to the dairy farms. It is a pattern that the technology company invents the new machine or has a breakthrough in the breeding of cows and then generalize these technologies to dairy farms. But the dairy farmers, who always have the firsthand information in this industry, do not have an efficient path to put their thoughts back to technology companies quickly and timely.

Knowledge is a kind of information. If well managed, it will contribute a lot to the dairy industry as well as dairy farmers themselves. So, it could be a future improvement to add more the knowledge management system in the architecture of information system of dairy farms.

3.3 Application architecture

Then the application layer is added in Figure 19. The business layer and application layer are presented in this step. The business layer only keeps the core business process and expunge the side business and logistic, for it is out of this research boundary (session 3.1.5). IT systems are divided into internal information system and information system from external service vendors (session 3.1.1). The outsourced information systems are delegated with "Outsourced Testing Systems" in the architecture and it serves "Monitoring systems" in the application layer and "Testing" process in the business layer (Table 18, No. 30, 33, 34, 35). And the internal information systems are adopted according to three main purposes: monitoring, automation and better management (session 3.1.4). The relationship

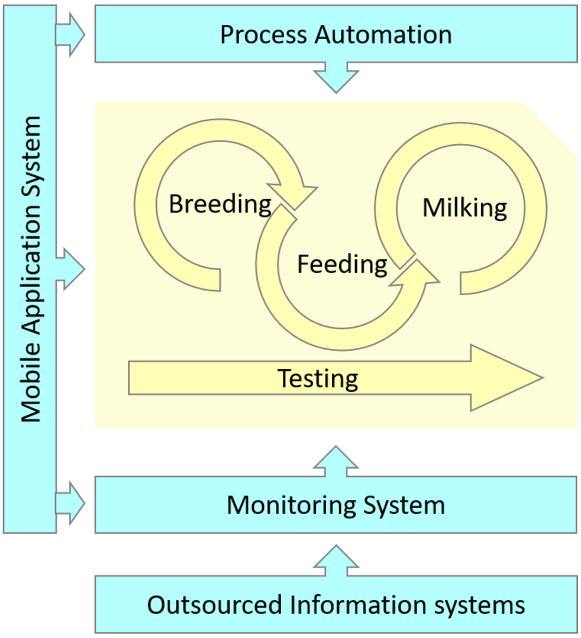

Figure 19. The developed business layer and application layer

between those three functions and relevant information systems are elaborated in the following Table 11.

Table 11. Relationships between business functions and information systems

Purpose	Information System (Application Component)	Application Function	Relationship	Source
Automation	Auto feeding system	Forage blending	Forage blending triggers forage allocation	Table 19, No. 47.
		Forage allocation	N//A	Table 19, No. 49.
		Cowshed	N/A	Table 19, No. 68.

		cleaning		
	Auto milking system	Tits locating	Tits location triggers tits cleaning; Tits location triggers automated milking	Table 19, No. 64. Table 19, No. 58.
		Tits cleaning	N/A	Table 19, No. 64.
		Automated milking	N/A	Table 19, No. 58.
		Extra feeding	Extra feeding serves tits locating; Extra feeding serves tits cleaning; Extra feeding serves automated milking.	Table 19, No. 66.
Monitoring	Monitoring system	Activities monitoring	Activities monitoring realizes Health care	Table 18, No. 13.
		Diet monitoring	Diet monitoring realizes Health care	Table 18, No. 12.
		Bioinformation monitoring	Bioinformation monitoring realizes Health care	Table 18, No. 13.
		Milking monitoring	Milking monitoring realizes Health care	Table 19, No. 63.
		Temperature monitoring	Temperature monitoring realizes Quality assurance	Session 3.1.7.
		Color monitoring	Color monitoring realizes Quality assurance	Session 3.1.7.
		Nutrient monitoring	Nutrient monitoring realizes Quality assurance	Session 3.1.7
Better management	Breeding support system	Breeding match	N/A	Appendix 6.4.1; Table 20, No. 86.
	Mobile application system	N/A	N/A	Table 19, No. 50.

The application layer connects business layer thorough application service, and the relationship among information systems, application services and purposes are elaborated in the following Table 12.

Table 12. Relationships among information systems, application services, and purpose

Purpose	**Information systems (Application Component)**	**Application service**	**Business function**
Automation	Auto feeding system	Feeding automation	Feeding

	Auto milking system	Milking automation	Milking
Monitoring	Monitoring system	Health care	Breeding; Feeding
		Quality assurance	Milking
Better management	Breeding support system	Breeding support	Breeding
	Mobile application system	N/A	N/A

With the information from Table 11, 12 and Figure 19, the application layer architecture is visualized in Archimate as Figure 20.

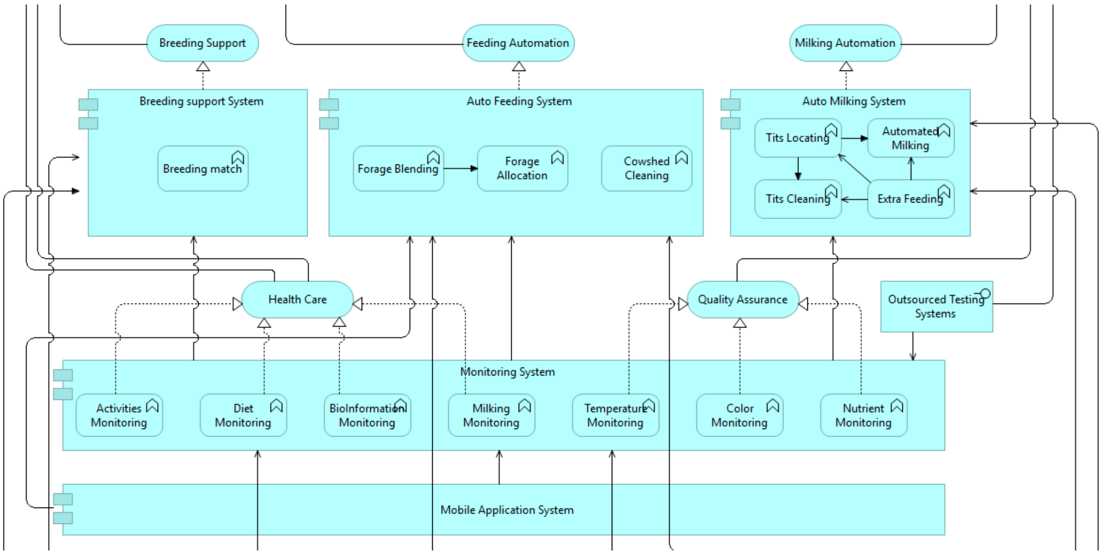

Figure 20. Architecture of application layer for dairy farms in the Netherlands

Some outsourced technology suppliers, such as Agrifirms and Eurofins, could provide the external monitoring services with the professional standard under the contracts with dairy farms. For example, GD will monitor germs on milk sampled from milk tank each month and some excepted reports are represented in Figure 21 and 22. Normally these reports will become an essential consideration for business decisions made in the next periods.

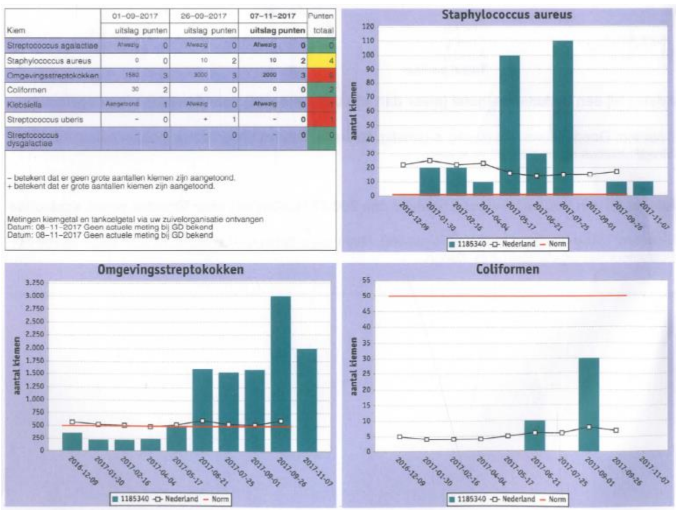

Figure 21. Part of the report provided by GD about the germ situation in the milk tank

Monitoring System serves the Breeding Support System, the Auto Feeding System and the Auto Milking System. And it also served by outsourced technology supplier through an application interface. Monitoring System is realized by seven incorporated application functions: activities monitoring, diet monitoring, bio-information monitoring and milking monitoring realize the healthcare service and are mainly focused on cows; temperature monitoring, color monitoring and nutrient monitoring realize the quality assurance service and are mainly focused on milk.

