How information availability because of Information systems affect the decision making and consequently the performance of Dutch dairy farms

-Final Report-

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Abstract

This thesis research is about how information from farm management information systems impacts the decision making on Dutch dairy farms and consequently impacts the farms' performance. Data about this topic has been collected by doing semi-structured interviews with 14 conventional Dutch dairy farmers. The interview questions were formulated based on a systematic literature study about the concepts “information availability because of information systems”, “decision making within farm management” and “farm performance”. This literature study revealed that that decision making within farm management can happen within four different functional areas: Production, finances, human resources and stakeholder relations. Within each of these functional areas three types of decisions can be made: strategic, tactical and operational. To make any of these decisions the decision-maker must go through the 5 steps of decision making. The performance of the farm has been measured using the concept “triple bottom line”. Results from this study indicate that information from information systems helps in all steps of the decision-making process and with all types of decisions. The information is mainly used in the functional areas “production” and finances. The use of information from information systems in the decision-making process seems to improve both financial performance and environmental performance of the farm.

Keywords: farm management information systems, decision making, dairy farming, triple bottom line, information.

Executive summary

Dairy farm management has seen rapid modernization the last few decades. Traditionally management decisions were made based on experience and intuition. The farmers learned by trial and error. Nowadays the decision-making process is supported by information that is produced by information systems, the decision making has become more data-driven. The literature states that this has many benefits for the farms' financial performance. Little research though has been done towards how these information systems impact the decision making, and what the impact is on the concept “performance” as formulated by the triple bottom line. The objective of this research is to determine how the information from information systems affects the decision-making process in the dairy farm management and consequently the dairy farms' performance.

A systematic literature study is performed to get a better understanding of the concepts “information availability because of information systems”, “decision making within farm management” and “farm performance”. From this literature study it was found that that decision making within farm management can happen within four functional areas: production, finances, human resources and stakeholder relations. Within each of these functional areas three types of decisions can be made: strategic, tactical and operational. To make any of these decisions the decision-maker must go through the 5 steps of decision making. The performance of the farm has been measured using the concept “triple bottom line”.

To answer the research questions 14 conventional dairy farmers have been interviewed. To get a good representation of the population 4 sub-groups have been formed: large farmers with a milking robot, small farmers with a milking robot, large farmers without a milking robot, and small farmers without a milking robot. From each group 3 or 4 farmers are interviewed. The questions that were asked in the interviews are based on the literature and the conceptual framework. The interviews have been transcribed and analyzed with the help of the software ATLAS.ti.

The results from this thesis indicate that for the three different types of decisions (strategic, tactic and operational) information from information systems is used by the farmers. The information is mostly used for decisions in the functional areas “production” and “finances”. The results also indicate that the information from the information systems is mainly used for steps 1 to 4 of the decision-making process in the strategic and tactical decisions. The information is mainly used in step 5 of the decision-making process with operational decisions. The information from the information systems has a positive impact on the environmental and financial performance of the farm.

The results from this research about the impact of information from information systems on the farms' performance are qualitative, it is based on the opinion of the farmer. It is recommended that follow-up research is conducted to investigate the impact of the information from the information systems on the performance in a quantitative way.

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List of abbreviations

IT:	Information technology
IS:	Information system
FMIS:	Farm management information system
HRM:	Human resource management
SSFMS:	Site specific field management systems

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1. Introduction

The management of dairy farms has traditionally been a process of trial and error. Farmers learned from their mistakes and accomplishments and used their knowledge and intuition to make farm management decisions (Jago et al. 2013). The knowledge that a farmer possessed would be passed on to the next generation. In this way, the manner at which a farm is managed has seen slow but steady improvements (Bieleman 2008). The way of managing a farm is changing, decisions on the farm are less driven by intuition and expertise. Rising herd sizes and increasingly complicated farming systems, in combination with new information technologies (IT), are causing a transformation to an increasingly data-driven management approach (Bewley 2010; Jago et al. 2013). The amount of IT on the dairy farm is rising rapidly (Borchers and Bewley 2015), some examples are milk robots and feeding machines (Bijl et al. 2007). These machines take over a lot of tasks on the farm, automatizing them. These machines also collect data while performing their tasks. Examples of these data are milk quality data, feed uptake and use data, and milk production data. These IT are usually part of an information system (IS), these are systems that generate, collect, process, store and distribute information (Laudon and Laudon 2012). In the literature, many different definitions for the concepts IT and IS have been used and in some studies, they are even used interchangeably. In this study, clear distinct definitions will be used. The literature writes about a lot of different benefits of IS, it may result in an operational excellence, result in new products, cause higher supplier-customer intimacy, and cause a competitive advantage (Laudon and Laudon 2012). In the core this is all due to two main benefits: Supporting the decision making by having more information available and automating tasks. In this thesis, the focus will be placed on the function of decision support as this function is focused on improving the management of a firm. Also, in the literature about IS on the farm the main benefit that is mentioned is improved decision making (Novkovic et al. 2017). These IS help the farmers in their decision making by translating the data the IT produces into usable output, information (Laudon and Laudon 2012). Information systems are already applied in all sections of farm management, they are used for example in the financial, operational and human resource management (Borchers and Bewley 2015). Al the data that is collected with this IT can be used in IS. On the farm these IS are called: farm management information systems (FMIS). These are software packages that combine and transform available data into usable information for the farmer (Fountas et al. 2015). There are many different types of FMIS, with a lot of different producers and different purposes (Tsiropoulos et al. 2017). These FMIS provide 14 different types of information about the farm, 11 of these types of information that are produced by FMIS are about general farm management tasks (Fountas et al. 2015).

- **Farm operations management**: These systems record all farm activities. With this information, the FMIS helps the farmer to plan future activities.
- **Best practice**: Information about the best way to farm under specific circumstances. These systems do not use real-life information from the farm. It is like an encyclopedia.
- **Finance**: Information about the current financial situation of the farm. Including the estimated cost of al farm activities and financial projections of future endeavors.
- **Inventory:** Information about the current status of the inventory.
- **Traceability:** Information about which resources (people, products) are used to produce a specific product on the farm.
- **Reporting:** Overview information about the output and operations of a farm.
- **Site-specific:** Information about specific locations on the field, a form of precision management, this is mainly for the agricultural side of the farm.
- **Sales:** Information about all orders and logistics that are associated with sales.

- **Machine management:** Information about the use of machines and when maintenance is expected
- **HR management:** Information about when an employee can work, how much he/she has worked. Also, specific employee information is included, if they have complaints or have specific requests.
- **Quality assurance:** Information about the quality of the produce

There are also three cow specific types of information that are produced by different FMIS (Voulodimos et al. 2010)

- **Feed intake:** information about the amount and kind of intake of feed by the cow
- **Cow health:** information about the health status of the cow
- **Cow productivity:** information about the quantity and quality of the milk production

This makes a total of 14 types of information based on the FMIS functions. The information that these FMIS produce can be helpful for farm management (Novkovic et al. 2017). Besides the type of information that is produced is the amount of information which is provided within one "type" also important in relation to the decision making. The FMIS can provide information on more than one "type" of information. Not only the type and quantity of information have an impact on farm management but also the quality of the information (Lee et al. 2002). There are a lot of dimensions that determine the quality of the information. Lee et al. (2002) determined that these dimensions can be divided into 4 categories:

- Intrinsic information quality: The quality of the information itself with dimensions like reliability and validity
- Contextual information quality: The quality of the information when seen in the context of the problem with dimensions like timeliness and completeness
- Representational information quality: The information must be easy to interpret
- Accessibility information quality: The information must be easy to access

The better the information scores on these categories the more useful it is (Lee et al. 2002). Management consists for a large part of making decisions (Drucker 1954). The theory says it is beneficial to have more information about the problem when the decision has to be made (Blackwell 1953). Being better able to make decisions within the farm management should be beneficial for the farm's performance. An improved farm performance will not only result in financial benefits, but it will also have an impact on the social and environmental farm performance. There are many aspects to the performance of a firm. A well-known concept when talking about firm performance is the triple bottom line (Norman and MacDonald 2004). The triple bottom line is an accounting concept that includes 3 dimensions of performance: environmental, social and economic (Hall and Slaper 2011). Within the animal farming industry a fourth dimension has been suggested: animal welfare (Aland and Madec 2009), this concept though can also be included in the social or environmental dimension. The triple bottom line is a way to measure the real impact of a company on to the world (Hall and Slaper 2011). When looking at performance the goal of a company must also be considered. A company that has a goal to have rapid growth will probably earn less money in the years that it is expanding, this does not mean that this company is performing poorly. Another example is a company that decides to take more environmental measures. This can cost the company some profit, but it does not mean that the company is performing less well. The triple bottom line tries to include all factors and thus includes all objectives of a firm. It gives an indication of the real value a company creates or destroys (Elkington et al. 2004; Hall and Slaper 2011).

1.1 Problem statement (knowledge gap)

IS have a positive impact on the availability of information, this in turn has theoretically a positive impact on the ability to make a decision within the firm's management (Armstrong, 2006; Asseldonk et al. 1999; Brynjolfsson et al. 2011; Drucker, 1954; Eugene F. Brigham, 2012; Galbraith, 1974; Kotler et al. 2001; Shridhara Bhat & Dim, 2010). Better firm management is positively correlated with better performance (Drucker 2007). Scholars have shown that decisions made based on more information, because of the implementation of IS, have a positive impact on the performance of firms (Brynjolfsson, Hitt, and Kim 2011; Santhanam and Hartono 2003). These studies though focus on large stock-listed industrial companies instead of farms. There have also been studies that focus on the impact of IS on dairy farms: Asseldonk (1999) and Novkovic et al. (2017) showed that some individual IS/IT systems/products can be beneficial for the profit of a farm. This research though has not made a distinction between the automatization component and the decision-making component of IS. IS are becoming more and more important on farms and the availability of information is rising rapidly (Bewley 2010). No research has been done towards the way the extra available information influences the decision-making processes in dairy farm management and consequently impacts the farm's performance. It is not known where in the dairy farm's decision-making process the extra information has an impact and if this is the same for all sections of the farm management. Some studies have even given arguments why more information could have a negative impact on the decision making and consequently on the performance. Bewley et al. (2010) and Hostiou et al. (2017) argue that too much information could make the farmer confused, or the information is "delivered" by the IS in a way that is too complex to understand and thus used in a wrong way (Alvarez and Nuthall 2006; Bewley et al. 2010). It should be investigated how the information from IS impacts the decision making and the performance. It is important to know where and if the farmer experiences benefits or disadvantages from the information that comes available. With this knowledge current systems can be improved. It becomes clearer if the farmer benefits from the increasing amount of available information that is associated with the increasing amount of IS. To investigate this the question is raised: How does the information from information systems affect the decision-making process in dairy farm management and consequently dairy farm performance? This study aims to better understand in which parts of the decision-making process and in which sections of the dairy farm management the information from IS has an impact. Also, the impact that this changed decision making has on the farm's performance will be investigated. A case study on conventional Dutch dairy farms is chosen for as Dutch dairy farms are implementing IS and IT at a fast rate (Bewley 2010; Steeneveld and Hogeveen 2015; Wolfert et al. 2017). The research population will consist out of conventional Dutch dairy farmers.

1.2 Research questions

MRQ: How does the information from information systems affect the decision-making process in dairy farm management and consequently the dairy farm performance?

SRQ1: How does the increased availability of information because of IS affect the decision-making process within the dairy farm management?

SRQ2: How does the changed decision-making process within farm management because of the changed availability of information affects dairy farm performance?

1.3 Research framework

To answer the sub-questions and in the end the main research question a literature study is conducted and farmers are interviewed. The research framework below (Figure 1) gives a structured overview of the research and explains which steps were taken to answer the research questions. From the research framework the structure of this research can be derived. The structure is precisely described in the next paragraph.

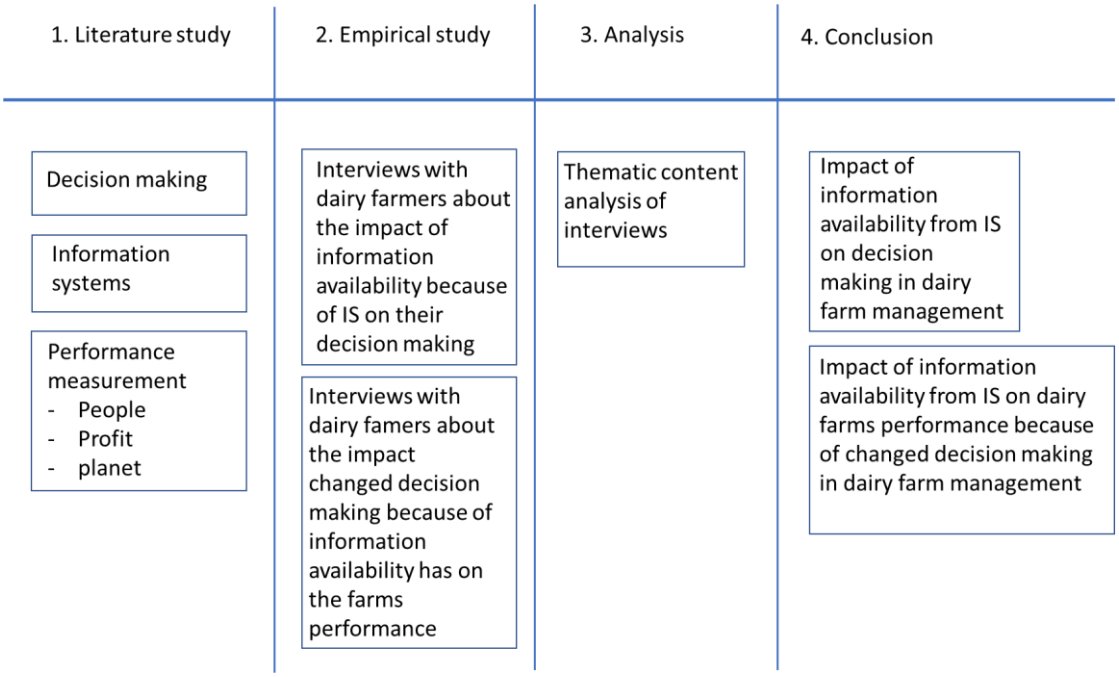

Figure 1: Research framework

1.4 Structure of the report

Chapter 2 will give an overview of the used theories and concepts in the form of a literature review. Chapter 3 will explain the methodology and material used in this research. In chapter 4 the findings of this research will be presented and chapter 5 will contain the discussion of the research. In the last chapter the conclusions are drawn.

2. Literature review

Structure of the literature review

This chapter will provide an overview of the knowledge that already exist about the use and impact of information from information systems on the dairy farm management. Information will be provided about the theoretical way the information from IS affects the decision making and consequently the farms performance. Also, domain specific information will be provided, this will give insight in the actual information that is produced by the information systems on the dairy farms and the way it is/can be used in the decision-making process according to the literature.

This chapter will start by giving an overview of the current use and benefits of information systems in general. Next an overview is given of the expected impact that information from IS will have on dairy farms in the future. This will give insight into the possibilities and expectations that the academics have regarding IS on dairy farms. As stated in the introduction, the information impacts the farm by impacting farm management decisions. To better understand this the main functional areas of the farm management will be examined and the concept “decision making” will be further explained. The different types of decisions that are taken and the decision-making process will be discussed. These concepts will be discussed from a theoretical point of view and a from a domain specific point of view. The next part of the literature review will provide information about what information is currently provided by the IS on dairy farms. Also, the way this information is produced by the IS will be discuses. Theoretically the information impacts the farms performance through an altered decision making. The impact of the alterd decision making because of information from IS on the farms performance is discussed in the final part of the literature review. This chapter will end with the conceptual framework.

Definitions

As stated in the introduction this research will use distinct definitions for information technology and information systems:

Information technology:

Information technology is all the hardware and software that a company uses to complete its business goals (Laudon and Laudon 2012; Lucas 2009). IT must support tasks like processing, storing, distribute and collecting data. These are tasks that are executed by information systems (IS). An article from Florida Tech online, (n.d.) states that IT falls under the umbrella of IS (Florida Tech Online n.d.). IT can be computers, software, cellphones, etc.

Information systems:

Information systems collect, process store and distribute information (Florida Tech Online n.d.). Data is entered in the IS, this data is translated into information. The literature writes about many purposes of IS, in the core, there are two main goals: 1. Supporting decision making 2. Automating tasks. In this article, the focus will be placed on the function of decision support as this function is focused on improving the management of a firm. When IS is used correctly it allows for an increase in the availability of the right information for the right people (Lucas 2009). With this information, the uncertainty of a state/event can be reduced (Lucas 2009). The reduction of uncertainty about a state/event helps managers of a company to make better decisions. This is the main advantage of IS in relation to firm management, helping in the decision making (Lucas 2009).

Another distinction is made in this research between the concept's "information" and "data". When talking about IT and IS a clear definition of these two concepts is needed. Data are quantified observations from the field. Examples of this are the weight of a cow, the amount of organic matter in the soil or the amount of money on the bank. These are all data points that attempt to describe the current state of a situation, they have no meaning when not placed in context (Ackoff 1989). When this data gets meaning it becomes information (Ackoff 1989). The weight of the cow gets meaning when it is known what the cow should weight and what it means when he/she diverts from this. The information that can be extracted from this data point could be: the cow is too light/heavy. When this "information" is obtained the reason for this phenomenon can be sought for and a solution can be decided upon. Information helps to turn the decision-making process into a logical and systematic process instead of a process of intuition (Blackwell 1953).

2.1 Current use of information systems in other industries

The use of IT in the industry is not a new thing, it started around 1960 with the first computer (Myers 1996) and since then a constant increase in the use of IT by firms is noticed (Power 2007). With the increase of IT the use of IS also started to increase (Power 2007). IS are used now in almost every industry and firm management discipline to improve the decision-making process (Brynjolfsson 1993; Brynjolfsson et al. 2011). IS are used to collect, process, store and transmit data about consumers, suppliers, partners, competitors and internal production processes (Brynjolfsson et al. 2011). The collecting, processing, storing and transmitting of this data can result in higher operational efficiency and competitive advantage for companies (Melville et al. 2004). The literature, in general, has a positive attitude towards IS with respect to decision making and the benefits that it brings to the performance of a firm. Brynjolfsson et al., (2011) showed that extra information has a positive impact on the performance of stock-listed companies. Other examples where more information has been beneficiary are: Marketing managers that have used information from IS to create more market segments and thus a more targeted marketing (Lacobucci 2013; Kotler et al. 2001) and in the finances

IT has resulted in better accounting systems which proved better indicators about the performance of the company (Ghasemi et al. 2011). Different sectors and industries show different levels and speeds of modernization with respect to IS. Some of the sectors can possibly be used as a predicting example of where the agriculture industry is moving towards with respect to IS.[1]

2.2 IS on the farm

IS are already implemented in a lot of aspects of the farm, the expectation though is that this is going to increase rapidly (Borchers and Bewley 2015). By collecting and analyzing data about the farm, models that predict the needs of the cows, for an optimal result, can be made (O'Grady and O'Hare 2017). To make these models it is needed to be able to determine what the impact is of a change on the farm. This can be an intentional change like other feed or an accidental change like a disease. By being able to determine the impact of these changes it becomes possible to detect involuntary changes based on the impact they have. To determine the impact of changes on the farm a lot of data must be collected and transformed into information. As shown in chapter one the IS give currently information on 14 different topics. These main topics of information will not change so much over the years, but the amount and accuracy of information within each of these topics is likely to expand rapidly (Wolfert et al. 2017). All this information could result in a future where sensors will abstract physical and environmental information from the cow. These sensors can be placed on the cow, like pedometers, or around the cow, like the milking robots. This information will make it possible to determine what inputs the cow needs, in terms of feed, medicine, treatments, etc. to result in an optimal production. Other information that could be included is purchase information, information about the environmental impact, and the impact on the worker. With this information the effect of all changes that are made on the farm become measurable. An approximation of the perfect description of the current situation as described by Blackwell, (1953) is potentially becoming possible with the help of IS. This would transform every decision-making process into an optimization problem that can simply be solved by IT systems. The farmer can let the system determine what the optimal inputs are for the outputs he desires, within the boundaries he sets. The literature is enthusiastic about the possibilities that this will bring: A higher resources use efficiency, higher dairy production, better quality of milk,

[1] The sector asset management is increasingly relying on IS (Bonnaud et al. 2018), this sector is interesting because it has a lot of similarities with farm management. Asset management is described as: coordinated activity of an organization to realize value from assets (ISO 55000). This is a very broad definition. A more precise definition is given by (Anthony and Hastings 2015), they describe asset management as: "The set of activities associated with: identifying what assets are needed, identifying funding requirements, acquiring assets, providing logistic and maintenance support for assets and disposing and renewing assets so as to effectively and efficiently meet the desired objective". A farmer's job is largely described by this concept. Asset management is mainly focused on production management, but also includes bits of financial management and HR management. This makes it a management type that is sector transcending. Physical asset management is a discipline that is well developed from a literature point of view (Anthony and Hastings 2015), but the link with agriculture has not yet been made. Biological assets management though is different from physical asset management because biological assets are alive and thus less predictable (Kay and Edwards 1999). Within the physical asset management a shift towards data driven decision making is observed (Bonnaud et al. 2018), in some industries to the point that the decisions are made completely autonomous and 100% based on collected data (Ruschel et al. 2017), a well know example are cars that know when they need to visit the garage. Some literature even states that this increase in use of IT and IS will result in a new industrial revolution (Drath and Horch 2014; Lasi et al. 2014). The shift towards data driven decision making is also happening within the agricultural sector with the introduction of more and more IT and IS (Bewley 2010). But nowhere near the point yet of completely autonomic farm management (Fountas et al. 2015). The increase of IS in agriculture is boosted by the developments in artificial intelligence, machine learning, internet of things and cloud computing (Pivoto et al. 2018). Within the agriculture it is clear that the amount of IT and IS will keep increasing (Borchers and Bewley 2015). The physical asset management gives insight in a direction that the dairy farming could be heading regarding the amount of IS and IT.

reduction of cost, improved animal health and better adaption capabilities against unexpected changes (Bewley 2010; Pivoto et al. 2018; Sundmaeker et al. 2016; Wolfert et al. 2017). These models can also prove to be useful to find the main environmental constraints within the farming process and make it easy to see what consequences alternative (environmentally friendly) options have (Boote et al. 1996).

