Investigating precision farming administrative processes at a South African Swine farm

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ABSTRACT

Agriculture has evolved over the past 50 years, with the recent use of techniques like precision agriculture. For pig farms, precision agriculture assists farm caretakers to monitor the health and well-being status of all animals in a continuous manner throughout the day. Adopting precision agriculture has its difficulties but using precision technologies to monitor the health and well-being of pigs can improve managing a pig farm and, by extension, the pork supply chain. Part of managing a pig farm are Quality Management Systems (QMS) and certifications. QMS's specify production standards, where certifications indicate the degree to which these standards are complied. Recently, QMS solutions incorporated traceability which resulted in an abundance of animal ear tagging and paperwork. Although it may sound commendable, the abundance of paperwork is a frustration for farmers. Unfortunately, QMS related administration for pig farmers cannot be neglected. The consequence of not complying with quality standards can mean substantial fines, or imprisonment. The aim of this research is to develop a management system for quality compliance that reduces the time spent on administration processing.

A critical artefact methodology research design was followed including three critical artefacts that produces a final artefact. The first critical artefact makes use of a systematic literature review (SLR) to identify current uses of Internet of Things systems in pig farming. The second artefact involves time studies and value stream mapping for current state analysis. The third critical artefact involves a focus group to identify thematic patterns in discussions surrounding Pork360 quality standards. Results from the SLR, time studies, and focus group were used to formulate system design requirements for the final artefact. The SLR shows that there is a growing interest in pig precision agriculture but revealed a research gap pertaining to research of pig precision farming in Africa. Moreover, precision agriculture technologies assist farm operations to be conducted remotely, but data inaccuracies, impractical technology, and farmer scepticism causes adoption failure. This research found that Pork360 standards do add value to a pig farm's operations but requires several administrative processes to be up to date. Due to this, the farm managers struggle to tend to these administrative processes along with disruptive unforeseen operational events and, more simply, not having enough time for it. Moreover, having an effective administrative structure is heavily dependent on the farm manager. From the three critical artefacts, a list of system requirements is compiled. The research then set out to design and develop a prototype administrative system using the defined set of system requirements.

The novelty of this research can be found in its identified system requirements. The system design requirements encapsulate all critical artefact findings to be used in a practical setting specifically for the pig farming industry. The identified barriers of technology, the factors to consider for

administrative processes, and the human interface attributes are what the research contributes to the endeavour of finding a solution to integrating Quality Management Systems (QMS) with pig farm operations while using Information and Communication Technologies.

For further research, it is recommended to investigate IoT as a solution to integrating QMS with farm operations. Furthermore, it is recommended to include implementation and training material in this investigation. Knowledge management systems can also be considered for future research.

Keywords: Administrative system; Precision technology; Pig farming; Quality Management Systems; South Africa; Systematic Literature Review; Time Study; Focus Group; V-Model

STATEMENT OF CO-AUTHORS

To whom it may concern,

The listed co-authors hereby give consent that Johan Christiaan van Dyk may submit the manuscript as part of this dissertation titled, "Exploring the future of precision farming: a systematic literature review" for the degree Master in Engineering in Industrial Engineering, at the North-West University (NWU).

	22 November 2024	Stellenbosch
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“The Road goes ever on and on,

Down from the door where it began.

Now far ahead the Road has gone,

And I must follow, if I can,

Pursuing it with eager feet,

Until it joins some larger way

Where many paths and errands meet.

And whither then? I cannot say.”

– J.R.R Tolkien, Lord of the Rings

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CHAPTER 1
INTRODUCTION

This chapter provides context to the problem to be researched and how it is addressed by the aim and objectives. Moreover, it defines the scope, ethical considerations, novelty, and research opportunity.

1.1. Background

The agricultural, forestry, and fishing industries form part of the primary sector and involves the production and trade of farmed crops, livestock, fish for food, and wood. Furthermore, fishing, forestry and agriculture are considered as key sectors for the South Africa economy. This is evident as Stats South Africa indicates that the agriculture, forestry and fishing industry jointly increased by 15.9% through the 3rd and 4th Quarters of 2022 (StatsSA, 2022, StatsSA, 2023).

Agriculture has evolved over the past 50 years, with the recent use of techniques like precision agriculture. Precision agriculture is defined as "the application of modern information technologies to provide, process and analyse multisource data of high spatial temporal resolution for decision making and operations in the management of crop production" (Fuglie, 2016). In South Africa, the aforementioned industries planned to make use of precision agriculture. The study by Fuglie (2016) shows that between 2016-2018, 52.9% of the agriculture industry, 18.3% of the forestry industry and 0% of the fishery industry made use of precision agriculture. This indicates that technology and systems used for data analysis and decision making in the agricultural industry are being incorporated. For animal farming, precision agriculture is used for animal protection. Systems that involve data capturing through sensors are used for animal monitoring purposes to ensure animal security and health (Onyango et al., 2021).

Amongst the mentioned industries, agriculture is considered the largest industry in South Africa. In 2017, animals and animal products made 52% of the total South African agricultural income of which pigs were the third most sold animals (StatsSA, 2020). It is important to note that there are several parties involved in the pork supply chain. Figure 1 includes a high-level process diagram illustrating the parties involved in the pork supply chain.

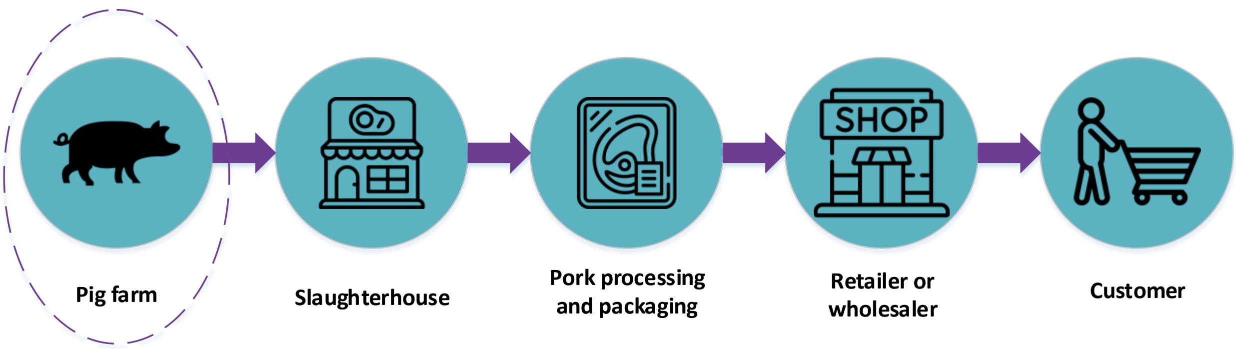


Figure 1. High level of Pork Supply Chain (Author's own compilation)

This research study's scope within the pork supply chain will be the pig farm, demarcated with a dashed ellipse in Figure 1.

For pig farms, precision agriculture assists farm caretakers to monitor the health and well-being status of all animals in a continuous manner throughout the day. Although technology can be useful to produce healthy pigs, a study that developed a sensor board which can be mounted on the pig's ear found health regulations as a development challenge (Pandey et al., 2021). Moreover, collecting and analysing large quantities of field data with cross validation by farmers is also a challenge and hinders technology adoption (Pandey et al., 2021).

Adopting precision agriculture has its difficulties, but using these technologies to monitor the health and well-being of pigs can improve managing a pig farm and, by extension, the pork supply chain. Part of managing a pig farm are Quality Management Systems (QMS) and certifications. QMSs specify production standards, where certifications indicate the degree to which these standards are complied (Trienekens and Wognum, 2013). To own a piggery in South Africa, three policy documents that include standards that should be complied with. They are:

- Agricultural Product Standards Act 119 of 1990
- Foodstuffs, cosmetics and disinfectants act 54 of 1972
- Meat Safety Act 40 of 2000

Furthermore, there are a variety of certifications available in South Africa such as Pork360 which is associated with the South African Pork Production Organisation (SAPPO), and A Greener World South Africa (AGWSA). A significant aspect of QMSs is health management on a pig farm, as a combination of QMSs may help to optimise service processes for the improvement of farm and health management as well as the final product. However, a challenge that farmers face is the coordination of various QMSs and certifications, as each QMS is certified and audited separately (Trienekens and Wognum, 2013).

Recently, QMS solutions incorporated traceability which resulted in an abundance of animal ear tagging and paperwork. The traceability motive aims at monitoring animal movement and the controlling of exotic disease outbreaks (Gregory and Grandin, 2007). Although it may sound commendable, the abundance of paperwork is a frustration for farmers (Escobar and Demeritt, 2017). Furthermore, it has been found that record keeping violations are the most common breach of animal welfare regulations in England (Escobar and Demeritt, 2017). Similarly in the Western Cape Province of South Africa, it has been found that on 51.4% of pig farmer keep records of their pigs and 27.5% of pig farmers do not tag their pigs (Cupido, 2020). Another study found that in the Western Cape Province of South Africa, from a sample size of 160 farmers only half kept records (Mathobela et al., 2024). One study suggests that the reason for this is that farmers do not consider paperwork as an importance for animal welfare. Conversely, farmers deem it as a hindrance to proper animal care (Overstreet and Anneberg, 2020).

An additional challenge for paperwork is the required hours it demands. In a study published in 1994 it has been found that farmers spend an average of 21.46 hours per week on work done related to paperwork (Woodburn et al., 1994). Interestingly, a Gemba walk was conducted on the farm (used as a case study in this research), where assistant managers shared that approximately 2 hours per day is spent on administration. It was also found that the piggery manager spends approximately 4 hours per day on administration.

Unfortunately, QMS related administration for pig farmers cannot be neglected. The consequence of not complying with quality standards can mean substantial fines, or imprisonment. Furthermore, the pork supply chain risks producing lower quality meat, and will be unable to mitigate possible disease outbreaks. Both can have a negative health effect on the customer community.

1.2. Problem statement

The piggery is experiencing long administration processing times for quality compliance.

1.3. Opportunity statement

Given the outlined studies in section 1, the combination of QMS and information technologies could provide an opportunity to significantly reduce processing times for quality compliance.

1.4. Aim

The aim of this study is to develop a prototype administrative management system for quality compliance that contributes to the reduction of time spent on administration processing.

1.5. Objectives

In order to achieve the aim of this study, the following objectives have been set:

- O1 Perform a systematic literature review (SLR) to identify current uses of Internet of Things systems in agriculture.
- O2 Determine the current state of the piggery, using Time studies, value stream mapping, and other tools.
- O3 Accumulate quality standards provided by partners in the value stream.
- O4 Collate System Design requirements from SLR, time studies, and quality standards.
- O5 Design a prototype system
- O6 Test the developed prototype system.

1.6. Scope

Figure 2 displays a pressure state response (PSR) model which provides a framework for the scope of the research. To ensure the farm business adheres to certification standards, the farm maintains compliance with yearly audits. Currently, to maintain administrative standards, administration is done manually. There are occasions where the auditing event has occurred, and the business fails to comply with standards which results in the hiring of a temporary consultant to remedy identified problems and enable the farm to remain certified. Other responses include technological solutions for administration, such as Microsoft Teams.

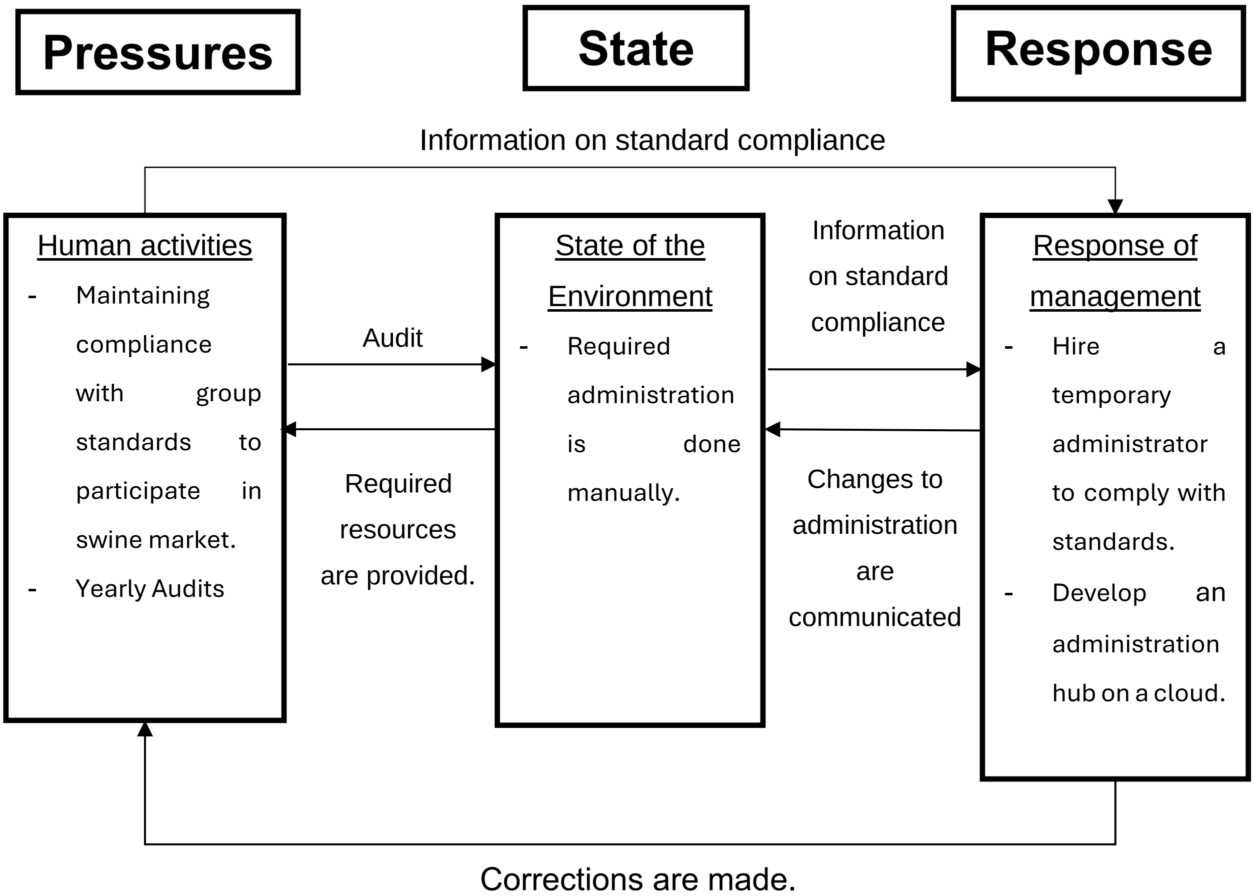


Figure 2. Pressure State Response model

The scope of the research is to assist the farm in maintaining quality compliance while reducing manual efforts and incorporating technological solutions. Therefore, the standards the farm is accountable to, the administration involved, and available technology that can facilitate the management thereof fall within the scope of the research. For the duration of the dissertation, the term ‘pig farm’ will be used which refers to ‘swine farm’.

1.7. Fields of Study

Industrial Engineering includes various fields. Seminal works by Salvendy (2001) specifies four basic areas namely: operations research, human factors engineering, management systems, and manufacturing systems engineering as illustrated in Figure 3. Each of these areas coincides with basic knowledge and/or application areas i.e., Statistics, Psychology etc.

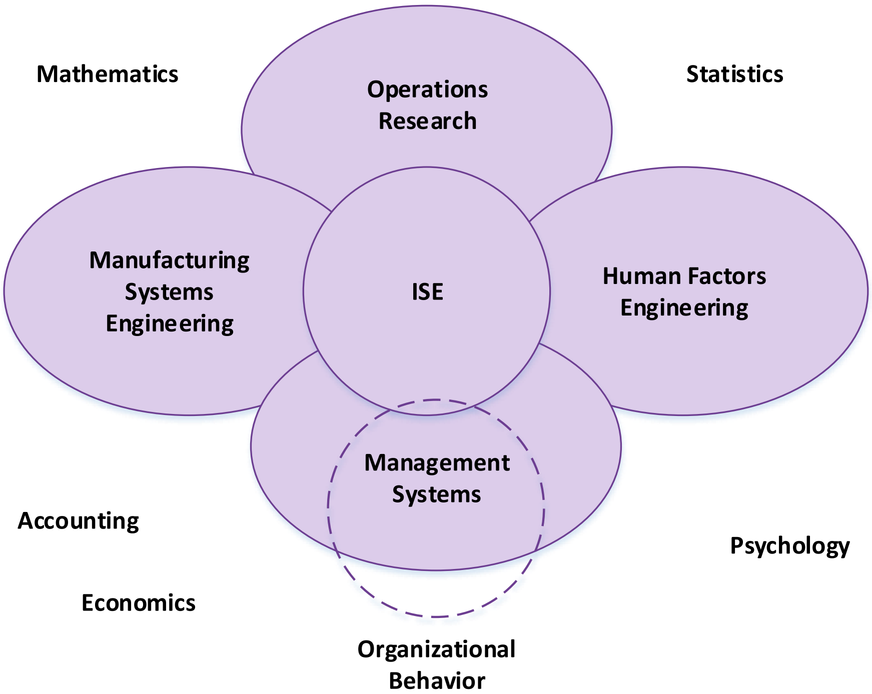


Figure 3. Domains of Industrial and System Engineering adapted from Salvendy (2001)

Despite this, by 2021 the four basic areas were expanded by the Institute of Industrial and Systems Engineering (IISE). IISE introduced 14 knowledge areas which are included in Figure 4**.**

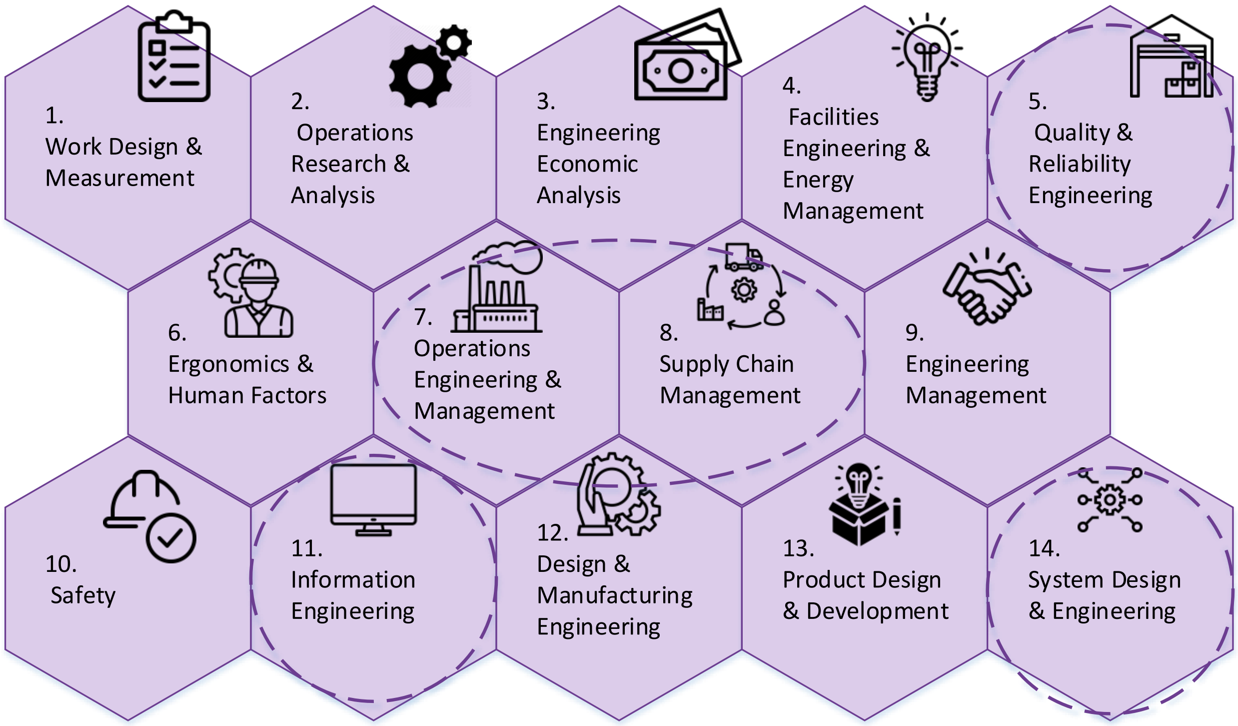


Figure 4. Knowledge areas of Industrial and Systems Engineering adapted from the Institute of Industrial and Systems Engineering Body of Knowledge (IISE)

In view of the domains (Figure 3) and knowledge areas (Figure 4) of industrial and systems engineering, the research will be conducted within the field of industrial engineering. Dashed lines are included in Figure 3 and Figure 4 which illustrate the focus areas of the proposed research namely, the management system domain (Figure 3), Quality and Reliability Engineering, Supply Chain Management, Information Engineering, and System & Design Engineering (Figure 4). These areas are supported by the basic area of Organisation behaviour.