Activities monitoring could provide the motion track and distance of a cow through a sensor on the neck of the cow. Diet monitoring provide diet information about each cow with the feedback from feeding robots. And it could provide data for potential improvement of diet formula in the future. Bio-information is collected from sensors as well, and it covers the basic information for each cow. Milking monitoring is achieved by milking robots and it could warn farmers that certain cows haven't been milked for a long time. Any abnormal data from these four functions could be a sign of sickness or pregnancy and should be noticed. Temperature, color and nutrient are all monitoring factors of milk and they could be collected from milking robots and verified by outsourced technology supplier. It will make the quality assurance of the milk for storing and selling in the business process.

Auto Feeding System is realized by three application functions: forage blending, forage allocation and cowshed cleaning. Cowshed cleaning is achieved by cleaning robots to make sure the cycle of feeding is fluent. Forage blending and forage allocation are achieved by feeding robots. They could precisely fetch materials from the warehouse with preset parameters and blend them into a mixture of fodder, and then allocate the fodder to different sectors in the barn. Forage blending triggered forage allocation.

		Stafylokokken[1]			Streptokokken[2]			Coliformen[3]			Klebsiella		
		2017	2017		2017	2017		2017	2017		2017	2017	
Antibioticum	Toedieningswijze	Feb	Jul	Trend	Feb	Jul	Trend	Feb	Jul	Trend	Feb	Jul	Trend
Eerste Keuze													
Cloxacilline	M, D			=	O	O							
Erythromycine	I			↑	O	O							
Lincomycine	M			=	O	O							
Nafcilline	M, D			=	O	O							
Penethamaat	I, D			↑	O	O							
(benzyl-)Penicilline	M, I, D			↑	O	O							
Pirlimycine	M			=	O	O							
Trimethoprim/sulfa	I			=	O	O		O	O		O	O	
Tylosine	I			↑	O	O							
Tweede keuze													
Amoxicilline/clavulaanzuur	M			=	O	O		O	O				
Ampicilline	M, I			↑	O	O		•O*	•O*				
Cefalexine (1ste gen.)	M			=	O	O		•O*	•O*				
Cefalonium (1ste gen.)	D			=	O	O		•O*	•O*				
Cefapirine (1ste gen.)	M, D			=	O	O		•O*	•O*				
Framycetine	D			=				O	O		O	O	
Kanamycine	M			=				O	O		O	O	
Neomycine	M, I, D			=				O	O		O	O	
(dihydro)Streptomycine	M, I, D			=				O	O		O	O	
Derde keuze													
Cefoperazone (3de gen.)	M			=	O	O		O	O		O	O	
Cefquinome (4de gen.)	M, I, D			=	O	O		O	O				
Marbofloxacine	I							O	O		O	O	

1: *Staphylococcus aureus* en CNS
2: *Streptococcus uberis, Streptococcus dysgalactiae en Streptococcus agalactiae*
3: Coliformen (o.a. *E. coli*) exclusief Klebsiella

Figure 22. Part of the report provided by GD about the germ situation in the milk tank

Auto milking system is realized by four application functions: tits locating, tits cleaning, automated milking and extra feeding. Tits locating is achieved by lasers and it is the per-step and trigger titles cleaning and automated milking. And extra feeding is a small feed bar inside the milking robots to comfort the cows during the whole process.

The mobile application system moves monitoring system and auto feeding system from computer to a mobile device, a smartphone for example. Mobility is another big advantage that ICT brings to the agriculture sector. Farmers could remotely control the feeding process from their smartphone and do not need to be onsite. Besides, they could glance the real-time situation, such as the milk production, cows feeding and the fodder inventory, about their farms, even when they are out of farm for a vocation. The mobile application system is a link to the future prospect of the smart dairy farm, where the farm could be fully automated and operate without the presence of farmers.

3.4 Technology architecture

At last, the technology layer is added to serve the application layer and the business layer. The central control system (session 3.1.4) and related components, such as UI, OS, PC, Interface (Table 18, No. 12; Table 19, No. 54; Table 20, No.87). At the same time, an instruction chain about the operation of robots is clear: i.e., the central control system generates orders; those orders control robots; and robots collect data for analysis and decision-making process (session 3.1.4; Table 19, No. 48, 51, 62). With those information, the technology layer is constructed, as presented in Figure 23.

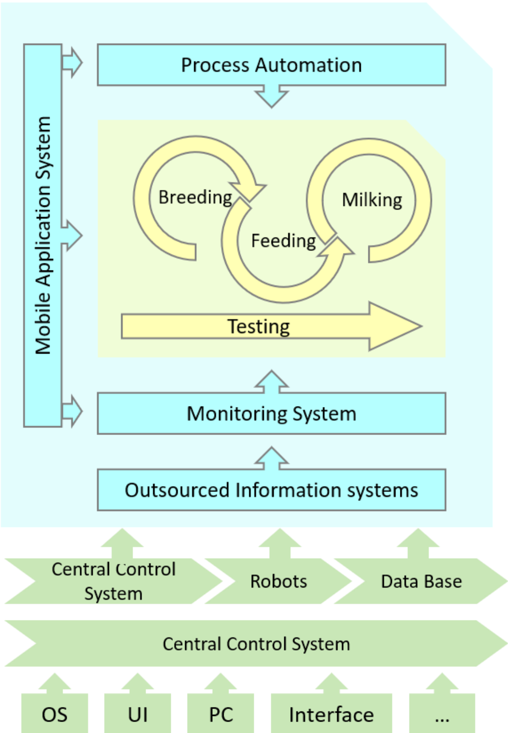

Figure 23. The developed technology layer, application layer and the business layer

The central control system is the core of technology layer, the farmers interact with this system to monitoring data from farms and make instructions to farms. The central control system and its relationship with other components in the application layer is elaborate in the following table 13.

Table 13. Relationships between the Central control system and other components

Component	Type	Function	Relationship	Source
Operation system	System software	Operate the information system	Operation system serves Central control system	N/A
User interface	Application interface	Interact with users	Operation system is composed of user interface	N/A
Communication network	Communication network	Communicate with other users	Communication network is associated with central control system	Table 19, No. 55.
Computer	Device	Hardware	Computer is associated with central control	Table 18, No. 13; Table 20, No. 87.

			system	
DBMS	Node	Manage the data	Central control system serves DBMS	Table 19, No, 54; Table 20, No 82.
Milking robots	Device	Milking process automation	Central control system serves milking robots	Table 19 No. 42, 56,57,58,60.
Feeding robots	Device	Feeding process automation	Central control system serves feeding robots	Table 19, No. 48.

And central control system and the DBMS realizes four technology services to support the application layer, the relationship between those three are elaborated in the following table 14.

Table 14. Relationships between the Central control system, DBMS and four technology services

Node	Technology Service	Relationship	Source
Central control system	Control	Control serves breeding support system	Appendix 6.4.1; Table 20, No. 86.
		Control serves auto feeding system	Table 19, No. 48.
		Control serves auto milking system	Table 20, No. 62.
		Control serves monitoring system	Table 18, No. 12, 13.
DBMS	Data visualization	Data visualization serves monitoring system	Table 18, No. 27.
		Data visualization serves data sharing	Table 20, No. 85.
	Data management	Data management serves breeding support system	Table 20, No. 86.
		Data management serves auto feeding system	Table 19, No. 49.
		Data management serves auto milking system	Table 19, No. 65, 66.