Problems will not only be solved better but, they will also be detected faster. The IS will constantly monitor the situation, this will result in real-time information, problems will be spotted earlier and decisions can be made faster (Wolfert et al. 2017).

2.3 Company management

As stated in the introduction, having more information has been linked with better decision-making capabilities, this is beneficial for the management of a firm. To really grasp this theory the concept "management" needs some explanation. Managing a company is for a large part making decisions (Drucker 1954). The object of management is to work with and through individuals and groups to accomplish organizational goals (Hersey et al. 2001). Within each company there are five main functional areas that have to be managed: production, marketing, finances, human resources, and stakeholder relations (Gloy et al. 2002; Shridhara Bhat and Dim 2010; Slack et al. 2013). These five functional areas will be explained shortly below. The management of a dairy farm is usually done by a farmer, he must make all the decisions. The farmer should have a clear company goal in mind when acting as a manager in these different departments (Drucker 1954).

Production

The functional area production is about the process of creating goods and services (Shridhara Bhat and Dim 2010). In this process inputs are transformed into outputs, value is created in this process. The additional value that is created on top of the initial value of the inputs can be created via multiple processes: transportation, alteration, preservation, and quality assurance (Shridhara Bhat and Dim 2010). Figure 2 gives a systematic overview of the production system. The control subsystem is the place where the acquired data from the system (feedback 2 and 3) is transferred into knowledge. This knowledge is used when making managerial decisions to optimize the production system (Feedback 1). Feedback 1, 2 and 3 together with the control subsystems make up an information system. The stakeholders influence the inputs, conversions and outputs depending on their relationship with the farm (Figure 2). They do this by having demands about the outputs or conversions and limited abilities for the inputs.

On a dairy farm, the main value-creating processes is the production of milk. Secondary income from other businesses like selling calves will not be included in this research. Besides high production, quality assurance is becoming more important, a differentiation trend has become visible where farmers produce different types of milk: biological, weidemelk and jersymelk (Albert Hein n.d.; Beldman et al. 2010). The difference in these products lies in the way they are produced, the farmer must be able to show to certain stakeholders that the milk is produced by the standards that are set for these different types of milk. The farmer will have to act as a production manager on his farms, the core of this job entails converting the inputs efficiently and effectively into the desired outputs. Another important task that falls within the functional area "production" is the purchasing of resources.

Information from IS is used in the functional area production to improve the quality of the products and the efficiency of production (Shridhara Bhat and Dim 2010).

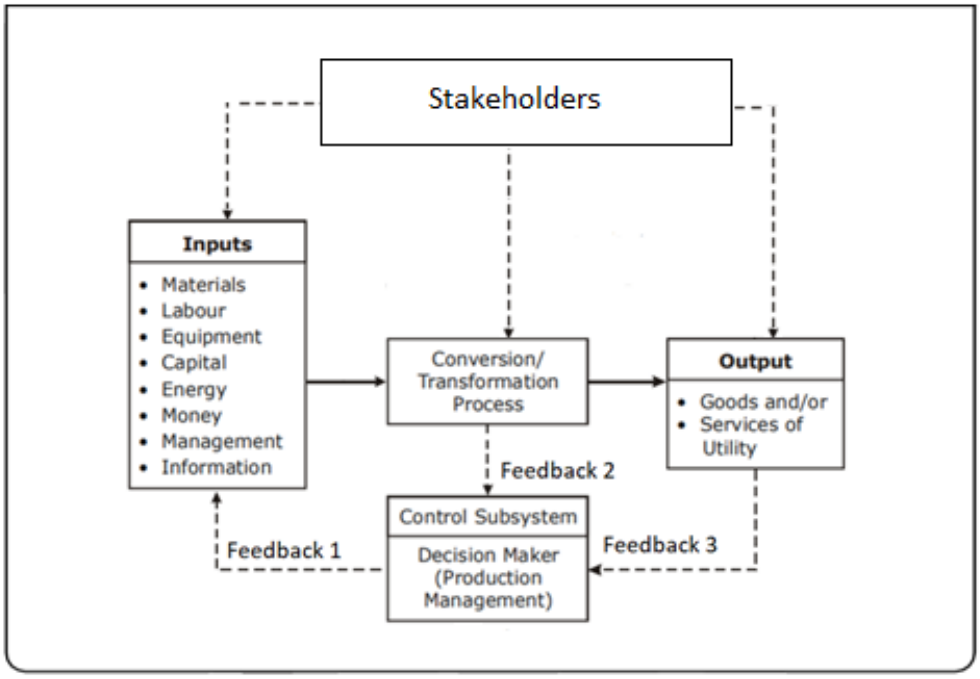

Figure 2: production and operation management system

Marketing

The purpose of the functional area marketing is as described by Kotler et al. (2001) twofold: New customers have to be attracted by delivering superior value and the existing customers have to be kept happy.

Dairy farms are usually part of a dairy cooperative that takes care of the marketing for them (Wolf 2012). They get paid according to the quality and quantity they deliver (Cropp 2012). This means that the farmer is not working on attracting new customers (Gloy et al. 2002). The companies that eventually buy the milk can have quality and production demands. FrieslandCampina for example, demands a certain level of hygiene and quality in the production process (Kwaliteit begint op de boerderij, met "Focus planet" 2019). Other milk processing companies also have quality demands (Handboek melkveehouderij 2019). To maintain a good relationship with the buyer the farmer must be able to show that in his/her production process/product these demands are met (Kotler et al. 2001). Information that is produced by IS can be helpful to give insight into the production process and the quality of the product. IS are also used in marketing management to generate information about the needs of the customers allowing greater customer insights and competitive advantage (Kotler et al. 2001). This though is less important for dairy farmers, they usually only produce raw material, which is transformed into consumer products by dairy companies.

It is chosen to not include the functional area marketing in the rest of this paper because it is mostly outsourced to dairy cooperatives. Extra information from IS will thus not have a direct impact on the marketing of a dairy farm from a farmer's perspective.

Finances

The management of the functional area finances, consists of a diverse set of tasks, investment decisions and financing the company are two of the main tasks (Horne and Wachowicz 2008).

Investment decisions**:** These are decisions about which assets a firm needs to invest and how much a firm can invest without obtaining liquidity problems (Horne and Wachowicz 2008). Disinvestment also has to be taken into account, when certain assets are not economically functional they need to be replaced or eliminated (Horne and Wachowicz 2008). This is where information from IS can come into play. It becomes easier to assess the economical functionality of assets when more data is collected about assets and the processes (Brigham 2012). A farmer has to make a lot of investment decisions (Maart-Noelck and Musshoff 2013).

Financing decisions: These are decisions about how to finance the company; how much money can be borrowed and how much own capital is invested in the company (Horne and Wachowicz 2008). When money needs to be borrowed decisions must be made where and in what form this is going to happen.

Brigham, (2012) states that information from IS is used in the functional area finances to "take much of the guesswork out of financial decisions " (p. 15).

Human resources management

The functional area Human resource management (HRM) is defined by Armstrong, (2006) as: "A strategic and coherent approach to the management of an organization's most valued assets – the people working there who individually and collectively contribute to the achievement of its objectives" (p. 3). The human resource manager of a firm has multiple functions according to Fombrun and Tichy, (1984):

- Selection, the right people must be matched to the right jobs.
- Appraisal, the performance of people must be noted down.
- Rewards, performance of employees must be rewarded.
- Development of employees, the employees must work in an environment where they can perform optimally and develop themselves.

A dairy farmer usually doesn't have a lot of employees, depending on the size of the farm and the type of farm (biological dairy farming is more work-intensive than conventional farming) (Bijl et al. 2007; Rienks et al. 2003). The farmer himself will put in a lot of hours on the farm himself (Rienks et al. 2003). It is important that the farmer, as an employee of his own farm, and his other employees function optimally. HRM has the objective to achieve this. The better the workers and processes around the worker are understood the better this can be accomplished (Armstrong 2006).

Information from IS is used in the HRM to share information between workers, create insight into the performance of employees, create easily accessible planning about when to work and to keep track of the overall personnel administration (Armstrong 2006; Laudon and Laudon 2012).

Stakeholders

An important factor when managing a firm are the stakeholders (Freeman 2010; Slack et al. 2013). A dairy farm has many stakeholders (Blokland et al. 2017). The farmer must manage the expectations and interests of the stakeholders in his company in such a way that the farm can perform optimally. The farmer and the stakeholders are to a more and lesser extent depended on each other. Having a good relationship with the stakeholders is said to help in achieving a superior company performance (Verbeke and Tung 2013). The intensity of the relationship should be dependent on the power and interests of the stakeholder (Johnson 2018). Information about the farm processes can help in determining the importance of the different stakeholders. This will help in determining what kind of relationship would be preferred (Johnson 2018). For example, when it is known what the impact of specific feed is on the performance of the farm, the need for the relation with the specific feed

producer becomes better quantifiable. Also, the dependability can be determined based on information from the farm. What food supplies are usually on the farm and how long can de farm keep producing without resupplies. All this information will help in determining what kind of relationship should be opted for with the feed producers. The option of another supplier should also be included when determining the type of relation. Each of the stakeholders, in their own way, can impact the way the farm is managed (Freeman 2010; Verbeke and Tung 2013). This influence of the stakeholders can have an impact on the way information is used and decisions are made. The impact of stakeholders on the use of the information from FMIS is never investigated though. There are eight important stakeholder types in the Dutch dairy farming industry according to Blokland et al., (2017):

- Research institutions: Institutions like the WUR are performing research on dairy farms, among other things research about how to make the farms more efficient and how to reduce their environmental impact.
- Dairy cooperatives/milk processing companies: Cooperatives/companies like FrieslandCampina and Arla buy the milk from the dairy farms. They have requirements about the way the milk is produced (Handboek melkveehouderij 2019).
- Cow breeders: The breeders of cows deliver new varieties of cows to the dairy farmers. They come up with new subspecies of dairy cows that have their own specific requirements (Oltenacu and Broom 2010).
- Banks: Banks have a relation with the farms because most farmers have a loan on their company (Zijlstra et al. 2012). These loans can come with certain demands for the farmer.
- Advice companies/institutions: There are many institutions and companies that provide help for the farmers to improve their operations (Blokland et al. 2017).
- Veterinarian: The veterinarian has a close relation with the farmer. The veterinarian helps making a health plan for the cows and when cows get sick a veterinarian is called. Depending on the veterinarian that works on the farm different topics, in relation to the health of the cows, can have priority.
- Governments: The different governments in the Netherlands have all types of regulations for the farmers, for example about the use of antibiotics and the animal welfare (Declercq 2009; Handboek melkveehouderij 2019; Rijksoverheid.nl, (n.d.)). When the government introduces new regulations for dairy farms the farmers often must make changes in the way they manage their farm.
- Feed producers: Dairy farmers often buy a part of their cow diet by feed producers. The diets that the feed producers formulate have an impact on the health and productivity of the cow (Handboek melkveehouderij 2019).

As shown above, information from IS can have its benefits on the decisions making in all aspects of farm management. Based on the literature the department production seems to be the department that has most to gain from IS (Asseldonk et al. 1999). The information IS uncovers can help in the decision-making process and, according to the literature, improve the overall farm management.

2.4 Decision making

Decision making on the farm

All the information that is available on a farm can be used to make decisions. Everything a manager does, he does through the making of decisions. Some decisions are based on intuition, other decisions have extended systematic analysis behind them. Some decisions have long term impact, others barely any impact at all (Drucker 1954; Fountas et al. 2006). FMIS provide a lot of information for the farmer. This information is used to make decisions within the four farm management disciplines. These

different decisions can be divided into 3 main types of decisions (Anthony 1965; Schmidt et al. 2000; Shridhara Bhat and Dim 2010):

- Strategic decisions: The manager decides on long term objectives and allocates resources to obtain these objectives.
- Tactical decisions: Decisions that are about the use of resources, so the production demands are met. These decisions should be in line with the strategic decisions, they further explicate the strategic decisions
- Operational decisions: Decisions about the day-to-day operations, they are in line with the tactical decisions, they further explicate the tactical decisions.

An overview of topics that are playing on the farm and about which decisions must be made is given below:

Strategic decisions

There are many strategic decisions that have to be taken on a farm (Handboek melkveehouderij 2019). Examples of strategic decisions that have to be taken on a farm are decisions about, investments in new machinery, the purchases of more land, more environmentally friendly farm practices, types of cows that are used, and the possible purchases of robots to take over tasks. Research from Wageningen University has shown that there are five strategic decisions that are a hot topic within the Dutch dairy farming community (Zijlstra et al. 2008):

1. How to improve the business?
2. How to grow the business?
3. How to deal with the milk price fluctuations?
4. How to keep the organization of the company simple?
5. Personnel of more robots on the farm?

The second topic, the possibilities of growth of the company, will not be included. This is decided because the legislation on phosphate rights has changed sins the article from Zijlsta et al. (2008) was published. This has made it very difficult to make the farm grow (CBS 2018). Instead, another subject is highlighted: How to deal with the increasing amount of legislation regarding dairy farming. The amount of legislation for farmers is growing rapidly, it has become a subject that gets a lot of attention from the farmers and the media. These 5 strategical decisions will be shortly explained:

1. How to improve the business?

Interviews with farmers have shown that this is one of the most urgent problems, the farmers experience a low return on investment (Zijlstra et al. 2008). They feel they need to have more of a vision and strategy which will translate into concrete plans. They also feel that they need to have more knowledge about entrepreneurship (Zijlstra et al. 2008). All these subjects are all caught in the topic, “how to improve the business” and they require strategic decisions from the farmer.

2. How to deal with the increasing legislation pressure?

The government has recently decided that the intensive agricultural sector of the Netherlands needs to become more extensive and needs to go in the direction of circular agriculture (Rijksoverheid.nl n.d.). To achieve this a lot of new legislation on top of the already existing legislation can be expected for the farmers. This can have a large impact on the operations of the farmer. An example is the phosphate duties that are implemented which cause a lot of struggles for the farmers. To meet the new legislations strategic decisions must be made by the farmers.

3. How to deal with the milk price fluctuations?

The profit margin on milk is small, this makes that a small change in the selling price of milk has large consequences for the farmers. In previous years there have been moments where the farmers where selling their milk below the production price (Jongeneel and van Berkum 2015). The fluctuating milk price is a problem for the farmers, and they are looking for ways to overcome this.

4. How to keep the organization of the company simple?

With the introduction of more legislation by the government, more complex farming systems and larger farms, the organization of a dairy farm has rapidly become more complex. Solutions about how to keep the organization as simple as possible must be found by the farmer, decisions about this subject must be made.

5. Personnel of more robots on the farm?

The possibilities for robotics on the farm are growing rapidly, the farmer must make decisions about if he wants to make the investments to implement robotics on his farm. He also must think about the consequences these changes bring on his farm, like possibly having to let go of personnel.

Tactical decisions

On a farm, many tactical decisions must be made. The manual for dairy farming gives an overview of all tasks that have to be performed on a dairy farm (Handboek melkveehouderij 2019). This manual also shows all the tactical decisions that must be made on a farm. A large part of the decisions that have to be made on a dairy farm are related to the feed production that happens on the farm (Handboek melkveehouderij 2019). Therefore, the tactical decision will be divided into an agriculture part and an animal part. With all these decisions different interests “fight” for attention. When a farmer makes decisions, he must think of the economic, social and environmental effects, short and long term. The decisions must be balanced to keep all the interests on the desired level. An overview is given of the main tactical decisions that have to be made on the dairy farm based on the handboek melkveehouderij, (2019):

Tactical decisions agriculture:

- The type and square footage of roughage that is going to be grown
- What maintenance is going to be applied to the roughage
    - Fertilizer, amount and type
    - Type of applied tillage
    - Are herbicides and pesticides going to be used?
- Equipment needs for the roughage, rent or buy it
- Is the farm going to make use of subsidy schemes (for example “akkerranden”)
- How to store the yields/feed

Tactical decisions cows

- General diet plans for the cows
    - Content of the diet
    - Where to get the feed (buy/produce)
- Grazing plan (cows will be kept in stable or can graze outside)
- Rearing calves or outsource it and buy adult dairy cows
- What cows to buy and what semen to use to fertilize the cows
- What preventive measures to take to prevent diseases?

- What measures to take to ensure animal welfare
- Amount of staff
- The type of milking equipment that is on the farm
- The maintenance that is done on the milking equipment
- Way of cleaning the milking equipment
- The layout of the stables

Operational decisions

The operational decisions are decisions about the day to day operations. Hundreds of operational decisions are made each day on a dairy farm (Handboek melkveehouderij 2019). Too many decisions to give an overview of. What helps in providing clarity is that almost all operational decisions are a further specification of the tactical/strategic decisions that must be taken. An important aspect of this is the logistics and planning. Each day, the right equipment and the right people need to be at the right place at the right time, this requires a lot of planning and thus decision making. Operational decisions are small decisions that adjust the course of action based on parameters that are observed/measured in the field to reach the objective (Shridhara Bhat and Dim 2010). To get an idea of the operational decisions that have to be taken on dairy farms a few examples are given based on the handboek melkveehouderij, (2019):

The decision about the general diet for the cow is a tactical decision. This decision helps to decide how much feed needs to be present on the farm and creates a general strategy in relation to the feeding of the cows. This is however only the first of many decisions that must be taken in relation to feed. A cow doesn't get the same feed the whole year, the type and amount of feed changes depending on the state that the cow is in. Factors that influence the feed the cow gets are: The amount of milk that the cow produces, if the cow is pregnant, if the cow just has given birth and the overall health status of the cow (Handboek melkveehouderij 2019). Other factors that also play a role are: Is the right feed present on the farm and works the equipment that is needed to prepare the feed. These are things that the farmer observes and decide on every day. Based on his decisions about the needs of the cows, and the objectives the farmer has operational decisions are made about the amount and type of feed.

Another example is related to the maintenance that is applied to the roughages and the field. With the tactical decisions a global maintenance plan is decided upon, but based on the information the farmer gets from his fields and surroundings he will decide on things like: The exact date of sowing, the exact amount of fertilizer each section of his fields should get, when and how much to water his roughage, when and how much pesticides and herbicides to apply, when to harvest etc.

Another example is related to the operational decisions that a farmer must take when a cow gets sick. A farmer can get a lot of information about the conditions of his cows, from observation, FMIS or his veterinarian. Based on this information the farmer must make each day for each of his cows the decisions: is the cow healthy. When the cow is not healthy the farmer must deduce what could be the reasons for the sickness. The treatment the cow gets when showing symptoms of sickness is based on the type of symptoms. To determine the treatment a whole range of decisions must be made: First the farmers must decide upon what the symptoms are. Then a decision must be made about what disease belongs to the symptoms, then a treatment must be decided upon.

When looking at the decisions that must be made and the information that can be provided by the different FMIS (Appendix 1.1) it becomes clear that some of the information from the FMIS can add value in relation to the decisions that have to be made.

Steps of decision making

The concept of decision making is a good research concept. Drucker, (1954) states that the process of decision making has 5 steps: 1. Defining the problem, 2. Analyzing the problem, 3. Developing alternative solutions, 4. Deciding upon the best solution, 5. converting the decision into effective action.