1.8. Novelty

Precision agriculture in pig farming is under-researched within the South African context. This study aims to explore this by analysing current pig precision farming literature. Furthermore, the collection of design requirements for the design, development, and testing of a prototype administrative system will be performed. The developed system aims to contribute to precision farming in an administrative context. Moreover, this study aims to showcase industrial engineering work in precision farming.

1.9. Outline of Chapters

In Chapter 1 the dissertation introduces the problem it seeks to investigate, and the research design followed. To provide more literature on research methods introduced in Chapter 1, Chapter 2 provides a literature review which discusses each method pertaining to the dissertation, its value to the dissertation, and its alignment to objectives of the dissertation. Chapter 3 provides more detail on the research design the dissertation aims to follow. Chapter 4 includes the systematic literature review conference paper and acts as the first critical artefact (CA1) as part of the research design discussed in Chapter 3. Chapter 5 discusses the current state of the piggery and acts as the second critical artefact (CA2). Chapter 6 provides an analysis on Pork 360 quality standards discussed in a focus group and acts as the third critical artefact (CA3). Chapter 7 includes a discussion on the design and development of a final artefact (FA1) by first compiling identified system requirements from Chapter 4, 5, and 6. Chapter 8 includes the verification and validation of work conducted in Chapters 4, 5, 6, and 7. Lastly, Chapter 9 discusses findings throughout the dissertation, provides recommendations for further research, and conclusions.

1.10. Chapter Summary

This chapter introduced the research problem, aim, and objectives. Moreover, the chapter provided the research scope and its relevance to Industrial Engineering research. Lastly, the chapter illuminated the novelty of the research, this being the contribution the research makes to precision agriculture in pig farming literature.

CHAPTER 2
LITERATURE REVIEW

This chapter explores literature on tools and concepts used for data collection and analysis pertaining to the research.

2.1. Introduction

Theoretical concepts and methods that pertain to this research are discussed in this chapter. Figure 5 illustrates the sections of literature investigated on various concepts and methods.

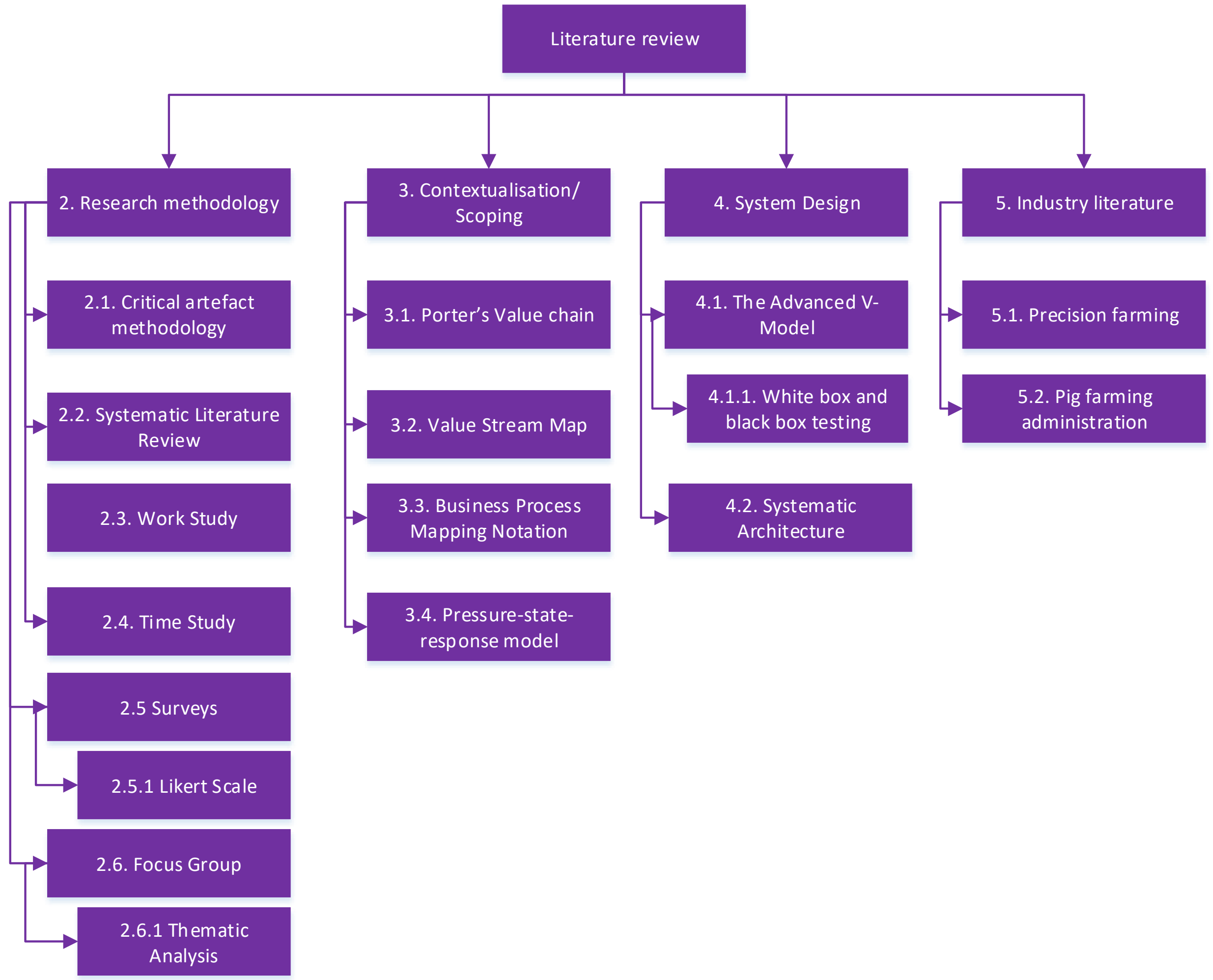


Figure 5. Literature review theme analysis

Sequential referencing has been included in Figure 5 in order to discuss each concept in light of the research.

2.2.1 Critical Artefact Methodology

The Critical Artefact Methodology (CAM) incorporates the interaction between stakeholders and designer to design and develop artefacts (Bowen, 2009). This interaction involves the designer developing their understanding of the final artefact by designing and processing critical artefacts and engaging stakeholders (Bowen, 2009).

Figure 6 illustrates that as the stakeholder' understanding and designer's understanding overlap, an innovative artefact that complies with a set of requirements is developed according to relevant stakeholder needs.

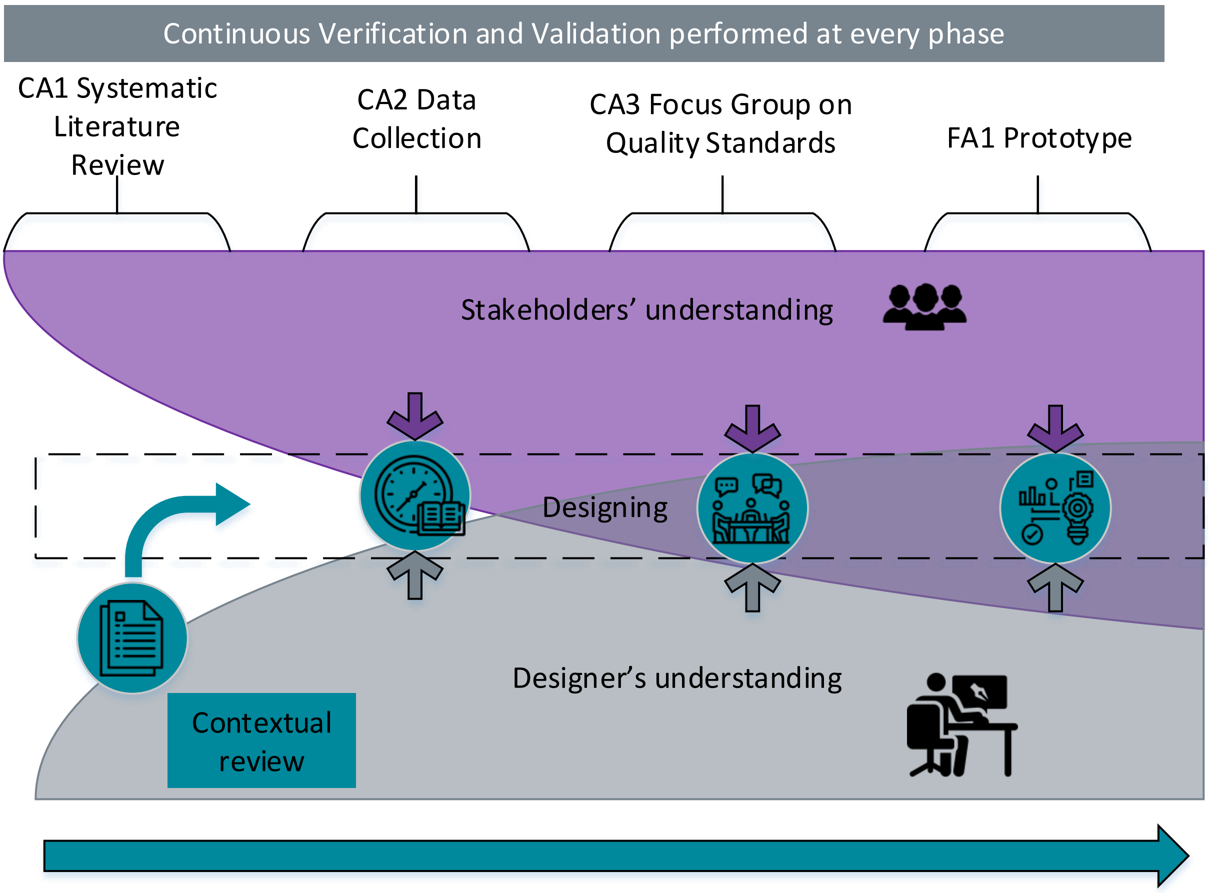


Figure 6. Critical artefact methodology adapted from Bowen (2009)

There are several basic features of CAM, some of which are that CAM positions itself within Human-centred design and is directed towards innovation relevant to stakeholders (Bowen, 2009).

Upon introducing CAM, Bowen explores lessons learned in applying CAM. In this paper, Bowen (2009) reflects on a project wherein CAM was used and learned that when using CAM one needs to identify the appropriate contexts for application. Moreover, selected stakeholders should be capable of effectively engaging with critical artefacts and need to be educated about the design of the artefact in order to encourage imaginative thinking. After applying lessons learned in the second project, it was found that stakeholders were more engaged (Bowen, 2009).

The challenge of encouraging imaginative thinking and transferring it into practice is highlighted by Larsen and Hedvall (2012). Larson and Hedvall (2012) investigates how basic design artefacts can question and spur practices and refers to CAM as engaging imagination and criticality, and promoting divergent thinking (Larsen and Hedvall, 2012).

CAM seeks to overlap the stakeholder's understanding and designer's understanding to produce an innovative artefact that complies with a set of requirements. In addition, the application of CAM several areas are revealed that require investigation. For it has been observed that it is a challenge to continuously encourage imaginative thinking and bring into practice stakeholder ideas.

CAM has been used to investigate the challenge of transitioning knowledge from academia to industry while accommodating gamification. In this dissertation, three critical artefacts were developed to deliver an experimental prototype with the purpose of assisting future research in this area (Linde, 2022).

The CAM provides a framework to complete all objectives. Moreover, the structure of the CAM allows the research to formulate a practical deliverable. The deliverable, or final artefact, requirements are extracted from the results or findings of each completed critical artefact.

2.2.2 Systematic Literature Review

A literature review is described as an essential feature of academic research and as a method to identify research gaps that can be explored (Xiao and Watson, 2019). Moreover, a literature review evaluated against a criterion can reveal weaknesses, inconsistencies, and contradictions.

Xiao and Watson (2019) introduce steps to follow in conducting a systematic literature review, illustrated in Table 1.

Table 1. Steps on conducting a Systematic Literature Review adapted from Xiao and Watson (2019)

Steps	Objective
Step 1: Formulate the problem	Develop specific research questions to guide the literature review process.

Step 2: Develop and validate the review protocol	Create a pre-set plan that specifies the methods used in conducting the literature review.
Step 3: Search the literature	Search selected electronic databases with predetermined keywords. In addition, optionally do a backwards and forward's search.
Step 4: Screen for inclusion	Screen abstracts, titles and keywords based on pre-determined keywords and set criteria.
Step 5: Assess quality	Assess the full text for quality work.
Step 6: Extract data	Extract findings relevant to the research.
Step 7: Analyse and synthesise data	Organise extracted data for analysis and formulate conclusions.
Step 8: Report findings	Report findings in a research paper.

When following the Literature Review process, it is suggested that a two-stage screening procedure (Xiao and Watson, 2019). In the first stage the researcher reviews abstracts only and the second involves a full-text quality assessment review. Once the screening process is complete, data can be extracted, analysed and synthesised.

Xiao and Watson (2019) highlight several lessons when conducting a systematic literature review, namely:

Step 1: Start with a research question
Step 2: Decide on a review type/methodology
Step 3: Develop a review protocol.
Step 4: Search in multiple databases, identify up-to-date literature, and be aware of the quality of identified literature
Step 5: Be adaptable to new situations or ideas that may emerge throughout the process.
Step 6: Document decisions made in the process

The systematic literature review contributes to objective 1 and will assist determining technological integration requirements in pig farming by assessing existing literature. The identified requirement will contribute to the formulation of a final artefact.

2.2.3 Work Study

Work study is defined as "the systematic examination of the methods of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out" (Kanawaty, 1992).

The basic procedure of a work study is as follows (Kanawaty, 1992):

Step 1: Select the process to be studied
Step 2: Record or collect all relevant data about the process
Step 3: Examine collected data and the purpose of the process
Step 4: Develop the most efficient method
Step 5: Evaluate the attained results
Step 6: Define the new method by sharing it with all process stakeholders
Step 7: Install the new method
Step 8: Maintain the new method through monitoring the results

The procedure provided by Kanawaty (1992) has been used in a study to structure the work associated to stump biomass harvesting (Eker, 2023). Moreover, the procedure was used in a study to evaluate and compare several factors of roundwood measurement and grading (Borz and Proto, 2022). Although the provided procedure was introduced in 1992, it is still recently used to investigate work operations.

A useful tool used to map processes studied when making use of a work study is Business Process Mapping Notation (BPMN), refer to Section 2.8. BPMN has been previously used to build a process flow model while undergoing a work study (Werner-Lewandowska and Grzelczak, n.d.).

The work study methodology has been used in combination with Time studies with the purpose of taking a scientific approach to measuring productivity in both manufacturing and service sectors (Duran et al., 2015). Interestingly, work and time studies are perceived as useful to create productivity models which can be used for cost analysis, simulations, or system development (Böhm and Kanzian, 2023).

Objective 2 aims to investigate the current state of the piggery and requires an examination of methods used to carry out administrative activities. Therefore, the discussed procedure of a work study will assist determining the current state for further analysis. Furthermore, for analysis purposes the procedure requires recording of relevant data about the process. This provides a framework in which time studies, value stream maps and other tools mentioned in objective 2 can fall under.

2.2.4 Time Study

Time study is defined as the procedure of establishing standards using stopwatch timing (Freivalds and Niebel, 2009). Freivalds and Niebel (2009) suggests that in preparation for the time study, there are several requirements for a time study to be made, namely:

- Whether the standard is required on a new or old job
- The operator should be well acquainted with the operation
- The method of operations must be standardised

There is several equipment involved in time study such as a stopwatch and time study forms and elements which include recording significant information, positioning of observer, and dividing the operation into elements (Freivalds and Niebel, 2009).

Freivalds and Niebel (2009) mention two methods of time study, namely, the snapback method and continuous method. The snapback method involves timing an element of the operation and then restarting the stopwatch to time the next element of the operation. The continuous method involves time the whole operation without restarting the stopwatch. The snapback method is more useful for lengthy elements whereas the continuous method is useful for brief elements.

A time study is performed in a set number of cycles. Table 2 includes a recommended number of observation cycles dependent on the operation cycle time.

Table 2. Suggests number of cycles (Freivalds and Niebel, 2009)

Cycle time (min)	Recommended number of cycles
0.1	200
0.25	100
0.5	60
0.75	40
1.00	30
2.00	20
2.00-5.00	15
5.00-10.00	10
10.00-20.00	8
20.00-40.00	5
40.00-above	3

The time study method has been used to examine logistic activities such that the activities can be improved effectively, efficiently, and ergonomically (Korkmaz et al., 2020). The time data is useful and has an influence on planning and quality control (Hedman and Almström, 2017).

Objective 2 aims to investigate the current state of the piggery. One aspect of this investigation is analysing the period of administration for further analysis. Time studies will be used as a method to measure and analyse the time attribute of the current state.

2.2.5 Survey

Surveys are defined as “an information collection method used to describe, compare, or explain individual and societal knowledge, feelings, values, preferences, and behaviors” (Fink, 2015). A questionnaire is defined as a research instrument that consists of a set of questions with the aim of capturing participant responses in a standardized manner (Bhattacherjee, 2012). Inexpensive online surveys can be communicated to participants which immediately records responses on an online database making it simpler for both the participant and researcher.

Table 3 provides five general stages of a survey.

Table 3. Five general stages of conducting a survey adapted from Czaja and Blair (2005)

Stages	Description
Survey design and preliminary planning	This involves the specification of the research problem and the research questions that the survey will address.
Pretesting	This step involves preparing the sampling frame or drafting the survey
Final survey design and planning	This step involves refining the original survey design upon results of drafted survey.
Data collection	This step involves monitoring the results and data collection activities.
Data coding, data-file construction, analysis, and final report	This step involves data analysis

Surveys were used in a case study to measure medical office processes which included administrative and physician tasks (Keshavjee et al., 2001). An interesting article compiled a survey to identify the relationship between herd size, adoption of precision technology, and perception of future precision technologies (Gargiulo et al., 2018). These case studies provide insight on surveys that are compiled to measure administrative processes and help identify relationships between farm production and precision technology.

Objective 2 aims to investigate the current state of the piggery. A compiled survey aims to validate research findings to complete the current state analysis. Results from the surveys can provide further insight in the relationship between participants in the current state, the technology used, and the administrative process followed.

2.2.5.1. Likert Scale

The Likert Scale is defined as a set of statements offered for a situation under study in order to measure an 'attitude' in a quantifiable way (Joshi et al., 2015).

A Likert scale is describes as composed of a series of four or more Likert type questions which are combined to provide a quantitative measure of a character trait (Boone Jr and Boone, 2012). Included in the scale is five response alternatives, otherwise known as a 5-point scale. These response alternatives are:

- strongly approve (1),
- approve (2),
- undecided (3),
- disapprove (4),
- and strongly disapprove (5).

Table 4 includes Likert scale data analysis procedures. Some data analyses procedures included in Table 4 is the mean which conveys the average response received by participants. Moreover, the standard deviation shows variability in responses which can indicate a level of agreement between participants.

Table 4. Likert scale data analysis procedures adapted from Boone JR and Boone (2012)

Likert Scale Data	
Central Tendency	Mean
Variability	Standard deviation
Associations	Pearson's r
Other Statistics	ANOVA, t-test, regression

Likert scales are used for several purposes. The Likert scale has been used in a survey to investigate students and markers perception of quality, format and timeliness of feedback of written assignments delivered electronically and on paper (Sopina and McNeill, 2015). The 5-point Likert scale has been used in questionnaires with the aim of assessing dairy farmers' satisfaction with veterinary advisors and the perceived preparedness to adopt veterinary advice (Ritter et al., 2019). These case studies make use of Likert scales in surveys to measure participants 'attitudes' towards paperwork, and also that Likert scales can be used in various industries from education to agriculture.

The Likert scale method will form part of the survey and by extension align with the purpose of the survey for the research.

2.2.6 Focus Group

A focus group is defined as “a carefully planned discussion designed to obtain perceptions on a defined area of interest in a permissive, non-threatening environment” (De Vos et al., 2011a, De Vos et al., 2011b). The purpose of a focus group is to determine what people think and feel about a specific topic.

Table 5 includes several approaches to focus groups:

Table 5. Focus group approaches (De Vos et al., 2011a)

Approach	Description
Exploratory	This approach is used to generate theoretical hypotheses for future research
Clinical	This approach is used to obtain specific information about the inner experiences of participants which is then subjected to clinical, and scientific interpretations.
Phenomenological	This approach is used to understand the daily experience of the participant.

The phenomenological approach is an epistemological perspective that recognizes there are culturally defined meanings attached to participant perceptions (Chism et al., 2008). Therefore, the goal of this approach is to identify the true essence of the shared experiences. An iterative process of identifying patterns tied to a phenomenon can assist in developing an informed essence of the whole phenomenon (Levitt et al., 2018).