With the information from Table 13, 14 and Figure 23, the technology layer architecture is visualized in Archimate as Figure 24.

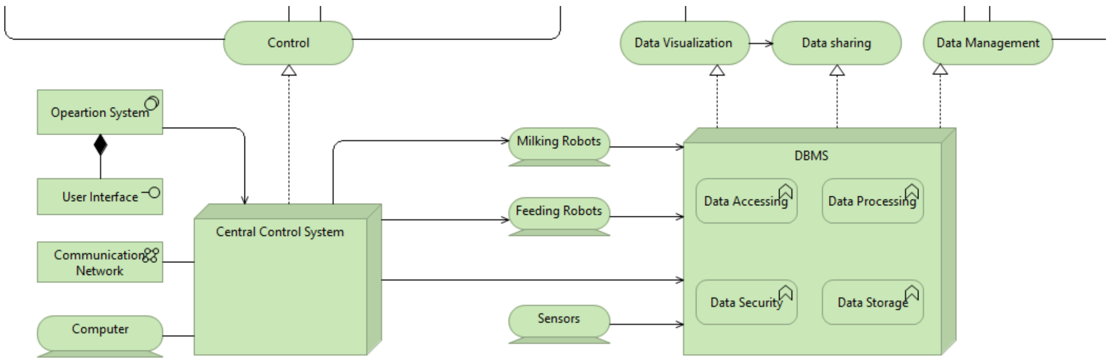

Figure 24. Architecture of technology layer for dairy farms in the Netherlands

Data Visualization could automatically draw charts and tables out of the data they collect from different resources. From the charts and tables, farm owners could get a well understand about the situation of cows, barn, fodder, milk and pasture. So, it serves monitoring system. The tables and charts are various, and some example could be like Figure 25 and 26. Figure 25 is about the quality and nutrient of the milk they delivered, and Figure 26 is about the quality and conditions of pasture and grass. With these regular reports, the data about every perspective inside the dairy farm are visualized to farm owners. Farm owners could use this data to support their operational decisions. For example, purchasing the concentrate, selling calves, restoring the grass preparing the breeding, and so on.

Onderzoek Onderzoek-/ordernummer: 344440/003894863 Oogstdatum: 01-08-2016 Kopiehouder: Agrifirm H. Marsman, Themisln 99 1702 AV HEERHUGOWAARD

Resultaat in gram/kg, tenzij anders vermeld.		Resultaat product	droge stof	Streef-traject	Veen najaar		Resultaat droge stof	Streef-traject	Veen najaar
	DS	487		300-500	552	Ruw as	119	90-120	104
	pH	4,9		4,7-5,7		VCOS (%OS)	73,5	76-80	72,1
	Boterzuur		1,3	< 3,0	1,2	NH_3-fractie (%RE)	6	< 7	6
	Azijnzuur		14	10-20	5	Nitraat	2,5	< 7,5	3,2
	Melkzuur		30	10-30	9	Ruw eiwit	174	160-190	153
	VEM	412	845	880-940	831	Ruw eiwit totaal	186	170-210	163
Voederwaarde en analyse-resultaat	VEVI	418	859	900-980	840	Oplosbr.ruw eiwit(%RE)	54	40-60	52
	DVE*	32	65	60-80	62	Ruw vet	40	30-50	38
	OEB*	27	55	40-80	33	Ruwe celstof	241	230-280	267
	VOS	316	648	680-720	646	Suiker	68	80-140	92
	FOSp*	257	527	525-600	520	NDF	488	420-500	527
	OEB* 2 uur	29	59	40-95	43	NDFvert.br.hd(%NDF)	65,3	70-80	65,9
	FOSp* 2 uur	112	230	225-300	212	ADF	272	240-290	288
	Structuurwaarde		3,1	2,6-3,0	3,3	ADL	27	20-30	24
	Verzadigingswrd.		1,00	0,95-1,10	1,05				

Figure 25. Part of the report about the quality of the milk

Data Sharing is served by Data Visualization. And it is accomplished through a portal incorporated in the data system. For example, Lely Company is providing the portal for farm owners to share their milking data within the milking system and every farm installed Lely milking robots could know the milking quantity and quality from other farms. Data management is the fundamental service for the three automation components in the application layer. And this service contained all perspectives about data. From the technology node DBMS, the data accessing, data processing, data security and data storage all are parts of data management.

20 april 2017

Bedrijfsnummer: 881910

Management 07-2017

Geleverde melk van 01 april t/m 15 april 2017

MEDEDELINGEN

KWALITEIT ( ) = datum

jr	mnd	kiem	geo. kiem	cel	geo. cel	reinh.	boterz.	zg. vet	vr. punt	chlorof.	rec. punt	kw. punt
16	okt	7 (24)	7 (24)	166 (18)	218 (18)			0,20 (30)	-0,521 (30)			
16	nov	6 (02)	7 (02)	88 (05)	175 (05)	Goed (02)	+ - (02)	0,21 (29)	-0,522 (29)			
		7 (23)	7 (23)	104 (26)	160 (26)							
16	dec	9 (08)	7 (08)	202 (11)	143 (11)	Goed (08)	-- (08)	0,21 (29)	-0,523 (29)			
		6 (20)	7 (20)	81 (26)	130 (26)							
17	jan	5 (04)	6 (04)	90 (04)	106 (04)	Goed (04)	-- (01)	0,21 (31)	-0,524 (31)			
		6 (16)	6 (16)	77 (19)	101 (19)							
17	feb	6 (06)	6 (06)	134 (09)	109 (09)	Goed (27)	-- (06)	0,21 (27)	-0,522 (27)			
		8 (21)	6 (21)	189 (21)	119 (21)							
17	mrt	8 (05)	7 (05)	145 (05)	121 (05)	Goed (08)	-- (05)	0,20 (29)	-0,521 (29)			
		9 (17)	8 (17)	196 (23)	131 (23)							
17	apr	10 (07)	9 (07)	116 (13)	153 (13)	Goed (13)	-- (07)			0,00 (04)		

Leverantiegegevens

Datum	Tijd	Liters	Kg	Temp.	Eiwit %	Vet %	Lact. %	Ureum	Bac.	Zg.vet	Vr.pnt	Tank
01.04.2017	07:14:12	7.002,3	7.226	3,8	3.46	4.11	4.56	24	-	0,2	-0,519	881910
04.04.2017	07:58:58	7.142,1	7.371	3,6	3.50	4.07	4.58	25	-	0,2	-0,522	881910
07.04.2017	08:04:32	7.568,6	7.811	3,6	3.55	4.11	4.60	24	-	0,2	-0,521	881910
10.04.2017	10:38:44	7.515,1	7.756	3,8	3.53	4.19	4.59	23	-	0,2	-0,523	881910
13.04.2017	07:08:19	7.367,7	7.603	3,7	3.54	4.20	4.58	25	-	0,2	-0,524	881910
Totaal		36.595,8	37.767		3,52	4,14	4,58	24				

Figure 26. Part of the report about the condition of pasture

From a business perspective, the data management service supports the business operation process and even predict the future performance from an accounting view. For example, Figure 27 shows the prediction of future performance for certain farm, and it is conducted from historical data as well as the modeling of dairy farm operations. From this figure, the accounting company predicts the current account balance in the upcoming year with different expectations.

The central control system is directly facing the farm owners. It incorporates an operating system with and User Interface so that the farm owners could easily interact with systems.

A computer is a good choice for such Central Control System. Normally, a computer installed inside the farm could control the operation of feeding and milking robots, monitoring the cows and milk as well as pasture. All automation could be integrated into one single computer.