1. Defining the problem: The real problem must be found before any decision can be made. When a problem is detected it is almost never directly the underlying cause: A farmer notices that his milk production has gone down. This can have multiple reasons, the cows can be sick, the feed can be wrong, the milking equipment can have a problem or the measurements about the milk production are just wrong. Before a decision can be made to improve the current situation the real problem must be defined. The problem can better be defined when more information is available about the current situation.
2. Analyzing the problem: When the problem is defined it must be analyzed, data about the problem must be gathered and analyzed to specify the obstacles and pinpoint the exact location of the problem. The more data that is available about the situation the better the problem can be analyzed, and the core of the problem can be pinpointed. An example of this: In step 1 it is concluded that milk production has gone down because the cows are sick. The next step for the farmer would be to determine what specific disease the cows have. He determines this based on the symptoms the cows are presenting.
3. Developing alternate solutions: When the problem is analyzed the manager can start forming solutions to the problem. The better he knows the current situation the better he can predict what solutions will work. An example of this: In step two the exact disease that has been troubling the cows and has decreased the milk production has been determined. Now the right cure needs to be found. The farmer will make an inventory of the different cures that are available with the help of the veterinarian. This inventory of the possible cures will be made based on the information that is available about the disease, the stage that it presents itself and the cures that are available.
4. Deciding upon the best solution: When the possible different solutions are determined, the best solution must be selected. This is not per definition the best solution for the specific problem. It must be a solution that is best for the company. Again, having data about the current state of the company allows to better predict the impact of a solution and helps to choose the best solution. An example of this: In step 3 the different options to cure the disease have been found. Now the best cure needs to be determined, to do this the impact of the cure on the total farm needs to be determined as best as possible so the right cure can be selected.
5. Converting the decision into effective action: When a solution is decided upon it must be implemented. The company must agree upon the decision and the implementation must go in a way that is best for the company. Knowing the consequences of the different solutions will make it easier to convince the company to go with the chosen option. Knowing the current state of the company will also help to make the implementation go smoothly. An example of this: In step four a decision about the cure that is going to be used is decided upon. Now the cure needs to be administrated to the cows. It is possible that based on the age or build of the cow the cure needs to be administrated in a different way, information about the cows is needed to make this decision.

As shown, the 5 steps of decisions making can only be completed when information about the current status of the system is available (Drucker 1954). Information has always been a driver for decision making. Blackwell, (1953) states that the decision-maker tries to determine what the current state prevails, with that information a decision can be made, which will result in an action that has as

objective to obtain the highest value. If the current state can be determined perfectly the decision process becomes a simple optimization problem. This, though, is never the case and thus sub-optimal decisions are made. Blackwell, (1953) showed that better/more information always leads to improved decision making. Galbraith, (1974) states that a higher uncertainty of a task results in a larger amount of information that needs to be processed before a good decision can be made. This indicates that more complex systems need more information to make good decisions (Brynjolfsson et al. 2011). IS can help improve the amount of information and thus reduce the uncertainty and improve the decision making (Galbraith 1974). Other advantages of information from IS are: The IS provides quantified information that is not tainted with a personal bias. The information from IS is available for all authorized personnel, the information is not contained to one specialist. This gives the possibility to give other people more responsibility's/decision-making tasks because they can access the needed information (Dessein 2002; Dobrajska et al. 2015).

2.5 Farm management information systems

The farm management information systems (FMIS) can provide the farmer with a lot of different information. The goal of these FMIS is to maximize the farms' potential, within the social, environmental and economic constraints that the farmer and society decide on (Bewley 2010). The information that is obtained from FMIS is only useful if the farmer uses it in its decision-making process (Devaraj and Kohli 2003). Because there are many different FMIS that don't integrate with each other the farmer can become overwhelmed with data and it can become difficult for him to abstract the right information (Tsiropoulos et al. 2017). All these FMIS use data and they transform it into information. The data that these FMIS use are often produced by IT (Tsiropoulos et al. 2017). A few examples of different IT that is used and the information it can provide with the help of IS is listed below:

- More and more farmers are implementing milking robots, these milking robots monitor the daily milk yields and the percentage of present milk components. This information helps the farmer in multiple ways. Sudden changes in the milk yield per cow will tell if there are health-related problems developing in the cow (Nielen et al. 1992). The quality of the milk is also a health indicator (Hamann and Krömker 1997) and an indicator if the right type and amount of feed is used. Also, for the finances, quality assurance and sales this information can be valuable.
- Within the dairy industry, RFID chips are used to monitor and collect information about each individual animal, this provides the opportunity to give each individual an optimized treatment (Feng et al. 2013). Individual information can also be interesting for financial management.
- Pedometers are used to keep track of the walking behavior, if a cow starts to walk more than average it means the cow is ready for insemination. With the help of this information, the insemination period is never missed and the farmer doesn't have to check if and when the cows are ready (Roelofs et al. 2005). The walking behavior of a cow also tells something about his health (Maatje et al. 1997).
- Milking robots also measure milk conductivity, this data is used to check the milk for mastitis infections (Maatje et al. 1997; Nielen et al. 1992).

The data that these IT systems produce is transformed with the help of IS into information. Not only data from IT is used, but also data that is entered by hand. This results in a lot of information on the 14 different topics that were introduced in the introduction. Within these 14 topics, 2 topics are focused on roughage production, this can be explained by the fact that Dutch dairy farms produce a large part of their feed (Handboek melkveehouderij 2019). An overview of the main topics of information that is produced on dairy farms by information systems is listed in Appendix 1.1.

2.6 Farm performance

It is expected that improved ability to make decisions causes a better firm performance as stated in the introduction. In this research, the performance of the farm is defined by the triple bottom line. The triple bottom line has 3 levels on which the firms' performance is quantified, people, profit and planet (Hall and Slaper 2011; Slack et al. 2013). The definition of each of the three P's in the triple bottom line is not strictly noted down. Because of this, there is no universal standard to measure each of the three p's (Hall and Slaper 2011). The measurements that are performed to determine the performance as indicated by the triple bottom line are dependent on the type, level of entity and the geographical scope of the company (Hall and Slaper 2011). Some relevant indicators for dairy farms' performance that are likely to be influenced by the extra information availability will be presented below.

Profit: This stands for economic measurements, on a dairy farm there are two factors that are important for the economic performance (Zijlstra et al. 2012):

- The production quantity and quality: This determines the total value of produced milk (The value of the produced milk is calculated by multiplying the milk price with the production quantity, where the milk price is partly depended on the quality of the milk. Examples of quality properties are: the amount of protein, the amount of fats, stomatic cell count and bacteria plate count (Handboek melkveehouderij 2019)).
- The production cost: all cost that are made to produce the milk, including depreciation on machines and equipment

The price the farmer eventually gets for his milk is determined by the buying company. The farmer wants to produce as much milk as possible while keeping the cost of his operations as low as possible. This is where extra information from IS can play a role. It can help improve the production by keeping better track of the needed diets of each individual cow and by spotting diseases earlier on (Bewley 2010; Jago et al. 2013). Extra information can also help to keep the cost low. It will help determine the amount of stock that is needed and determine when assets should be written off (Van Horne and Wachowicz 2008). The farmer needs to find the right balance between production quantity and cost, extra information can help here as well. It can help to give better insights if changes in the operations have a financially positive or negative effect (Bewley 2010).

People: This is an indicator of the social performance of a company, this performance measure will mainly be focused on the quality of the working days of the employees and the farmer himself. This results in two social performance indicators.

- Flexibility of working hours
- Length of working day

The extra information and the easier accessibility of the information give theoretically the possibility to have a more flexible working day. For example, the farmer doesn't have to check as regularly if his cows are sick, the information systems on the farm take over this task for a large part. This means that the farmer can feel free to go to a meeting in the morning without worrying if things go wrong on the farm. Another advantage is that the information is easier accessible, as a result, the farmer can outsource more tasks (Laudon and Laudon 2012). There will be less often the situation where only the farmer can perform the tasks because he is the only one with the needed knowledge. This means that it becomes easier for the farmer to reduce his workload. These benefits can result in the possibility for the farmer to take up jobs he previously didn't have time to do. Resulting in a possibly better financial and environmental performance and maybe giving the farmer a more fulfilling feeling (Deary et al. 1997; Hostiou et al. 2017).

Planet: This is an indicator of the impact the company has on the environment. Dutch dairy farms are under a lot of pressure from the government to become more environmentally friendly (Handboek melkveehouderij 2019). A couple of hot topics are the emission of methane and nitrous oxide and the surplus of nitrogen and phosphorus (De mestproblematiek, PBL Planbureau voor de Leefomgeving 2010; Olesen et al. 2006). Another hot topic is the way the animals are treated, the consumers are demanding a better life for the production animals (Oosterkamp, Jager, and Buurma 2008). These problems translate into 3 performance measurements:

- Greenhouse gasses
- Animal welfare
- Manure production

The extra information that is produced by the IS can in theory be beneficial for these indicators. The information that is produced can possibly give a better insight into the greenhouse gas emissions and manure production. It becomes better known how much manure is produced and how much greenhouse gasses are released. Information from the IS can also result in a higher resource use efficiency which in turn will cause lower levels of nitrogen and phosphorus in the manure and less released greenhouse gasses per L milk (Bennetzen et al. 2016; Goselink and Sebek 2012). Information about the health of the animals can be beneficial for the welfare of the animals. When diseases are detected early they can be treated quickly and issues like claw problems can be prevented better. By bringing more insight into all these processes the farmer will be able to better determine if adjustments on the farm are beneficial for environmental indicators.

2.7 Conceptual framework

As shown in Figure 3, it is expected that the increased availability of information because of IS, both the quantity as the quality will impact the decision making within the farm management. There are three different types of decisions that must be made within the farm management. Each of these decisions happen within the four different functional areas of farm management. Each of these types of decisions consists of 5 steps, as indicated by Figure 3. It is expected that the impact on the decision making consequently will cause an improved financial, social and environmental farm performance.

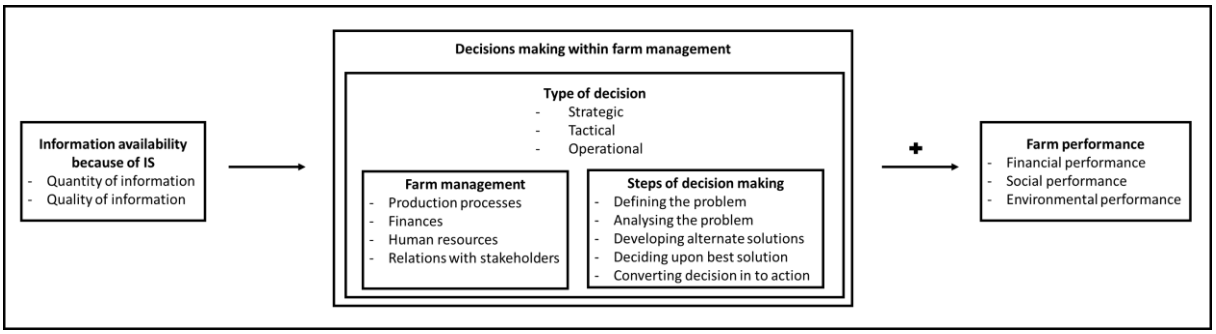

Figure 3: Conceptual framework

3 Material and methods

3.1 Methodology

This chapter will explain how the research is executed and what methodology is used. First, the key concepts and definitions of this research are defined. Next, the study population and the test group will be explained. Then it is explained how the data is collected and analyzed.

3.2 Key concepts and definitions

Information technology:

Information technology is all the hardware and software that a company uses to complete its business goals. IT must support tasks like processing, storing, distribute and collecting data (Laudon and Laudon 2012; Lucas 2009).

Information systems:

Information systems collect, process, store and distribute information. IT can be part of an information system, its purpose is to support the information system (Florida Tech Online n.d.).

Farm management information system:

Information systems that are used by farmers to optimize, plan and control farm activities (Novkovic et al. 2017).

Dairy farm performance:

This concept consists out of 3 sub-concepts, environmental performance, social performance and financial performance (Elkington et al. 2004; Hall and Slaper 2011).

Dairy farm management:

The management of a dairy farm is divided into four main functional areas: production, finances, human resources, and stakeholder management (Gloy et al. 2002; Shridhara Bhat and Dim 2010; Slack et al. 2013; Wolf 2012).

Decision making:

Decision making is a process that consists of transforming information into effective actions, it knows five steps: 1. Defining the problem, 2. Analyzing the problem, 3. Developing alternative solutions, 4. Deciding upon the best solution, 5. converting the decision into effective action (Drucker 1954).

Information availability because of FMIS:

The information that comes available from the FMIS is classified based on quality and quantity. The quality of the information is established based on quality properties as determined by Lee et al. (2002). The quantity of information is based on the number of different types of information that are present on the farms as defined by Fountas et al. (2015) and Voulodimos et al. (2010) and how often the different types of information are used.

3.3 Study population

This research will focus on Dutch dairy farmers, this is a large and diverse group. To have a more consistent and defined study population a selection will be made. Based on different characteristics many different types of dairy farmers in the Netherlands can be defined. These typologies can be based on size, type of cows, type of farming, age of farmer, type of land, etc. For this research a division will

be made based on the “type of farming”, the focus will be placed on conventional dairy farmers. Biological farmers and bio-organic farmers will not be included in the study population. A division is made based on the type of farming because it is expected that this typology will show large differences between different types. This is expected because organic and biodynamic farmers have different ways of farming and a different mindset when farming (Flaten et al. 2005; Zwald et al. 2004), they have thus different decisions to make and are likely to use other data and use it in a different way. Based on information from (Alvarez and Nuthall 2006) is it expected that the size of the farm and the extent to which a modern farming approach is used by the farmer impacts the use of information from FMIS. The extent to which a modern farming approach is used is checked by asking if the farmer uses a milking robot. Four “types” of farmers are established within the population of conventional dairy farmers to make sure that the test group will be a good representation of the study population while collecting data from a limited number of farmers:

1. small not modern farmers
2. small modern farmers
3. large not modern farmers
4. large modern farmers

The size of the farm will be based on the average number of dairy cows that have been present on the farm in the last year. 50 – 100 cows will be a “small farm” more than 100 cows will be a large farm (Fernhout et al. 2013).

Study population: All conventional Dairy farmers that have their farm located in the Netherlands

3.4 Test group

The test group consist out of farmers from all four types of farms within the defined study population. Farmers will be interviewed until saturation in terms of new information is reached or time constraints prohibit further interviews. Based on the literature saturation is most likely reached anywhere between 5 and 50 interviews (Dworkin 2012). Dworkin, (2012) states that the point of saturation depends on a lot of factors like: how homogeneous is the population, how is the test group selected and when thinks the researcher that saturation is reached. Based on the literature and the time constraints that are on this project a test group of 16 people is opted for. Four interviews for each type of dairy farmer is strived for. When time constraints don’t allow for 16 interviews the number of interviews will be dropped to 14.

The test group is obtained by using stratified convenient sampling. The test group will be established using the researcher’s network. The researchers' network consists mainly out of sons and daughters of farmers that attend Wageningen UR. The network will be contacted using social media and WhatsApp. These sons and daughters will define the “type of farm” their parents/friends have. For the farmer to join the research has he to have one of the four previously defined types of farms within the defined study population. When the son/daughter indicate that their parents/friends have the right type of farm and that the farmer is willing to participate in the research they will be asked to help establish contact with the farmer. New farmers will be contacted until four interviews are planned with each of the four types of farmers. All interviews will be conducted at the homes of the farmers. Each interview will start with a small introduction chat, the farmer will be asked to tell about his farming operations. This question will set the farmer at ease thus reducing the test anxiety. During the introduction chat the interviewer will ask permission to make an audio recording of the interview. The duration of the interviews will be between 30 and 90 minutes depending on the answers of the farmer. All interviews will be conducted in Dutch because all interviewees are native Dutch speakers. All

interviews will be conducted on working days between 09:00 and 17:00 in a time period of 4 weeks by the same interviewer.

3.5 Data collection and analysis

This thesis has a theory-testing approach, to achieve this a case study design is used for sub-research questions one and two. This design is applicable because there is insight needed into the way higher information availability because of IS affects the decision making within the dairy farm management and consequently affects the dairy farms' performance. This insight will give the knowledge to see if the theory as stated in the conceptual framework applies in the case of a dairy farmer. The first sub-question will provide information on the extent that higher information availability because of IS affects the farm management decision-making process. The second sub-research question will examine how this changed decision making in dairy farm management translates into the dairy farms' economic, social and environmental performance. To answer the main research question, the sub research questions will first be answered. The farmers will be supplied with a small summary of topics of the interview (Appendix 2.2). This will enable them to already think about the research subject and will provide them the information they need to answer the questions. The following methods will be used to answers the sub and main questions.

Literature review

To get an initial overview of the topic, literature research is carried out based on the snowball system using the Scopus database and Google scholar. Different databases are used because of the different contend that they provide and the different ways they rank the articles (Meho and Yang 2007). By using these two databases a relative complete picture will be obtained of the relevant literature. Based on articles from (Brynjolfsson, Hitt, and Kim 2011; Fountas et al. 2015; Wolfert, Verdouw, and Bogaardt 2017) an outline of the topics “information systems”, “data-driven decision making” and “performance” is created. Texts that quote or are quoted by these articles are analyzed to set the basis. For further literature research, a structured approach is opted for. In the Scopus database and the Google Scholar search engine the following search terms are used to find useful literature: *data-driven decision making, information systems, smart farming, farm management, production management, financial management, HR management, marketing management, decision making, Information technology,* and *dairy farms*. Different combinations of these search terms are used.

Sub question 1:

The first sub-question investigates the way that information availability because of IS affects the decision making on dairy farms. This question will be answered by doing a semi-structured interview with dairy farmers. This type of interview is opted for to keep the questions as structured and uniform as possible while still having the possibility to ask follow-up questions. In these interviews, different aspects of the impact of the information provided by the IS toward decision making will be analyzed. The questions can be found in Appendix 2.1. First, the farmers will be asked about the quantity and quality of information that the FMIS provide and if they use the information for assistance in decision making. To determine the quantity of information a question will be asked about the types of information that are available via FMIS. The classification of the “types” of information will be based on the literature. The quality of the information will be established based on information quality properties as established in the literature study. Following, the farmers will be asked for which types of decisions the information is used and in what manner it is used. This will provide information about where the extra information impacts the farm management and where in de decision-making process the extra information plays a role. To make the questions easier to understand for the farmer the 5 steps of decision making that are indicated by the literature will be reduced to three steps: Determine

the problem, finding a solution to the problem and converting the decision into action. Sub-question 1 will give an overview of the way the information from the FMIS affects the decision making within dairy farm management.

Sub question 2:

The second sub-question investigates the way the changed decision making because of changed information availability affects the perceived farms' performance. To research this question the semi-structured interview will be extended with some extra questions (Appendix 2.1) about in which way their changed decision making because of extra information affects the perceived economic, social and environmental performance of their dairy farm.

Data analysis

The data from the answers as given by the farmers will be analyzed by thematic content analysis. First, the interviews will be transcribed, following they will be coded. This will be done with the help of ATLAS.ti. The coding scheme will be made with a deductive approach and will be complemented with an inductive approach. For the deductive approach the conceptual framework will be used as a basis.

3.5 Operationalization

As explained is the data that is needed to answer the sub research questions collected through semi-structured interviews. Before these interviews can be executed all concepts need to be operationalized so they can be measured. Per sub-question the defined variables will be explained.

3.5.1 Effect of information from IS on the decision-making process

The first research question is: How does the increased availability of information because of IS affect the decision-making process within the dairy farm management? The concepts that need to be measured for this sub-question are 1. Information availability because of IS 2. Impact on the decision-making process.

The information availability

The information availability will be determined based on the quality and quantity of the information that is present on the farms. The quantity of information has the variables “present types of information” and “number of times the information is checked” These variables will be defined as followed:

- Present types of information: The presence of a “type” of information that is produced by an information system. The “types” of information are as defended by the literature in Chapters 1 and 2.
- The number of times the information is checked: How often a farmer subtracts information from an IS. This is divided into 5 steps
    - 1: Once a year
    - 2: Couple times a year
    - 3: Once a month
    - 4: Once a week
    - 5: Every day

The quality of information has multiple characteristics:

- Intrinsic information quality: The quality of the information itself with dimensions like reliability and validity

- Contextual information quality: The quality of the information when seen in the context of the problem with dimensions like timeliness and completeness
- Representational information quality: The information must be easy to interpret
- Accessibility information quality: The information must be easy to access

All these characteristics are measured on a Likert scale from 1 to 5 where 1: very poor, 2: Poor, 3: fair 4: Good and 5: Excellent

Impact on the decision-making process

The concept "impact on the decision-making process" also has multiple sub-concepts:

- Functional areas of dairy farm management
- Type of decision
- Steps of decision making

Each of these sub-concepts has its own characteristics.