Focus groups are considered as a method for evaluating artefacts by means of an interactionist approach (O'Raghallaigh et al., 2012). The interactionist approach aims to incorporate stakeholder interests and perspectives to achieve a consensus on whether the artefact works, and why it works.

In the digital era, new research methods using online technologies for computer-mediated communications are being considered. For example, using the Zoom platform for focus groups (Poliandri et al., 2023).

De Vos et al. (2011) provides four basic steps for focus groups, included in Table 6.

Table 6. Four basic steps for focus groups provided by (De Vos et al., 2011a)

Steps	Description
Planning	The planning process involves defining the purpose and outcomes of the focus group, obtaining permission, setting up a question guide, and developing a recruitment plan.
Recruiting	Define the target population, an exclusion criterion for individual participants, and follow-up procedures to ensure attendance.
Conducting	Define the role of the facilitator and clarify the arrangements for the focus group
Analysing and reporting	Organise field notes, transcripts etc., study recorded data to determine key themes or conclusions, and report findings.

The size of focus groups is usually six to 10 participants, where smaller groups include four to six people. De Vos et al. (2011) mentions that smaller groups are preferable if the participants have much to share about a topic. Focus groups have been used to study small-scale forest owners' management practices (Kumer and Urbanc, 2020).

Objective 3 of the study aims to accumulate quality standards provided by partners in the value stream. The research will make use of the focus group method to achieve this objective. Using the focus group method will contribute a concentrated accumulation of quality standards in the value chain and collect views or opinions of these standards held by the partners in the value stream. Collected data will be used for further analysis to identify themes.

2.2.6.1 Thematic analysis

Thematic analysis is defined as a method for systematically identifying, organising, and offering insight into patterns of meaning or themes across a data set (Braun and Clarke, 2012). Furthermore, it is through analysis that an answer to an explored research question is produced.

Thematic analysis is useful in that it accompanies the mechanics of coding and analysing of qualitative data systematically that can then be linked to other conceptual issues (Braun and Clarke, 2012). Braun introduce a six-phase approach to thematic analysis that are included in Table 7:

Table 7. Six phase approach to thematic analysis adapted from Braun and Clarke (2012)

Phase	Description

Phase 1: Familiarizing yourself with the data	This phase involves listening to, watching, or reading captured data, and making of notes throughout the phase.
Phase 2: Generating initial codes	Coding is used to identify and provide a label for a feature of the data potentially relevant to the research question.
Phase 3: Searching for Themes	This phase entails the analysis of the data and codes used to identify patterns (themes) in the data set.
Phase 4: Reviewing Potential Themes	Developing themes are reviewed in relationship to the coded data and data set.
Phase 5: Defining and Naming Themes	This phase entails providing developed themes a name and definition that is unique and specific.
Phase 6: Producing the Report	This phase entails providing a compelling story about the data based on your analysis.

The thematic analysis method has previously been used to provide information to policy makers. The thematic analysis method has been used to examine the perception of small farmer's towards utilizing hydroponic farming systems with the purpose of providing valuable information to policymakers, and agricultural industry stakeholders (Velasco et al., 2023).

The thematic analysis method contributes to the analysis of data collected from a focus group and by extension objective 3. The method will assist the research to identify themes from the focus group which will further contribute to the formulation of requirements for the final artefact.

2.3.1 Porter's Value Chain

Porter describes the purpose of a value chain as disaggregating a business into its strategically relevant activities to understand the behaviour costs and potential sources of differentiation (Porter, 2001). The motive for making use of Porter's value chain is to enable the business to gain a competitive advantage by performing identified activities better and more cheaply (Porter, 2001).

Porter defines a value chain as a set of activities that an organisation practices, creating value for its customers (Simatupang et al., 2017, MindTools). Porter's value chain consists of two sets of activities namely, primary activities and support activities. Primary activities directly influence the product of a business. Support activities don't have a direct influence on the product but include functions that support primary activities (MindTools, Porter, 2001).

Porter's Value chain assists in identifying primary and support activities within a value chain which in turn reveals value chain relationships within a business or across sectors. Porters value chain is attributed as a tool to disaggregate a business into major activities which permits the identification of advantageous sources (Zamora, 2016). Porter's value chain has been used to study tourism and agriculture sector linkages in Tanzania by identifying and analysing primary and support activities (Anderson, 2018). Both articles reveal that porter's value chain can be used as a tool to identify major activities, analyse relationships between activities, and determine the added value of identified activities. Moreover, it is also used to find areas to increase value through cost saving at different levels of activities across the value chain (Shank and Govindarajan, 1992, Chen et al., 2022).

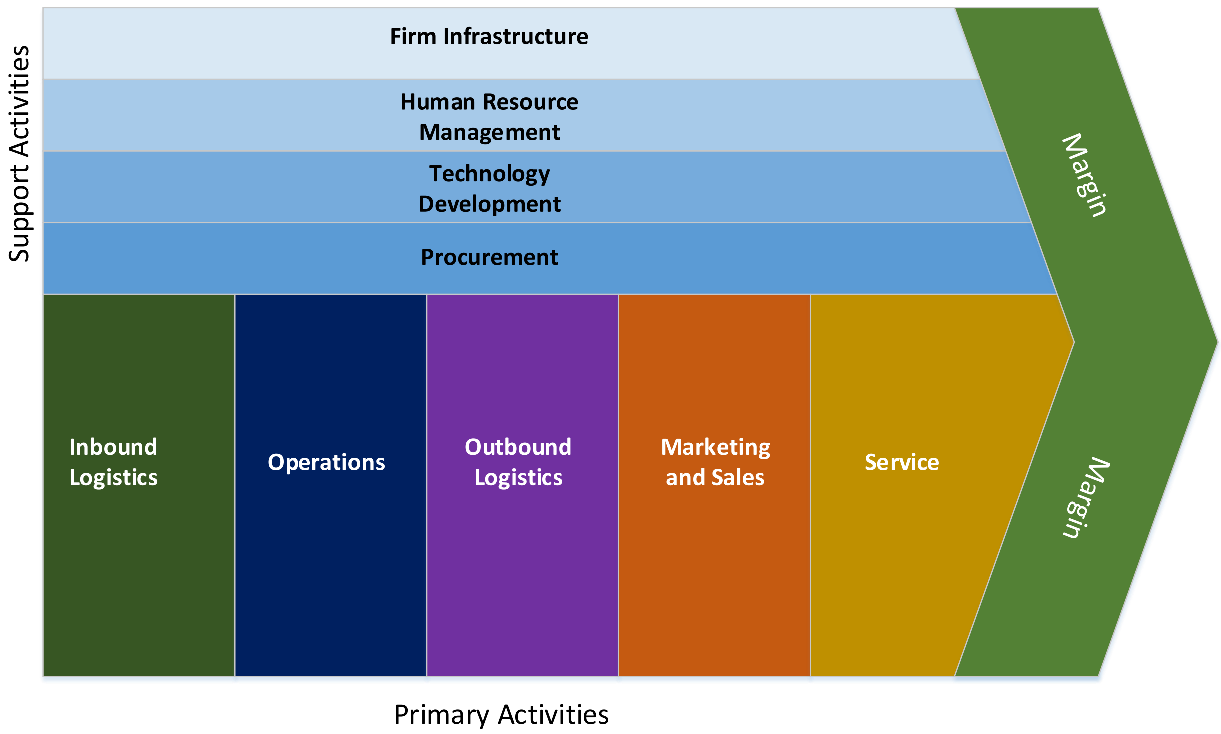


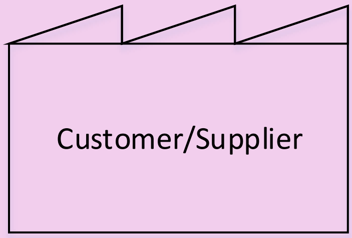
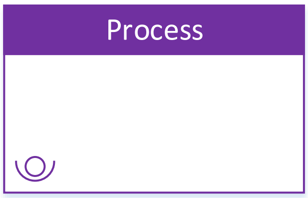
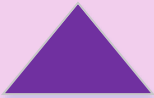
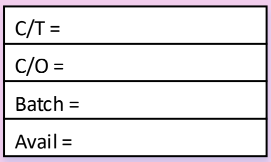
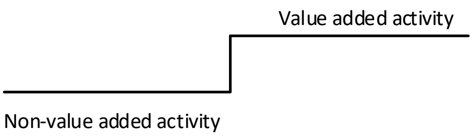
Figure 7. Diagram of Porters value chain (MindTools)

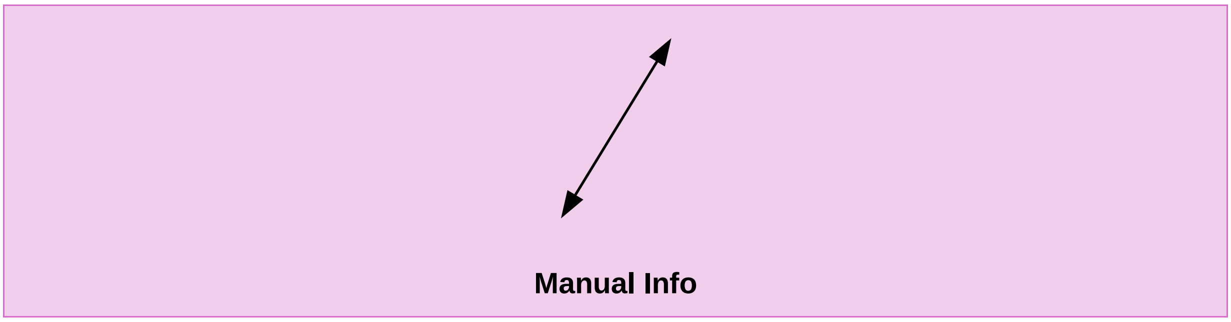
The Porter's Value chain diagram illustrated in Figure 7 contributes to objective 2 by categorising primary and supporting activities of the current state of the piggery. Categorising the process activities provides distinction between value-adding and non-value-adding activities and revealing problems contributing to the problem statement.

2.3.2 Value Stream Mapping

Value Stream Mapping (VSM) is defined as a flow chart tool used as a graphical way to analyse where value is or is not being added as material flows through a process (Jacobs and Chase, 2018). VSM makes use of several mapping symbols as a visualisation method for analysis purposes. These symbols are illustrated in Table 8.

Table 8 Sample of Value stream mapping symbols provided by Jacobs and Chase (2018)

Value Stream Mapping Symbols
 **Customer or Supplier**
 **Process**
 **Inventory**
 **Shipment**
 **Data Box**
 **Value-added, non-value-added Time**



Although VSM is attributed to material processing (Jacobs and Chase, 2018), VSM has been used for administrative processes as well, that is, document processing. Costa et al. (2013) applies lean philosophy tools, of which VSM is one, to their administrative tasks such as buying and suppliers' payment processes (Costa et al., 2013). Interestingly, this study was embarked because flaws were identified such as lack of standardisation and excessive work.

Jacobs and Chase (2018) describe VSM as a useful visual way to analyse existing system and to identify areas of waste reduction. Costa et al. (2013) experienced this after applying their future VSM and found a 25% reduction on process cycle time.

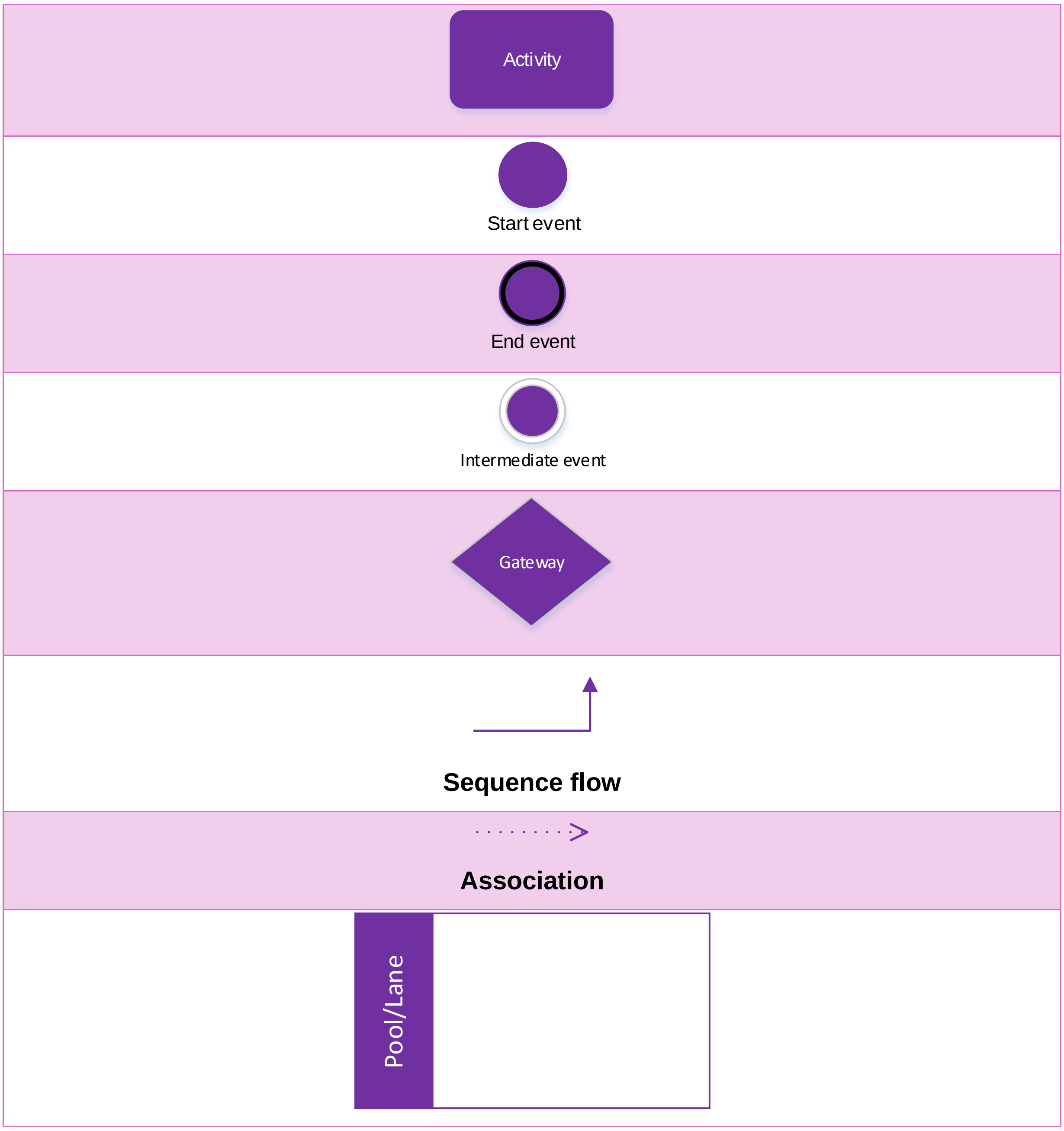
VSM can be used as a tool to understand the current state of the piggery, contributing to objective 2. VSM facilitates time values such as change over time (C/T) further contributing to the analysis of the relationship between time spent in a process, to the process itself. This relationship can contribute to the formulating of requirements for the final artefact.

2.3.3 Business Process Mapping Notation

Recker (2012) describes Business Process Model and Notation (BPMN) as becoming the global standard for modelling business processes (Recker, 2012). BPMN allows the creation of end-to-end business processes and incorporates several types of tasks that are constrained to relevant business processes (Aagesen and Krogstie, 2015). Moreover, there are two types of sub models in BPMN, one of which is private business processes which pertains to a specific organization's workflow process (Aagesen and Krogstie, 2015). Table 9 includes a sample of symbols used for mapping/modelling a BPMN model provided by BPMN2.0 which is used in this research.

Table 9. Sample of Business Process Modelling Notation symbols provided by Aagesen and Krogstie (2015)

Business Process Modelling Notation symbols



BPMN is widely supported and used by industry (Aagesen and Krogstie, 2015). Verdouw et al. (2010) made use of BPMN to map supply chains in several agri-food sectors with the purpose of revealing agri-food supply chain's need for interoperability and agility of information systems (Verdouw et al., 2010). Moreover, BPMN has been used as a tool to assess business processes with the purpose of providing recommended process adjustments (Nuzulita et al., 2020).

BPMN provides the research the ability to map the current state process technically. Notation symbols provided a summarised view of activities, and activity relationships. Mapping the process allows the research to determine the documental role in the current administrative process. Determining this role contributes to objective 2 and identify requirements for the final artefact.

2.3.4 Pressure-State-Response Model

Neri et al. (2016) describes the pressure-state-response (PSR) model as a framework that considers human activities which exerts pressures on the environment. These exerted pressures as a result change the state of the environment. Moreover, responses are perceived as social initiatives that aim to mitigate exerted pressures. PSR can be used to provide a structured understanding and framing of impacts on a system (Neri et al., 2016).

Staff (2001) introduces the PSR model as a tool to highlight links between a state of an environment, the pressures it experiences, and responses made due to identified pressures (Staff, 2001). Moreover, the PSR model can be adjusted accordingly to account for greater or specific features. Figure 8 illustrates an example of a PSR model.

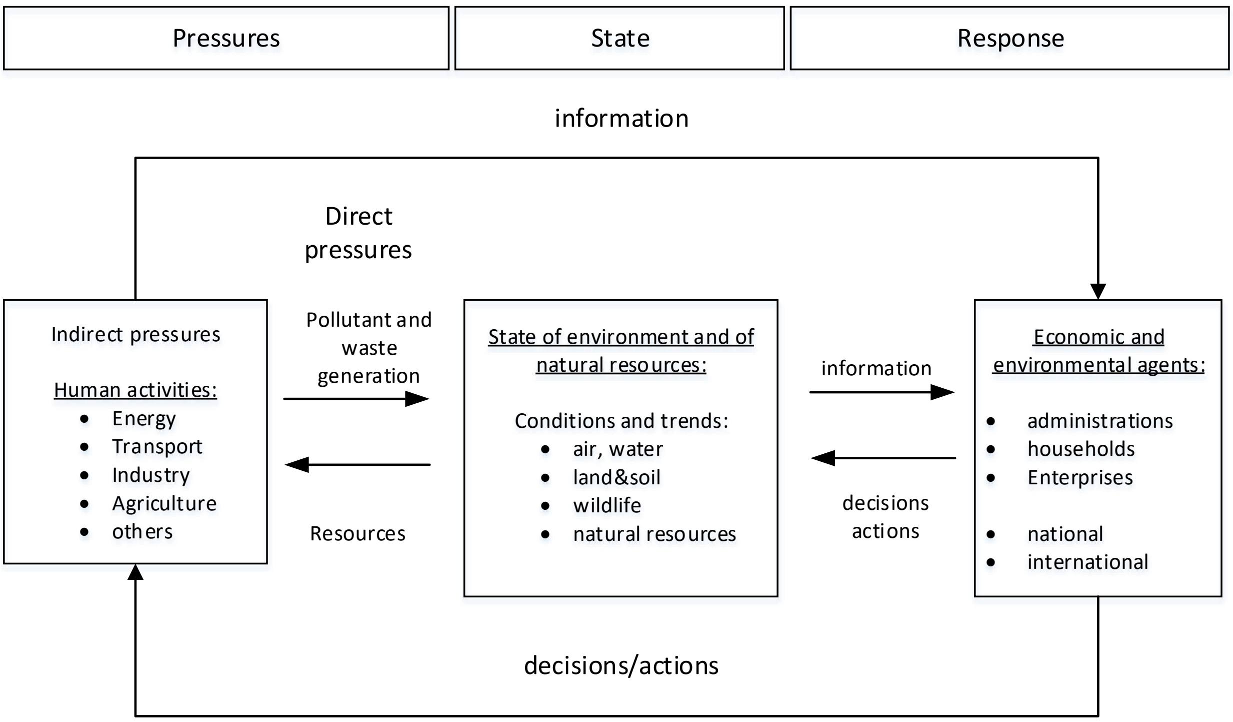


Figure 8. Pressure-state-response model extracted from Staff (2001)

Goswami (2017) makes use of the PSR model as a method for formulating smallholder farm sustainability indices as a measure for long-term sustainability assessment of smallholder farms in developing countries (Goswami et al., 2017). Van Dyk (2022) makes use of the PSR model to evaluate the framework of a work environment with the purpose of identifying decision-making roles and information flow.

The PSR model gives insight in the current state of the piggery by showcasing several pressures experienced by the piggery, and the piggery's reaction to these pressures within a defined scope.

In witnessing these pressures and reaction, the PSR model contributes to objective 2 in understanding the current state of the piggery.