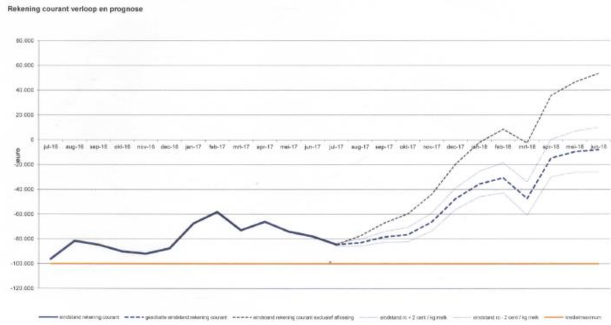

Figure 27. The prediction about the financial performance in the future by FLYNTH

3.5 Overall architecture

As it mentioned above, there are approximately 18,000 dairy farms operated in the Netherlands. The dairy farms could be divided into three categories in terms of the size: the small, medium and a large one. A farm with less than 100 cows will be considered as a small dairy farm; a farm with cows between 100-200 will be considered as a medium dairy farm, and a farm has over 200 cows is a large dairy farm.

Normally, the bigger a dairy farm’s size is, the more complex its information systems will be. The medium dairy farms will deploy some information technologies that are not necessary for a small dairy farm. For example, an owner of a small size dairy farm expressed his unwillingness of using monitoring sensors (a sensor is tie on the neck of a cow to monitor the health condition of cows) to collect the data of his cows, and considered it as a waste of time and money. “I could see from my eyes that which cow is sick and unhealthy” said by him. Because he only raised 40 cows on his farm, and he raised them for almost 30 years, he has enough time and experience to manage cows’ health without the help of information technology. But the monitoring sensor is a popular way among medium dairy farms. Because it is an effective and time-saving way during the operation of farms.

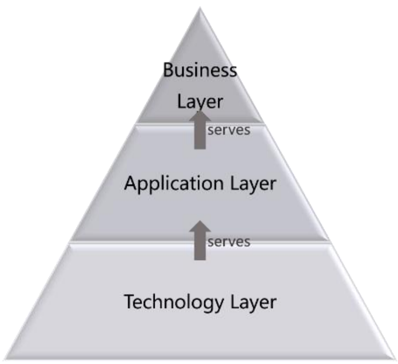

Figure 28. Relationship between layers in the architecture

The medium size farm is the majority in the Netherlands, to maximize the applicability of the architecture, all architectures in the following session are based on the medium dairy farm.

Based on the theoretical model in the session 2.2 and the case study result in the session 3.1, an overall reference architecture for dairy farming is constructed from three layers: business layer, application layer and the technology layer. In Figure

28, we could easily find the relationship among three layers. According to the

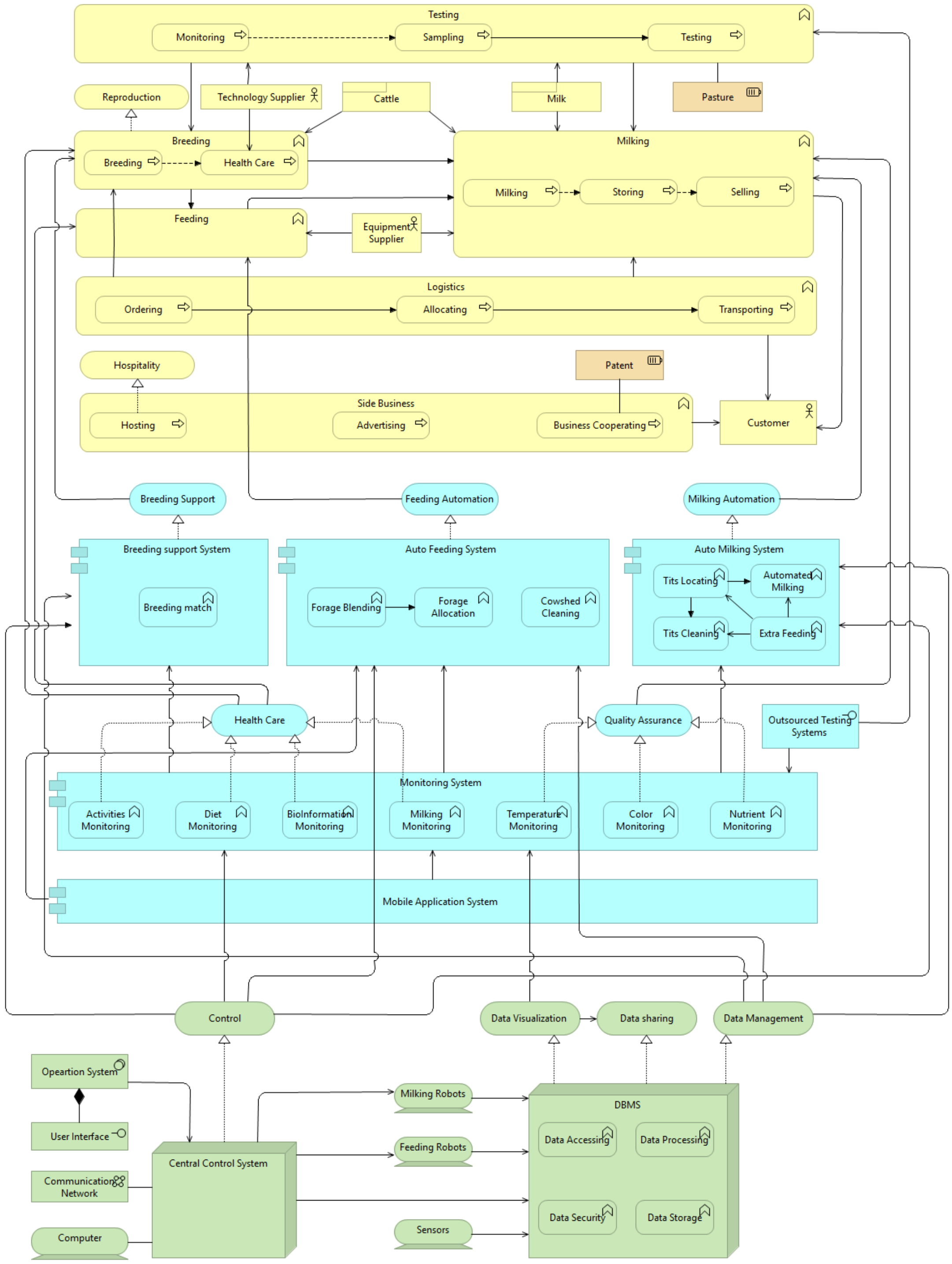

Figure 29. The overall architecture of dairy farm in the Netherlands

architecture results in session 3.2-3.4 from three layers, the overall architecture of dairy farms in the Netherlands is presented in Figure 29. In this architecture, the yellow components are from business layer; the blue components are from application layer; the green components are from technology layer and the orange components are resources in the business. The definition of different components could be found in the Archi user guide (Phillip Beauvoir, 2017) and more supportive resource could be found in Archi support (Beauvoir, 2018).

3.6 Interaction model

After the whole information systems architecture on the dairy farm is elaborated, the interaction model in Figure 30 will be a complementary document for clarifying the interaction behaviors between components inside this architecture. In this model, the related roles and factors relate to each other through interaction behaviors, with the support of information flow under them. Through the information system, the farmers could optimize their interactions with machines and cows and other roles in the dairy industry, such as government and suppliers. The arrows in the model start from the active part of interactions and point to the passive part, and they also represent the direction of information flow between two actors.