Functional areas of dairy farm management

The management of a dairy farm consists out of 4 different functional areas. 1. Production, 2. Finances, 3. Human resources, and 4. Stakeholder relations. Each of these functional areas is defined with the help of the literature in Chapter 2. The information helps within a functional area when the decision topic has overlap with the functions of the functional areas.

Type of decision

The decisions that must be taken on a dairy farm can be divided into three different types.

- Strategical decisions: Decides about long-term objectives and allocation resources to obtain these objectives.
- Tactical decisions: Decisions about the use of resources, so the production demands are met. These decisions should be in line with the strategic decisions, they further explicate the strategic decisions
- Operational decisions: Decisions about the day-to-day operations, they are in line with the tactical decisions, they further explicate the tactical decisions.

It will be determined for what type of decision the information is used. This will be done based on the description of the decision that the farmers talk about. This description of the decision will be matched with the best fitting description of the three types of decisions.

Step of decision making

The decision making knows 5 steps according to the literature (Drucker, 1954). In this research, this will be reduced to 3 steps to make it easier for the farmers to answer the questions.

1. Defining and analyzing the problem: The real problem must be found before any decision can be made. When a problem is detected it is almost never directly the underlying cause. When the problem is defined it must be analyzed, data about the problem must be gathered and analyzed to specify the obstacles and pinpoint the exact location of the problem.
2. Developing alternate solutions and deciding upon the best solution: When the problem is analyzed the manager can start forming solutions to the problem. When different solutions are formed, the best solution must be selected. This is not per definition the best solution for the specific problem. It must be a solution that is best for the company.

3. Converting the decision into effective action: When a solution is decided upon it must be implemented. The company must agree upon the decision and the implementation must go in a way that is best for the company.

It will be determined for what step of decision the information is used. This will be done based on how the farmers talk about the use of the information. This description of the use of information will be matched with the best fitting description of steps of decision making.

3.5.1 Effect of information from IS on the farms' performance

The second research question is: How does the changed decision-making process within farm management because of the changed availability of information affect the dairy farms' performance? The concept that needs to be measured for this sub-question is “dairy farms' performance”.

The concept “dairy farms’ performance” exist out of sub-concepts each of these sub-concepts has its own characteristics:

- People performance: This is an indicator of the social performance of a company, this performance measure will mainly be focused on the quality of the working days of the employees and the farmer himself. This sub concept has two characteristics: 1. Flexibility of working hours, how easy can the farmers make changes to the work schedule. 2. Length of working day.
- Planet performance: This is an indicator of the impact the company has on the environment. This sub-concept has three measurable characteristics: 1. Greenhouse gas emission, 2. Animal welfare, and 3. Phosphate regulations, how easy can the farmer maneuver through the regulations
- Profit performance: This stands for economic measurements, the economic performance of a farm. This sub-concept has two characteristics: 1. The deliveries: total value of delivered milk (With a price premium for quality variables like fat and protein content) 2. The production cost: all cost that are made to produce the milk, including depreciation on machines and equipment

The information from the information systems can have 3 types of effect:

1. It can have a positive effect on the specific characteristics of the sub-concept. Positive effect means an improved performance as perceived by the farmer
2. It can have a neutral effect on the specific characteristics of the sub-concept. Neutral effect means that no noticeable differences have been perceived by the farmer
3. It can have a negative effect on the specific characteristics of the sub-concept. Negative effect means a decrease of the performance as perceived by the farmer

4 Results

14 Dairy farmers were interviewed, a summary of the results will be given in this chapter. All interviews are completely transcribed. The coding is done according to the method that is described in Chapter 3. This chapter will follow the structure of the conceptual framework. First, the results regarding the information availability because of information systems will be given. Then the impact of this information on the decision-making process will be shown. Finally, the impact that the information has on the performance of the farm via altered decision making will be presented. In the material and methods, it is explained that a distinction is made between 4 types of farms. This is done to have a good representation of the population while having a small sample size. Because the sample size is small no significant distinctions have been observed between the different types of farms. Therefore, the results will not show the differences between the 4 types of farmers. Table 1 gives an overview of information about the farmers that were interviewed. The information that is provided by the IS according to the farmers is not the same as is indicated by the literature (Appendix 1.1). An overview of the differences between the information that is provided by the IS according to the literature and according to the farmers is given in Appendix 1.2

Table 1: Types of farmers that have been interviewed

Farmer	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of cows	60	110	90	145	650	95	110	70	190	105	90	87	160	64
milking robot (yes/no)	No	yes	No	No	No	Yes	No	No	Yes	No	Yes	No	Yes	Yes
sex	F	M	M	M	M	M	M	M	M	F	F	M	M	M
Location (province)	Fr	Nb	Ge	Gr	Gr	Nb	Dr	Nb	Ge	Fr	Ge	Fr	Fr	Nb
age (years)	30	28	45	53	24	35	50	24	47	58	55	61	49	26

Small + Robot	
Small	
Large + Robot	
Large	

Female	F
Male	M

Friesland	Fr
Noord brabant	Nb
Gelderland	Ge
Groningen	Gr
Drente	Dr

4.1 Information availability because of IS

4.1.1 Quantity of information

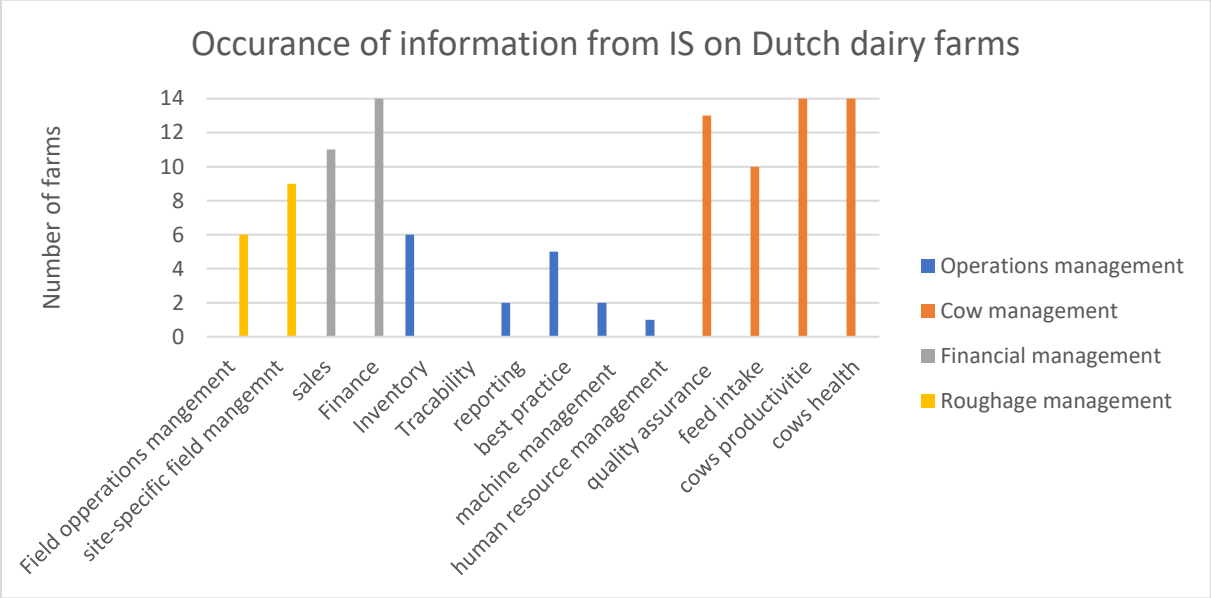

Figure 4: The 14 types of information and the number of farmers that have them on the farm. Only the systems that were indicated to be used are included. The information types are divided into four categories: Operational management, Cow management, financial management, and roughage management.

The interviewees possess information systems that provide information on 13 of the 14 types of information that were determined in advance (Figure 4). The information types are divided into 4 sub-groups to make the results clearer. This division is not perfect and is based on the use of the information. Systems that provide information on traceability are not present on any of the farms. Farmer 5 mentioned that this type of systems are only found on really big farms, with over 500 cows and a number of employees. These big farms are barely found in the Netherlands. Farmers (5, 8, 9) stated that dairy farming is all about the cows, they are their livelihood, the milk they produce is their income. When looking at the types of information that are produced by the IS this corresponds. The information types that are mostly found on the farms are about cow management and finances. A reason for the large number of financial management systems is given by Farmer 14 who stated that eventually also a farm is a company that needs to make money. Another reason is that it is obligatory for a company to have an accounting system. Systems that provide information about roughage management are found only on half the farms, and between these farms, there are large differences between the sophistication of the information their roughage management systems provide. Farmer 2 for example uses imagery data to keep track of his roughage, where the other farmers that have these systems mainly use if for determining the fertility of the soil and making a fertilization plan. Systems that provide information on operations management are found only on a few farms.

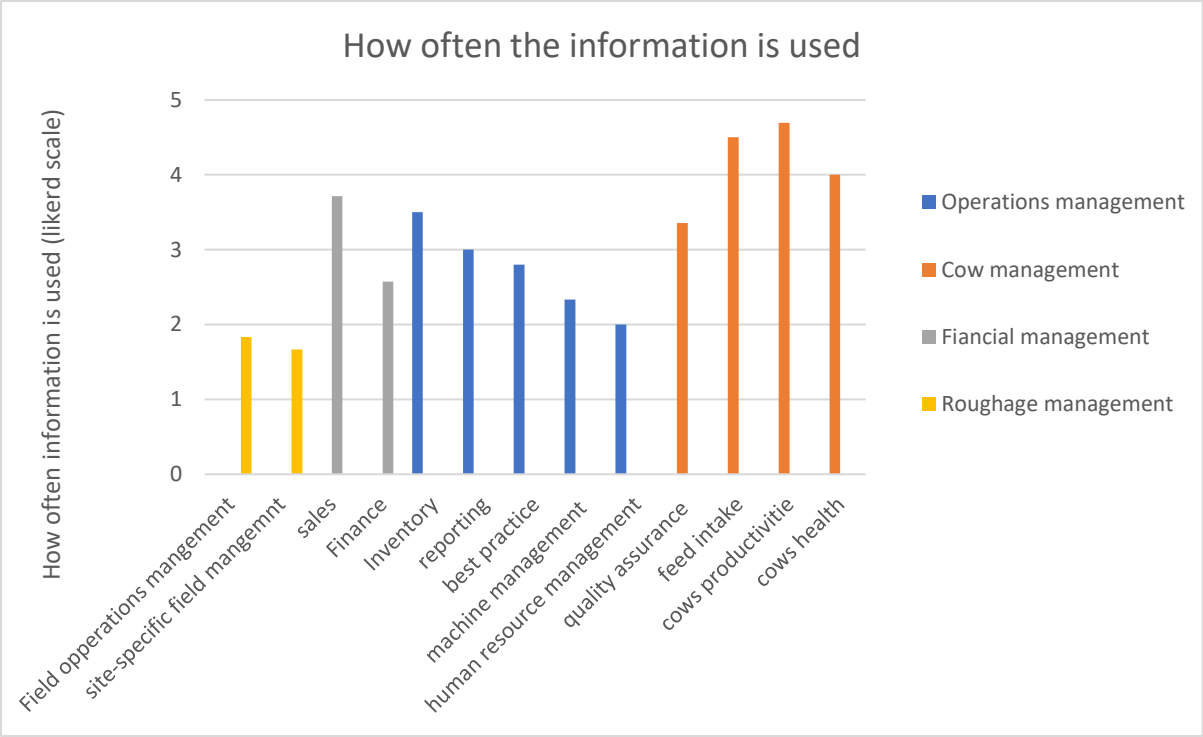

Figure 5: This graph represents the average response on the question of how often a type of information is used on the farm. This question is answered by each of the 14 farmers on a scale from 1 to 5 for all types of information systems that were present on their farm. 1 = once a year, 2 = a couple times a year, 3 = once a month, 4 = once a week, and 5 = every day.

The number of times the information from the IS is used differs quite a lot between the different systems (Figure 5). The information from the roughage management systems showed the lowest scores. The farmers that possess these systems all indicate that the information is checked when it is time to fertilize the fields, this happens around 5/6 times each year. Farmers 6 and 9 mentioned that the information is checked once in spring, and then the knowledge is used for the rest of the growing season.

The usages of the financial management information shows quite some differences between the finance information and the sales information. This is mainly because the sales information is delivered by the company that buys the milk, in most cases, this is FrieslandCampina. Together with the sales information, information about the quality of the milk is provided. Milk quality information is very interesting for the farmer. This makes that the farmer automatically looks at the sales information quite often. The sales information is used by the farmer to get an indication of the current state of his operations (Farmer 9,14). The farmers indicated that the financial information is mainly used when large investments are done and every quarter when the VAT must be submitted. Also, at the end of the year, there is 1 day when the finances are sorted out together with an accountant.

The cow management information systems are checked most regularly by the farmers. One farmer indicated that this is due to the fact the cows are living animals, the information that comes forth from the cows is very fast outdated because the cows and their environment are changing constantly. This makes it necessary to check this information regularly (Farmer 14).

Within the operations management systems mainly the inventory system has some remarkable results regarding the regularity the information from these systems are checked. Within the test group either the feed inventory is checked daily or once every month. The difference is related to the modernity of the information system that is used on the different farms to keep track of the concentrate feedstock. This system can work in two ways, either there is a tell-tale on the concentrate feed silo that sends out

a message when it is time to order the concentrate again, in that case, information is received only once a month when the stock of concentrate feed is low and it is time to order new (Farmer 12). The other possibility is that the concentrate uptake by the cows is monitored, in that case, the farmer will check daily what the uptake is. The farmer can consequently determine what the status of his stock is (Farmer 5, 8). In the second example information from the feed intake system is used in the inventory system.

Overall the observation is made that mainly information systems that provide information about the cows and finances are present on the farms. The number of times information from the information systems is used seems to depend on the number of times a decision needs to be made in the domain of a specific type of information.

4.1.2 Quality of the information

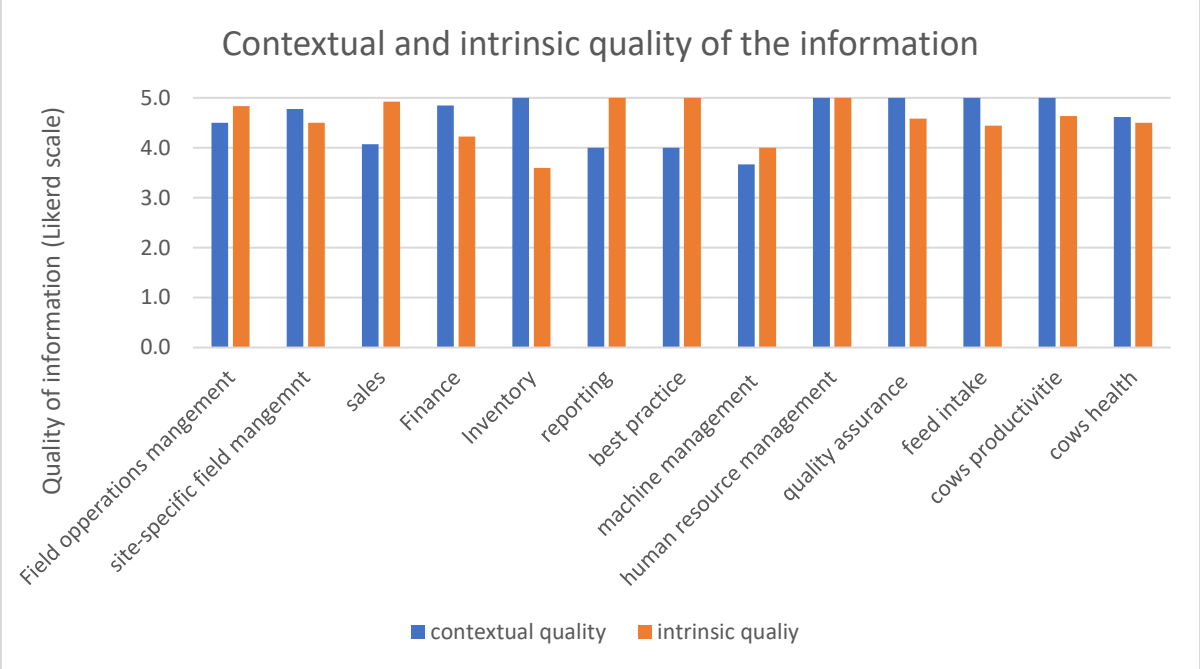

Figure 6: The average contextual and intrinsic quality of the information from the 13 different types of information that were present on the 14 farms as indicated by the farmers. 1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = excellent.

As shown in Figure 6 the average contextual and intrinsic quality of the information that is provided by the different information systems is experienced as good to excellent. The contextual quality is the quality of the information when seen in the context of the problem. Is the information provided on time and is all the information provided that is needed? The intrinsic quality is the quality of the information itself with dimensions like reliability and validity. Only the contextual quality of machine management and the intrinsic quality of inventory is a little below good. The low score for the contextual quality of the machine management can be explained. Only 3 of the interviewed farmers have these systems on their farm, this makes that one outlier has a lot of impact. Farmer 10 behaved as an outlier, he indicated that only a limited portion of the information that is provided by the machine management information system is used. The reason for this is that a lot if the maintenance information, like when the oil was last changed, is already known by the farmer without using the information system. Another reason is that a large part of the maintenance of the machines is done on feeling. The intrinsic quality of the inventory data gets a lower rating because there is one big problem. Some of these systems keep track of the available bulk feed (grass and maze). The initial values that the systems work with are based on an estimation of the current stock which is made by the farmer. This is a very inaccurate estimation (Farmer 2, 14). The answers about the quality of the

other systems also contained some interesting outliers: There are a couple of farmers that have reasons to be less positive about the contextual quality of the information that is provided to them by the information systems. Sometimes only a small portion of the information that is provided by the IS is used where the rest is supplemented by the farmers' own knowledge (Farmers 2, 10, 11). Another difficulty was appointed by farmers 10 and 11. The information provided by the best practice systems is very broad and for a lot of subjects, only a limited amount of the information is interesting. Farmer 11 explained that information about milking robots was very useful when they were in the process of buying one. But when the robot was bought the information became quickly less interesting. Farmers 3 and 4 indicated that all the information could also be too much and "you should not let all those numbers make you go crazy" (Farmer 4).

The intrinsic quality also knows some outliers in the responses, Farmer 7 indicated that information produced by the pedometers to detect a drafty cow (cow health) was not trusted, so also not yet used. Farmers 1 and 2 indicated that their milking stables are relatively old and sometimes have trouble with their software. This then resultes in wrong information about the productivity and food intake of the cows. Another problem is that sometimes the data the system must work with has to be entered by hand. For example, when a cow gets sick or maintenance is done on a machine it has to be entered into the IS. Farmers often forget to enter data which results in wrong information from the systems (Farmer 2, 5).

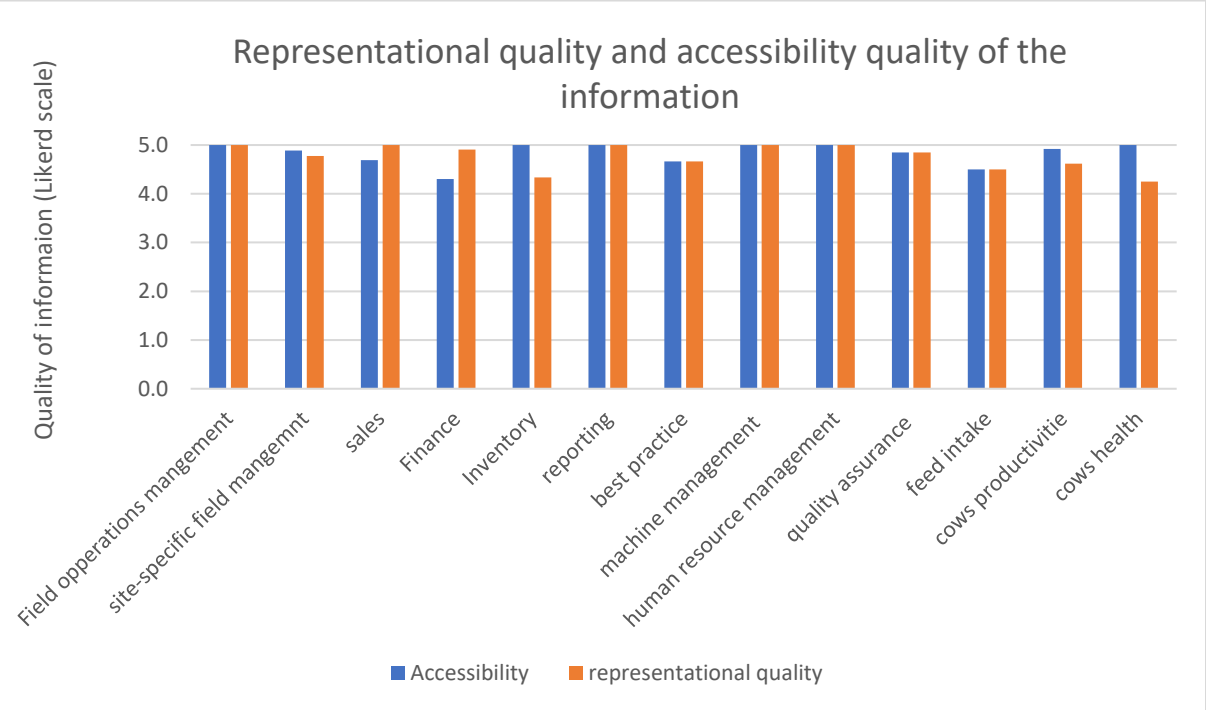

Figure 7: The average representational quality and accessibility quality of the information from the 13 different types of information that were present on the 14 farms as indicated by the farmers. 1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = excellent.