2.4.1 The Advanced V-Model

In order to understand the advanced V-Model method, a definition of the traditional V-Model method is provided. The traditional V-Model method is defined as a method that demonstrates the relationships between each phase of the development cycle and its associated phase of testing (Mathur and Malik, 2010, Akbar et al., 2017). The advanced V-Model method is described by showing the relationships between development activities, test activities, and maintenance activities (Mathur and Malik, 2010, Yadav, 2012). Figure 9 illustrates the advanced V-Model method.

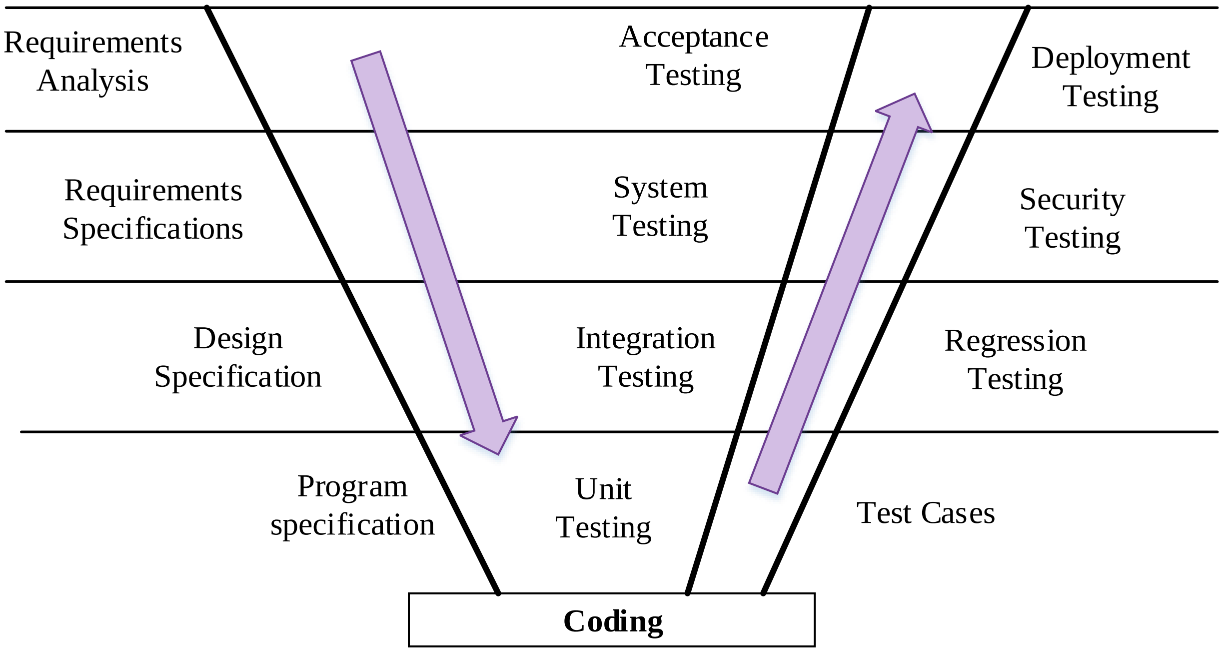


Figure 9. Advanced V-Model provided by Mathue and Malik (2010)

Table 10 includes a list of categories, introduced in Figure 9, and the associated definitions.

Table 10. Advanced V-Model Categories and definitions provided by (Mathur and Malik, 2010)

Testing Categories	Definition
Unit Testing	Focuses on each component individually for component success functionality. Makes use of white box testing techniques.
Integration Testing	Addresses assembling and integration of components to form the complete software package. Makes use of black box testing techniques.

Testing Categories	Definition
System Testing	Testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements.
Acceptance Testing	Testing to verify whether it meets the customer's specified requirements.
Maintenance categories	
Test Cases	A set of conditions or variables under which a tester will determine whether an application or software system meets its specification at the unit level.
Regression Testing	A Technique that detects spurious errors caused by software modification or corrections.
Security Testing	Evaluation of the presence and functioning of the application security to ensure integrity and confidentiality of the data.
Deployment Testing	The testing and/or simulation of system assets in the physical and operational environment in which the system is expected to perform.

Shakirat et al.(2023) makes use of the V-Model method to develop a Pest Informatics System (PIS) for integrated pest management in crop farming (Shakirat et al., 2023). Wacas (2023) developed smart greenhouse system that automatically regulates temperature, humidity, lighting, irrigation, and CO2 levels using the V-Model method (Wacas, 2023). These two case studies provide indication the usefulness of the V-Model method in developing technologies for agricultural processes.

The V-model method provides a step-by-step approach to developing a technological system. It incorporates several phases for effective design, development, and deployment which is useful for objectives 4, 5, and 6. All three objectives relate to the development of the final artefact of the study being a prototype system.

2.4.1.1. White box and black box testing

Nidhra et al. (2012) describes white box testing as structural testing. This method of testing involves designing test cases based on the information derived from source code. White box testing is concerned with the internal mechanisms of a system (Nidhra and Dondeti, 2012). The developer is usually the tester and writes test cases by executing methods with specified parameters. A testing type provided by Nidhra et al. (2012) is unit testing which involves testing individual units separately. The units can be small units of codes, or no longer than a class. Several strategies for unit testing are included in Table 11 (GeeksforGeeks, 2023d).

Table 11. Unit testing strategies provided by (GeeksforGeeks, 2023d)

Testing strategy	Description

Logic checks	Verification of expected system calculations and paths followed.
Boundary checks	Testing of invalid, extreme case, and typical inputs.
Error handling	Tests whether system handles errors properly
Object-oriented checks	Tests whether objects that the code intends to modify, does so correctly.

Black box testing is described as functional testing and focuses solely on the outputs generated from selected inputs and execution conditions (Nidhra and Dondeti, 2012, GeeksforGeeks, 2023a). Integration and regression testing is a method for black box testing. involves checking how the software behaves from the user's perspective.

Regression testing involves retesting the previously tested functionalities to verify recent code changes have affected the existing features (Nidhra and Dondeti, 2012, GeeksforGeeks, 2023c). GeeksforGeeks (2023c) provides several regression testing techniques such as selecting higher priority test cases which involves selecting test cases with the highest priorities according to the purpose of the system.

Integration testing involves the process of testing the interface between two software units and takes place after unit testing (GeeksforGeeks, 2023b, Nidhra and Dondeti, 2012). Integration testing is used to verify that individual system components work together correctly as a whole. GeeksforGeeks (2023b) provides several approaches for integration testing such as Big-Bang integration testing. Big-Bang integration testing involves verifying the functionality of a system after all components and functionalities of the system have been built. The goal of this approach is to verify the overall functionality of the system and identify any integration problems that arise. This approach is described as ideal for small systems (GeeksforGeeks, 2023b).

White box and black box testing fall part of the V-model method and contributes to efficient development of a final artefact. The testing methods align specifically with objective 6 with the purpose of developing a system without fault.

2.4.2. System Architecture

System architecture is a method used to define the structure, behaviour, and other relevant characteristics of a system. Moreover, it is defined as the formal description and representation of a system, such that it supports the reasoning behind the structure and behaviours of the system (Madni and Sievers, 2018).

There are four layers to be considered when designing a system architecture for information management technologies which are the sensing layer, networking layer, service layer, and interface layer (Da Xu et al., 2014). Table 12 provides the descriptions for each layer.

Table 12. Layer description provided by (Da Xu et al., 2014)

Layer	Description
Sensing layer	This layer integrates with existing hardware i.e., sensors, to sense/control the physical world and acquire data.
Networking layer	This layer provides networking support and data transfer over a wireless or wired network.
Service layer	This layer provides services to satisfy user needs and relies on the middleware technologies e.g., data management.
Interface layer	This layer provides user interaction methods and other applications.

The system architectural design has been used to develop an IoT based tracking and tracing platform for the prepackaged food supply chain (Li et al., 2017). In this case study five layers were used following a service-oriented architecture. The five layers are perception layer, data layer, service layer, application layer, and users layer. Table 13 includes the list of five layers with their associated descriptions.

Table 13. Service-oriented architecture layers and descriptions provided by (Li et al., 2017)

Layer	Description
Perception layer	This layer refers to the physical assets and corresponding devices.
Data layer	This layer stores the collected data from the perception layer and execution data from the other layers. There are three parts namely object data, event data, and XML Schema.
Service layer	This layer provides services in data analytics, data management, and system management.
Application layer	This layer includes the applications built upon the services provided by the service layer.
User layer	This layer includes the system stakeholders

System architecture has been used for visualising food traceability systems as a visualisation approach in the system design process to identify inefficiencies (Islam et al., 2021). The different layers can be considered to build capability for IoT for the future.

System Architecture assists with the designing of a system and aligns with objective 5. Moreover, identifying the several layers conjoins with V-model method ensuring a more effective approach to design and development of a system.

2.5.1. Precision farming

Precision agriculture can be defined as “the application of modern information technologies to provide, process and analyse multisource data of high spatial temporal resolution for decision making and operations in the management of crop production.” (Fuglie, 2016). The International Society for Precision Agriculture (ISPA) defines precision agriculture as “a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.” (ISPA, 2021). Mizik (2023) argues that the primary components of a precision farming system should oversee variability. Moreover, precision farming technology should be viewed as information-based and decision-focused.

Although the ISPA (2021) definition provides a more encompassing definition than Fuglie (2016), both definitions speak to the purpose of precision agriculture as using data and data technologies to support decision making. Moreover, these technologies are used to improve operational activities for a variety of reasons. Mizik contributes to this by stating that precision farming systems assist with variability oversight. This suggests that having information-based and decision-focused technologies can assist with variability oversight and contributes to informed management decisions.

For the study, precision farming and precision agriculture are viewed as having the same meaning and definitions. This literature relates to two objectives (O5, O6) of the study which speak to designing, developing, and testing an administrative technology that captures, processes, and views data relevant to farming.

2.5.2. Pig farming administration

Administration consists of five functions with the purpose of ensuring best practice (Madugu, 2018). A significant aspect of QMSs is health management on a pig farm, as a combination of QMSs may help to optimise service processes for the improvement of farm and health management as well as the final product. However, a challenge that farmers face is the coordination of various QMSs and certifications, as each QMS is certified and audited separately (Trienekens and Wognum, 2013).

Recently, QMS solutions incorporated traceability which resulted in an abundance of animal ear tagging and paperwork. The traceability motive aims at monitoring animal movement and the controlling of exotic disease outbreaks (Gregory and Grandin, 2007). Trienekens and Wognum (2013) adds to this by stating that traceability is a key capability for the pig supply chain to find the origin of problems to mitigate hazardous products more quickly.

For the study, objectives O2 and O3 aims to investigate the current administration process of a pig farm and seeks to accumulate quality standards relevant to the current administration process.

2.6. Chapter Summary

This chapter set out to investigate literature on research methods, contextualisation methods, and system design methods used in for the research. Research methods the chapter discusses include the Critical Artefact Methodology, Systematic Literature Review, Work Study, Time Study, Surveys, and Focus Groups. Contextualisation methods include literature on Porter's value chain, Value Stream Mapping, Business Process Mapping Notation, and the Pressure-state-response model. System design methods discuss literature on the Advanced V-Model and System architecture. A discussion on the relevance of the literature to the study and its alignment with the objectives are provided in each section. Literature on the research methodology largely align with objectives 1, 2, and 3 of the study. Literature on Contextualisation methods align with objective 2, and System design methods align with objectives 4,5, and 6. Lastly, the chapter provides literature on precision farming and pig farming administration contributing to the theme of the study.

CHAPTER 3
RESEARCH DESIGN

This chapter introduces the research methodology that is followed. Further elaboration of additional methods used in accordance with the overarching research methodology are provided.

3.1. Overarching research design

The critical artefact methodology (CAM) is used to conduct the research. CAM incorporates the interaction between stakeholders and designer to design and develop artefacts (Bowen, 2009). As this research will involve the design and development of a deliverable used by stakeholders, CAM is used as the research methodology. Figure 10 illustrates that as the stakeholder's understanding and designer's understanding overlap, an innovative artefact that complies with a set of requirements is developed according to relevant stakeholder needs.

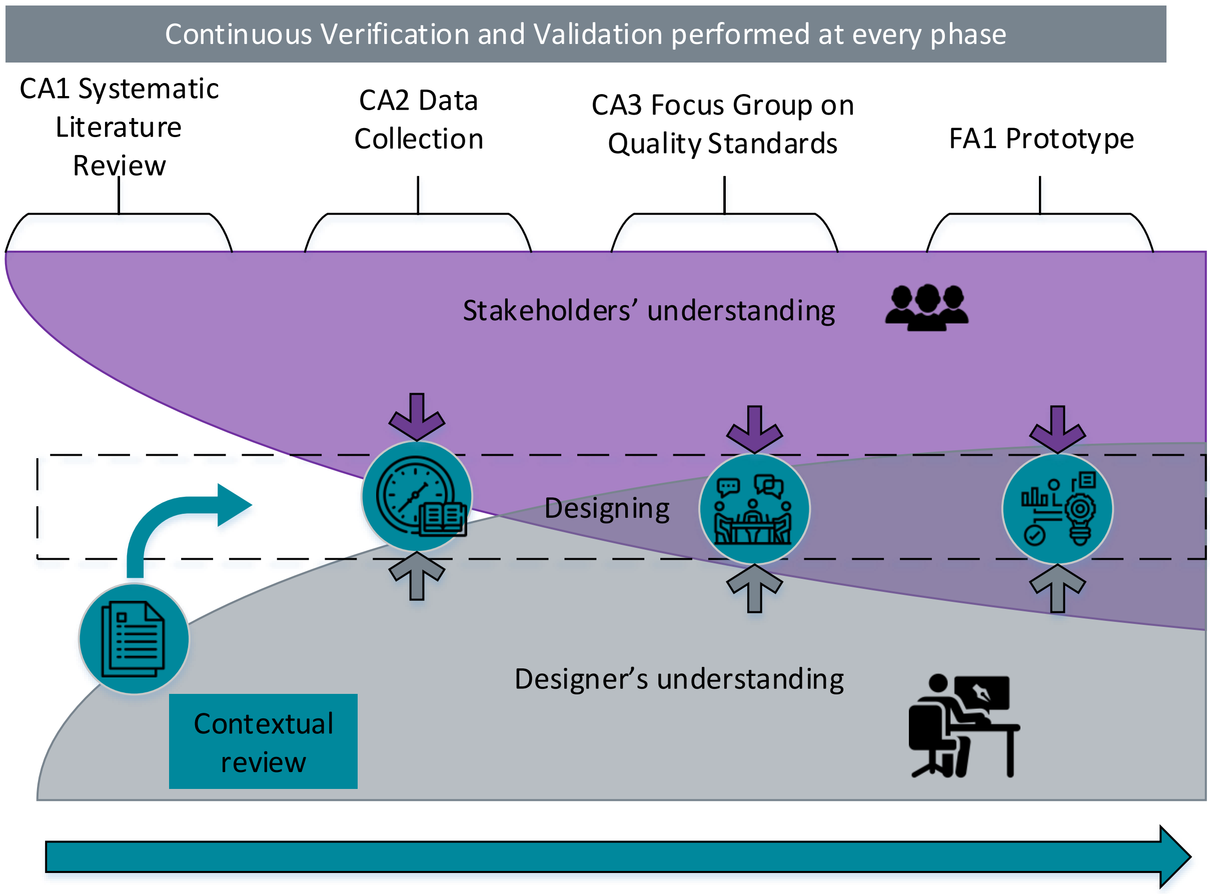


Figure 10. Critical Artefact Methodology adapted from Bowen (2009)

Three critical artefacts are conducted and verified in this research which are elaborated in Sections 2-4. In addition, a final artefact is developed for implementation purposes. Further explanation on the design and development methodology of the final artefact can be found in Section 8. Table 14 illustrates the chapter location of critical artefacts and the final artefact.

Table 14. Chapter location of Critical artefacts (CA) and the Final artefact (FA)

Chapter	Chapter title
Chapter 1	Introduction
Chapter 2	Literature Study
Chapter 3	Research Design
Chapter 4	SLR paper (CA1)
Chapter 5	Current State analysis (CA2)
Chapter 6	Quality Standards Analysis (CA3)
Chapter 7	System Design (FA)
Chapter 8	Verification and Validation
Chapter 9	Conclusion

3.2. SLR Method (CA1)

A systematic literature review (SLR) is conducted to investigate studies on precision farming applied in the swine industry. This was achieved by searching selected databases with predetermined keywords.

This allows for the summarising, analysing, and synthesis of literature found to identify research gaps which can be explored. The SLR has explored the literature research for method of precision farming, purpose of precision farming, and results of precision farming in said industry.

Table 15 illustrates the method that is followed to conduct the SLR (Xiao et al., 2019):

Table 15. Steps on conducting a systematic literature review provided by Xiao and Watson (2019)

Steps	Objective
Step 1: Formulate the problem	Develop specific research questions to guide the literature review process.
Step 2: Develop and validate the review protocol	Create a pre-set plan that specifies the methods used in conducting the literature review.
Step 3: Search the literature	Search selected electronic databases with predetermined keywords. In addition, optionally do a backwards and forward's search.
Step 4: Screen for inclusion	Screen abstracts, titles and keywords based on pre-determined keywords and set criteria.

Step 5: Assess quality	Assess the full text for quality work.
Step 6: Extract data	Extract findings relevant to the research.
Step 7: Analyse and synthesize data	Organise extracted data for analysis and formulate conclusions.
Step 8: Report findings	Report findings in a research paper.

The reliability of the SLR results will be verified by including it in a manuscript that is submitted to the ISEM2023 conference. The submitted manuscript undergoes a double-blind review by two impartial researchers for it to be accepted in the conference proceedings.

The SLR aligns with objective 1 which sets out to perform a systematic literature review (SLR) to identify current uses of Internet of Things systems in agriculture. Furthermore, SLR findings will provide insight into technological contributions to farm operations, and will be considered for the investigation of long administration times.

3.3. Current State Analysis (CA2)

For the Current State Analysis, the current state of administrative process will be investigated and data collection will be performed in the form of a Time Study (Freivalds and Niebel, 2009). A continuous timing method will be followed while using the Clockify Mobile App during the time study whilst making observations of the current administrative process followed. A non-disclosure agreement or informed consent form will be communicated to the company to acquire permission for data collection. In addition, the participant in the time study will receive information of the purpose of the research and an informed consent by the researcher. Anonymity of the participant will be held throughout data collection, analysis, and reporting.

Figure 11 illustrates the Time Study Form template that will be used for the recording of times.

Time Study Observation Form	Study No.:	Date:	Page:
	Operation:	Operator:	Observer:

Element No. and Description																									
Note	Cycle	R	W	OT	NT	R	W	OT	NT	R	W	OT	NT	R	W	OT	NT	R	W	OT	NT	R	W	OT	NT
	1																								
	2																								
	3																								
	4																								
	5																								
	6																								
	7																								
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	9																								
	10																								
	11																								
	12																								
	13																								
	14																								
	15																								
	16																								
	17																								
	18																								

Summary						
Total OT						
Rating						
Total NT						
No. Observations						
Average NT						
% Allowance						
Elemental Std.Time						
No. Occurances						
Standard Time						
			Total Standard Time (sum standard time for all elements):			

Foreign Elements					Time Check		Allowance Summary	
Sym	W1	W2	OT	Description	Finishing Time		Personal Needs	
A					Starting Time		Basic Fatigue	
B					Elapsed Time		Variable Fatigue	
C					TEBS		Special	
D					TEAF		Total Allowance %	
E					Total Check Time		Remarks:	
F					Effective Time			
G					Ineffective Time			
Rating Check					Total Recording Time			
Synthetic Time				%	Unaccounted Time			
Observed Time					Recording Error %			

Figure 11. Time Study Form adapted from Freivalds and Niebel (2009)

Data collection will be verified via a survey shared with observed operators. The Time study technique aligns with objective 2 as it provides insight into the current state of the administrative process from a time point of view. Furthermore, the time studies will reveal the amount of time spent on administration by the piggery contributing to the problem statement stating that the piggery is experiencing long administration processing times.

3.4. Quality Standards (CA3)

Quality management systems specify production standards, whereas certification indicates the degree of conformance with the standards. South African Pork Producers Organisation has its own certification to maintain best practices throughout the pork chain called Pork 360 (Pork360, 2023). Pork 360 products are exclusively available on the Food Lover's market and Winelands Pork in the Western Cape. Furthermore, to be involved in the pork industry (WYNGAARDT, 2023), farmers will have to abide by the regulations stipulated in:

- Agricultural Product Standards Act 119 of 1990
- Foodstuffs, cosmetics and disinfectants Act 54 of 1972
- Meat Safety Act 40 of 2000

Failing to comply with these laws, which are checked via a yearly audit, may result in the penalty of a fine or imprisonment. Furthermore, failing to comply with Pork 360 standards may result in losing certification and associated benefits (Online South Africa, 2023).