For convenience, the logos of Eurofins and Lely are selected as the representatives

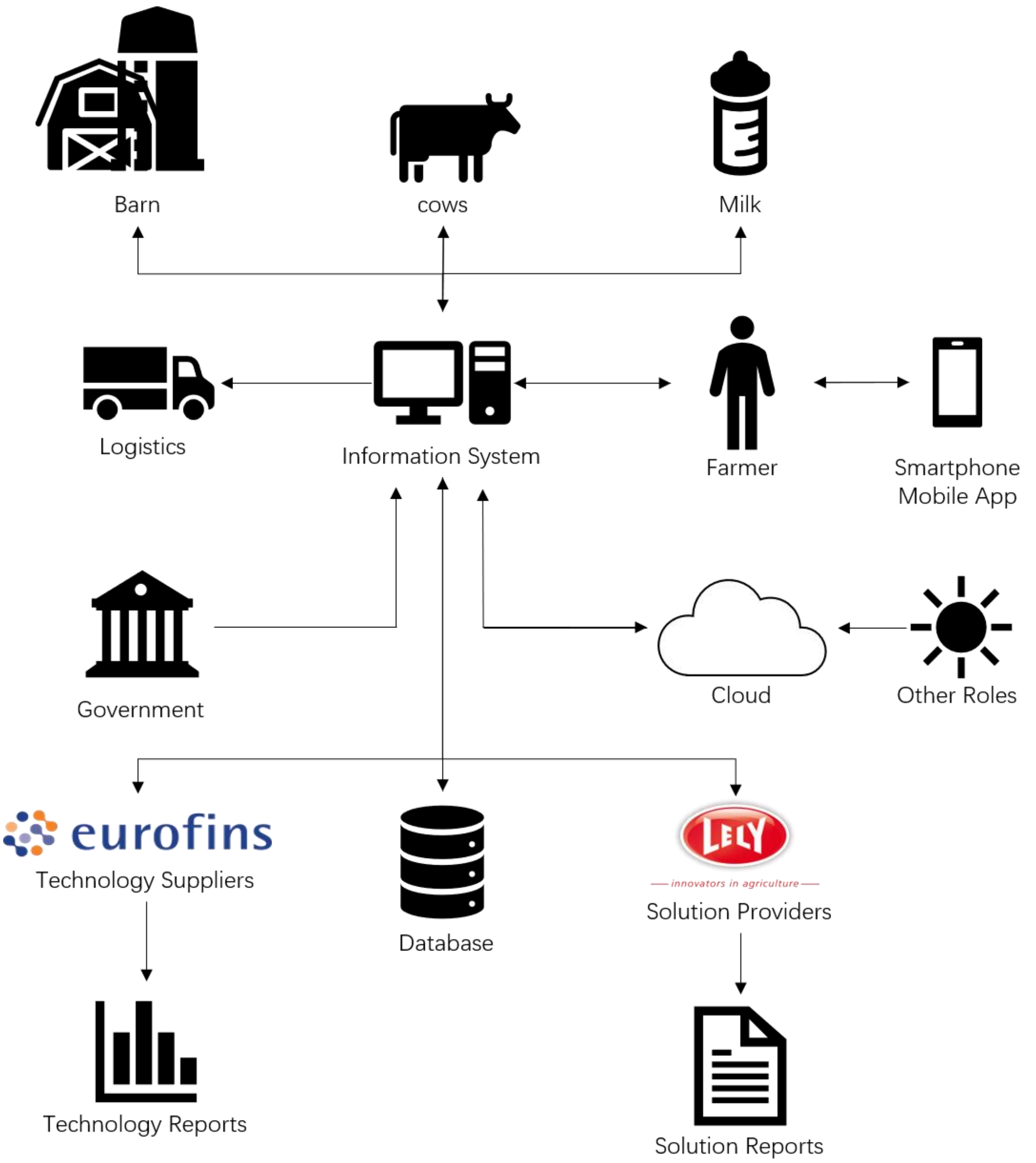

Figure 30. The interaction model of dairy farms in the Netherlands

of technologies suppliers and solution provides respectively, though, there are dozens of companies in the industry.

Table 15 concludes the detailed interaction behaviors and information flow between those roles and factors.

Table 15. Interaction behaviors and information flow between roles

Active role	Passive role	Interaction behaviors and information flow
Information system	Barn	IS controls the automation process inside the barn, such as auto feeding, auto milking and auto cleaning
Information system	Cows	IS collects information from cows, including bio-information, activities, and milking data
Information system	Milk	IS monitors the quality of milk and collect the information of milk such as yield, color and temperature
Information system	Logistics	IS controls the order from milk company and for fodder suppliers, IS controls the data from logistics process
Information system	Farmers	IS provides farmers with a dashboard of information inside their farms and send farmer alerts when necessary
Information system	Technology suppliers	IS provides data and information about farms for technology suppliers for research purpose
Information system	Solution suppliers	IS provides feedback to solution suppliers about their solutions
Information system	Database	IS stores and accesses data from the local database
Information system	Cloud	IS fetch related information from cloud to support the operation, such as weather
Barn	Information system	Robots in the barn will transform the working information back to the information system
Cows	Information system	Cows provide information for the information system
Milk	Information system	Milk is the data source of information system
Farmers	Information system	Farmers make decisions in information system and manage their business through IS
Farmers	Smartphone mobile App	Farmers use smartphone mobile application for remote control of the farm operations
Smartphone mobile App	Farmers	Smartphone mobile App provides farmers a remote interface to access data in the farm
Government	Information system	Government makes regulations about dairy industry and surveilled the operations of dairy farms
Cloud	Information system	Cloud responses to requests from the information system, such as the data access and streaming analysis
Other factors	Cloud	Other factors will migrate related data and information to the cloud
Technology suppliers	Information system	Technology suppliers provide professional testing service to support the decision-making process
Technology suppliers	Technology reports	Technology makes technology reports, such as testing reports about milk, cows and pasture
Database	Information system	Database responses the data-related operation from information system
Solution suppliers	Information system	Solution suppliers provide business plan and related equipment for farmers, such as milking robots
Solution suppliers	Solution reports	Solution suppliers makes solution reports, such as the plan of upgrade of the barns or milking process automation

In this table, the interaction behaviors are listed and described. This model helps the understanding of the information architecture in the above session 3.2 – 3.5.

4. Conclusions and recommendations

4.1 Conclusions

Baes on the research question (session 1.1), this research is conducted. The conclusions of this research are:

This study builds a general-adoptable reference architecture (see Figure 29.) of information systems used on dairy farms of Netherlands. This reference architecture is based on the case study conduct on two dairy farms and validated by the owners of those farms. This reference architecture is efficient when suiting medium size dairy farms. After the analysis of three different layers, the architecture is designed in business layer, application layer and technology layer. and how will information system support the business operations and decision-making process of dairy farms.

Dairy farmers organize their business process according to the natural process of milk producing. After the business process is established, IT is introduced to support the business process from three main perspectives: for better management, for monitoring and for automation. Dairy farmers organize information systems on their farms according to different business process, and each business process corresponds to an information system. The information systems support the business and they also corelated with each other. The reference architecture in Figure 29 describes these relationships.

Users (dairy farmers) adopts information system to support their dairy business, and most of information system are satisfied by farmers. The potential improvement of information systems could be discussed in future researches.

4.2 Recommendations

In the further research, there are several potential research directions and some improvements could be done based on this study:

1) The strategy layer is not involved. The architecture process involves the business layer, application layer and technology layer. But the strategy layer is not yet incorporated. The future researcher could add this part to the architecture.
2) This research considered the factors influence business operations from chemistry, biology, physics, technology, climate, economics. Yet the human factor is not well considered in the business process and decision-making process. Actually, the human-related factors have huge potential influences on the business process. S. Fountas et al. analysis the 141 existing FMIS and mentioned one future perspective to improve the FMIS. They believed the evolution of FMIS must take the human-related nature of business process into consideration, which means the FMIS should also consider the social aspects to truly support the owners' decision-making process (Fountas, 2015). It provides a possible future improvement also for the smart dairy farming information system, for human factors are making more and more influence during business and sales process.
3) Due to the geographic restriction, the migration of this architecture to other areas are not yet verified. the future research could start from the experiment about applying this model to another area, and study the possibility, preparations, requirements and conditions of this architecture migration.