In general, the farmers are very satisfied with the accessibility and representational quality of the information (Figure 7). The accessibility represents how easy it is to access the information. The representationally represents how easy it is to interpret the information. The providers of the information systems have tried to make the systems easy to use. Farmer 12, for example, gets all the information from the different systems on a few apps on his phone and Farmer 3 uses one computer program where all the different information systems are coupled. Though there are a few remarks from different farmers.

Farmer 2 uses a site-specific field management system to keep track of the growth of his roughage. To use this, he needs to upload a lot of data into the program. This data results from visual observations from the field, this data is not quantitively measured and is thus a very subjective. Because both he and his bother use the system, differences in the data that result from the subjective measurement get uploaded which causes confusion and result in a sub-optimal representational quality. Another problem is strongly related to the representational quality of the information. The information that is provided by the different systems is often easy to find and given at the right time, often this information indicates that there is a problem. The difficulty that the farmers experience is that it can be hard to pinpoint the cause of the problem. Another problem is that it can be difficult to decide on the right response to the problem. An example of this is related to the cow productivity. A system can indicate that the productivity of the cow has dropped by 10 % overnight. When a farmer gets this information, he must decide on how to respond. Is it just coincidence or is there something wrong? and when there is something wrong what is wrong? Is it related to the feed, the health or something completely different? A lot of the systems are good at warning the farmer that there is a problem, but the farmer still needs to determine the exact problem and find a good solution (Farmers 2, 4, 5, 11). Farmer 14 stated it the following way: "you see that something is wrong, but it is the point of action that follows that can be hard. That requires a lot of experience. I know a lot of farmers that struggle with this. The amount of data and warnings becomes so large, you can get lost in it." There is a lack of decision support systems. Another problem with the accessibility and representational quality is related to the hardware of the systems that are on the farm. Farmers 1 and 2 indicated that their milking stables/robot is relatively old, which causes a lot of problems regarding the data generation and supply of information. What also plays a role is that not all farmers are very skillful when it comes to computers. Farmer 9 indicated that he has a hard time keeping up with the fast changes regarding information systems.

Overall are all aspects of the quality of all types of information rated good to excellent by the farmers. The complaints that were given by the farmers about the quality of the information can be divided into four categories: 1. The IS provides too much information and it becomes hard to select the right information. 2. People must enter data into the system, this is accompanied by mistakes. 3. The IS is lacking a decision support component. 4. The hardware/software of the IS is old, which causes errors and breakdowns.

4.2 Impact of information from IS on the decision-making process

This subchapter will present the results regarding the impact that the information from the IS has on the decision-making process. Information will be provided about in which of the three types of decisions (strategic, tactical, and operational) the information is used (Table 2). With each type of decision that is taken the information is used to make a decision in one of the four types of functional areas that are present on the farm ("production", "finances", "human resources", and "stakeholder relations"). Also, all information that is used for the decision making process can assist in any of three steps of decision making (1. defining and analyzing the problem, 2. developing alternate solutions and deciding upon the best solution, 3. converting the decision into action). First, an elaborate breakdown is given per type of information system and then a global overview of the result is given by Tables 2,3, and 4.

4.2.1 Field operations management

The field operations management information is used for strategical decisions. Farmer 2 and 8 use the information to keep track of the roughage that have grown in their fields. (Regulation obligates a farmer to change grassland at least once every 5 years into another crop.) The information system functions as a reminder that the farmer must change his roughage. In the process of decision making

it helps the farmer to determine what the best time is to change the roughage on a field. Not to determine what roughage should replace it. This is a clear example where the information is used to convert a decision into action. These farmers use this information to make strategic decisions in the functional area “production”.

The information is also used for tactical decisions. The system uses information about which roughage is going to be sown, which roughages have been sown last year and the amount of organic fertilizer that is present on the farms. With this information, the system helps the farmer to decide which type and amount of fertilizer should be applied to the fields (Farmer 3, 4, 10, 11). It also helps the farmers in deciding on which field which roughages should be sown (Farmer 8). These are both examples where the information helps in deciding upon the best solution within the functional area “production”.

When the fertilizer must be applied the information helps in making operational decisions by reminding the farmers what amount, and type of fertilizer have to be applied to which fields. It helps to convert the decision into an action (Farmer 11).

4.2.2 Site-specific field management

The information that is produced by site specific field management systems (SSFMS) is used to keep track of the quality of the soil and roughages on different plots. The information from SSFMS is only used in the functional area “production”. Farmers 6 and 9 indicated that they use the information for strategic decisions. Information about the quality of the soil tells them which pieces of land have problems in relation to PH and organic matter content. It serves as a kind of warning system. After being warned they can start making a plan on how to improve the soils. This means that the information helps with defining and analyzing the problem. Farmer 2 uses the SSFMS in the same way but then related to his roughages. Based on aerial photos the quality of the roughage is established, the farmer gets warned when problems become visible.

The impact that the information from SSFMS has on tactical decision making has a lot of overlap with the information from field operations management. The difference is that with the help of SSFMS the information is more detailed. SSFMS use data that comes directly from the field. Field management operations systems use indirect sources of data. For example, SSFMS use soil samples to determine the fertility of the soil. Field management operations systems derive the fertility based on the fertilizer application and type of roughage that has been grown. The SSFMS tell the farmer what type and amount of fertilizer should be applied to each specific section of the field instead of a general manure plan for the farm. It helps the farmers to choose the best solution for optimal soil fertility (Farmers 4, 6, 7, 9, 12-14). The information is also used to decide what roughages should be sown on which fields. Farmer 2 stated that information about the height of the fields is used to give an indication of the drought stress that could occur in summer. The farmer includes this information when choosing a roughage, it helps in defining and analyzing the problem but also with deciding upon the best solution.

When the fertilizer must be applied and the roughages must be sown the information helps in making operational decisions in the same way as with field operations management, it reminds the farmers, it helps to convert the decision into an action (Farmer 10)

Summary of the impact of information from roughage management systems on decision making:

Overall are the roughage management systems (both field operation management as site specific field management) help to maintain the roughages and the soil. These systems only provide information in the functional area “production”. Most decisions that are made with the help of these systems are tactical. The information from these systems can help with all steps of decision making. These systems are mostly used by the farmers to help with the fertilizer application rates.

4.2.3 Sales

The sales information systems provide the farmers with information about the amount of milk that they deliver to the buyer and the income that is generated with it. All farmers use a system that is designed by the buyer of the milk. The sales information is used for strategic decisions in different manners. All interviewed farmers only have one buyer for the milk, in most cases, this is FrieslandCampina . The sales information helps the farmers decide if the company that buys their milk is still paying enough money and if the milk price is not fluctuating too much. When this becomes a problem, the farmer can start looking for another buyer (Farmer 2, 10). This decision is within the functional areas “finances” and “stakeholder relations” and an example of defining/analyzing the problem and deciding upon the best solution. Farmer 2 states that the information also helps to maintain a good relationship with the bank. When large investments need to be done the bank wants to see the sales information. This information will help in creating different options to finance the investment. Again, a decision in the function areas “stakeholder relations” and “finances”. Thirdly the information is used as an indication of how the company is performing (Farmer 5, 12, 14). The long-term performance of the company will help the farmers in deciding upon long term strategies. When the milk price is good and there is a lot of income more investments can be done. When the milk price is low, and the income is low it warns the farmer that he must watch his expenses. The information helps in defining the problem and is used in the functional area “finances”.

The sales information is also used as an indication of how the company is performing when talking about tactical decisions. For example, the sales information can show that the milk price has dropped which has made the concentrate feed cost relatively too high in relation to the extra milk income that the concentrate feed generates. Farmer 14 emphasized though that intervention in the production management happens less on tactical level based on sales information because: “Cows like a constant environment when you start changing things every time the sales change a bit they won't like it.”

The sales information also shows when the milk money will be transferred. This helps the farmers in making the operational decision when expensive expenses can best be paid. This again is a decision in the functional areas “finances” and it helps to convert a decision into an action (Farmer 3, 12).

4.2.4 Finance

The information from the financial information system is used for strategic and tactical decisions. None of the farmers use the information for operational decisions. The farmers have indicated that they use financial information for multiple strategic decisions. All farmers stated that the information is being used to make investment decisions. What investments are possible, what is the best way to finance it and which product/service is the best buy. With these decisions the question: “What will the impact of the investment on the production and income be?” is always raised. An example of this was given by farmer 6: Half a year ago they switched from milking two times a day to milking three times a day. This resulted in an increase of 10% milk production from the cows and thus a higher income. But they are rethinking this decision because the profits are less than hoped. Milk is not paid per liter but per Kg of protein and fat. The amount of protein and fat has dropped quite a bit as a result of milking three times a day. Nevertheless, when only looking at milk production they are still making more money. But it turns out that the production costs also have increased. The people that milk the cows must be paid more and are complaining that they must work too hard. Another cost is related to phosphate rights. The amount of phosphate rights that you need to have is related to the liters of milk that is being produced. This makes it relatively expensive to produce more milk with less fat and protein. With the help of the finance system, farmer 6 can overthink this decision and come to the best conclusions. The information helps farmer 6 to define and analyze the problem but also to decide upon the best solution. This problem is related to the functional areas “management”, “finances”, and “human

resources". Another example of how finance information helps in investment decisions is related to the concentrate feed. When more concentrate feed is given to the cows, they start to produce more milk. The information helps to analyze if the increase in milk production outweighs the increased cost of concentrate feed. To make this decision also information about the productivity of the cows is used (Farmer 10). Another strategic decision that is supported with information from finance information systems is the decision when to replace certain tools/machines. Farmer 2 indicated that information about maintenance costs is very important in determining if a machine gets replaced. The financial information helps with defining/analyzing the problem. Another way in which the financial information is used is in determining if the tax pressure is getting too high. Farmers 4, 7 and 8 indicated that that would be a signal to start investing. This is a clear case where the information is used in the functional area "finances" and where the information helps with defining the problem. The financial information is also used to find the weak spots of the business operations. Farmer 8 stated that the financial information revealed that the cost of his calves were too high, this has encouraged him to make changes. This is a decision that both relate to the functional areas "finances" and "production". The information helps in defining and analyzing the problem. Farmer 14 used the information from the finance information system for a different purpose. He stated that when the finances were good, he buys some extra from the suppliers. This is done to create a good relationship with the suppliers. Here the financial information is used to prohibit a problem in the future, the information is used in the functional area "stakeholder relations"

The financial information is also used for tactical decisions. Farmer 6 indicated that he sources out more work when the financials allow it. The financial information is used to decide if he can outsource work, so he has more time for himself. He uses the information to decide upon the best solution. The information is used to make a decision in the functional areas "finances" and "human resources".

Summary of the impact of information from finance management systems on decision making:

Overall are the financial management systems (both finance and sales) mainly used in the functional area "finances". The financial information is an important driver for determining what the possibilities are in relation to investments and farming strategies and helps with deciding upon the best solution. Another important function of financial information is to detect if there are problems on the farm.

4.2.5 Inventory

The information from the inventory systems is used for strategic, tactical, and operation decisions. All these decisions are taking place within the functional area "production". The farmers that use an inventory system all indicate that the system is only used to keep track of the feed of the cows. The strategic decision where the inventory information plays a role all related to the bulk feed. Farmer 2 and 14 indicated that constant shortages in the bulk feed could be a reason to buy more land or use the existing land in a different manner. The information serves as a warning and helps to define/analyze the problem.

The information is also used for different tactical decisions. The inventory information helps the farmer decide when the cows will be transferred to the winter diet. If there is a lot of bulk feed in stock the switch from summer to winter diet can be made earlier (Farmer 2). The information helps the farmer decide what the best solution is regarding the diet of the cows. The information also warns the farmer if there isn't enough feed (Farmer 8). In that case, a decision has to be taken. Is the diet going to change or is feed going to be bought, the information helps to define the problem. By looking at the feedstocks in spring the farmer also gets an idea of the amount feed that needs to be produced which translates to the number of hectares of the different roughages that must be sown. The information helps to decide what the best solution is regarding the planting schedule (Farmer 5).

the information is also used for operational decisions, this relates to the concentrate feedstock. Farmer 2-5, 8 indicate that they get a warning when it is almost time to order new feed. This information functions as a reminder and helps to convert the decisions that when the silo is empty new food needs to be ordered into an action. Farmer 4 had the following to say about it: " When I buy food I do it a bit early. I can then tell the deliverer you can come on Tuesday, Wednesday or Thursday. In that way they can plan it over a time period of 3 days, that way I get a nice discount and they can plan it is such a way that they can also visit other farmers in the same run." The information in this example is also used in the functional area "finances".

4.2.6 Reporting

The information that comes forth from the reporting information systems does not help any of the farmers with strategic decisions. The two farmers that indicated to have reporting systems use it for tactical and operational decision making. The reporting systems provide overviews from different aspects of the farm. Farmer 2 told that he uses the information when new tasks come into play, for example when a new quality mark is put into place. A scheme is created so no mistakes are made. This information helps to convert the tactical decision, to work in a new way, into action. The system is also used to make reports about the finances and check if all expenses are correct (Farmer 3). It helps with detecting mistakes. When a mistake is found the farmer must make the operational decision what to do. The information helps to define the problem in the functional area "finances".

4.2.7 Best practice

The best practice information systems are used by different farmers and help with all 3 types of decision making. The farmers have used information from the best practice system for multiple strategic decisions. Farmer 7 used information from best practice systems when he was looking to build a new stable. The best practice information helped to make decisions about the design and layout of his farm. On strategic level the best practice information mainly helps to develop alternative solutions and to make an informed decision, it helps with deciding upon the best solution (Farmer 7, 10). This information can help in the functional areas "production" and "finances".

On a tactical level, the best practice information also helps in the decision-making process. Farmer 7 stated that last summer when it was extraordinary warm in the Netherlands the best practice systems were consulted to find the best solution for the cows. Farmer 6 also used the best practice information to deal with the heat, he stated that the information had helped 1 year ago. It was a very bad maize year and in the best practice systems was information on how to handle it. Also, within tactical decisions, the best practice systems help to give alternative solutions and to decide upon the best solution. This information can help in the functional areas "production" and "finances".

For operational decisions, best practice is used the least. Farmer 7 explained that the reason for this is that operational decisions are often to context-specific. They won't be described in best practice systems. Farmer 8 does use the information for operational decisions. He uses it to help diagnose his cows when they show signs of sickness. In this case, the information helps to analyze the problem.

4.2.8 Machine management

Only two farmers have systems that provide them with machine management information. This information is used for strategic, and operational decisions. Farmer 5 uses the information for strategic decisions. The decision about when to replace a machine/trekker is supported by the information that is produced by a machine management information system. When a machine has had a lot of downtime and maintenance last years it can serve as an indication that it has to be replaced. This information helps to define and analyze the problem and is used in the functional areas "production" and "finances".

Farmer 5 uses the information for operational decisions. The system keeps track of when maintenance has been done and warns when this must happen again. The decision about how often maintenance must happen is already made. The systems only prohibit forgetting it. It helps with converting the decision into action at the right time. The information is used in the functional area “production”. Farmer 2 uses the information for operational decisions. Whenever the milking robot on the farm has a problem a message is sent to the farmers' phone, this message warns him to look. On the computer the farmer can find more information about the specific error. This information helps the farmer to define and analyze the problem, it also helps to decide upon the best solution. This information is used in the functional area “production”.

4.2.9 Human resource management

Only one farmer uses a human resource system. This is possibly since this is the only farmer that has staff employed. The system is used by farmer 5 to keep track of the hours that the staff has worked. When the staff has made too much overtime the farmer can decide to help more or to give some time off. These are tactical decisions, the information helps to define and analyze the problem. Another example where the information also helps in strategical decisions is given in the chapter 4.2.4 “finance”. Farmer 5 considers going from three times a day milking back to two times a day. As stated above, is this partly due to the work pressure that the employees experienced.

Summary of the impact of information from operation management systems on decision making:

The information from the operations management systems (inventory, reporting, best practice, machine management, and HR management systems) are used for all types of decisions and all steps of decision making. This information helps the farmer to let the processes that support the milk and feed production function optimally. This is obtained by these IS by providing information that warns the farmer for problems and providing information that helps the farmer with developing alternate solutions/deciding upon the best solution. Also, the information is in some cases used to help the farmer convert the decision into action at a time that results in the best result for the farmer.

4.2.10 Quality assurance

Most of the farmers have a quality assurance system. The quality assurance systems the farmers have give information about two different topics. The systems can be about the quality of the milk or about the quality of the bulk feed that is produced on the farms. The information about the quality of the milk is used for all three types of decisions. The farmer gets regular updates about the cell count and bacterial count of the milk. When these numbers get too high, it warns the farmer that something is wrong related to the hygiene or the health of the cow. The farmer immediately must react and find the source so he can fix the problem. The information is used to detect an operational problem. When the problem requires larger changes, this can become tactical or even strategic decisions (Farmer 1-5, 8-11, 13). Farmer 8, for example, changed the litter that is used in the stables partially based on a bacterial count that was too often too high. Farmer 4 indicated that when building new stables preventive measures were taken to keep the bacterial count low. With all these examples the information serves to find the problem, it helps to define the problem and is used in the functional area “production”. The information is also used for another strategical decision. Most farmers breed their own cows. A cow will not be included in the breeding programme when she constantly has a high cell and bacterial count. Here the information helps in deciding upon the best decision (Farmer 3,6,11).

The information about the quality of the feed is used for tactical decisions. Samples are taken from the bulk feed, these samples tell the farmer what the quality of his bulk feed is. This information is used for different purposes. This information helps the farmer to see what nutrients are missing in the bulk feed, and thus what should be added to the diet (9,12,13). The information is used in the functional

area “production” and is used to analyze the problem. The information is also used to reflect upon the previous growing season. Did the decisions regarding roughage production turn out well (Farmer 7)? By reflecting upon last season, the information is used to define and analyze a problem. Data from multiple years and different treatments can also be used to decide upon the best solution.

4.2.11 Feed intake

A lot of the interviewed farmers have systems that provide information about the feed intake of the cows. All these systems provide information regarding the concentrates that are fed to the cows. The farmers that have these information systems give the concentrates separate from the bulk feed to the cows via a concentrate feed box or via the milking robot. The system determines the amount of concentrates that are given to the cows. This is dependent on the amount of milk that a cow gives and how far she is in the lactation period. This system can operate completely independent from the farmer and can make the 5 steps of decision making autonomous. It has taken the decision of how much concentrate each cow should get away from the farmer. The system also detects if the cow eats all her concentrates. This information is used for tactical and operational decisions.

A farmer has regularly to make the tactical decision of selling a couple of cows, to make room for new young cows or just to shrink a bit. The feeding behavior of a cow can play a role when making the decision which cows must go (Farmer 10, 12). A cow that is always eating badly will go earlier that a cow that eats his concentrates. This information helps in deciding upon the best solution and is used in the functional area “production”.

The information is also used for operational decisions. Farmers 4,5,7,10,11,13 indicated that they use the feed intake information system to detect problems. They get a notification when a cow doesn’t eat his concentrates, this can mean that something is wrong with the cow. When the farmers get this notification, they check what caused it. The information is used to define a problem in the functional area “production”. The information is also used to check if the system doesn’t make mistakes regarding the amount of concentrates that is given to the cows. Again, the system is used to detect and define problems (Farmer 4).