A focus group will be scheduled where the subject of discussion will be the quality standards that the farm has to uphold. In addition to this, a prioritisation of discussed quality standards will be performed by the participants themselves. The steps illustrated in Table 16 will be followed (Powell and Single, 1996):

Table 16. Steps to conduct a Focus Group according to Powell and Single (1996)

Step	Description of step
Step 1: Identify and formulate discussion points for research topic	Compile list of quality standards relevant to the farm and formulate discussion questions.
Step 2: Identify participants to invite to the focus group	Invite the owner of the farm, the farm manager, the farrowing manager, the weaning manager, the grower manager, and the breeding manager of the farm.
Step 3: Organise a focus group session	Organise a 30–60 minute focus group session. More sessions can be organised if all questions have not been addressed.
Step 4: Decide on a neutral place to meet	The meeting will be held in a boardroom.
Step 5: Clearly state the role of the moderator	Develop an informed consent document and share with participants. Facilitate the discussion, take notes and make recordings.

The conducted focus group will serve as a method of verification and validation which is further discussed in Section 8.4.

3.4.1. Research Approach

In this research, quality standards will be explored by using qualitative design. This enables the researcher to collect and analyse data from participants based on their individual experiences on specific phenomenon (Levitt et al., 2018). Moreover, enabling the identification of informed patterns (Levitt et al., 2018).

A critical phenomenology paradigm or epistemological perspective will be used throughout the study. Critical phenomenology provides a platform to explore culturally defined meanings that are attached to our perceptions (Chism et al., 2008). Phenomenology primarily strives to describe the critical parts of a phenomenon, thereby finding the authentic, cornerstone of experiences (Chism et al., 2008).

3.4.2. Research strategy

This research will utilise the expert knowledge of a panel, to explore and understand the quality standards by means of a focus group as part of CA3. The following questions will be asked:

1. What pork production Quality Standards are you aware of?
2. What would you say is the three most important standards to comply with?
3. On a scale of 1 to 5, with 1 being strenuous and 5 being effortless, how difficult is it for you to comply with these standards, and why?
4. Does compliance require large amounts of paperwork, if so, why?
5. What does the administration look like for compliance?
6. On average, what percentage of your time is spent on administration?

The focus group technique aligns with objective 3 seeking to accumulate quality standards provided by partners in the value stream. Furthermore, the focus group will contribute to the understanding quality compliance as stipulated in the problem statement.

3.4.3. Research setting

Data will be collected from Pork360 quality standard experts throughout South Africa that will be invited as participants in the study. These experts will be identified using snowball sampling and will be invited to a focus group wherein the experts will identify and discuss the Pork360 quality standards. Professional conduct will be exercised by the researcher while facilitating the focus group. Thereafter, the data will be analysed via applied thematic analysis and used to for understanding of concepts.

3.4.3.1. Entrée and establishing researcher roles

Before initiating the focus group, the researcher will have obtained permission from the participants. Moreover, the researcher will have obtained permission from the NWU-ENG-REC with ethics number NWU-00222-23-A3. The researcher will request experts to participate in the research by sharing an invitation. It is imperative to note that the poster invitation will provide information about the basis of the research and the roles of prospective participants. Furthermore, the researcher and the poster will inform prospective participants that their participation is voluntary and can withdraw at any time from the research. The researcher will distribute informed consent forms to participants. Participants will be informed that no remuneration nor any direct benefits from the research will be provided to them.

The researcher will fulfil several roles during this research. The researcher will personally facilitate the focus group. Additionally, the researcher, in collaboration with supervisors, will develop the focus group questions. Upon initiating the focus group, the researcher will explain the purpose of the research to all participants in a responsive manner. Moreover, analysing and interpreting collected data will be done by the researcher.

3.4.3.2. Sampling

Participants are selected for predetermined reasons resulting in the research utilising non-probability and purposive sampling (De Vos et al., 2011a). Snowball sampling is considered as the appropriate non-probability technique, which implies that the researcher will rely on experts to recommend other experts (De Vos et al., 2011a). The criteria for selecting participants for the focus group include:

- Must have awareness of SAPPO’s Pork 360 certification.
- Participates in administrative processes related to SAPPO’s Pork 360 certification
- Consultants or employees of pig farms that work to comply with SAPPO’s Pork 360 certification.

3.4.3.3. Data collection methods

A focus group with experts will be conducted for data collection by the researcher. Focus groups provide the appropriate platform for data collection in this research due to enabling the researcher to gain an understanding of a participants expertise on a subject (De Vos et al., 2011a). Discussions held during the focus group will be recorded using a voice recorder and thereafter transcribed.

The focus group took place in a private location (i.e., Boardroom or closed office), to ensure participants’ freedom of expression. Before initiating the focus group, the researcher will leave the room and allow participants to sign an informed consent form. Once this is done, the researcher will re-enter the room and begin the 30-60-minute meeting.

3.4.3.4. Recording of data

The focus group will be recorded using a voice recorder, upon permission granted to the researcher by the participants. Thereafter, the recordings will be uploaded to a cloud storage platform and a computer for secure storage. It is imperative to note that the storage of collected data will be password-protected for ethical reasons. This data will then be transcribed, transcripts will also be stored on a computer and cloud storage platforms. All collected raw data will be stored for five years after the completion of the research. This is in accordance with record management policies provided by ENG-REC. After five years the collected raw data will be permanently deleted.

3.4.3.5. Data analysis

This research will utilise the four-phase cycle for data interpretation as described by Creswell and Creswell (2017), the phases being detailed as follows:

Phase 1: Organise and prepare the data for analysis: The researcher will send an invitation to selected focus group participants. During the focus group discussion, the researcher will collect all the focus group data by voice recordings. The researcher will make use of Microsoft Team's transcribing functionality and refine its transcript using the voice recordings.

Phase 2: Read and/or look at all the data: The researcher will review all the transcripts and attempt understanding the meaning of what was discussed by using a coding process. Codes will be created in Atlas.ti web and tagged to sections of the transcript associated with the code name. Moreover, Atlas.ti provides sentiment analysis functionality which will also be incorporated for data analysis purposes.

Phase 3: Start coding all of the data: The researcher will conduct the coding process, that is, to break down data into relevant groups of information. Sections of the transcript tagged with the relevant codes are then grouped for analysis purposes. These sections are also exported from Atlas.ti to Microsoft excel for visualization or for additional data processing.

Phase 4: Generate descriptions and themes: After assigning codes to the data, the researcher will group the relevant data together to formulate patterns. Formulated patterns will be interpreted to develop conclusions. The researcher provides meaning to the research by converging themes to develop findings. The researcher will utilise Atlas.ti software for data analysis phases. The Sankey diagram provided by the Atlas.ti software will be utilized for theme convergence analysis. Moreover, a code co-occurrence table will be developed in Microsoft Excel show casing code occurrence with identified sentiments.

3.4.3.6. Strategies to ensure data quality and integrity

Multiple strategies will be implemented by the researcher to ensure data quality and integrity throughout the research process. In order to achieve this, the researcher will be guided by the validity and reliability suggested by Creswell and Creswell (2017).

Creswell and Creswell (2017) suggest multiple validity procedures to be utilised throughout the research. Triangulation will be considered to examine the data and to build coherent justification for identified themes. The research will be presented by rich and thick descriptions to convey the connotations and meanings of the shared experiences. Additionally, negative or discrepant information that runs against the identified themes will be presented by the researcher (Creswell and Creswell, 2017, Brink, 1993).

Creswell and Creswell (2017) states that qualitative reliability is essential for research. In order to achieve this, the researcher will review the transcripts to ensure that the transcripts do not contain any errors. Moreover, all codes developed will be tracked consistently used throughout the study (Creswell and Creswell, 2017).

3.4.3.7. Reporting of data

After data analysis, identified themes and patterns will be displayed in tables and figures. This is to convey theme trends and convergences which will be documented in Chapter 6.

3.5. Verification and validation methods

The Oxford Dictionary defines verification as the act of showing or checking that something is true or accurate, and validation as the act of proving that something is true or correct (Press, 2024). The CAM contains continuous verification and validation. In this study this occurs at each critical artefact in various ways.

The systematic literature review (SLR) will be submitted into a conference proceeding where it will undergo a double-blind review process. The SLR that undergoes a double-blind review process will serve as an effort for verification and validation. A survey will be communicated to time study participants. Survey results will be analysed and discussed which will serve as an effort for verification and validation purposes. The focus group will undergo a rigorous discussion on the procedure followed. Moreover, reference to the analysis of fundings will be provided to provide evidence of triangulation and reflexivity for verification and validation purposes.

3.6. Prototype Design (FA1)

The research will make use of an advanced V-model as a method for design and development of the final deliverable. The advanced V-Model is a software development process which demonstrates the relationship between each phase of the development lifecycle and the associated testing phase (Mathur and Malik, 2010). The research deliverable aims to develop a technological system as well as a means to determine design requirements for such system. Therefore, the advanced V-Model deems most appropriate as it includes requirements and specification phases. Moreover, the deliverable will interact with stakeholders and may need testing in several phases (Mathur and Malik, 2010). Figure 12 illustrates the advanced V-Model.

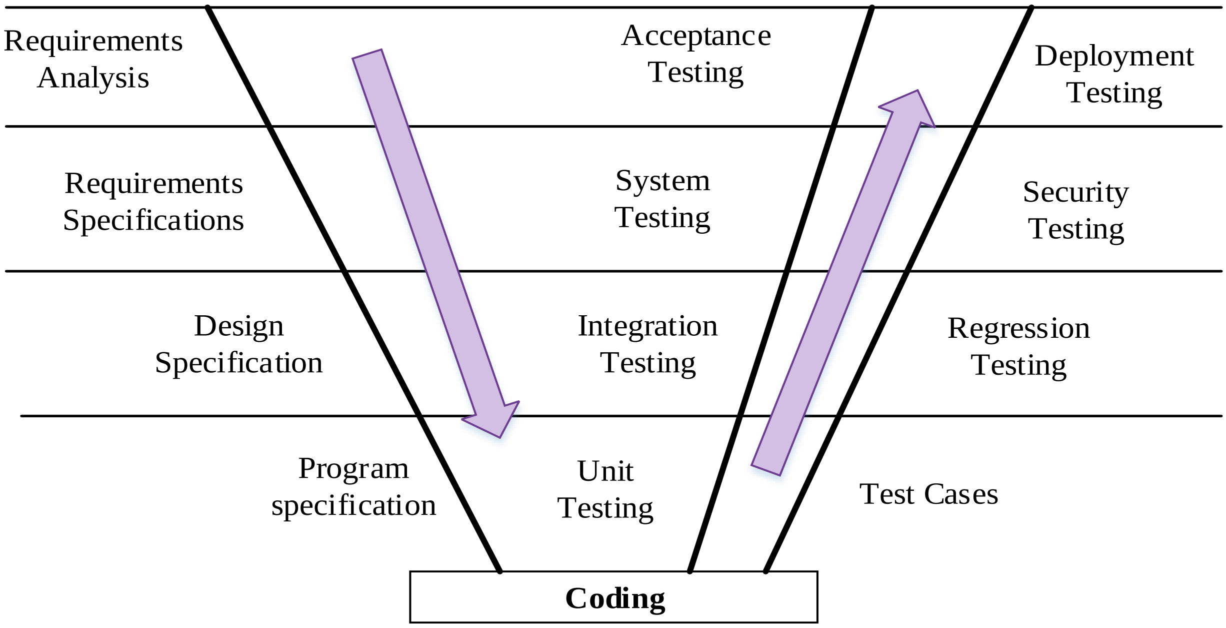

Figure 12. Advanced V-Model adapted from Advancements in the V-Model (Mathur and Malik, 2010)

Requirements specifications, or system requirements will be identified from the critical artefacts discussed in sections 3.3, 3.4, and 3.5. Identified system requirements will be used to determine design specifications for the development of a prototype design.

The Advanced V-model method provides a framework that facilitates objectives 4 to 6 (O4-O6). The technique does this by requiring design specifications (O4), design and development of a system (O5), and testing the developed system (O6). Furthermore, the method aims to produce a deliverable that is deployable, aligning with the CAM which aims to make use of critical artefacts for the development of an innovative deliverable.

3.7. Ethics

The research aims to conduct an ethical research study. Ethical guidelines included in Table 17 will be followed.

Table 17. Ethical principles provided by (Roestenburg et al., 2021)

Ethical principle	Description
Non-Maleficence	The safety of participants during the research will be ensured. The focus group will be conducted in a safe private venue such as a boardroom.

Ethical principle	Description
Beneficence	Focus group discussions will attempt to bring benefit to the participants by bringing awareness of what the quality standards are and what fellow participants think of these standards. Furthermore, the research will attempt to contribute a Systematic Literature Review to benefit the scientific community by revealing research gaps and opportunity for further research.
Voluntary participation	The research will include voluntary participants without coercion. No information from or about the participant(s) will be used without their unforced agreement.
Informed consent	Prospective participants will be provided with an informed consent form which includes descriptions of the research i.e., goal of the research, duration of involvement etc.
Transparency	Deceptive practices, such as withholding of information and misleading participants, will not be exercised to maintain transparency.
Privacy, anonymity and confidentiality	The research will respect the privacy of the participants by ensuring that no information is leaked at the venue of use. The anonymity of participants will be maintained by not asking for personal information. Furthermore, confidential information shared by participants will not be published and captured data will be password-protected.
Compensation	Participants will not be offered any compensation for voluntarily partaking in the research.
Debriefing	The focus group discussion will cover topics that are of minimal risk therefore participants will not require debriefing sessions.
Actions and competence of research	Competency, honesty and adequacy of skill will be ensured by the researcher to carry out the research.
Cooperation with contributors and sponsors	Confidentiality agreements will be signed by sponsors and contributors wherein their roles will be clearly outlined.
Publications of findings	Research findings will be published in a master's thesis.
Professional code of ethics	Code of ethics provided by the NWU and ECSA Engineering Professions Act 46 of 2000 will be adhered to.

Ethical principle	Description
Ethics committees	The researcher will apply for permission from the NWU-ENG-REC

3.8. Chapter Summary

This chapter sought to discuss the research design for the dissertation by providing a plan that will guide the research process. The chapter introduces the Critical Artefact Methodology (CAM) as its research methodology, followed by discussing the approach the research plans to take for each attribute of the CAM. The attributes of the CAM the chapter discusses is the systematic literature review (CA1), the current state analysis (CA2), the quality standards (CA3), and the Prototype Design (FA1). Moreover, the quality standards section includes further elaboration on the planned approach and strategy, and the expected research setting. The chapter also provides discussions on the approach the research will take for verification and validation of the three critical artefacts. The chapter discusses the planned approach for developing the Prototype Design (FA1). Lastly, the chapter discusses ethical principles that will be taken into consideration for the duration of the research.

CHAPTER 4 SYSTEMATIC LITERATURE REVIEW

This chapter includes the first critical artefact, as described in Chapter 3, which is a conducted Systematic Literature Review (SLR). The conducted SLR was submitted, accepted and published in the ISEM2023 conference proceedings (DOI: 10.52202/072261-0046).

EXPLORING THE FUTURE OF PRECISION FARMING: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The primary sector includes the agricultural, forestry, and fishing industries. For South Africa's economy, these industries are considered key sectors as StatsSA indicates a joint increase of 15.9% through the 3rd and 4th Quarters of 2022. In a similar vein, Statista explained that the market value of precision farming is expected to grow from approximately 7 billion to 14.5 billion U.S. dollars from 2021 to 2027. Despite the success of precision farming, there is limited research on farm management support systems in Sub-Saharan Africa, suggesting a major research gap. Therefore, this paper aims to conduct a systematic literature review (SLR) to investigate studies that pertain to precision agriculture applied in the swine industry. This research showcases themes such as the affiliated countries of identified studies, the distribution of studies, technologies and strategies used by researchers, and experienced enablers and barriers of implemented precision agriculture solutions.

Keywords: Precision farming, Swine industry, systematic literature review

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1 INTRODUCTION

The primary sector includes the agricultural, forestry, and fishing industries that involve the production and trade of farmed crops, livestock, fish or food, and wood. For South Africa's economy, these industries are considered as key sectors as there was a joint increase of 15.9% through the 3rd and 4th Quarters of 2022 [1, 2]. In a similar vein, Statista explained that the market value of precision farming is expected to grow from approximately 7 billion to 14.5 billion U.S. dollars from 2021 to 2027 [3].

As agriculture has evolved over the past 50 years, recent use of techniques such as precision agriculture has emerged. Fuglie [4] defines precision agriculture as "the application of modern information technologies to provide, process and analyse multisource data of high spatial temporal resolution for decision making and operations in the management of crop production." This has been noted in various industries, which include agriculture, forestry, and fishing. In South Africa, the aforementioned industries planned to make use of precision agriculture. Buchana et al., [5] shows that, between 2016-2018, 52.9% of the agriculture industry, 18.3% of the forestry industry and 0% of the fishery industry makes use of precision agriculture.

Agriculture is considered as the largest industry in South Africa compared to forestry, and fishery industries. In 2017, animals and animal products made up 52% of the total South African agricultural income of which pigs were the third most sold animals [6].

Despite the success of precision agriculture, there is limited research on farm livestock management support systems in Sub-Saharan Africa, suggesting a major research gap [7]. This suggestion motivates the research to cast a larger initial focus by expanding to a global search before contextualizing the findings to Sub-Saharan Africa. Therefore, the aim of this paper is to conduct a systematic literature review (SLR) to investigate studies that pertain to precision agriculture applied in the swine industry.

This paper comprises of an overview on the methodology (section 2), followed by the results (found in Appendix A), findings (Section 3), and conclusions and recommendations (Section 4).

2 Research Method

For this study a systematic literature review (SLR) is conducted [8]. Furthermore, this took the form of a scoping SLR, to allow for the investigation of available literature to scope and understand the current state of precision agriculture applied in the swine industry.

The sequence and grouping of the steps into research phases are captured in Figure 1, while the detail of each step is as follows:

- Step 1: Develop a research purpose and/or objective – Clearly state the goal of the SLR.
- Step 2: Develop research protocol – Create a research protocol that includes the purpose, inclusion criteria, exclusion criteria, databases, keywords and quality assessment criteria.
- Step 3: Establish relevance criteria – State the reasoning for if a resource is relevant to this study.
- Step 4: Search and retrieve the literature – Conduct searches on applicable scientific databases to find literature.
- Step 5: Selection of studies – Use the inclusion and exclusion criteria to select studies.
- Step 6: Quality assessment for relevant studies – Assess the quality of each paper.
- Step 7: Data extraction – Extract relevant information from the papers.
- Step 8: Analysis and synthesis of findings – Analyse and synthesise the data from the papers in order to find themes and patterns.
- Step 9: Report – Report the review in detailed results.
- Step 10: Dissemination – Publish the SLR

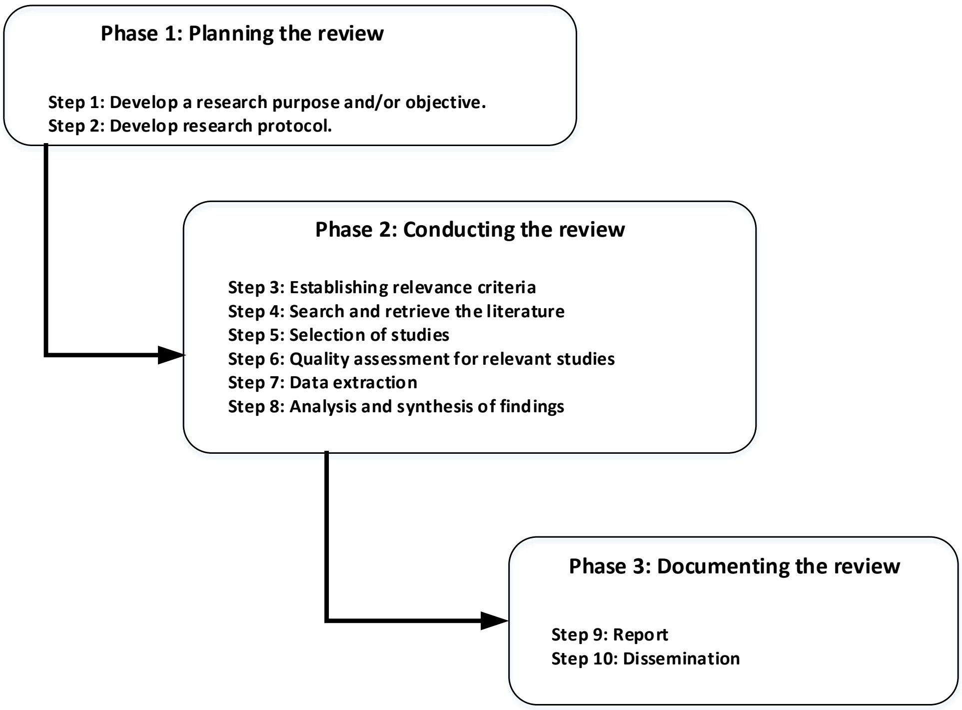

Figure 1: Research method for SLR (Adapted from(Albliwi et al., 2014))

2.1 Step 1: Develop a research purpose

The purpose of this research is to investigate studies on precision agriculture applied in the swine industry.