5. Acknowledgements

This research took place under the supervision of Dr. Werner Heijstek, Dr. Julia Wijnmaalen, Drs. Bas Kruiswijk and Dr. Xishu Li. I would thank dairy farmers Gerard de Groot, Els and Gerard Milatz, who provided me hospitality for the whole case study process and information about their farms. I would also want to thank Arjen van der Kamp, who is the information officer of Lely Company and contribute a lot to this architecture.

6. Appendix

6.1 Abbreviations

Table 16. Abbreviation table

Abbreviation	Full title
LEI	Institute for Agricultural Economics
CBS	Statistics Netherlands
IDF	International Dairy Federation
VIC	Village Information Center
ERP	Enterprise Resource Planning
FMIS	Farm Management Information System
EVAPs	Evaporative cooling systems
WSNs	Wireless Sensors Network
GD	Gezondheidsdienst voor Dieren (the health service for animals)

DBMS	Data Base Management System
IS	Information Systems

6.2 Research process and agenda

The duration of this research is five months, and the detailed schedule is in the following Table 17.

Table 17. Schedule of the research

Data	Location	Event
15th September 2017	Leiden	Decide the areas of research
16th September 2017	Leiden	Start the literature review
30th September 2017	Leiden	Decide the topic of research
7th October 2017	Leiden	The first meeting with the supervisor
22nd October 2017	Leiden	Finish the thesis proposal
26th October 2017	Leiden	The second meeting with the supervisor
27th October 2017	Leiden	The third meeting with the supervisor
28th October 2017	Zoetermeer	The first field survey
29th October 2017	Zoetermeer	The second field survey
31st October 2017	Leiden	Start the draft of the thesis
16th November 2017	Beets	The third field survey
6th December 2017	Leiden	The first meeting with information officer from Lely company
14th December 2017	Leiden	The fourth meeting with the supervisor
16th December 2017	Leiden	The follow-up interview with the information officer from Lely company
31st December 2017	Leiden	The first draft of the thesis
4th January 2018	Leiden	The fifth meeting with the supervisor
5th January 2018	Leiden	The revise of the thesis
10th January 2018	Leiden	The second draft of the thesis
20th January 2018	Leiden	The final version of the thesis
12th February 2018	Leiden	The defense of the thesis

6.3 Interview transcription result

The interview transcription results are elaborated in the following three tables.

Table 18. Classification of information from interview on Chestnut Dairy Farm

Interview with the owner of Chestnut Dairy Farm Interviewer: Hanxin Niu Interviewee: Els and Gerard Milatz Interview date: 16th November 2017 Interview location: Chestnut Dairy Farm, Beets		
No.	**Label**	**Related information**
1	context	Our farm's name is the Chestnut Dairy Farm
2	context	We raised 120 cows and 40 calves
3	context	I had this farm from 1981
4	context	I could handle all the business inside the farm by myself
5	context	My son came to help from time to time
6	vendor	We cooperated with FrieslandCampina, and they came to fetch the milk each three days
7	interaction	We stored the milk in a tank and wait for them to be fetched by Campina
8	function	The milk tank will keep milk cold and fresh
9	function	We make our payment and get money through RABO Bank
10	vendor	75% of farmers in the Netherlands use RABO Bank to do their business
11	context	We use a lot of information technologies to help our business

12	function	We use sensors to monitoring the health of cows and calves
13	interaction	We could monitor their moves and activities and other bio-information from the screen
14	vendor	Each year, Agrifirm will come and test the pasture and field
15	interaction	We buy concentrate, fertilizer, and other products, such as amygold, bostel, masterd from Agrifins
16	vendor	Eurofins provides laboratory services for us
17	function	They (Eurofins) will sample the soil and grass and test them
18	context	We do not have a feeding robot yet
19	function	We have tractors to do the feeding instead
20	context	We do have milking machines
21	function	The milking process is automated
22	context	We have three tractors
23	function	(tractors) One for feeding, one for throwing and mixing and another for heavy works
24	function	CRV provides detailed information about the conditions of our cows, including age, weight, milk yield, healthy condition and so on
25	other	We could find live weather condition from CRV systems
26	function	CRV also provide breeding service
27	function	CRV will help you generate reports for the government inspection
28	interaction	We do use management systems from CRV, it helps us a lot
29	relationship	CRV and GD cooperated with each other
30	function	GD is a healthy service provide
31	relationship	GD is started by the government
32	function	We could get health advice about cows from GD
33	function	They (GD) sample the milk and test it
34	function	GD has a system to track the condition of your milk and send the report back to you
35	other	GD runs these tests each month
36	vendor	We work with FLYNTH, which is an accounting company
37	function	FLYNTH will take charges in all financial work, including accounting, tax, and loan with the bank
38	interaction	They (FLYNTH) has accounting information system and will provide financial paper for us
39	function	They (FLYNTH) also provide financial advice according to our profit situation

Table 19. Classification of information from interview with information officer of Lely Company

Interview with the information officer from Lely Company **Interviewer: Hanxin Niu** **Interviewee: Arjen van der Kamp** **Interview date: 6th and 16th, December 2017** **Interview location: Central station, Leiden**		
No.	**Label**	**Related information**
40	context	Our company has run this business for 25 years
41	context	We provide farmers with equipment and solutions
42	function	The main products including milking robots, feeding robots, cleaning robots
43	function	We also provide cloud migration solutions for dairy farms
44	context	The biggest advantage for farmers to use robots is the economic efficiency they will get
45	context	50% of the cost in a dairy farm is feeding process
46	context	The adoption of feeding robots could apparently save the cost of feeding process in a long-term
47	function	Feeding robots will fetch different materials from storage and mixed them
48	interaction	Farmers could make their own formula for fodders, and robots will follow these instructions

49	function	Feeding robots could make different fodders for cows in different stages, such as calves
50	interaction	We provide mobile application so that farmers could manage their farm in remote
51	function	Mobile application will send warnings to farmers if something goes wrong in the farm
52	relationship	We cooperate with chips vendors to make sensors
53	function	These sensors could monitor the health situation and predict the breeding of cows
54	interaction	We collect lots of data from these robots every day
55	interaction	We have an information sharing platform for farmers
56	context	The milking robots are more advanced than the most milking machine in the market
57	context	Each milking robots could handle 60 cows
58	context	Milking robots will work 24 hours per day
59	context	Averagely speaking, each cow could milk 3 times per day
60	context	Milking robots will save the space of barns
61	context	We are promoting this barn update plan for farmers
62	interaction	The milking robots are controlled by computers
63	function	It (milking robot) will analyze the quality of milk when milking
64	function	It (milking robot) also clean the tits of cows, it makes sure the quality of milk as well
65	function	Milking robots will monitor the milk time of cows
66	function	It (milking robot) will send alert to farmers if some cow hasn't been milked for a long time
67	interaction	Farmers are satisfied with the free time and labor-saving once they get used to the robots
68	function	The cleaning robots take charge of cleaning inside the barn
69	context	It (cleaning robot) will save lots of time for farmers and release them from dirty work
70	context	The cleaning process is for the health of cows
71	interaction	It (cleaning robot) will automatically go out to clean as scheduled
72	other	We are trying to construct a cloud platform to response the requests of farmers
73	other	We have issued on connecting the systems inside the barn with the outside world

Table 20. Classification of information from interview on Dairy Farm "Gewoon Leuk"

Interview with the owner of Dairy Farm "Gewoon Leuk"
Interviewer: Hanxin Niu
Interviewee: Gerard de Groot
Interview date: 28th and 29th, October 2017
Interview location: Dairy Farm "Gewoon Leuk", Zoetermeer