4.2.12 Cow productivity

Information systems about cow productivity are used by all interviewed farmers. Seeing as the farmers must earn their income from milk production is it a very important parameter for the farmers. The farmers get different sorts of information from their systems. Every three days the milk is collected by a processing company like FrieslandCampina. These companies supply each delivery information on the quality and quantity of the milk. This is thus information about the complete herd. Most farmers also collect information about the quantity of milk that is given by each cow every time she is milked. The companies that have a milking robot also collect each time the cow is milked information about the quality of the milk. The companies that don’t have a milking robot have each 4 to 6 weeks a milk control. This is the moment that these farmers get information about the quality of the milk from each specific cow. The information that is provided by the cow productivity systems is used for all three types of decisions.

There are multiple strategic decisions where information about the cow productivity helps in the decision-making process. The information is very important in the decisions regarding the breeding of cows. Farmers 1,2,5-13 indicate that the information about the average quantity and the protein and fat concentrations of the milk that is produced by a cow are important factors for if a cow is suitable for breeding. When a cow is declared fit for breeding semen is pick out that complements the characteristics of that cow and is in line with the strategy of the farmer. With the introduction of phosphate rights, farmers are getting more focused on high concentrations of fat and protein in the

milk instead of the liters that are produced by a cow as it is economically more interesting (Farmer 8). The cow productivity information is used to decide upon the best solution regarding the breeding of cows. The cow productivity information is used in the functional areas “production” and “finances”. The productivity information is also used to reflect upon previously made decisions. This can be in relation to changes like, another diet (Farmer 2), another way of producing the feed (Farmer 6), changing the grazing schedule (Farmer 3). The information helps the farmers to quantify the impact of the change. The information is used to analyze the problem and to decide on the best solution. This can be driven from a financial point of view or a production point of view.

The information is also used for tactical decisions, because of the phosphate regulations the farmers can only produce a limited amount of milk each year. This means that the production information warns them when they are on track to produce too much milk. This usually means that the farmer must get rid of some cows. The information helps the farmer in deciding which cows should be sold (Farmer 7,12,13). The production information also helps to make the decision if a cow should be treated or not when he is sick. If it is a cow with a low production and a lot of problems the farmer can decide to sell her (Farmer 2,8-10,14). In both examples, the production information helps in deciding upon the best solution. When a lot of cows show low productivity, it can be an indication that something is wrong on the farm. It helps to define and analyze an existing problem. This can be a problem related to the feed of the cows (Farmer 1, 3), or the health of the cows (10).

The information is also used for operational decisions. Farmers indicate that cow specific information about productivity helps to find cow-related problems: The milk robot or milk control give information about the urea concentration in the milk. This tells the farmer if he is feeding the cows enough proteins (Farmers 1,3,4,8,9). The quantity of milk that is produced by the cow is also interesting information. A low milk output indicates that something can be wrong with the cow (Farmers 1,2,4,5,7-10,12-14). Some of these systems use the information about productivity together with the feed intake to make an attention list. This is a list of cows that possibly have problems. The information helps to define and analyze the problem in the functional area “production”. The milk output also helps the farmer to decide when a cow should be drying off (Farmer 2). It helps in deciding upon the best solution.

4.2.13 Cow health

Information systems about cow health are used by all interviewed farmers. This information system provides information about all health-related information from the cows. The information is very important in the strategic decisions regarding the breeding of cows. Most farmers (Farmers 1,3-14) use a system where the farmer indicates what qualities he desires from his offspring. The system also has access to information about the current values of the cows (this consists of information about the cow health, cow productivity, feed intake, and a body score). With this information, the system looks for the bull that best compliments the properties of the cow. The semen of the selected bull will then be used to fertilize the cow for optimal offspring. This system takes the steps of finding the best solution autonomous. The information is also used to detect if there is a high disease pressure within the herd which that possibly can be related to a specific problem. Farmer 5 indicated that the new stables that where build have innovations implemented regarding claw problems because this was a large issue in the old stable. He even stated that the claw problems were one of the reasons he took the strategic decision to build the new stable. Farmer 1 indicated that the disease pressure caused them to change the type of litter that was used on the farm, a tactical decision. In both examples the information is used in the same way, it helps to define and analyze the problem. Farmer 14 indicated that a high disease pressure that was present on his farm has resulted in a change in the type of cow. They used to have Holstein cows, but high disease pressure caused a lot of extra cost and loss of revenues. This made them take the decision to change to Fleckvieh cows. These cows produce a bit

less milk but are sturdier. The information about the cow health helped them to define and analyze the strategic problem.

The farmers indicated that there are more tactical decisions where the information is used. When a cow is sick very often this can be found in the cow health information system. This can be a motive for the farmer to sell the cow. Also, when a cow is sick a decision must be made: should the cow get treatment or is she is going to be sold instead? These decisions use information about cow health. The information helps to define and analyze the problem and helps to decide upon the best solution (Farmers 1,3,4,6,7,9,10,14). A couple of the farmers indicated that they know quite well the disease history of the cow by heard and that they mainly use the information to check if their memory is right (Farmers 2,3,4,5,10,13).

The information is also used on an operational level. Some of the systems warn the farmer when a cow is drafty. This helps the farmer to inseminate the cow at the right time, it helps to convert the decision that the cow must be inseminated into action. Farmer 9 stated that he also uses the information to diagnose the cow when she shows signs of illness. He does this by looking at the disease history, this gives an indication about what could be wrong again. In this example, the information is used to analyse the problem.

Summary of the impact of information from cow management systems on decision making:

There are 3 main decision topics that the cow management information systems (quality assurance, feed intake, cow productivity, and cow health) help with. 1. The information helps with decisions regarding the breeding of cows. 2. The information helps to detect health-related problems and making decisions about what to do about it. 3. The information helps to optimize milk production. The information is used in these topics for all 3 types of decisions. With these decisions the information is mainly used in the defining/analyzing step and the developing/deciding upon the best solution step. The information is mainly used in the functional area “production”.

4.2.14 Overview of the impact of information from IS on the decision-making process

Table 2: This table presents the percentage of farmers that use information from any of the 13 types of information systems that are present on the farms for any of the 3 different types of decisions. The percentages consist of the farmers that use the information for a specific decision divided by the farmers that have indicated to have an IS that provides that type of information.

	Strategic decision	Tactical decision	operational decision
Field operations management	33%	83%	50%
site-specific field management	33%	100%	22%
sales	45%	73%	64%
Finance	93%	64%	7%
Inventory	50%	83%	67%
reporting	0%	100%	50%
best practice	100%	100%	100%
machine management	100%	0%	100%
human resource management	100%	100%	0%
quality assurance	31%	38%	85%
feed intake	0%	60%	70%
cow productivity	93%	79%	71%
cow health	93%	100%	57%

Table 2 shows that the information from each IS is used for almost every type of decision. The information from reporting, machine management, and human resource management are not used for one type of decision. This can be explained by the fact that only one or two farmers used these systems, this gives a lot of weight to the answers of each farmer. The information from feed intake is not used for strategical decisions and the financial information is barely used for operational decisions. Another interesting point is that the roughage management systems are mostly used for tactical decisions.

Table 3: This table presents the steps of the decision-making process where the different types of information from the information systems is used by the farmers. The results are presented separately for strategic, tactical and operational decisions.

	Strategic decision			Tactical decision			Operational decision		
Step of decision making	1	2	3	1	2	3	1	2	3
Field operations management	No	No	Yes	No	Yes	No	No	No	Yes
site-specific field management	Yes	No	No	Yes	Yes	No	No	No	Yes
sales	Yes	Yes	No	Yes	No	No	No	No	Yes
Finance	Yes	Yes	No	No	Yes	No	No	No	No
Inventory	Yes	No	No	Yes	Yes	No	No	No	Yes
Reporting	No	No	No	No	No	Yes	Yes	No	No
Best practice	No	Yes	No	No	Yes	No	Yes	No	No
Machine management	Yes	No	No	No	No	No	Yes	Yes	Yes
Human resource management	Yes	No	No	Yes	No	No	No	No	No
Quality assurance	Yes	Yes	No	Yes	No	No	Yes	No	No
Feed intake	No	No	No	No	Yes	No	Yes	No	No
Cow productivity	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Cow health	Yes	No	No	Yes	Yes	No	Yes	No	Yes

Legend	
1	= Defining/analyzing the problem
2	= Developing alternate solutions/deciding upon the best solution
3	= Converting decision into action

Table 3 shows in which part of the decision-making process the different types of information from the information systems are used. Most of the information types is only used in a limited part of the decision-making process. The last step of the decision-making process, the conversion of a decision into an action, happens mainly with the help of information IS in operational decisions. The farmer uses the information from the IS in strategic and tactical decisions mainly for 1. Defining and analyzing the problem and 2. Developing alternate solutions and deciding upon the best solution. When looking at Table 3 a lot of variation is observed between the different information systems.

Table 4: This table presents the functional areas of farm management where the different types of information from the information systems is used by the farmers. The results are presented separately for strategic, tactical and operational decisions.

	Strategic decision				Tactical decision				Operational decision			
Type of management	1	2	3	4	1	2	3	4	1	2	3	4
Field operations management	Yes	No	No	No	Yes	No	No	No	Yes	No	No	No
site-specific field management	Yes	No	No	No	Yes	No	No	No	Yes	No	No	No
sales	No	Yes	No	Yes	No	Yes	No	No	No	Yes	No	No
Finance	Yes	Yes	No	Yes	No	Yes	Yes	No	No	No	No	No
Inventory	Yes	No	No	No	Yes	No	No	No	Yes	Yes	No	No
Reporting	No	No	No	No	Yes	No	No	No	No	Yes	No	No
Best practice	Yes	Yes	No	No	Yes	Yes	No	No	Yes	No	No	No
Machine management	Yes	Yes	No	No	No	No	No	No	Yes	No	No	No
Human resource management	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No	No
Quality assurance	Yes	No	No	No	Yes	No	No	No	Yes	No	No	No
Feed intake	No	No	No	No	Yes	No	No	No	Yes	No	No	No
Cow productivity	Yes	Yes	No	No	Yes	No	No	No	Yes	No	No	No
Cow health	Yes	Yes	No	No	Yes	No	No	No	Yes	No	No	No

Legend	
1	= Production
2	= Finances
3	= Human resources
4	= Stakeholder relations

Table 4 shows in which functional areas of the farm management the different types of information from the IS is used. From this table, it becomes clear that the information is mainly used in the functional areas “production” and “finances” . Decisions that are made within the functional area “finances” are mainly strategic decisions. The information from the different IS is not used a lot for decisions in the functional areas “human resources” and “stakeholder relations”.

4.3 Impact of information from IS on the performance of the farm

Figure 8 shows the impact that the information has on the 7 different performance measurements that are determined based on the literature (Chapter 2). Only a few farmers have the opinion that some information can have a negative impact. All 7 performance measurements and the corresponding opinions from the farmers are presented below in Figure 8.

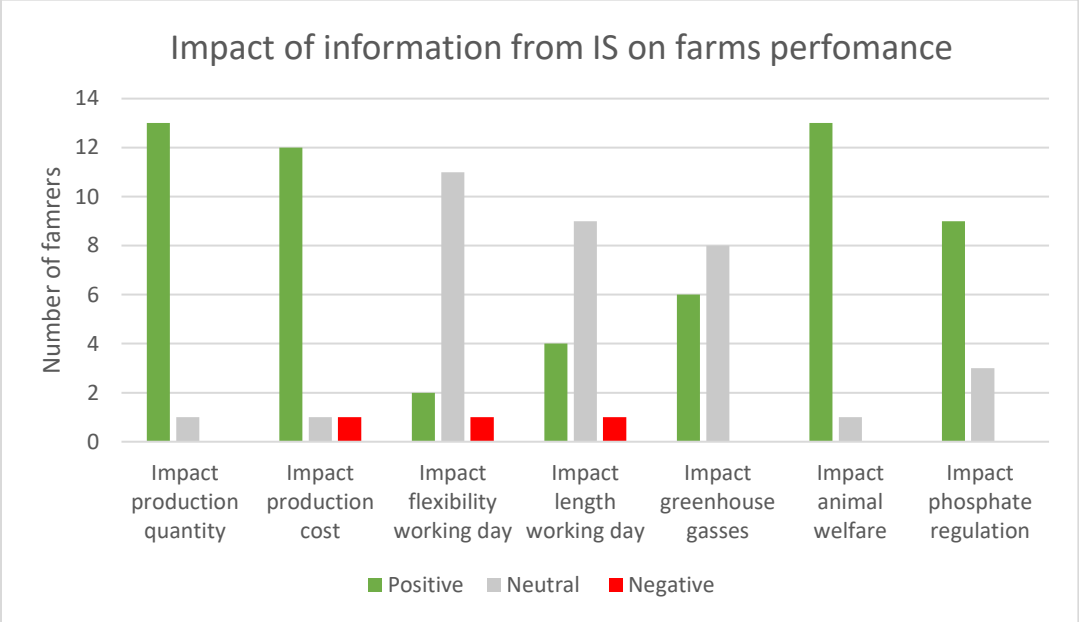

Figure 8: Impact of the information from the IS on the 7 different performance measurements as indicated by the 14 interviewed farmers. The information can have a positive impact, neutral impact, and negative impact on the 7 performance measurements.

4.3.1 Impact on milk production quantity

Figure 8 shows that the information that comes from the information system has a positive impact on the production quantity according to almost all farmers. The farmers stated that there are a couple of reasons why they experience this positive impact. Farmers (1,3,4,7-9,11,13) indicate that the information gives them more insight into the milk and feed production processes. This insight results in the possibility to adjust the management faster and easier. Another benefit that farmers 11 and 12 experience is that the impact of changes has become more visible because of the information systems. The information systems give feedback on the actions of the farmer. Examples of these benefits are stated in the previous chapter. Farmer 2 stated that the information encourages her to do better. The insights that have been obtained because of the information systems have made it possible to set targets and to strive for the optimum. Another benefit of the information systems is that it has become possible to perform precisions management. The cows are less managed as a herd, instead, each cow gets her own treatment. Also, the roughages are less managed as a whole, each section gets its own attention (Farmer 5, 7, 14). The extent to which this is applied depends of course on the sophistication of the systems that are present of the farms. Farmer 10 stated an interesting point: ”the information systems substitute the feeling”

4.3.2 Impact on production cost

Figure 8 shows that the information that comes from the information system has a positive impact on the production cost according to almost all farmers. Only farmer 6 indicated that the information has a negative impact on the production cost. Farmer 6 states that the collection of information and the purchase of information systems is very expensive. The cost does not outweigh the benefits on a finical level. Farmer 6 states that he mainly has benefits related to the length and intensity of the working

days. The farmers that experience a positive impact from the information systems indicate that this is due to a couple of benefits. Farmers 1,2,5,7,10-12,14 indicated that the information helps in determining if certain measures that have been implemented are financially interesting. An example of this is the concentrate that is fed to the cows. The farmer only wants to give more concentrate when the income of the extra milk yield outweighs the extra cost. The information from the information systems makes this more insightful for the farmer. Another benefit of the information systems is that it helps in preventing problems. An example of this is related to the health of the cows. The information about cow productivity helps the farmer to detect cows that show beginning seins of sickness. The disease can be treated before it really has started. Farmer 4 mentioned another benefit, the financial information system provides the farmer regularly with information about the current financial states of the farm, it will show if the expenses of certain components are not becoming too high. The information helps in detecting problems and looking at the big picture. All this information eventually results in a more efficient farm from a financial point of view (7,8,3)

Overall impact on profit performance

Most farmers indicate that the different types of information from the information systems has a positive or neutral impact on milk production. The farmers also indicated that the information helps with keeping the production cost low. This information indicates that the information from the IS has a positive impact on the "profit performance" of a Dutch conventional dairy farm. The benefits that the farmers experience from the information are mainly due to a better understanding/insight into the farming operations. This results in two benefits: 1. Problems are noticed earlier. 2. The production becomes more efficient.

4.3.3 Impact on flexibility of working day

Figure 8 shows that most farmers experience a neutral impact from the information on the flexibility of the working day. The farmers indicated that the information hasn't made them more or less flexible (farmers 1-8,10-12,14). Farmers 9 and 12 stated that they experience a positive impact from the information systems on their working day flexibility. The information systems enable the farmers to obtain a lot of information from behind a computer/smartphone where they first had to obtain this information by observation in the stables. This means the farmers don't have to spend so much time in the stables which gives them flexibility in their working days. Only farmer 2 indicated that they experience a negative impact form the information systems on their working day flexibility. Farmer 2 states that the information from the different information systems has made him see that the cows like it when they have a constant environment with a lot of regularity. This means that they have each day a strict schedule to keep.

4.3.4 Impact on length of working day

Figure 8 shows that the farmers are divided about the impact that the information from the different information systems has on the length of the working days. Farmer 2 states that the information that is provided by the systems requires a lot of work to handle. It has also become harder to stop working because a lot of the information is always available via the smartphone/computer. Farmer 2 claims that this has made the working days longer. Farmer 1,3-5,7,10 and 12-14 indicated that the information has no impact on the length of the working day because there is always enough work to do. Farmers 5 and 7 indicated that the information has made it possible to maintain more cows. It has allowed farms to grow without the need to hire additional staff. Farmers 6,8,9 and 11 indicated that they experience a positive impact from the information systems regarding the length of the working day. The information has made tasks more efficient. An example of this is the pedometer that predicts when a cow is drafty. This saves the farmer a lot of time inspecting the cows in the stables.

Overall impact on people performance

Most farmers indicated that the information from the different IS has a neutral impact on the social performance. The main reason for this neutral impact has to do with the fact that the farmers stick to their routine, the farmers don't like it to leave the farm and the cows still need to be milked twice a day. Another reason is that the work reduction that is achieved with the information from the IS is filled with other work that was first skipped because of lack of time. The work reduction is also used to expand the herd which results in more work for the framer.

4.3.5 Impact on the emission of greenhouse gasses

The farmers have a divided opinion about the impact of information from IS on the emission of greenhouse gasses (Figure 8). Half of the interviewed farmers thinks the information from the information systems doesn't have any impact on the number of greenhouse gasses that are emitted per liter of produced milk. Farmer 1 states that this is mainly because there is too little information about the consequences different decisions have on the emission of greenhouse gasses. The other half of the farmers think the information has a positive impact on the number of greenhouse gasses that are emitted per liter of produced milk. Farmers 2,7,8,9,13,14 state that this is because the farm operations have become more efficient. This has resulted in a decrease of feed inputs for a liter of milk. This consequently means that the amount of emitted greenhouse gasses has gone down. Farmers 12 and 14 mention that the increased efficiency that has, as a result, the decrease in emission of greenhouse gasses is not driven from an environmental point of view but mainly from a financial point of view. The decrease in the emission of greenhouse gasses is seen as a nice side effect.

4.3.6 Impact on animal welfare

Most farmers experience a positive impact from the information that is produced by the information systems on animal welfare (Figure 8). Farmers 1-8 and 10-14 state that the information allows them to notice health-related problems earlier. By detecting diseases early, the cow is suffering less. Farmer 9 indicated that the information about the feed of the cows allows them to supply the cow with better feed. This results in a cow that is overall healthier.

4.3.7 Impact on phosphate regulations

The opinions about the impact of information on the regulations are divided between the farmers (Figure 8). Most of the farmers think that the information from the information systems helps to handle the phosphate regulations (Farmers 1,2,4,5,7-9,11,12). A few farmers think the information doesn't make a difference (Farmers 6,10,14). There were also a couple of farmers that indicated that they didn't have a phosphate problem (Farmers 3,13). Farmers 1,2,4,5,7-9,11,12 indicated that the information helps to keep the phosphate emissions on the level that they are allowed to. This can be regulated by getting rid of cows, lowering milk production, giving less concentrates or by buying extra phosphate rights. The information from the systems helps the farmers in making these decisions.

Overall impact on planet performance

Overall the farmers seem to experience a positive impact from the information on their "planet performance". For animal welfare, this is mainly because problems are spotted earlier. With the phosphate problems, the information helps the farmer to get a better insight into the whole process. The Greenhouse gas emissions also experience a positive impact from the information, this is due to more efficient production.

5 Discussion

The 14 interviewed dairy farmers have answered questions on three subjects, the quality/quantity of the information from the information systems, the impact of the information on the decision-making process, and the impact of the information on the performance of the farm. When looking at the different answers that the farmers have given interesting results are found.