2.2 Step 2: Develop research protocol

The research protocol was developed and is shown in Table 1. The protocol breaks down the purpose, criteria, databases, keywords and quality assessment criteria.

Table 1. Research protocol

Purpose of the Study	To investigate studies on precision agriculture applied in the swine industry.
Inclusion Criteria	• Literature that contains "Precision", "farming", "agriculture", "Pig". • Time period for searched literature 2019-2023 • The explanation of techniques, tools, method, concepts in precision farming or agriculture is provided. • Information and communication management systems (ICM)
Exclusion Criteria	• Literature referring to other types farming. • Precision technology used in industries other than agriculture. • Non-English literature • Literature that relates to the advancement of technology
Search Databases	• Science Direct • Scopus • IEEE Explore • Web of Science • Emerald Insight Journals
Keywords	"Precision farming" OR "Precision agriculture" AND "Pig"
Quality assessment criteria	• All duplicate literature must be removed. • Negative results/findings are presented. • The conclusions are reliable and relate to the purpose of the study. • The aim or purpose of the study is clearly stated. • The overall methodology used is described in such a manner that the study can be replicated.

2.3 Step 3: Establish relevance criteria

The following relevance criteria was developed in order to screen studies for inclusion and exclusion:

- Inclusion criteria:
  - Literature that contains "Precision", "farming", "agriculture", "Pig".
  - Time period for searched literature 2019-2023
  - The explanation of techniques, tools, method, concepts in precision farming or agriculture is provided.
  - Information and communication management systems (ICM)
- Exclusion criteria:
  - Literature referring to other types farming.
  - Precision technology used in industries other than agriculture.
  - Non-English literature
  - Literature that relates to the advancement of technology

2.4 Step 4: Search and retrieve the literature

The search and retrieval of the literature was done on the databases captured in Table 1. The initial search yielded 431 studies. The search and retrieval process that was followed, is documented in the “Identification” section of Figure 2.

2.5 Step 5: Selection of studies

After reviewing the abstracts and titles of the studies 34 studies were deemed eligible for inclusion using the criteria stated in Table. The outcome of the selection process is captured in the “Screening” and “Eligibility” sections of Figure 2.

2.6 Step 6: Quality assessment for relevant studies

After all duplicates were removed, the quality of the studies were assessed using the assessment criteria outlined in Table 1. Studies were selected for inclusion. A total of 34 studies were finally used. Figure 2 captures step 4 through to 6 of the selection process, as discussed in section 2.4 – 2.6 (refer to Figure 1).

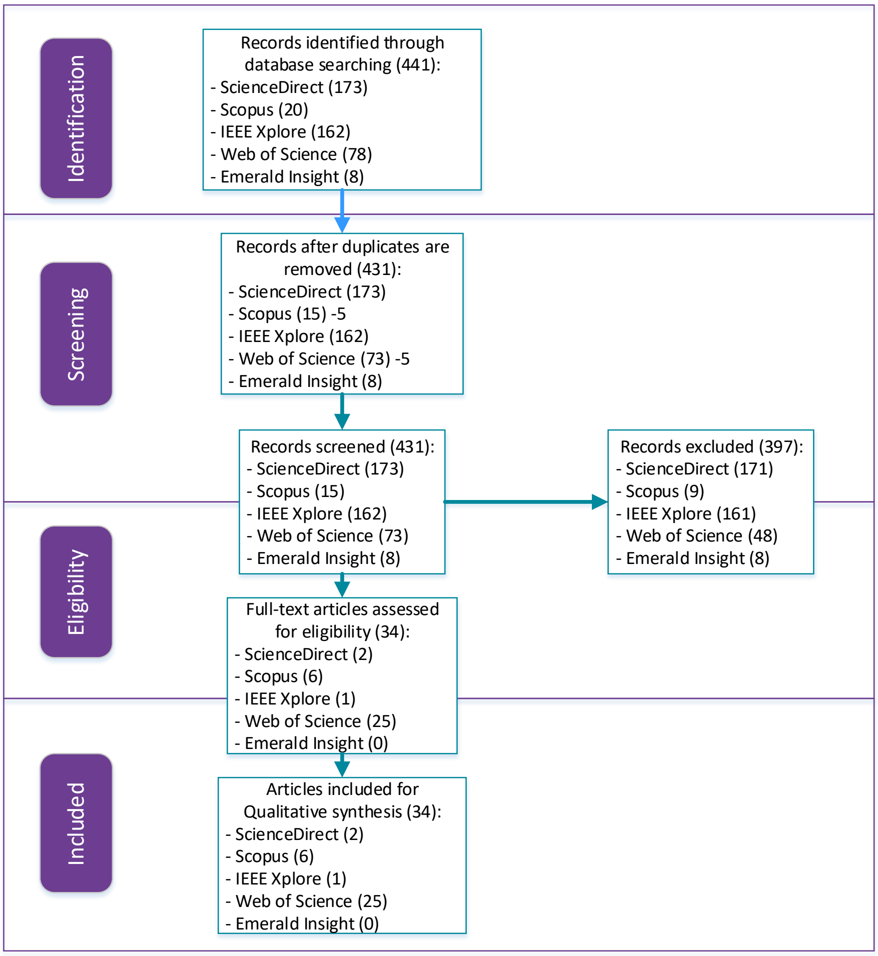

Figure 2. Systematic Literature Review (SLR) selection process chart

3 FINDINGS

The findings (step 7 and 8 in Figure) from the SLR methodology are discussed in the following sub-sections.

3.1 Step 7: Data extraction

After reviewing the literature a table was completed to capture and summarize technologies used, strategies/tools/techniques/methods/concepts, enablers and barriers to the implementation and use of the technology, as well as the core findings of the studies (Refer to Table 1 in Appendix A).

3.2 Step 8: Analysis and synthesis of findings

Using the research protocol described in Table 1, 34 publications were identified and used for analysis and synthesis. Findings include themes such as authors affiliated countries, distribution of publications per year, identified technologies, identified strategies, enablers, and barriers.

3.2.1 Authors affiliated countries of publication

Figure 3 illustrates a map distribution of authors' affiliated countries publications. Per continent, it was found that 10 studies are affiliated to North America, 10 to Europe, 17 to Asia, and 1 to Australia. More specifically, 13 studies are affiliated to China and 7 to the United States of America (USA). This suggests that China and USA are leaders in researching pig

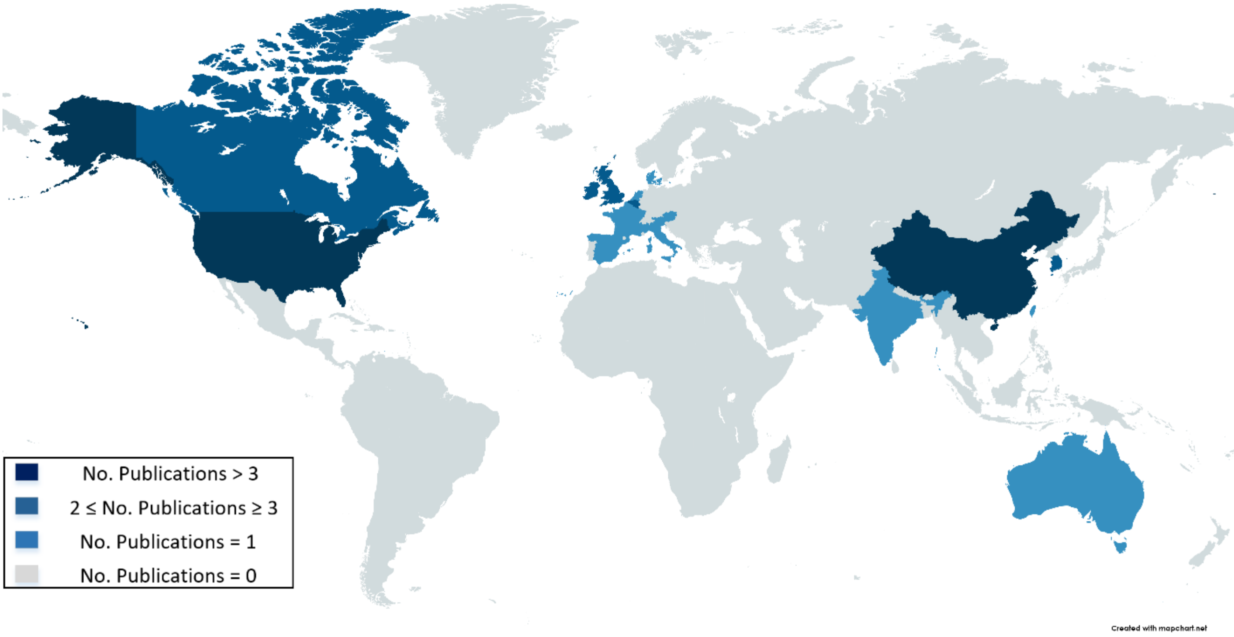

Figure 3. Map distribution of authors' affiliated countries of publication

precision farming. Interestingly, no pig precision farming research has been found that is affiliated with Africa.

China, The European Union, and USA are the top 3 global pork producers in 2022 and 2023 [9], which correlates with the map distribution of published research in pig precision agriculture techniques illustrated in Figure 3. It is important to note that given the research protocol (refer to Table 1), no studies were found within the South African context, specifically.

3.2.1.1 Distribution of Studies

Figure 4 illustrates the distribution of publications per year. Figure 4 illustrates that there is an increase of research in pig precision agriculture under the research protocol deployed the past 5 years. It is important to note that the low number of publications for 2023 is attributable to study being conducted in this year.

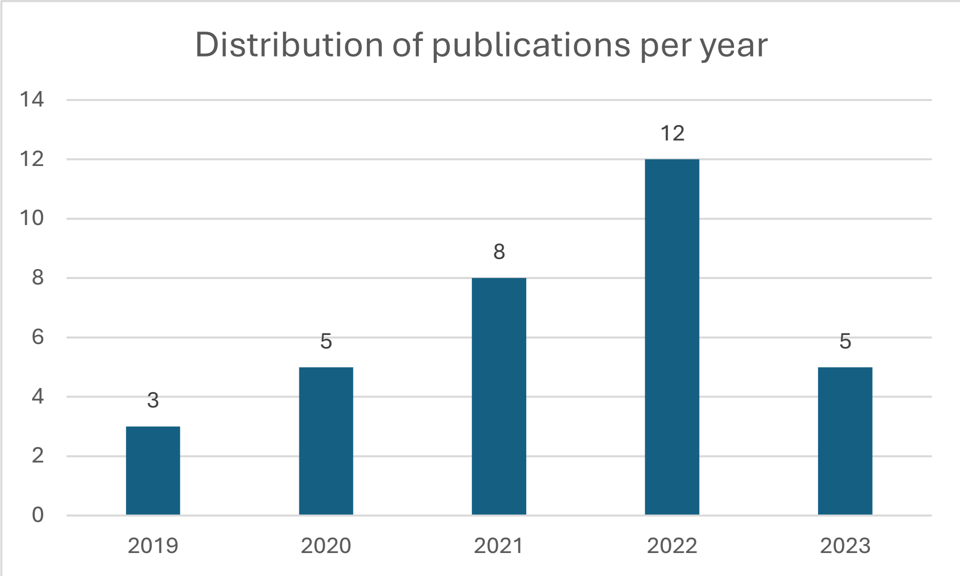

Figure 4. Studies published per year

This increase may suggest that there is an increase of interest in applying precision agriculture in the pig farming industry.

3.2.1.2 Identified Technologies

Table 2 includes brief descriptions of identified technologies. In general, the technologies involve the acquisition, processing, and analysis of data.

Table 2. Brief descriptions of identified technologies

Technologies	Brief Description
Thermal/infrared imagery	Infrared imagery is used to indicate pig growth efficiency, health and to improve pig identification.
Precision feed stations	Precision feed stations are used to indicate pig growth efficiency and to acquire data for relevant feed consumption indicators.
IoT systems	This technology involves the acquisition, management, and visualization of data for effective decision-making purposes.
Artificial Intelligence (AI)	AI is used for data analysis purposes and to improve pig detection.
Computer Vision systems (CVS)	CVS involves remote pig weighing and body weight prediction using camera recordings.

Deep learning software	Deep learning is a machine learning method that improves pig detection by analysing acquired data.
Coding Software	Coding software are platforms for development of data acquisition, and processing i.e., Matlab, RStudio, Visual Studio.
Sensors and Scanners	Several sensors and scanners are found in the SLR and are used to acquire data relevant to the purpose of the study i.e., humidity, temperature, motion, pressure, photoelectricity etc.
Cameras	Similar to sensors, cameras are used to acquire data that pertains to pig behaviour, health, and growth.
Qualtrics	In one of the studies, Qualtrics is used as a survey system,

Table 2 includes cutting edge technologies which suggests that precision agriculture gives rise to data driven farming. The implementation strategy of these technologies is discussed in Section 3.2.1.3. Furthermore, the enablers and barriers of implemented technologies are discussed in Section 3.2.1.4.

3.2.1.3. Strategies/tools/techniques/methods/concepts

Various strategies, tools, techniques, methods and concepts emerged from the literature. Table 3 includes a brief description of identified strategies.

Table 3. Brief description of identified strategies

Strategy	Brief description
Implementation of data acquisition technologies (Sensors, cameras etc.)	This involves the installation of software, sensors, cameras, and other equipment or technology used for the capturing of data. In some studies, specific pigs breeds and pig sizes were selected that meets the capacity of the technology used
The acquisition of data	The process of acquiring data occurs over a set period of time where pigs interact with technologies. This process presents the opportunity to determine the durability, effectivity, usability, and accuracy of the technology used

Pre-processing of data (i.e., data enhancement)	Pre-processing of data occurs when large sets of data have been acquired and requires filtering or, in the case of images, enhancement for algorithms or efficient datasets
Processing of data (i.e., Dataset creation)	The processing of data involves the dataset creation wherein pre-processed data is stored. The structure of the set is important as it determines the efficiency of the processing of the data.
Analysis of data (Using deep learning, AI, or other algorithms)	Data analysis involves analysing the acquired data to communicate a finding depending on the purpose of the research. Some studies analysed data using algorithms to determine which algorithm is considered more accurate, where some studies used deep learning to improve the technology's detection ability.
Visualization of analysed data	Visualization of analysed data involves graphs and tables with the purpose of conveying a finding of the methods or algorithms used.
Results of different scenarios are used for comparison and verification	Several studies applied a method in different scenarios and compared findings for verification purposes.

It is worth noting, a study's strategy involved infrared technology applied to four different pig age groups to determine if there is a differentiation in results [10]. Where a different study developed a CVS for the prediction of measurement variables and compared several algorithms to identify the most accurate predictor [11]. One study's strategy involved the processing of acquired data as an input for a nutritional model. The output of this nutritional model determines the nutrient requirements of an individual pig and instructions are communicated to automatic feeders [12].

These findings indicate the various utilization of techniques and technologies, coupled with the generalized strategy included in Table 3, to improve pig growth, behaviour, and health.

3.2.1.4 Enablers and barriers for the successful use of precision agriculture in Pig farming

Figure 4 illustrates identified enablers and barriers affecting pig precision agriculture. In summary, identified enablers involve utilizing technology to acquire, manage, and report data effectively and in a manner that is useful for decision making purposes. However, data inaccuracies, the impracticability of precision technologies, and farmer scepticism act as barriers to the adoption of pig precision agriculture. These barriers are further detailed in Appendix A relevant to the study.

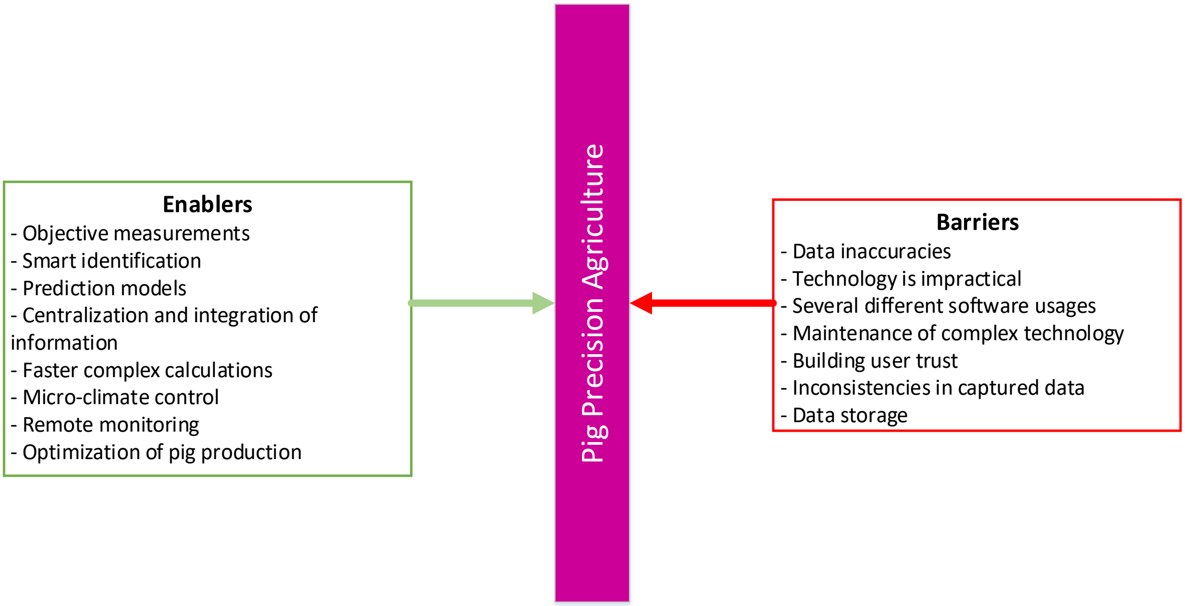

Figure 4. Identified Enalers and Barries for Pig precision agriculture

One study found that developed countries have the ability to invest in agricultural research and development projects where developing countries do not. This barrier for developing countries may serve as a reason for lack of published research in Africa (refer to Section 3.2.1.1.).

4 CONCLUSIONS AND RECOMMENDATIONS

This paper conducted a systematic literature review (SLR) to investigate studies that pertain to precision agriculture applied in the swine industry. It was found that China, the Europe, and the USA are leaders in researching pig precision farming which is understandable as these leaders are the top 3 global pork producers. Moreover, there is a growing interest of research in pig precision agriculture the past five years which suggests the increase of pig precision agriculture technique applications.

The SLR finds numerous technologies that are used for acquiring, processing, and analysing data. The technologies integrate with strategies used by researchers which involves the implementation of these technologies, the management and analysis of acquired data, and visualization of analysed data for discussion purposes. Discussions included enablers and barriers experienced by researchers where it was found that precision agriculture technologies assist farm operations to be done remotely, and automatically. However, failure of adoption remains a barrier due to events such as data inaccuracies, impractical technology, farmer scepticism and more.

Although IoT technologies bear several benefits for pig farmers, to mitigate the barrier of failed adoption, further research in technology usability and data accuracy is required in the technological development space of IoT to implement and realise benefits in pig farming operations.

The research synthesis shows that there is a growing interest in pig precision agriculture which agrees with the trend of the growing precision agriculture market. However, this study did not find relevant published articles that are affiliated to South Africa, or Africa, indicating a research gap in the research of pig precision farming. Yet, a barrier that South Africa may face is the lack of investment in agricultural research and development projects. Pig precision agriculture can be seen as valuable for South Africa due to the growing pork production market due to the benefits it has, but for efficient implementation further research, and investment in research and development projects may be needed.

It is recommended that investigation into the application of IoT in the administrative space of pig precision agriculture is explored. In addition, it is recommended to investigate the impact of IoT on the pig value chain.

This study highlighted the growing global interest of pig precision agriculture and the research involved in the implementation of IoT systems on pig farms. Pig farmers consider several variables that influence decision making and IoT enables the integration of these puzzle pieces to build the larger narrative. Effective decision making will have a ripple effect, improving the larger and more complex puzzle of an inefficient value chain. The study contributes one piece to the puzzle of the implementation of precision agriculture techniques.