No.	Label	Related information
74	context	I have run this dairy farm for 34 years
75	context	I raise 40 cows
76	context	The farm has 21.5 hectares of pasture
77	context	According to Dutch regulation, we could only raise 2 cows per hectare of pasture
78	context	I do not want to expand my farm
79	context	This farm could already raise my family
80	context	I do not use many information systems on my farm, but I do use some of them
81	context	I do not need robots to do my job, I could handle them myself
82	vendor	Lely Company provides milking robots for dairy farms and they have lots of data of cows
83	vendor	CRV is a great choice for the management
84	other	CRV is a mandatory system that required by government
85	function	CRV will provide me reports about my cows
86	function	I could find the breeding bull from CRV, but I don't have to
87	function	It (CRV) will provide a dashboard so that I can monitor all my cows in the office
88	context	I don't have to adopt ear sensors to monitor my cows
89	context	I could see from their (cows) eyes to know if they are okay

90	vendor	A company called AGIS provide ear sensors for cows
91	function	I use RABO Bank to do the payment and collect the money
92	context	I milk my cows twice per day
93	context	Each milking process will last 1.5 to 2 hours
94	other	I think the online transfer of bank could be improved and I heard the bank has already started doing it

6.4 Research company and farms

6.4.1 CRV

CRV is a worldwide service vendor based in Arnhem, the Netherlands. It provides farm and stock management system and technologies of breeding, health, and monitoring for dairy and beef farmers in the world. (CRV Avoncroft, 2017) It is formed as an organization with mutual support cooperated society, at where most of the farmers could be cooperated and collected. The organization will mainly assistant dairy and beef farmers from five perspectives: fertility, health, efficiency, longevity and production. As long as a farmer becomes a member of the CRV, the organization will provide the farmers best stock bull for best cow and a whole monitoring and management information system to manage their dairy farm. Besides, this organization with also automated generate the most of paper reports of farmers cow for the use of government supervision.

6.4.2 Lely Company

Lely company, located in the Netherlands, is a solution service vendor for livestock farms worldwide and supports their farm work to be pleasant and convenient. As it mentioned on the website "As an international family business in the agriculture sector, we are working daily to make livestock farmers' lives more pleasant with innovative solutions and targeted services. To this end, we offer solutions for almost all activities in the cow barn: from milking to cleaning. And advice for the smart organization of the dairy farm using management systems." (LELY Company, 2018) The company provides robots mainly for milking, feeding, and cleaning tries to automation the whole process of dairy farms. Meanwhile, the collecting data will help farm owners manage and operate their farms more efficiently and helps them saving cost. In the future, the Lely company wants to collaborate data from different sessions and make supportive decision-making for farmers.

6.4.3 GD (De Gezondheidsdienst voor Dieren B.V.)

"GD Animal Health is a leading organization in animal health and animal production. Over ninety years, GD Animal Health has supported industrial customers, governments, veterinarians and farmers by providing animal health program and laboratory diagnostic services." (GD, 2018) GD is started by the government. What the dairy farmer could expect from GD mainly focus on two perspectives: first, it will help farmers to control the health of the cows and provide advice about cows' healthy issues if needed; second, it will run the test on milk per three months (or on demand) to see if the milk remaining a good healthy condition.

6.4.4 Eurofins

"Eurofins Scientific is an international life sciences company which provides a unique range of analytical testing services to clients across multiple industries. The Group believes it is the world leader in food, environment and pharmaceutical products testing and that it is also one of the global independent market leaders in certain testing and laboratory services for agroscience, genomics, discovery pharmacology and for supporting clinical studies." (Eurofins, 2018) In the dairy farm industry of Netherlands, Eurofins provide the professional laboratory for farmers to run any possible test on their farms from grass to soil and even the animals.

6.4.5 Agrifirm

"Agrifirm is a cooperative in which around 17,000 Dutch livestock farmers and growers have combined their strengths. In this way, we achieve maximum purchasing advantage on high-quality products such as animal feed, sowing seeds, fertilizers and plant protection products." (Agrifirm, 2018) The firm will provide concentrate and fertilizer for the farmland as well as other products like mustard, amyloid. Besides, the company will also run a test about the grass in the field once a year to make sure the grass is in a perfect condition for the feed of cows. In a word, this firm will concern the grass for the farms and provide the related service about it.

6.4.6 Dairy farm "Gewoon Leuk"

Dairy farm "Gewoon Leuk" is located at Meerpolder 27, Zoetermeer, the Netherlands. It is a small size dairy farm operated by an individual family, and this farm covers a pasture field of 21.5 hectares, 1 milking machine and raises 40 cows. The owner is the member of CRV Avoncroft and he uses information system provided by CRV to manage this dairy farm.

Farm "Gewoon Leuk" is a representative example of the small dairy farms in the Netherlands. According to the Netherlands law, a pasture field of 1 hectare could raise up to 2 cows at the same time, which means Gewoon Leuk could raise a maximum of 42 cows in its pasture field. The size of farm decides the sophistication of the farm structure and workload, and a farm like Gewoon Leuk normally does not need extra employees if the family operated the farm on their own. Besides, because the owners sell the milk with a contract price and the milk will be transformed by the milk company, so the business process is simple and straightforward. A CRV dairy farm information system is enough for the owner to operate its farm fluently.

6.4.7 Chestnut Dairy Farm

Chestnut Dairy Farm is located at Beets 100, in the north of Amsterdam. This farm is operated by an individual family and is fully automated with machines and information technologies. According to the farm owner, the farm breeds 120 cows and 40 calves covering a pasture field of 60 hectares. So, from a size perspective, Chestnut could be a good example of a middle size farm. Furthermore, this farm is also hosting team building activities for companies, organizations and groups from society. Those activities, according to the farm owners, could advertise his farm with better reputation. Besides, what is interesting is that the farm owner of Chestnut is also kind of tech guy and developed a machine especially for the cleaning of the cowshed. This machine has a patent and sold to other farmers. This could provide the farm with extra income.

Like farm “Gewoon Leuk”, the Chestnut Farm also use information system provided by CRV. Furthermore, it also cooperated with an organization called GD, who is providing the set of solution about animal health for the farm. Other organizations and companies like Eurofins and Agrifirm are also providing professional laboratory and fertilizer service respectively.

The Campina will collect the milk from the farm per three days and the settlement will automatically conduct through Rabo Bank per month.

6.5 Interview guide questions

6.5.1 Interview guide questions for employees of dairy farms

1. What is your position on this farm? And what is your responsibility on the farm?
2. How long have you done your job?
3. What kind of information technology do you use during your work? For example, Web application, mobile phone, sensors, information system, data technology etc.
4. Which technology do you think, that helps you doing your job the most? And how?
5. Which technology still need to be improved? And why?
6. What kind of technology do you expect in the future to help you doing your present job?

6.5.2 Interview guide questions for owners of dairy farms

1. For how many years do you operate your dairy farm?
2. Can you describe the size of your farm? For example, how many cows do you have, how large is the pasture field?
3. What is the total yield of milk per day? Are you satisfied with it?
4. Can you describe the business process of your farm’s daily operation?
5. What kind of information technology do you use during your work? For example, Web application, mobile phone, sensors, information system, data technology etc.
6. Which technology do you think, that helps you doing your job the most? And how?
7. Which technology still need to be improved? And why?
8. What kind of technology do you expect in the future to help you doing your present job?

7. References

A. Kassahun, R. H. (2014, October 2). Enabling chain-wide transparency in meat supply chains based on the EPCIS global standard and cloud-based services. *Computers and Electronics in Agriculture*, pp. 179-190.

A. Kassahun, R. H. (2016, March 16). Realizing chain-wide transparency in meat supply chains based on global standards and a reference architecture. *Computers and Electronics in Agriculture*, pp. 275-291.

Agrifirm. (2018). *Agrifirm in the Netherlands*. Retrieved from Agrifirm: https://www.agrifirm.nl/over-ons/agrifirm-in-nederland/

Alexandros Kaloxylos, A. G. (2013, November 27). A cloud-based Farm Management System: Architecture and implementation. *Computers and Electronics in Agriculture*, pp. 168-179.