5.1 Information availability because of IS

5.1.1 Quantity of information

The farmers have indicated that the systems that provide information related to cow management and financial management are present on most of the farms. The systems that provided information on operational and roughage management where only present on a limited number of farms. This is in line with the literature, Jofre-Giraudo et al, (1990) observed this trend already in 1990. Also, Jago et al. (2013) indicate that mainly systems that provide information about cow management are present on dairy farms. These findings are not in line with the information needs of the farmers in 1999 as described by Asseldonk (1999). In his study, he found that dairy farmers where mostly in need of information about roughage production. The results from this research indicate that the IS haven't provided in the information need about roughage production as described by Asseldonk (1999). It is unclear if the need for this information is solved in another way.

The absence of information from information systems about operations management can partly be explained by the relative limited size of the Dutch dairy farming operations in relation to the number of dairy cows a Dutch dairy farm owns[2]. The really large dairy farming operations (as are found for example in New Zealand) need information systems to keep an overview of the operations, farmers with a smaller farming operation can do this by heart (Farmer 4). Fountas et al. (2015) state that the traceability systems are still in their infancy in commercial FMIS. This explains why none of the interviewed farmers possessed such a system. The relative low quality of the information from these systems could be another explanation for limited number of farmers with operation management systems (Figure 6).

The information that is provided by the information systems according to the literature does not always match with the information from information systems that is found on the farms (Appendix 1.2). The literature writes about information that is provided by IS of which the farmers have indicated to not have it. An explanation for this phenomenon was given by farmer 10. She indicated that a lot of the information that can be given by IS can also be obtained through observation. Observation is in a lot of cases preferred because it allows the farmer to get information about everything that happens in the stables. Another explanation was given by the literature, Bewley et al. (2010) explain that a lot of innovations that are described in the literature are not yet implemented in the market. Examples of this are the traceability systems and advice about diet based on the health and physical status of the cow (Fountas et al. 2015).

The occurrence of information from information systems on dairy farms does not match with the number of times the information from the different IS is used. This can possibly be explained by the research from Davis and Olson (1985) and Verheijden et al (1985). They state that information that is used in operational decisions needs to be relatively new. With the roughage management systems that were present at the interviewed farmers this happened a few times a year when either maintenance was done to the fields or field samples where collected. Whereas the systems that provide cow management information can receive 2/3 times a day new data and the systems that provided the

[2] In 2014 the average Dutch dairy farming operation owned around 85 cows, while for example an average dairy farming operation in the New Zealand owned around 390 dairy cows in 2014 (Barkema et al. 2015).

inventory information and the sales information received frequently new data according to the farmers. Figure 5 shows that the information from these systems is used a lot. Another possible explanation has to do with the way the concept “how often the information is used” is measured. As stated in Chapter 3 it is measured as: How often a farmer subtracts information from an IS. The farmers indicated that they sometimes subtract the information only once but then use it for multiple decisions in a longer time period.

Overall is it clear that the focus of the information from information system is on cow management and financial management. With every decision, 2 questions are raised by the farmer. How will the decision impact milk production and how will this translate to the earnings? It seems that to answer these questions the farmer needs additional information in the domains finances and cow management which can provided by the IS.

5.1.2 Quality of the information

Overall the farmers are very satisfied with the quality of the data. This is an interesting result as it contradicts the literature from Alvarez and Nuthall, (2006) and Bewley et al. (2010). What must be considered is that the data in these reports was gathered at dairy farms in Uganda, New Zealand, and Florida. In these countries the dairy farmers differ in a lot of aspects from Dutch dairy farmers, aspects like number of cows and modernity of the farming equipment. This could explain why the research in the Netherlands shows different results. Another possible explanation for the positive attitude of the farmer is related to the way the data about the quality of the information has been gathered in the interviews. The way the questions were asked triggered the farmers to only think about the information they use. It could be that the information that is lacking in quality is not used for that exact reason. When the farmers did not use the information no quality data was collected.

Two remarks that were made by the farmers regarding the quality of the information have overlap with the literature. Some farmers indicated that they were overloaded with information. This is a remark about information systems on dairy farms that is found in the literature (Bewley et al. 2010; Hostiou et al. 2017). Another remark relates to the representational quality of the information. The farmers find it difficult to come up with a response to the information that is provided by the information systems. These problems are mainly found in cow management information systems. An example of this is when an IS gives a warning about a cow that has produces less milk the last day. The farmers indicated that they find it difficult to determine if it is only a one-time deviation or something more significant, and when it is something more significant what the cause is of the reduction in milk production. The farmers find it difficult to determine the right way to respond to such a warning. This problem can be explained by the fact that most of the IS don’t have a decision support component built in. The information systems provide the farmer with data about the cows and environment. The data is often not translated into information by the systems. At that point the data cannot be placed into context (Ackoff 1989). Reasons for the lack of decision support systems on farms is given by Van Meensel et al., (2012) he states that “decision support systems are too complex, use a terminology and logic unfamiliar to farmers, are not frequently updated, requires tedious data input, are irrelevant, unreliable and/or inflexible and are not easily accessible for users.” (p. 164).

Lee et al. (2002) state that the better the quality of the information the more useful the information is in the decision-making process. Based on the results no correlations are observed between the quality and the quantity of the information and the use of the information. This could be because all the farmers scored the quality of their information very high. Not enough results have been collected to draw conclusions about the relations between the quantity of the information and the use of the information. In a follow up research more and sharper questions need to be asked about the quality and quantity of the information to get a better understanding of it.

5.2 Impact on decision making

5.2.1 Type of decision

The information from the IS is used for all 3 types of decisions (Table 2). This corresponds to the expectation as indicated by the conceptual framework. The different types of information from IS that are distinguished can each contain a lot of different information, the fact that these information types are so broadly defined could explain why almost all information types are used for all types of decision making. Another explanation could be that all decisions on a dairy farm a so intertwined that almost all information is relevant for all decisions. Further research needs to be done to determine which theory is right.

Based on the literature an overview has been made about the decisions that a farmer has to make within each type of decision (strategic, tactic, and operational). The decisions that the farmers must make according to the literature match rather well with the decisions that the farmers describe (Handboek melkveehouderij 2019; Zijlstra et al. 2008). This is remarkable as the research from Zijlstra et al. (2008) is already more than 11 years old.

5.2.2 Functional areas

The results show that the information systems predominately help in making decisions in the functional area production. This is in line with the literature, Shridhara et al. (2010) state that the information from the IS is used in the functional area production to improve the quality of the products and the efficiency of production. Van Asseldonk (1999), states that the extra information resulting from IS will mainly be beneficial within the functional area production. Besides production is the functional area finances also an area where the information is used relatively a lot. For a lot of strategic and tactical decisions the financial information is used to determine which alternative is best/can be afforded by the farm. Van Horne and Wachowicz (2008) indicated in their research that this is one of the purposes of financial management. The information is also used by the farmers to determine if changes that have been done on the farm are economical viable.

The farmers are barely supported by information systems when making decisions in the functional area Human resource or stakeholder relations. A possible reason for the limited use of information from IS in HR is the lack of personnel on Dutch dairy farm. This is supported by the work of (Stup te al., 2006) who state that mainly large farms with personnel benefit from active HR management. The literature is clear about the importance of good stakeholder relations (Freeman 2010; Slack et al. 2013), the farmers though don't seem very concerned about it. Based on the interviews the impression has formed that farmers are unknowingly involved with their stakeholders, choosing the right people/businesses to be their partner and establishing the right type of relation with them without thinking to actively about it. Farmer 14 stated that he sometimes buys extra equipment from a supplier to keep him happy. Farmer 14 does this so that when he needs a favor from the supplier it is easier. Farmer 2 stated that he always makes a nice chat with the contract workers, he stated that he does this because: "they can better be your friend". These are examples where no information is used from IS but where the farmers are thinking about their stakeholders. Stakeholder relations could be a functional area where there is still a lot to gain for the farmers, possibly also with the help of information from information systems.

5.2.3 Steps of decision making

The results show that with strategic and tactical decisions the information mainly helps with the first 4 steps of decision making. The fact that these two types of decisions show similar usage of the information that is produced by information systems is noteworthy. In the literature no clear explanation for this phenomenon can be found. Further research is needed to investigate this.

The information is mainly used for the last step of the decision-making process, converting the decision into an action when the farmer must take an operational decision. These operational decisions are decisions that the farmer must take on a day to day basis. Operational decisions are often decision take in line with the strategic and tactical decisions. For a strategical decision to be implemented a lot of operational decisions must be taken. The operational decisions occupy part of the process of implementing the strategical decision (Shridhara Bhat and Dim 2010). This can explain why the farmers use the information from the IS mainly with operational decisions for the last step of the decision-making process.

It is unclear if the lack of usages of information from IS in some type of decisions is because the IS that produce this information are not yet available/too expensive or that the farmers have no need for the information. Further research needs to be conducted to get more clarity on this.

The results show that the different types of information from the IS have an impact on the decision-making process. These findings are in line with the literature about the impact of information from IS on dairy farm management (Laudon and Laudon 2012; Novkovic et al. 2017). The results per type of information are very variable. The types of decisions that are impacted, the steps in the decision-making process and the functional areas where the information is used differ a lot per type of information. Because of the limited number of respondents and the limited number of farm characteristics that are incorporated in this research is it not possible to draw conclusions about why the results show so much variation between the different types of information. It is also possible that the way the information is used is not so much depended on the type of information but more on the type of decision that must be made. The division between the type of decisions that has been made shows to have some predictive property. But there could be other parameters of the concept "decision" that better explain the way the information is used. Further research needs to be done to come up with a theory that explains the way the information is used.

5.3 Impact on performance

The farmers have indicated that the information has a positive impact on their financial performance. This is in line with the research from Asseldonk (1999) and Novkovic et al., (2017) who showed that some individual IS/IT systems/products can be beneficial for the profit of a farm. By interviewing the farmers about the impact of the IS on decision making this research has made a distinction between the automatization component and the decision-making component of IS. This has resulted in a more in-depth understanding of the results from Asseldonk (1999) and Novkovic et al. (2017). A better understanding is created of how the information from IS impacts the decisions making process and how this impacts the performance on the farm. An image is created about where in the decision-making process the information helps, and which functional areas of the farms' management benefit most from the information.

One question was raised by the farmers: Outweigh the benefits of the information the cost of the information? Most farmers indicated that it does, but they were not able to quantify it properly. It could be an interesting follow-up study to quantify the benefits and costs of the information and see how it relates to each other.

The farmers indicated that the information from IS gives them more insight into the farming operations, helps them to spot problems faster and makes the decisions more efficient. This is in line with the literature. Lucas, (2009) states that with information, the uncertainty of a state/event can be reduced. The reduction of uncertainty about a state/event helps managers of a company to make better decisions. Boote et al. (1996) explaines that the IS monitor constantly the situation, this will result in real-time information, problems will be spotted earlier and decisions can be made faster.

Bewley (2010), Pivoto et al. (2018), Sundmaeker et al. (2016), and Wolfert et al. (2017) state that the information will result in a higher resources use efficiency, higher dairy production, better quality of milk, reduction of cost, improved animal health and better adaption capabilities against unexpected changes. This is also directly in line with the findings of the environmental impact of the information. The farmers indicated that they experience a positive effect from the information on animal welfare because diseases/problems are spotted faster.

The farmers also indicated that the information reduces the emission of greenhouse gasses of their farms. They argue that this is because the information has made the farms more efficient. Fewer inputs are needed for the same output, this reduces the emission. This reasoning is in line with the works of Bennetzen et al. (2016) and Goselink and Sebek (2012). The farmers said though that the increased efficiency that has, as a result, the decrease in emission of greenhouse gasses is not driven from an environmental point of view but mainly from a financial point of view. The decrease in the emission of greenhouse gasses is seen by the farmers as: “a nice side effect”. Farmer 1 indicated that the current information produced by information systems doesn’t give enough insights into the environmental consequences of the decisions that are taken. This makes it difficult for the farmers to include the impact on the environment in the decision-making process. The result from Meul et al. (2014) indicate that information systems focused on providing information about the environmental performance of the farm can improve the environmental performance of the farms. This can be an opportunity to make dairy farms more sustainable in times that there is a lot of pressure from society and the government to become more sustainable.

The farmers are predominantly neutral about the impact of the information on their flexibility and length of the working day, they don’t experience any impact. The literature talks about two benefits from the information regarding the “social performance” 1. Problems are indicated by the information systems so farmers don’t have to visit the cows that often (Bewley 2010). 2. The information is easier accessible, as a result, the farmer can outsource more tasks (Laudon and Laudon 2012). These benefits are not seen at the interviewed farmers. A possible explanation is given by the farmers: They want to stay in touch with the cows, the systems are not completely trusted, and they don’t like it to leave the cows alone. Another interesting point was stated by the farmers: The information hasn’t shortened their work day, but it has allowed them to keep more cows without hiring additional staff. This statement is supported when looking at the growth of the herds on Dutch dairy farms and the number of employees that work on the farms (Barkema et al. 2015).

Overall the farmers experience a positive impact from the use of information in the decision-making process on their performance.

5.4 Limitations

This study knows multiple limitations that reduce the validity and reliability of this study. An initial sample size of 16 farmers was opted for, this sample size is already too small to generalize conclusions over the whole population. But in the last two weeks of the interviewing period the government announced new regulation regarding the nitrogen emissions from farms. The farmers, in general, did not agree with these proposed regulations and started to protest on the Malieveld in the Hague and at town halls throughout the Netherlands. As a result of these strikes the last two planned interviews were canceled by the farmers. Because of time constraints and a lack of other dairy farmers that met de predetermined requirements the decision was made to reduce the sample size to 14 farmers. This has reduced the external validity. The researcher noticed saturation of new information with the last interviews. But because the test group is small and nonrandomly selected are the results not enough to draw conclusions about the whole conventional Dutch dairy farming population. Only conclusions about the interviewed farmers can be drawn. To strengthen these conclusions and make them more

generalizable two options are available, 1. More farmers can be interviewed 2. The test population can be made smaller. The results do contribute to the theoretical generalization of the findings.

The test group is selected based on the network of the researcher. This gives the advantage that farmers are more likely to participate. The test group will barely have a precedence toward farmers that are more willing to participle, something that could be a predictive factor for the use and impact of information from IS. The disadvantage is that all these farmers have some connection with the researcher. Because the researcher is a student at the WUR a lot of the farmers have some connection with the university. This can be a predictive factor for the use and impact of information from IS and thus have a negative impact on the external validity of the research.

A lot of the farms where a farmer has been interviewed are owned and operated by multiple people. When this is the case it often happens that each of the farmers has his own specialty. The farm where farmer 10 is interviewed is an example of this, the farm is operated by two people. Person 1 oversees the cows and person 2 oversees the finances and roughage production. With most interviews only one person answered the questions. This has resulted in a situation where some questions could not be answered by the farmer that was interviewed. This has reduced the reliability of the research.

Another limitation has to do with determining in which step of the decision making the information has an impact. The step in the decision-making process where the information assist is depended on the initial problem statement. For example, a cow is not producing well because she is constantly sick. The cow health information helps the farmer to discover that it is the same cow that is constantly sick. It helps the farmer to define and analyze the problem. The decision of what to do with the cow will in most cases be made based on the financial information, not the cow health information. The other scenario is when a farmer is producing more milk than is allowed by the phosphate rights and he decides that a few cows must go. The information about the health of the cow will help the farmer to decide on which cows he can best sell. In this way the information helps to decide on the best decision. Both decisions use the same information but in another step of decision making. This can make it difficult to determine in which step of the decision-making process the information is used. This problem has resulted in a reduction of the reliability and validity.

To measure the “quantity” of information from information systems two different questions were asked. First, the farmers where are asked which of the 14 types of information produced by IS where present on the farm, secondly was asked how often the farmers use the information from the information systems. This has two drawbacks, 1. The measurements don’t consider the sophistication of the information 2. One type of information can contain a lot of information, with these questions all this information is treated as one and the same. This implies that the quantification of the “quality” of information is far from perfect. This has reduced the validity of the research.

When the farmers were interviewed an overview was given of the different types of information and the different types of decisions that are made on the farm. This could have steered the answers from the farmers in a certain direction. This was unavoidable though, the farmer needed some background information to be able to answer the questions.

The literature indicated that the process of decision making has five steps. To make the interview easier to understand for the farmers the five steps were reduced to three steps. This makes it harder to correlate the answers to the literature.

With this research, qualitative data is collected, to analyze this data parts of it had to be interpreted by the researcher, this has made the results subjective.

The test group that must represent the population has been divided into 4 types of conventional dairy farmers. This division has been made so the test group will represent the diversity within the population. The “types” of conventional farms are established based on the number of dairy cows that are present on the farm and the extent to which a modern farming approach is used by the farmer. The extent to which a modern farming approach is used by the farmer is determined based on the use of a milking robot. This is not a perfect way of determining the “modernity of the farmer”. Also, are these two parameters not the only differences between the farmers that could have impacted the way the information from IS is used. This reduces the validity of the research.

6 Conclusion

The first objective of this study is to discover how the increased availability of information because of IS affects the decision-making process within the dairy farm management. To investigate this first the quality and quantity of information from the information systems that are present on the Dutch dairy farms have been mapped.

The conclusions that are presented in this chapter will be about the farmers that are interviewed, not about the whole conventional Dutch dairy farming population as the external validity is to low to draw such conclusions.

From the information the following conclusions can be drawn:

- The information systems that are present on Dutch dairy farms from the interviewed farmers mainly provide data that is used in the cow management and the financial management.
- The interviewed dairy farmers are satisfied with the quality of the information from the different IS.

Different aspects of the concept “decision making within farm management” are investigated to answer the question how the increased availability of information because of IS affects the decision-making process within dairy farm management. From this research the following conclusions are drawn:

- In all three types of decision making (strategical, tactical and operational) information from different information systems is used but in different manners.
    - With strategic and tactical decisions, the information is used for defining, analyzing the problems, developing alternate solutions, and deciding upon the best solution.
    - With operational decisions, the information predominately is used to define and analyze the problems and to convert de decisions that are taken into action.
- The information from the information systems on dairy farms is used predominately for making decisions in the domain of production management.
- Decisions that are taken with the help of information from information systems in the field of financial management are predominately strategic and tactical decisions.
- The farmers are barely supported by information systems when making decisions in the domain of HR management or stakeholder management

The second objective of the research is to determine how the changed decision-making process within farm management because of the changed availability of information affects the dairy farms' performance. From this research the following conclusions are drawn:

- The interviewed dairy farmers are mostly positive about the impact of the information on financial and environmental performance. The information helps the farmers to gain insight into the farming operations, helps to spot problems faster, and makes the farmers more efficient.
- The interviewed dairy farmers are mostly neutral about the impact of the information on the social performance, they don’t experience any impact.

Overall can be concluded from this research that the information from the information systems is used in the decision-making process by providing information in all steps of the decision making which results in a positive effect on the profit and planet performance of the farm.