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Appendix A

Table 4. Data extracted from applicable studies

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
1	Shi Shuaia, Yin Linga, Liang Shihao, Zhong Haojie, Tian Xuhong, Liu Caixing, Sun Aidong, Liu Hanxing	2020	China	Research on 3D surface reconstruction and body size measurement of pigs based on multi-view RGB-D cameras	Thermal imaging	Measuring of pig size using a low-cost depth camera. 3D point cloud acquisition. Point clouds pre-processing and registration. Feature extraction and body size measurement.	Provides a method for objective measurement of pig size.	Data acquisition had missing data due to environmental conditions i.e., railings and pig behaviour. The technology is unfriendly to ordinary workers and needs a specialized worker for installation and maintenance.	The method used improves registration precision and increases the accuracy in the curve-fitting.	[13]
2	A.L.Schaefer, O. Iheshiulor, H. von Gaza, P. Charagu,	2023	Canada	Thermal Profiles: Novel phenotypic measurements of animal	Infrared thermography Infrared thermal scanner	Feed station technology and infrared thermography are used to indicate pig growth efficiency in a	The technological results present a correlation between animal performance and	The method is not useful for mid test weights for removing animals from	The results indicate that the tool is useful for reducing cost of production and	[14]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	G. Simpson, A. Huisman			growth and metabolic efficiency	Nedap feed station technology Google cloud Microsoft Access MedCalc	controlled environment.	thermal biometrics. Assists in identifying top performing pigs thus channelling feed costs effectively.	feed stations is disruptive and stressful for the animal, negatively affecting their growth.	greenhouse gas impact.	
3	Stephan Rosengart, Bussarakam Chuppava, Lea-Sophie Trost, Hubert Henne, Jens Tetens, Imke Traulsen, Ansgar Deermann, Michael Wendt and	2022	Germany	Characteristics of thermal images of the mammary gland and of performance in sows differing in health status and parity	Infrared thermography Artificial Intelligence	Infrared thermography of the mammary gland is used to identify diseased sows with poor milk production. The method is applied to four different parities to determine whether there would be differentiation between PDS-affected and non PDS-affected sows or not.	The technology used does help identifying diseased sows.	Using the warmest pixel offers a risk of inaccuracies.	Infrared thermography coupled with precision livestock farming and smart farming can provide the tool to detect old diseased sows earlier which will assist in better piglet feeding and improved animal health.	[10]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	Christian Visscher									
4	Arthur F. A. Fernandes, João R. R. Dórea, Bruno Doura do Valente, Robert Fitzgerald, William Herring, and Guilherme J. M. Rosa	2020	United States of America	Comparison of data analytics strategies in computer vision systems to predict pig body composition traits from 3D images	Computer vision systems (CVS) Elastic networks Artificial neural networks Deep learning image encoder Matlab, R, EziWeigh5i,Python, TensorFlow,	The approach involves firstly, the development of CVS for prediction of body weight, muscle depth, and back fat from top view 3D images of pigs. Secondly, the comparison of predictive approaches such as multiple linear regression, partial least squares, and machine learning techniques.	3D imaging enables easier image processing and removal of background. Results show that CVS improves the prediction of body composition in live finishing pigs.	At least three different predictive models would need to be deployed to apply the study's models in the field.	The study demonstrates the possibility to predict muscle depth and back fat with CVS in an automated setting using 3D images from farm conditions, without needing to pre-process images.	[11]
5	Zhiwei Hu, Hua Yang, Tiantian Lou, Hongwen Yan	2023	China	Concurrent channel and spatial attention in Fully Convolutional Network for individual pig	Ubuntu 16.04, 16GB Tesla V100 GPU, Adam, ImageNet, MobileNetV2, VGC16, ResNet50, ResNext50,	The most suitable encoder-decoder combination is identified through evaluating several encoder and decoder structures.	The method used improves the distinguishing of the pig area from the background and the outline of the pig is clearer	While the study was conducted, it was found that debris, light intensity, and grouped pigs provide challenges for	The study shows that concurrent channel and spatial attention can capture contextual information effectively	[15]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
				image segmentation	UNet, LinkNet, FPN, PSPNet	A novel model that combines channel with spatial attention information is proposed. The model is implemented on an individual animal and then to a grouped pig environment. The results of implementation in different scenarios is used as verification.	in captured images.	accurate segmentation.	resulting in performance gains. The study found that spatial attention is more effective than channel attention. The study's model can be moved to complex scenarios	
6	Rachel Schambow, Yoder Colin, Wright Dave, Daniella N. Schettino, and Andres M. Perez	2022	United States of America	Enhancing passive surveillance for African swine fever detection on U.S. swine farms	Qualtrics	The study characterized regularly collected swine data and disease surveillance activities. It then explored how characterized activities can be used for ASF surveillance. Lastly, it	The study found that management software usage is high across all farm types in the U.S which can facilitate API connections, smart phone	Software usage varied greatly which may hinder the development of a uniform, data-monitoring EPS protocol.	Results from the study demonstrate the potential role for enhanced passive surveillance (EPS) to improve African Swine Fever	[16]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
						identified how advancing swine industry technologies and initiatives for disease preparation could be used to improve ASF surveillance.	devices, and the uploading of a centralized management software.		detection in the United States.	
7	Eduarda M. Bortoluzzi, Mikayla J. Goering, Sara J. Ochoa, Aaron J. Holliday, Jared M. Mumm, Catherine E. Nelson, Hui Wu, Benny E. Mote, Eric T.	2023	United States of America	Evaluation of Precision Livestock Technology and Human Scoring of Nursery Pigs in a Controlled Immune Challenge Experiment	NUtrack system, Dell-Alienware GPU, RStudio	The sensitivity, specificity, and area under the curve (AUC) of the curve of skilled technicians to correctly identify induced sick pigs from control pigs using time point sampling was established. Furthermore, the evaluation of the sensitivity, specificity, AUC, and cut-off values of behavioural outputs	The study discusses that the precision technology had less false positive and negative identifications than human observations.	The technology does not facilitate a moderate disruption of pig behaviours hinders the technology's identification ability.	The introduced technology in combination with timepoint human observations may act as an optimum system for semi-real time sick pig identification.	[17]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	Psota, Ty B. Schmidt, Majid Jaberi-Douraki, and Lindsey E. Hulbert					that were continuously collected by visually based precision technology.				
8	Giovani Trevisan, Kent J. Schwartz, Eric R. Burrough, Bailey Arruda, Rachel J. Derscheid, Michael C. Rahe, Edison de Souza Magalhães, Marcelo N. Almeida, Rodger G. Main, Daniel	2021	United States of America	Visualization and application of disease diagnosis codes for population health management using porcine diseases as a model	SAS, R, Power BI	Data to capture was first structured and then captured. This captured data was then prepared for visualization. A connection was established between prepared dataset and the visualization platform where reports were visualized.	Visualization and coding tools have flexibility which is helpful for users.	Visualization tools should be user friendly so that meaningful visualizations can be developed for decision-making purposes.	Insights made from data visualizations can be used to optimize the diagnostic process and help guide and monitor interventions for improved animal health.	[18]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	C. L. Linhares									
9	S.A. Shaik Mazhar, G. Suseendran	2021	India	Precision Pig Farming Image Analysis Using Random Forest and Boruta Predictive Big Data Analysis Using Neural Network and K- Nearest Neighbor	Kinect sensor, Camera, R, Python	The study followed a process of Image input which involves the acquisition of images, acquired images are then processed, data captured from processed images are analysed which results in the opportunity of decision making.	A neural network and big data makes the process of calculating pig weight estimation, captured from images, quicker.	Picture images were shallow on numerous pigs which caused errors with statistical results.	The study increased the robustness of predicting pig weight and growth.	[19]
10	Alessia Dianaa, Lenn Carpentierc, Deborah Piettec, Laura Ann Boylea, Daniel Berckmansc,	2019	Ireland, Belgium	An ethogram of biter and bitten pigs during an ear biting event: first step in the development of a Precision Livestock Farming tool	2 Panasonic camera's	The study developed an ethogram of ear biting behaviour. Through observing the developed ethogram, researchers sought for behavioural features for the development of an algorithm to monitor	The technology shows the potential development of an intervention strategy that monitors ear biting behaviour and escalation prevention.	A third of ear biting instances were incompletely identified by an ethologist because the bitten pig did not react, or the action of ear-to-	A combination of biter behaviours and bitten pig responses can be used as variables in an algorithm. Furthermore, the duration of non-vocal behaviour is explored to	[20]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	Tomas Nortonc					ear biting behaviour continuously.		mouth did not occur. This suggests that future technologies may encounter similar problems.	automatically extract mentioned variables from video recordings.	
11	Nicholas J. Black, Luis E. Moraes, Andreia G. Arruda	2021	United States of America	Association between different types of within-farm worker movements and number of pigs weaned per sow in U.S. Swine farms	Pig Champ Pro Europa, STATA 15	The study utilized an internal movement monitoring system beacon sensor technology to describe farm-worker movements. From the data captured, the study investigated the association of farm-worker movements and number of pigs weaned per sow.	The monitoring technologies have shown the impact of internal biosecurity on farm-worker movements which may affect measures of productivity.	Sensor inoperability may have caused bias in the study. Moreover, the lack of direct oversight of compliance to the internal movement monitoring system may have introduced misclassification bias.	Internal movement monitoring technologies can be successfully applied in the field.	[21]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
12	Ali Alameer, Stephanie Buijs, Niamh O'Connell, Luke Dalton, Mona Larsen, Lene Pedersen, Ilias Kyriazakis	2022	United Kingdom, Ireland, Denmark, Belgium	Automated detection and quantification of contact behaviour in pigs using deep learning	GoPro cameras, Adobe Premier Pro., Monacar infrared surveillance cameras, Microsoft video codec, YOLO detector, Matlab R2021a, Ubuntu 20.04.2 LTS	The study developed an automated system that quantifies frequency of pig head-to-rear contacts. Furthermore, it proposes a system that identifies complex body parts.	The method provides a means for timely intervention of behavioural changes that occur due to health and welfare compromises.	The method shows a higher rate of incorrect classification for pens with higher pig interaction rates which is due to pig-to-pig occlusions.	The study's method enables quantifying interactions between group housed pigs by using machine learning, image processing, deep learning, and video surveillance.	[22]
13	AliAlameer, Ilias Kyriazakis & Jaume Bacardit	2020	United Kingdom	Automated recognition of postures and drinking behaviour for the detection of compromised health in pigs	RBG cameras, YOLO, Faster R-CNN, MatlabR2019b, ResNet-50	A whole encompassing system was developed to detect postures. From this system Pig behaviours were obtained from images. Individual pig profiles were generated from obtained pig behaviours.	Subtle changes are identified by the method used which a person observing from pen side will not be able to detect.	The proposed system does not account for the pig's head, but instead the structural features of the pig. Detection is limited to the	Methods presented in the study automatically detect change in posture and drinking behaviours.	[23]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
								camera field view.		
14	Kuan-Ying Ho, Yu-Jung Tsai, Yan-Fu Kuo	2021	Taiwan	Automatic monitoring of lactation frequency of sows and movement quantification of new-born piglets in farrowing houses using convolutional neural networks	EfficientNet, LSTM, RetinaNet, SORT, wide-angle USB camera, Pytorch toolbox, ResNet101	The study built embedded systems to acquire the videos. These videos were then transmitted to a cloud server. Videos on the server were converted to images. Software was trained to recognize the behaviour of lactation sows and localize piglets. Once, training was complete, piglets were then tracked.	The proposed method is objective and automatic making observation quicker and less labour-intensive.	Some Piglets were partially occluded by metal railing or heat lamps.	The proposed automated method recognizes the lactation behaviour of sows. Moreover, it tracks and quantifies the movements of individual piglets in complex videos.	[24]
15	Hengyi Ji, Jionghua Yu, Fengdan Lao, Yanrong Zhuang, Yanbin Wen and	2022	China	Automatic Position Detection and Posture Recognition of	YOLOX, YOLOv5, Hikvision 2D camera, LabelImg, SimOTA,	The study established a human annotated dataset captured by a 2D camera. Data captured was processed to mitigate the problem of class imbalance.	The lack of a class in a dataset was improved resulting in better recognition of pig sitting postures therefore	The learning ability of technology used may be insufficient if more pigs than accounted for in	The proposed method meets the needs of pig position detection and posture recognition in pig production farms.	[25]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	Guanghui Teng			Grouped Pigs Based on Deep Learning		Processed data was used to create an automatic recognition algorithm for pig posture and behaviour.	improving data quality.	the study are in camera view.	Moreover, it addresses the challenge of automatic recognition of sitting postures among grouped pigs.	
16	Santosh Pandey, Upender Kalwa, Taejoon Kong, Baoqing Guo, Phillip C. Gauger, David J. Peters and Kyoung-Jin Yoon	2021	United States of America, Korea	Behavioral Monitoring Tool for Pig Farmers: Ear Tag Sensors, Machine Intelligence, and Technology Adoption Roadmap	Infrared temperature sensor, 3-axis accelerometer, gyroscope, sound sensor, Bluetooth low energy module	The study built an electronic sensor board. Tests were conducted on the built sensor boards both in the laboratory and on farm. Lastly, an investigation in possible machine learning methodologies were conducted to identify attributes of normal versus abnormal pig behaviour and behavioural pigs' well-being indicators.	Automation and integration of various swine activities in swine production.	The collection and analysis of massive qualities of field data with cross validation by farm animal caretakers is a challenge. There is also a risk of damage to the sensory board. Lastly, winning the trust of users is a highlighted challenge for	A electronic sensor board concept that attaches to the ear tags of individual pigs was developed to record pig activities.	[26]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
								technology adoption.		
17	Maciej Oczak, Florian Bayer, Sebastian Vetter, Kristina Maschat, Johannes Baumgartner	2021	Austria	Comparison of the automated monitoring of the sow activity in farrowing pens using video and accelerometer data	IP camera, infrared spotlights, Multicam Surveillance system, SMARTBOW system, Interact and Boris labelling software, RetinaNet, Computer Vision Annotation Tool, PyTorch, ResNet-152	The study applied a state-of-the art object detection algorithm of sow activity. Accumulated data were stored in a dataset which involved data processing and data labelling. Evaluation of data was then conducted to compare measurements of sow activity between ear tag, tri-axial accelerometer, gold standard based on human observation, and automated camera-based method.	The object detection technology allows to directly measure the movement of different body parts where an accelerometer is limited to the movement of an ear.	Part of the sow's body are occluded because of the farrowing pen structure. Lighting and the position of camera's determine image quality.	Ear tag accelerometer and object detection of body and head of sows provide similar information on activity levels of animals.	[27]
18	Miguel Garrido-Izard, Eva-	2019	Spain, The	Continuous Monitoring of Pigs in Fattening	iButton DS1922E loggers, OneWireViewer,	The study distributed pigs accordingly in pens. Temperature	The study shows the possibility of establishing a	Results show that the rate of pig feed intake is	The study found that registering the high	[28]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	Cristina Correa, José-María Requejo and Belén Diezma		Netherlands	Using a Multi-Sensor System: Behavior Patterns	Matlab R2018b, Compident MLB	measurements and electronic feeding stations were implemented. Captured data was then analysed	connection between thermal parameters and intake parameters which may be useful for precision phenotyping and animal management	not consistent requiring further data processing to make meaningful visualizations.	frequency of animal temperatures in a complete fattening period makes it possibles to identify individuals with different thermal patterns.	
19	Kaidong Lei, Chao Zong, Ting Yang, Shanshan Peng, Pengfei Zhu, Hao Wang Guanghui Teng and Xiaodong Du	2022	China	Detection and Analysis of Sow Targets Based on Image Vision	Azure Kinect DK, Pytorch, Ubuntu16.04,	The study first developed a sow target detection method that is based on deep learning algorithms. An assessment of two algorithms was conducted to evaluate the algorithm segmentation and recognition performances in sow detection. Lastly, from the results of	The use of the study's method enables users to efficiently and accurately identify physiological behaviours of the sow.	Markings on the pig, the pen railing, and the drinking trough affect image segmentation performance negatively.	Sows in a pen can be detected through image segmentation. Moreover, identification of the sow's behaviour of eating, drinking, and lying is possible.	[29]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
						implementation of algorithms, identity and analysis of sows' behaviours, based on segmentation, was conducted.				
20	Chen Shi, Jianlong Zhang and Guanghui Teng	2020	China	Division of Pig Growth Stages According to Body Component Variation using Computer Vision	RFID tags, ground scale with pressure sensors, serial port server, binocular stereo vision acquisition system, photoelectric sensors, Embedded Vision System, relay output model, Laboratory Virtual Instrumentation	The study involved the selection and housing of pigs to be experimented on. Weight scales and relevant sensors were used to capture data. Data captured was analysed using several methods.	The system could enable automatic grouping of pigs based on data analysis results. In addition, it is a simple, low manufacturing cost structure which could be combined with precision feeding systems.	Results show that grower stages ended at different kilograms requiring further data processing to better understand the data.	The study introduces a system that monitors and manages individual pigs which collects data accurately.	[30]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
					Engineering Workbench Environment.					
21	Wim Gorssen, CarmenWinters, Roel Meyermans, Rudi D'Hooge, Steven Janssens & Nadine Buys	2022	Belgium	Estimating genetics of body dimensions and activity levels in pigs using automated pose estimation, RFID, ground scale platform, camera	DeepLabCut, Python-based Graphical User Interface, markerless pose estimation Convolutional Neural Network-based technology	The study combined traditional pig weighing with video analysis.	The study expands pig weighing with a computer vision system, which is able to accurately phenotype pigs body dimensions and activity traits.	The study found that defining and scoring behavioural read-outs in pigs is challenging to do on a large scale for application in breeding programs.	Pigs' body dimensions and activity traits were estimated using automated pose estimation and recorded videos	[31]
22	Charlotte Gaillard, Nathalie Quiniou, Raphaël Gauthier, Laetitia Cloutier and Jean-Yves Dourmad	2020	France, Canada	Evaluation of a decision support system for precision feeding of gestating sows	Python, automatic feeder	Farmers and Sensors collect data and store it in a database. Captured data is processed and serves as an input for a nutritional model. The outputs of the nutritional model determines the individual pig's daily	The decision support system has the potential to integrate several real-time data collections by making use of different sensors which are installed on-farm	Information availability is dependent on the equipment available on the farm and the type of data collected.	The developed decision support system allows for the adaptation of the quantity and quality of daily ration's given to sows throughout gestation	[12]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
						nutrient requirements. Requirement instructions are communicated to the automatic feeders.	to characterize housing conditions and animal behaviour. This enables better nutrient supply and requirement decision making.		according to a set criterion.	
23	Harry Wooseuk Ryu, Joo Ho Tai	2022	Korea, Canada	Object detection and tracking using a high-performance artificial intelligence-based 3D depth camera: towards early detection of African swine fever	AI-based 3D depth camera, Direct X, Unity, ZED software development kit	AI-based 3D depth cameras were used to acquire 3D depth data. The captured data is processed and integrated with AI models. Results after integration are then analysed to formulate a conclusion.	AI will enable farms to detect African Swine Flu symptoms as early as possible remotely and automatically.	Object detection is generally incapable of differentiating individual objects of the same classification.	Prepared custom data sets in an appropriate model farm can train AI models for proper 3D detection. This will be critically important in operating object tracking.	[32]
24	Christian Taylor,	2022	United	Prediction of growth in	Nedap feeding station,	Relevant data was captured and	The study shows all developed	Presented results in the	The study found that an ensemble	[33]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	Jonathan Guy, Jaume Bacardit		Kingdom	grower-finisher pigs using recurrent neural networks	environment control system, temperature sensors	processed. Processed data was used to generate a dataset and served as an input for various machine learning models. Results were then analysed to formulate conclusions.	models were able to predict the length of time it would take for grower pigs to reach the target finished weight.	paper may have limited use in the global pork industry because of the limited data available to researchers. In addition, few commercial farms can facilitate the collection of individualised daily data on pig liveweight and food consumption.	of long short-term memory models proved the best predictor of pig growth as it utilised average daily temperatures and full daily temperature.	
25	Zhixiong Zeng, Fanguo Zeng, Xiaoteng Han, Hamza Elkhouchlaa,	2021	China	Real-Time Monitoring of Environmental Parameters in a Commercial Gestating Sow	Sensors, Mobile devices, Wireless Sensor Network, wireless communication technology,	Mobile devices, Cloud servers, and transmitting terminals are installed in a gestation sow house. Sensors capture relevant data which is	The system practically contributes to monitoring the microclimate from spatial and	Wired communication technology encounters problems such as difficult wiring, complex	The proposed system, applied in a commercial gestating sow confinement building, proves to be helpful with	[34]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
	Qiaodong Yu and Enli Lü			House Using a ZigBee-Based Wireless Sensor Network	Internet of Things, transmitting terminals	then processed. Processed data is communicated to the transmitting terminals which is then displayed on a web page.	temporal perspectives. By deploying the system, real-time monitoring and timely intervention could take place resulting in the possibility of providing effective climactic adjustment and human labour adaptation suggestions.	maintenance, and high costs. The capturing of data encounters null entries and requires further processing.	microclimate management accurately and effectively by real-time monitoring of four environmental parameters.	
26	Yuanqin Zhanga, Jiahao Caia, Deqin Xiaoa, Zesen Lia, Benhai Xiong	2019	China	Real-time sow behavior detection based on deep learning	Infrared network camera, webcam, NVR device, MobileNet	Once the video of sows is taken, irrelevant features in the video are removed manually. The image undergoes further pre-processing	Monitoring of sow behaviours can be done remotely.	Redundant computation and storage, which makes the extraction process tedious.	The study proposes a real-time video of sows drinking, urination, and mounting are	[35]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
					classification network, single shot multibox detection network,	i.e., data enhancement. Finally the image is processed and undergoes MobileNet classification and single shot multibox detection network for further image refinement.			detected by using an object detection method based on deep learning.	
27	Yue Gao, Kai Yan, Baisheng Dai, Hongmin Sun, Yanling Yin, Runze Liu, Weizheng Shen	2023	China	Recognition of aggressive behavior of group-housed pigs based on CNN-GRU hybrid model with spatio-temporal attention mechanism	Hikvision camera, conv-block, Gated Recurrent Unit,	A behaviour video dataset including aggressive and non-aggressive behaviours was built and used for model training and testing. A novel model was proposed to undergo training and testing. This model's results were evaluated to determine effectivity.	Because the designed model presents a means of identifying aggressive behaviour, it enables the ability of strategic assignment of aggressive behaving pigs.	Misclassification of behaviour due to camera vie limits, lighting, and angles.	The study designed a hybrid model that consists of the spatial feature extractor module with a special feature mechanism. This model recognizes aggressive behaviour of group housed pigs accurately (94.8% accurate)	[36]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
28	Qi-an Ding, Longshen Liu, Mingzhou Lu, Kang Liu, Jia Chen, Mingxia Shen	2022	China	Social density detection for suckling piglets based on convolutional neural network combined with local outlier factor algorithm	camera, network hard disk recorder, switch, local server, Python 3.7, PyTorch 1.7, OpenCV 4.1, YOLOv5	A system of data acquisition is implemented at each farrowing pen. Acquired data undergoes pre-processing and dataset creation. A piglet detector is developed that makes use of the created dataset for functionality.	The method enables the analysis of piglet distribution and the relationship between piglet growth and social status.	The method encountered false detections which influences the accuracy of detection. Data has inaccuracies due to piglet deviations which makes social density detection inaccurate.	The study quantified social density of piglets which achieved detection of piglet clusters, non-clusters, and outlier piglets.	[37]
29	Jinxin Chen, Jie Zhou, Longshen Liu, Cuini Shu , Mingxia Shen and Wen Yao	2023	China	Sow Farrowing Early Warning and Supervision for Embedded Board Implementations	cameras, a network hard disk video recorder (NVR), a switch, and a local server, Power over Ethernet, Python, OpenCV, YOLOv5s-6.0,	Cameras are installed over farrowing pens. Recorded video are transmitted to an Ethernet switch and stores videos on a network video recorder. The videos are manually screened and processed into image data. Image data	The method is low cost, low latency, high in efficiency, is easy to implement, and enables breeders to transition to intelligent pig breeding.	Missed and false detection sow postures is affected by the change of light.	The study proposed a method that automatically predicts and detects of sow farrowing duration using an embedded development board which	[38]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
					Jetson Nano, TensorRT,	undergoes data labelling and data enhancement. Enhanced data is used as a dataset for an Object-Detection algorithm	The detection of new-born piglets and the communication thereof increases the survival rate of piglets.		includes and early warning of approaching farrowing and farrowing behaviour supervision.	
30	Haiming Gan, Chengguo Xu, Wenhao Hou, Jingfeng Guo, Kai Liu, Yueju Xue	2022	China	Spatiotemporal graph convolutional network for automated detection and analysis of social behaviours among pre-weaning piglets	Camera, Labelme, Pytorch	Piglets are first detected and tracked using software in the authors' previous study. A convolutional neural network node detector is used to precisely detect piglet body nodes. Acquired data undergoes classification of suspected behaviour. Experiments are conducted to validate the feasibility of classification.	The method incorporates different types of social behaviours associated with different body parts which enables piglet behaviour analysis.	It was found that piglets that engage in playing behaviours move their bodies rapidly resulting in image problems such as motion blur.	The study shows a positive detection performance detecting body part associated social behaviour in piglets using graph convolutional networks which also demonstrates the feasibility of the method used.	[39]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
31	Elanchezhian Arulmozhi, Anil Bhujel, Byeong-Eun Moon and Hyeon-Tae Kim	2021	Korea	The Application of Cameras in Precision Pig Farming: An Overview for Swine-Keeping Professionals		A literature review is conducted.	Technological developments provide a solution to the food insecurity challenge in developing countries. The review suggests that solving multiple issues in one system, fewer sensors, affordable price, reliability, and easy handling increases the adoption rate ,and improves production and quality.	The review found that there are significant differences between models and ground level occurrences. Models also do not account for regional-level genetics which could have a user apply an incorrect algorithm affecting results. Data captured from video recordings produces large amounts of data points making it expensive.	The review finds that in the future, Artificial Intelligence algorithms for automatic monitoring, control, and overall management will be depended on by farmers. Furthermore, developed countries have the ability to invest agricultural R&D, but developing countries do not.	[40]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
								Integrated technological systems cannot solve multiple issues.		
32	Shunli Wang, Honghua Jiang, Yongliang Qiao, Shuzhen Jiang, Huaiqin Lin and Qian Sun	2022	China, Australia	The Research Progress of Vision-Based Artificial Intelligence in Smart Pig Farming		The study summarizes summarises research progress of Artificial intelligence in pig farming.	Intelligent analysis systems transforms data of animal response characteristics into key indicator information and can analyse transformed data using AI and machine learning for farm management decision making. These systems enable pig farmers to	Technology reliability, ease of maintenance, and use of intelligent devices remain a challenge. In practice, lack of large high-quality datasets and data standards are a challenge due to pig farms growing and increases of data captured.	Modern farming utilizes sensors for temperature, weighing, and tracking pigs to capture data about the pig environment or pig. Moreover, for the same purpose 2D and 3D cameras are used.	[41]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
							optimize production/reproduction processes to avoid over-feeding, waste reduction, cost reduction, and make livestock farming more sustainable economically, socially, and environmentally.			
33	Chun-Peng J. Chen, Gota Morota, Kiho Lee, Zhiwu Zhang and Hao Cheng	2022	United States of America	VTag: a semi-supervised pipeline for tracking pig activity with a single top-view camera	Python OpenCV, laptop controlled camera, Intel RealSense Viewer, YOLOv5, Mask R-CNN, Sparse Optical Flow, multiple instance	Data acquisition is done with video cameras. Successful tracking algorithms are implemented that learn representatives from the object of interest and find the similar image region in the next input video frame. Results are evaluated.	The Vtag does not require laborious work in setting up the training system. The system enables individual-level activity per unit time and walking speed measurements. In	Trackers lost tracking the correct pig due to frequent interactions between two pigs in a short period. Moreover, video quality adds to this problem.	The study proposes a semi-supervised pipeline, VTag, that can track pigs in video recordings. Minimal human supervision is needed for adequate precision.	[42]