Alexandros Kaloxylos, J. W. (2013, November). The Use of Future Internet Technologies in the Agriculture and Food Sectors: Integrating the Supply Chain. *ScienceDirect*, pp. 51-60.

B. van de Kerkhof, M. v. (2015, July). Spatio-temporal analysis of remote sensing and field measurements for smart farming. *ScienceDirect*, pp. 21-25.

Beauvoir, P. (2018). *Archi Resources*. Retrieved from Archi: https://www.archimatetool.com/resources

C.G. Sørensen, L. P. (2011, February 15). Functional requirements for a future farm management information system. *Computers and Electronics in Agriculture*, pp. 266-276.

C.N. Verdouw, R. R. (2015, April 3). ERP in agriculture: Lessons learned from the Dutch horticulture. *Computers and Electronics in Agriculture*, pp. 125-133.

Chakchai So-In, S. P. (2014, October 5). A hybrid mobile environmental and population density management system for smart poultry farms. *Computers and Electronics in Agriculture*, pp. 287-301.

CRV Avoncroft. (2017). *CRV Avoncroft*. Retrieved from CRV Avoncroft: https://www.crvavoncroft.com/

Dutch News.nl. (2017, May 2). *Dutch dairy farms get bigger, with more cows producing more milk*. Retrieved from Dutch News: http://www.dutchnews.nl/news/archives/2017/05/dutch-dairy-farms-get-bigger-with-more-cows-producing-more-milk/

Eurofins. (2018). *Eurofins Fact Sheet*. Retrieved from Eurofins: https://www.eurofins.com/about-us/eurofins-fact-sheet/

Fabian Aulkemeier, M. S.-E. (2016, January 29). A Service-Oriented E-Commerce Reference Architecture. *Journal of Theoretical and Applied Electronic Commerce Research*, pp. 26-46.

Fountas, C. C. (2015, May 28). Farm management information systems: Current situation and future perspectives. *Computers and Electronics in Agriculture*, pp. 40-50.

GD. (2018). *About us-GD*. Retrieved from GD: https://www.gdanimalhealth.com/about-us

Gorden, R. (1992). Coding Interview Responses. In R. Gorden, *Basic Inteviewing Skills.* Itasca: F. E. Peacock.

Herrero, M. F. (1996). Integrating simulation models to optimise nutrition and management for dairy farms: a methodology. *Livestock Farming Systems: Research, Development, Socio-economics and the Land Manager.*, pp. 322-326.

IFCN. (2017). *Dairy Report 2017- For a better understanding of the dairy world.* The Dairy Research Network.

Irish Farmers Journal. (2016, December 7). *Robots on a Dutch dairy farm*. Retrieved from Youtube: https://www.youtube.com/watch?v=oD4KTkuf0uQ

J.W. Kruize, J. W. (2016, April 16). A reference architecture for Farm Software Ecosystems. *Computers and Electronics in Agriculture*, pp. 12-28.

J.W. Kruize, R. R. (2013, April 27). Improving arable farm enterprise integration – Review of existing technologies and practices from a farmer's perspective. *Computers and Electronics in Agriculture*, pp. 75-89.

James W. Jones, J. M. (2016, May 20). Brief history of agricultural systems modeling. *Agricultural Systems*, pp. 240-254.

James W. Jones, J. M. (2016, September 29). Toward a new generation of agricultural system data, models, and knowledge products: State of agricultural systems science.

Agricultural Systems, pp. 269-288.
Jeffrey P. Walters, D. W. (2016, April 19). Exploring agricultural production systems and their fundamenta components with system dynamics modelling. *Ecological Modelling*, pp. 51-65.
John M Antle, B. B. (2016, October 4). Towards a new generation of agricultural system data, models and knowledge products: Design and improvement. *Agricultural Systems*, pp. 255-268.
Kerkhof, Persie, Noorbergen, Schouten, & Ghauharali. (2015, July). Spatio-temporal analysis of remote sensing and field measurements for smart farming. *ScienceDirect*, pp. 21-25.
Kraatz, S. (2012, April 27). Energy intensity in livestock operations – Modeling of dairy farming systems in Germany. *Agricultural Systems*, pp. 90-106.
Kruiswijk, B. (2017, March 14). ArchiMate. Leiden, Netherlands.
Kruize, J., Wolfert, J., Scholten, H., Verdouw, C., Kassahun, A., & Beulens, A. (2016, May 4). A reference architecture for Farm Software Ecosystems. *Computers and Electronics in Agriculture*, pp. 12-28.
LELY Company. (2018). *About Lely*. Retrieved from Lely company: https://www.lely.com/nl/over-lely/
Lihua Zheng, M. L. (2010, November 4). Development of a smart mobile farming service system. *Mathematical and Computer Modelling*, pp. 1194-1203.
Mayer, W. H. (2013, November). Integral ICT Solutions Supporting Farmers Businesses as well as Environmental Caretaking incl. Carbon Optimization. *ScienceDirect*, pp. 550-553.
Michael J. O'Grady, G. M. (2017, May 8). Modelling the smart farm. *INFORMATION PROCESSING IN AGRICULTURE*, pp. 179-187.
Mohammad Mehdi Matinzadeh, A. K.-L. (2017, January 5). Development of an innovative integrated model for the simulation of nitrogen dynamics in farmlands with drainage systems using the system dynamics approach. *Ecological Modelling*, pp. 11-28.
Mohammad Mehdi Matinzadeh, J. A.-L. (2017, January 5). Development of an innovative integrated model for the simulation of nitrogen dynamics in farmlands with drainage systems using the system dynamics approach. *Ecological Modelling*, pp. 11-28.
Osterwalder, A. (2008, July 5). *The Business Model Canvas*. Retrieved from Nonlinear Thinking: http://nonlinearthinking.typepad.com/nonlinear_thinking/2008/07/the-business-model-canvas.html
Phillip Beauvoir, J.-B. S. (2017). *Archi User Guide.* Retrieved from ArchiMate: https://www.archimatetool.com/downloads/release/Archi%20User%20Guide.pdf
Pilaiwan Phupattanasin, S.-R. T. (2014, March). Applying Information-Centric Networking in Today's Agriculture. *ScienceDirect*, pp. 184-188.
Raimo Nikkilä, I. S. (2009, August 31). Software architecture for farm management information systems in precision agriculture. *Computers and Electronics in Agriculture*, pp. 328-336.
S. Fountas, C. S. (2014, November 7). Farm machinery management information system. *Computers and Electronics in Agriculture*, pp. 131-138.
S. Senthilkumar, M. C. (2013, July 31). Factors associated with utilization of ICT enabled Village Information Centres by the dairy farmers in India: The case of Tamil Nadu. *Computers and Electronics in Agriculture*, pp. 81-84.
Sander J.C. Janssen, C. H. (2016, Novermber 10). Towards a new generation of agricultural system data, models and knowledge products: Information and communication technology. *Agricultural Systems*, pp. 200-212.
Sjaak Wolfert, L. G.-J. (2017, February 7). Big Data in Smart Farming – A review. *Agricultural*

Systems, pp. 69-80.

Susan M. Capalbo, J. M. (2016, October 24). Next generation data systems and knowledge products to support agricultural producers and science-based policy decision making. *Agricultural Systems*, pp. 191-199.

Tan, L. (2016). Cloud-based Decision Support and Automation for Precision Agriculture in Orchards. *ScienceDirect*, pp. 330-335.

The Open Group. (2017). *The Open Group*. Retrieved from The Open Group: http://www.opengroup.org/aboutus

The Open Group. (2017). *The Open Group*. Retrieved from TOGAF, an Open Group standard: http://www.opengroup.org/subjectareas/enterprise/togaf

ZuivelNL. (2015). *Dutch dairy in figures 2015.*