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Appendices

Appendix 1.1 Information produced by the information systems according to the literature

- **Field operations management:** These systems give information real-time to operate the field. These systems use real-time information so the information they give can be adjusted to the current situation. Examples of information are: (Fountas et al. 2015):
    - Adaptive fertilizer rate based on the current situation
    - Adaptive spraying rate based on the current situation
    - Adaptive advice about when to sow, harvest, plow, etc. based on the current situation
- **Best practice**: These systems give maintenance information for roughage and animal production. This type of system is unique in this list because it is the only system that gives information based on general data and not based on the specific farm where it is used. It can have an animal section and a roughage section. It can be seen as an encyclopedia for dairy farms. Information that these systems provide are (Handboek melkveehouderij 2019):
    - roughage section
        - Time schedule, when to sow, harvest, plow, etc.
        - Fertilizer and pesticides/herbicides advice
        - Crop rotation advice
        - Estimated yields
    - Animal section
        - Information on the housing of cows
        - Information on the diet of cows
        - Information on disease prevention and disease treatment
        - Information on reproduction
        - Estimation of milk production
- **Finance**: These systems give information about the current financial status of the farm (Fountas et al. 2015; Laudon and Laudon 2012). The main information that is provided by these systems is:
    - Estimated cost of every farm activity.
    - The balance sheet: an overview of assets, liabilities and net worth of company.
    - The income statement: overview of all income and cost.
    - Cash flow statement: overview of in and outflow of cash.
- **Inventory:** These systems provide information about the current status of the inventory, (Fountas et al. 2015; Laudon and Laudon 2012). The main information that is provided by these systems is:
    - Current amount of inventory
    - Usage and expenditure of inventory
    - Needed stock of specific goods
- **Traceability:** These systems provide information about the current and historical status of all assets used in the farming activities (Cheng and Simmons 1994; Fountas et al. 2015). This consist of:
    - Which persons worked on which projects
    - Which equipment was used for which projects?
    - Real-time information about the current activities/location of the equipment and employees

- **Reporting:** Systems that provide reports about farm activities. These systems provide information on multiple farm aspects (Fountas et al. 2015):
    - The planning of tasks
    - The work progress
    - Instructions overview
    - Orders and purchases overviews
    - Financial reports
- **Site-specific field management:** These systems provide information for precision roughage farming. They provide information about site-specific field properties. This information enables the farmer to give site-specific treatment for his roughages. The information consists of (Grisso et al. 2011):
    - Site-specific disease and weed pressure
    - Site-specific soil fertility
    - Site-specific plant properties and harvest predictions
- **Sales:** These systems provide information about all the sales that happen on the farm, in the case of dairy farmers is this mainly the sales of milk. These systems provide information for the farmer to get insight into his relationship with the buyer. Types of information that these systems deliver are (Fountas et al. 2015):
    - Logistics information, when the buyer comes to collect the milk
    - Overview of deliveries
    - Overview of receivables
- **Machine management:** These systems provide information about the current status of the machinery that is used on the farm. Farmers can have a lot of machines on their farm, some of the most used machines are tractors, machinery for behind the tractor, harvesting machines, milking robots and feeding robots. The information that these systems can deliver are (Fountas et al. 2015):
    - When the machinery is used and for what
    - cost of using the machinery
    - information about when maintenance has been and must be performed
- **HR management:** These systems provide information about the personnel that works on the farm. The topics of information that these systems contain are (Fountas et al. 2015):
    - Availability of personnel
    - Performance of personnel
    - Expertise of personnel
    - Payment of personnel
    - Qualifications of personnel
    - Training of personnel
- **Quality assurance:** The systems collect data about the production process and compares it with the legislation that is put in place by the government and the customer. The systems will deliver data about the extent to which the farm has produced according to legislation. Major dairy companies have put into place hazard analysis and critical control points (HACCP) principles to ensure the quality of the dairy (Papademas and Bintsis 2010). These principles contain the “rules” the farmer must abide by. These systems provide information about the extent to which all the rules are followed. Some of these rules are (Vilar et al. 2012):
    - Regular water supply check and cleaning
    - Cleaning of the milking room
    - Cleaning of the milking equipment
    - Cooling tank must be of sufficient quality + temperature must be accurately measured

- **Feed intake:** These systems provide information about the feed that the cows consume. Some of these systems can collect data about the individual cow feeding behavior, but this happens only very limited. The topics of information that these systems deliver are (Grothmann et al. 2012; Khan et al. 2009):
    - Eating behavior, time that the cow is feeding or ruminating is monitored (Bikker et al. 2014)
    - Amount and type of feed that is eaten
    - Advice on diet based on the health and physical status
- **Cow health:** these systems provide information about the health status of the cows. This can be historical information but also predictive information. The topics of information that these systems can deliver are (Berger and Hovav 2013; Tullo et al. 2016):
    - Disease history of individual cows
    - Prediction of insemination period
    - Age of the different cows
    - Treatments that the cow has had
    - Treatment that cow will need in the future
    - Predictive information about possible diseases that the cow has. This is based upon factors like the weight of the cow, milk production, etc.
- **Cow productivity:** These systems provide information about the productivity of the cows. This information can be used for financial purposes, animal health purposes and to see how the farm performs. The topics of information that these systems can deliver are (Berger and Hovav 2013):
    - Quantity and quality of produced milk of each individual cow
    - Trends that individual cows show in relation to productivity

Appendix 1.2 Information produced by the information systems according to the farmers and the literature

Information type	Literature	Farmers
Field operations management		
Adaptive fertilizer rate based on the current situation	Yes	Yes
Adaptive spraying rate based on the current situation	Yes	No
Adaptive advice about when to sow, what to sow, harvest, plow, rotate etc. based on the current situation	Yes	Yes
Best practice		
Roughage section		
Time schedule, when to sow, harvest, plow, etc.	Yes	No
Fertilizer and pesticides/herbicides advice	Yes	No
Roughage rotation advice	Yes	Yes
Estimated yields	Yes	No
Animal section		
Information on the housing of cows	Yes	Yes
Information on the diet of cows	Yes	Yes
Information on disease prevention and disease treatment	Yes	Yes
Information on reproduction	Yes	Yes
Estimation of milk production	Yes	No

Finance		
Estimated cost of every farm activity.	Yes	No
The balance sheet: an overview of assets, liabilities and net worth of company.	Yes	Yes
The income statement: overview of all income and cost.	Yes	Yes
Cash flow statement: overview of in and outflow of cash.	Yes	Yes
Inventory		
Current amount of inventory	Yes	Yes
Usage and expenditure of inventory	Yes	Yes
Needed stock of specific goods	Yes	No
Traceability		
Which persons worked on which projects	Yes	No
Which equipment was used for which projects?	Yes	No
Real-time information about the current activities/location of the equipment and employees	Yes	No
Reporting		
The planning of tasks	Yes	No
The work progress	Yes	No
Instructions overview	Yes	Yes
Orders and purchases overviews	Yes	Yes
Financial reports	Yes	Yes
Site-specific field management		
Site-specific disease and weed pressure	Yes	Yes
Site-specific soil fertility	Yes	Yes
Site-specific plant properties and harvest predictions	Yes	yes
Site-specific areal properties like height and waterlogging	No	yes
Sales		
Logistics information, when the buyer comes to collect the milk	Yes	yes
Overview of deliveries	Yes	Yes
Overview of receivables	Yes	Yes
Machine management		
When the machinery is used and for what	Yes	No
cost of using the machinery	Yes	No
information about when maintenance has been and must be performed	Yes	Yes
HR management		
Availability of personnel	Yes	Yes
Performance of personnel	Yes	No
Expertise of personnel	Yes	No
Payment of personnel	Yes	Yes
Qualifications of personnel	Yes	No
Training of personnel	Yes	No
Quality assurance		
Regular water supply check and cleaning	Yes	No
Cleaning of the milking room	Yes	No
Cleaning of the milking equipment	Yes	No

Cooling tank must be of sufficient quality + temperature must be accurately measured	Yes	Yes
Quality of bulk feed	No	yes
Feed intake		
Eating behavior, time that the cow is feeding or ruminating is monitored	Yes	Yes
Amount and type of concentrate feed that is eaten	Yes	Yes
Advice on diet based on the health and physical status	Yes	No
Cow health		
Disease history of individual cows	Yes	Yes
Prediction of insemination period	Yes	Yes
Age of the different cows	Yes	Yes
Treatments that the cow has had	Yes	Yes
Treatment that cow will need in the future	Yes	yes
Predictive information about possible diseases that the cow has. This is based upon factors like the weight of the cow, milk production, etc.	Yes	Yes
Cow productivity		
Quantity and quality of produced milk of each individual cow	Yes	Yes
Trends that individual cows show in relation to productivity	Yes	Yes

Appendix 2.1 Research questions

nummer	vragen	mogelijke antwoorden	doel
1	Wat voor soort strategische besluiten zijn er afgelopen jaren genomen?		
1	Welke soorten informatie systemen heeft u op uw boerderij?	-	quantiteit info
	type specifieke vragen		
2	hoe vaak kijkt u naar de informatie die uit het IS komt?	1-5 weing-veel	quantiteit info
3	In hoeverre past u deze informatie toe in uw bedrijfsvoering?	1-5 weing-veel	contextual quality
4	In zitten er fouten in deze informatie/is de informatie onjuist?	1-5 weing-veel	intrinsic quality
5	Hoe makkelijk is deze informatie uit het informatie system te krijgen	1-5 weing-veel	accesebility quality
6	Hoe makkelijk is deze informatie te begrijpen?	1-5 weing-veel	intrepretability quality
7	heeft u de informatie uit dit systeem voor strategische besluiten gebruikt?		type of decision
7a	heeft u hier voorbeelden van?	-	insight 3 steps of decision making/type of manangement
7b	Wat zou het gevolg met betrekking tot strategische besluiten zijn als deze informatie wegvalt?	-	insight 3 steps of decision making/impact of information
8	Gebruikt u de informatie uit dit systeem voor tactische besluiten?	-	type of decision
8a	heeft u hier voorbeelden van?	-	insight 3 steps of decision making/type of manangement
8b	Wat zou het gevolg met betrekking tactische besluiten zijn als deze informatie wegvalt?	-	insight 3 steps of decision making/impact of information
9	Gebruikt u de informatie uit dit systeem voor operationele besluiten?	-	type of decision
9a	heeft u hier voorbeelden van?	-	insight 3 steps of decision making/type of manangement
9b	Wat zou het gevolg met betrekking tot operationele besluiten zijn als deze informatie wegvalt?	-	insight 3 steps of decision making/impact of information
	Algemene vragen		

10	Heeft de extra informatie de productie hoeveelheid van de melk veranderd?	1-3 negatief-neutraal-positief	impact on financial performance
10a	Kunt u dit uitleggen/heeft u hier een voorbeeld van	-	insight 3 steps of decision making/ functional areas /type of decisoin
11	Heeft de extra informatie de productie kosten veranderd?	1-3 negatief-neutraal-positief	impact on financial performance
11a	Kunt u dit uitleggen/heeft u hier een voorbeeld van	-	insight 3 steps of decision making/ functional areas /type of decisoin
12	Heeft de extra informatie de flexibiliteit in uw werkuren veranderd?	1-3 negatief-neutraal-positief	impact on social performance
12a	Kunt u dit uitleggen/heeft u hier een voorbeeld van	-	insight 3 steps of decision making/ type of management/type of decisoin
13	Heeft de extra informatie de lengte van uw werkdagen veranderd?	1-3 negatief-neutraal-positief	impact on social performance
13a	Kunt u dit uitleggen/heeft u hier een voorbeeld van	-	insight 3 steps of decision making/ functional areas /type of decisoin
14	Heeft de extra informatie de uitstoot van broeikasgassen veranderd?	1-3 negatief-neutraal-positief	impact on environmental performance
14a	Kunt u dit uitleggen/heeft u hier een voorbeeld van	-	insight 3 steps of decision making/ functional areas /type of decisoin
15	Heeft de extra informatie het welzijn van de koeien veranderd?	1-3 negatief-neutraal-positief	impact on environmental performance
15a	Kunt u dit uitleggen/heeft u hier een voorbeeld van	-	insight 3 steps of decision making/ functional areas /type of decisoin
16	Heeft de extra informatie de fosfaat problematiek veranderd?	1-3 negatief-neutraal-positief	impact on environmental performance

16a	Kunt u dit uitleggen/heeft u hier een voorbeeld van	-	insight 3 steps of decision making/ functional areas /type of decision

Appendix 2.2 Introductory story for the farmers

Op een boerderij moeten iedere dag veel keuzes worden gemaakt. Dit varieert van simpele besluiten zoals: moet de stal worden aangeveegd, tot moeilijke besluiten zoals: moet er een stuk land worden bijgekocht. Vroegen gingen deze keuzes op basis van intuïtie en ervaring. Tegenwoordig is er steeds meer informatie beschikbaar die kan helpen in het maken van al deze keuzes. Deze informatie komt voort uit informatie systemen, dit zijn veelal computersystemen die informatie leveren. Een paar voorbeelden van informatie systemen zijn: een boekhoud systeem, een systeem dat bijhoud hoeveel melk een koe geeft enz. Het interview zal gaan over hoe de informatie die voortkomt uit deze informatie systemen de besluitvorming heeft veranderd op de boerderij. Gebaseerd op vooronderzoek is gebleken dat de bestaande informatie systemen 14 verschillende soorten onderwerpen aan informatie kunnen leveren. Deze onderwerpen zijn te vinden in bijlage 1 samen met voorbeelden van informatie. Het is mogelijk dat u 1 systeem heeft dat meerdere van deze 14 onderwerpen aan informatie levert.

De keuzes die gemaakt worden op een boerderij kunnen worden ingedeeld in 3 verschillende soorten keuzes.

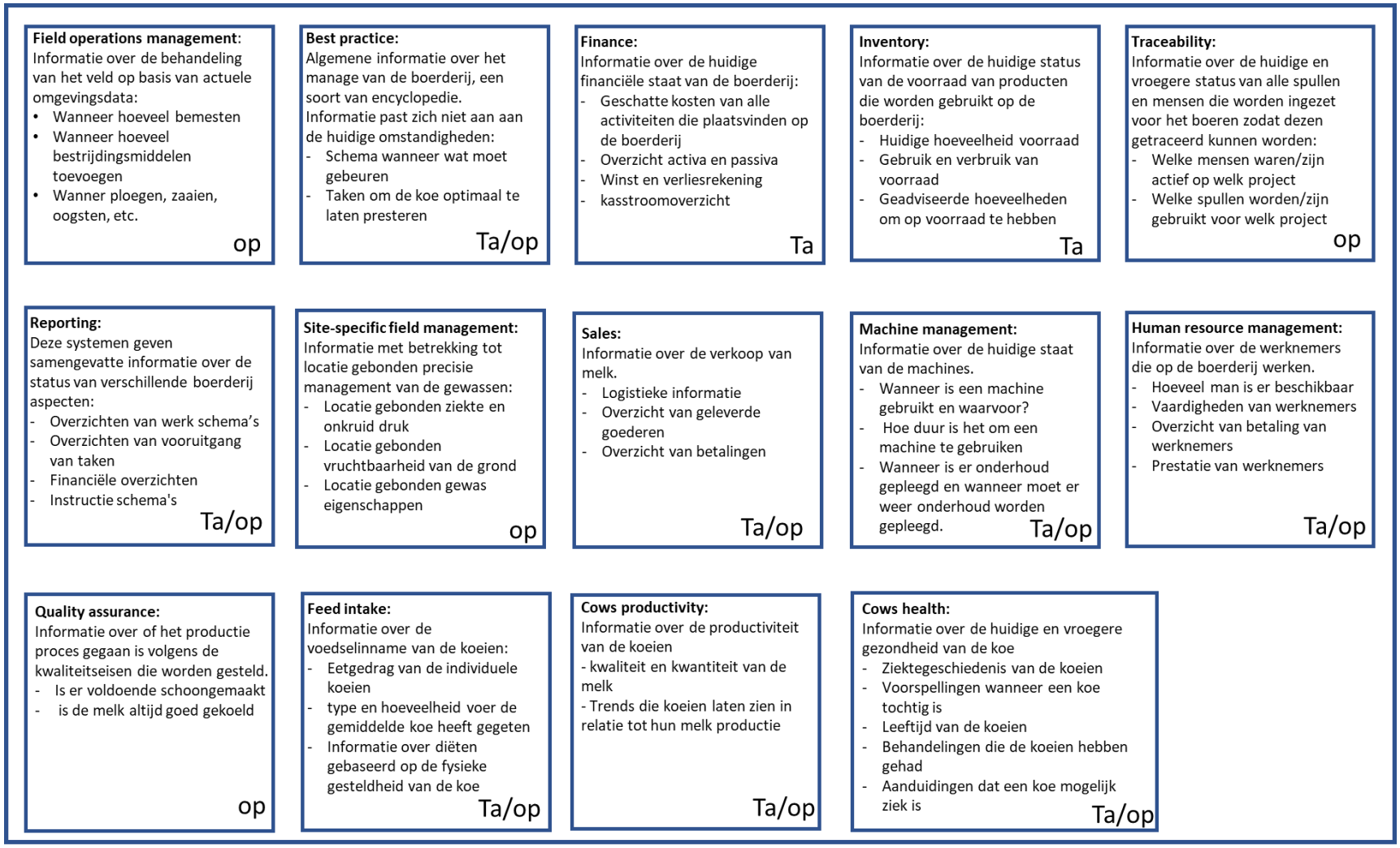
- Strategische keuzes: Langer termijn (meer dan 1 jaar vooruit) keuzes die zorgen voor ingrijpende veranderingen
- Tactische keuzes: Keuzes over waar welke middelen ingezet gaan worden. Een verdere invulling van de grote lijnen die bij de strategische keuzes zijn bepaald.
- Operationele keuzes: Keuzes over de dag tot dag activiteiten. Bij de tactische keuzes zijn de grote lijnen al ingevuld maar ook de tactische keuzes moeten verder ingevuld worden.

In bijlage 2 is een overzicht gegeven van voorbeelden van de verschillende keuzes. De informatie die wordt geleverd door de informatiesystemen kunnen op 3 manier helpen in de besluitvorming. De informatie kan zorgen voor het vinden van een problemen, voor het vinden van oplossingen voor problemen of het implementeren van de oplossing. Een voorbeeld hiervan is: een koe geeft relatief te weinig melk. Het blijkt achteraf dat dit komt omdat de koe ziek is. De informatie “te weinig melk” kan in dat geval hebben geholpen dit probleem te vinden. Informatie die verteld wat een goed geneesmiddel is een voorbeeld van informatie die helpt met het oplossen van het probleem. Informatie over de koe kan helpen met bepalen hoe het geneesmiddel het beste kan worden toegediend. Uiteindelijk is het zo dat alle informatie die wordt geleverd door de informatiesystemen moet zorgen voor een betere besluitvorming en dus een beter bedrijfsresultaat. Bedrijfsresultaat wordt vanuit verschillende oogpunten benaderd. Dit wordt gedaan om een zo’n compleet mogelijk plaatje te krijgen van de impact van de informatie uit informatiesystemen op het bedrijfsresultaat. In het interview zal gevraagd worden naar of de informatie uit de informatiesystemen een invloed hebben gehad op de onderstaande onderwerpen:

- Financieel resultaat
    - Kwantiteit en kwaliteit van melkproductie
    - Kosten van productie
- Sociale resultaat
    - Lengte van werkdagen
    - Flexibiliteit van werkuren indelen
- Milieu resultaat
    - Uitstoot van broeikasgassen
    - Dierenwelzijn
    - Mestproblematiek

Bijlage 1: De 14 verschillende informatie onderwerpen + voorbeelden

Op: informatie die vooral voor operationele besluiten wordt gebruikt. **Ta**: informatie die vooral voor tactische besluiten wordt gebruikt. Alle informatie kan voor strategische keuzes worden gebruikt. De info kan gebruikt worden om een probleem te vinden of om een oplossing te vinden!



Bijlage 2: De 3 soorten besluiten op een boerderij + voorbeelden

Strategische besluiten

Langer termijn besluiten, (meer dan 1 jaar) besluiten die zorgen voor ingrijpende veranderingen. Een aantal strategische besluiten waar melkveehouders nu tegenaan lopen zijn:

- Personeel behouden of meer robotica op de boerderij?
- Hoe de organisatie van de boerderij “simpel” te houden? Met de toenemende regelgeving, ingewikkelde systemen op de boerderij en grotere boerderijen kan het overzicht verloren gaan.
- Hoe om te gaan met de fluctuerende melk prijs?
- Hoe ervoor te zorgen dat het bedrijf “beter” wordt? Bedrijven kunnen streven naar een hogere return on investment of een betere strategie willen.
- Hoe om te gaan met de toenemende regulatiedruk vanuit de overheid?

Tactische besluiten

Besluiten over waar welke middelen ingezet gaan worden. Een verdere invulling van de grote lijnen die bij de strategische keuzes zijn bepaald. Voorbeelden van tactische besluiten op een melkvee bedrijf zijn:

- type en hoeveelheid gewassen die worden geteeld
- Hoe de gewassen worden geteeld, welk onderhoud, welke machines?
- Welke machines worden er aangeschaft/gehuurd
- Gaat er gebruik worden gemaakt van subsidie regelingen?
- Hoe word het voer opgeslagen?
- Wat voor dieet gaat er aan de koeien worden gegeven?
- Word het voer ingekocht of zelf verbouwd
- Gaan de koeien naar buiten in de zomer?
- Worden kalven opgefokt of doorverkocht?
- Welke maatregelen worden genomen om de koeien gezond te houden?
- Wat voor onderhoud gaat er gedaan worden aan de machines/robots?
- Enz.

Operationele besluiten

Besluiten over de dag tot dag activiteiten. Bij de tactische keuzes zijn de grote lijnen al ingevuld maar ook de tactische keuzes moeten verder ingevuld worden. Op een melkveebedrijf worden dagelijks honderden operationele besluiten genomen, te veel om op te sommen, daarom worden er een paar voorbeeld gegeven:

- Als een bezem kapot gaat, moet hij vervangen worden of gerepareerd?
- Een koe vertoond ziekte verschijnselen, is dit ernstig of gaat het vanzelf over?
- Als het ernstig is word de dierenarts gebeld of kan de boer zelf iets doen?
- Welke dag gaat het mais geoogst worden?
- Wanneer word het mais ingezaaid?
- Moeten de gewassen beregend worden?
- Moeten de koeien geïnsemineerd worden?
- Moet de stal worden schoongemaakt?
- Moet er een herinneringsmail worden gestuurd voor een niet betaalde rekening?
- Heeft de werknemer een vrije dag verdient?
- Kan de boerderij een halve dag alleen gelaten worden
- Enz.

Appendix 3: Gannt chart