#	Author(s)	Year	Country	Title	Technologies	Strategies/tools/techniques/methods/concepts	Enablers (success)	Barriers (failure)	Core finding	ref
					learning, channel and spatial reliability		addition, it enables the monitoring of tail biting behaviour.			
34	Chong Chen, and Xingqiao Liu	2019	China	An intelligent monitoring system for a pig breeding environment based on a wireless sensor network	Wireless Sensor Network, Sensors, ASP.NET, Matlab, Visual Studio 2012	Sensors are implemented that acquire relevant data. Acquired data is stored and managed. Managed data is communicated to users and analysed for decision making purposes.	The system provides high quality and efficient control of environment temperature and humidity.	The system endures long calculation times, consumes a lot of computer memory, and has difficulty in modifying control rules.	An intelligent control system for livestock was developed which improved piggery environmental quality, and pig welfare.	[43]

CHAPTER 5 CURRENT STATE ANALYSIS

This chapter addresses the current state of administrative processes using several methods. Porter's value chain and Business Process Mapping Notation reveals the embeddedness of these standards in the day-to-day operations of the pig farm. Furthermore, Value Stream Mapping and Time studies reveal the current time and efforts required from farmers to participate in the administrative processes.

5.1. Current State Analysis

The current state analysis made use of Porter's value chain, Business Process Mapping Notation, Value Stream Mapping, and Time studies. These tools enabled the researcher to formulate a context to the problem described in Chapter 1.

5.1.1. Porter's Value Chain

Porter defines a value chain as a set of activities that an organization practices, creating value for its customers (Simatupang et al., 2017, MindTools). Figure 13 illustrates the farm's set of activities identified by a Gemba that add value for its customer using Porter's Value Chain.

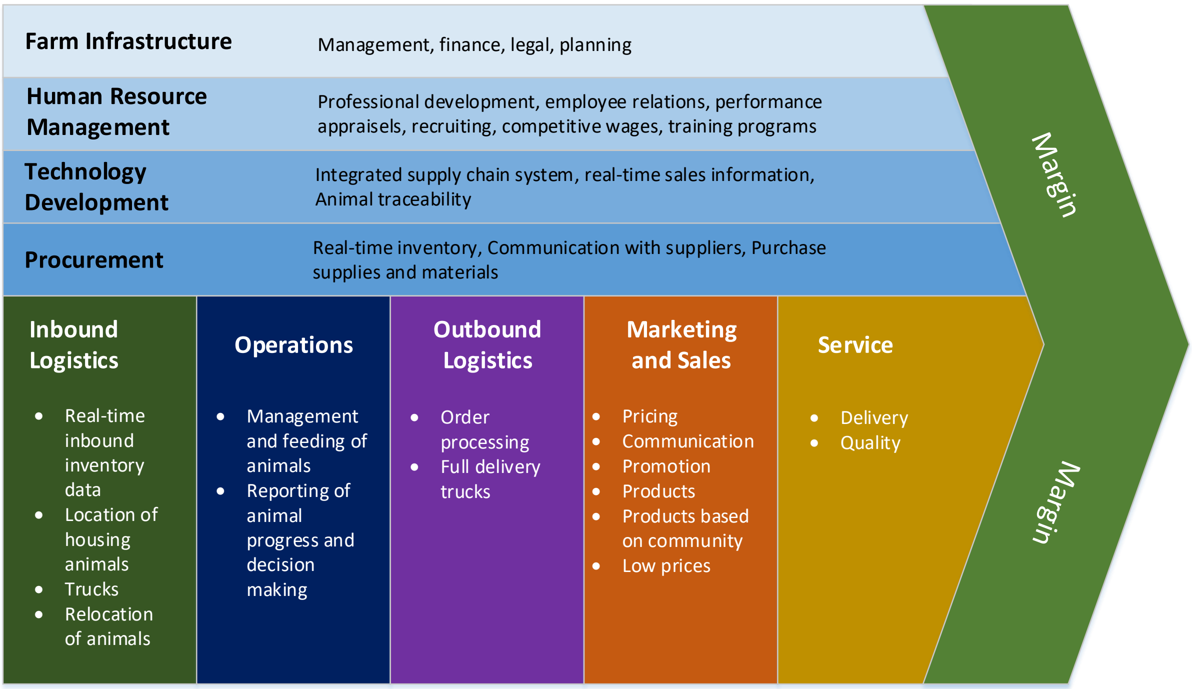

Figure 13. Porters Value Chain applied to farm in case study

Figure 13 reveals several areas of value adding activities that occur on the farm. To determine whether the Pork360 standards participate in these activities, Figure 14 attempts to categorise Pork360 standards according to defined activities in Figure 13's Porter's Value chain. It is worth noting that there are standards that are categorized in more than one activity.

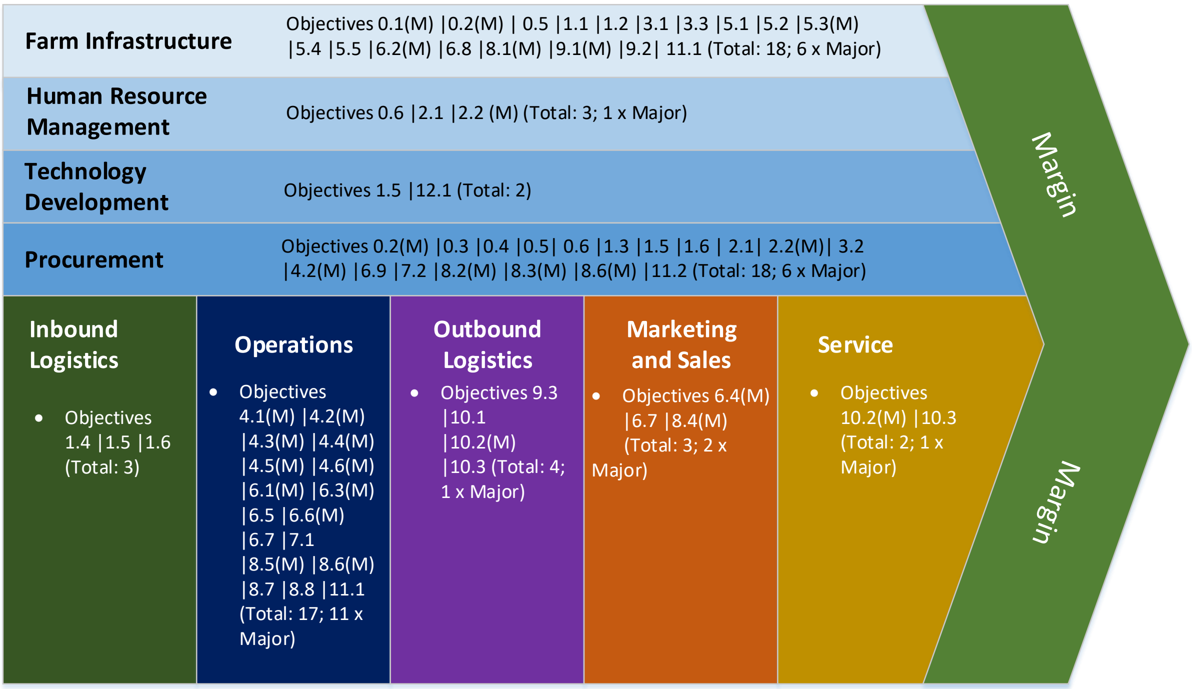

Figure 14. Pork360 standards categorised in Porters Value chain

Figure 14 reveals that these standards participate in all areas of value-added activities and activities where standards are most occurring, namely two supporting activities: Farm Infrastructure and Procurement, and one primary activity: Operations.

Pork360 has a total of 56 items of which 22 are major items each including item descriptions (Refer to Appendix A.2.). From the Gemba walk it was found that a major item/task is considered more significant than the other tasks and if the farm does not adhere to the standard of a Major task, its likelihood of receiving certification after an audit is very low.

Figure 14 illustrates the number of Major items that occur per activity. Using this to prioritize activities, the 'Operation' activity is viewed as the most important activity. Joint second is Farm infrastructure and Procurement. Figure 14 illustrates the importance and value of administration as a procurement supporting activity. To investigate the administration process further, a value stream map and business processing model notation are formulated to map the farm's weekly administration process.

5.1.2. BPMN of weekly administration

At the case study farm, managers are required to participate in administrative tasks on a weekly basis. Figure 15 includes a Business Process Mapping Notation (BPMN) diagram of the weekly administrative process undergone by managers. Moreover, each addressed major task is marked with the letter 'M'. An unaccounted Major task, the feed ordered and delivered reconciliation task, has been included outside of the pool lanes.

Figure 15 illustrates the Pork360 standards administrative process taken by managers via a BPMN. The Enterprise Resource Planning (ERP) system, called Cloudfarms, is primarily used for medicine reconciliation and is an IoT solution for medicine stock take and reconciliation. In addition to the IoT system, paperwork is still used due to discrepancies between the ERP system and actual stock. Therefore, there is a physical file including registers of needle and medicine stock usage, and an ERP database including needle and medicine stock usage.

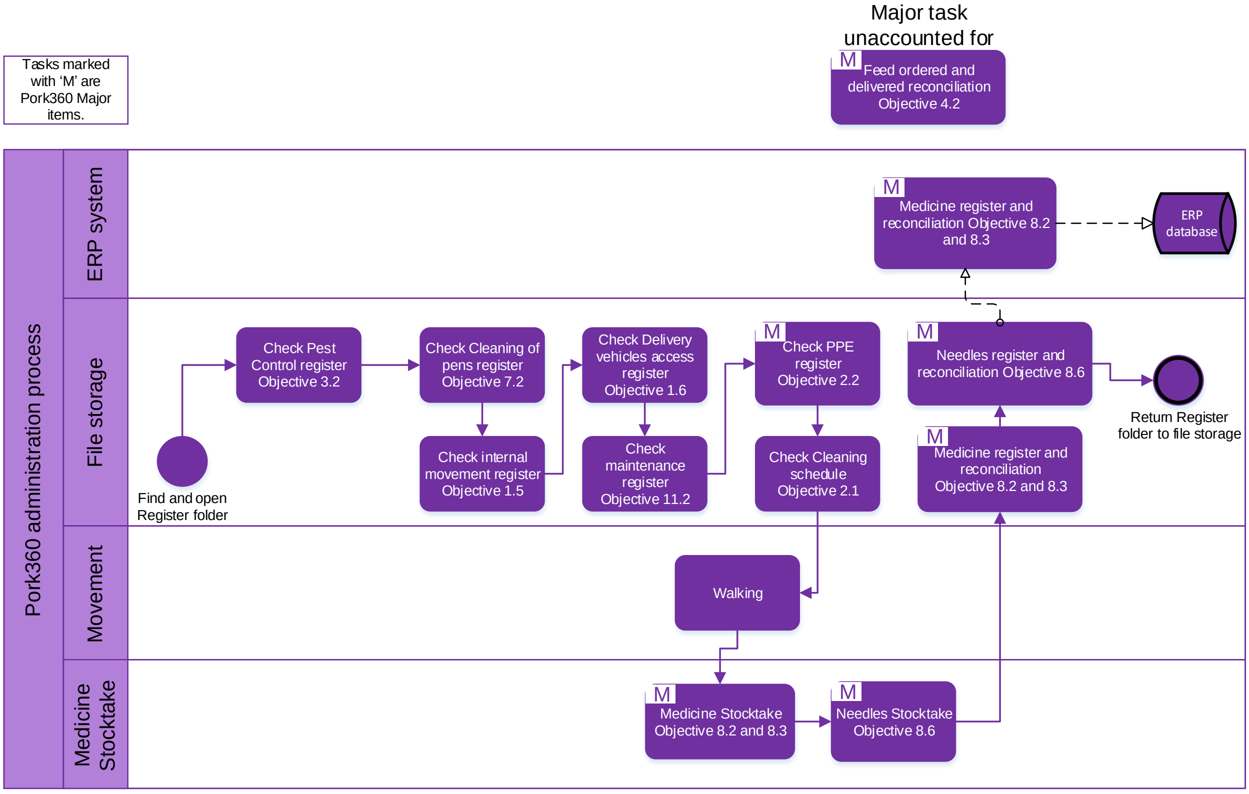

Figure 15. BPMN of weekly administrative process

It is worth noting that not all procurement tasks, mentioned in Figure 14, are part of the weekly process. Table 18 includes tasks and a description of these tasks that are not included in the weekly process.

Table 18. Pork360 Procurement objectives not included in the weekly process

Objective and item code	Consumer Assurance and Traceability Standard	Description
Objective 0.2	Standard Operating Procedures (SOP's)	A master file including all SOP's checked and updated on a yearly basis.
Objective 0.3	Registers & other documents	List of current registers used on farm. This is addressed in other objectives.
Objective 0.4	Document storage	Description of document storage period. (5 years)
Objective 0.5	Contingency plan	SOP documentation (updated on a yearly basis).

Objective 0.6	Training	Documentation only occurs when training takes place.
Objective 1.3	Visitor Access	Documentation only occurs when the farm receives visitors.
Objective 6.9	Post-Mortem Records	Register occurs when post-weaning animals die. No mentioning of checking of registers.

5.1.3. High-level VSM of weekly administration

The weekly process is further investigated by using Niebel's Time Study methods (Freivalds and Niebel, 2009), refer to section 5.1.4. The results from these time studies are used to map a Value Stream Map (VSM) of the weekly administration process (Jacobs and Chase, 2018). A VSM can be used to map administration processes (Haron and Ramlan, 2015, Costa et al., 2013) to indicate non-value-added activities involved in the administration process and to reveal the lead time of an administration process. Figure 16 illustrates the VSM of the current weekly administration process at the piggery.

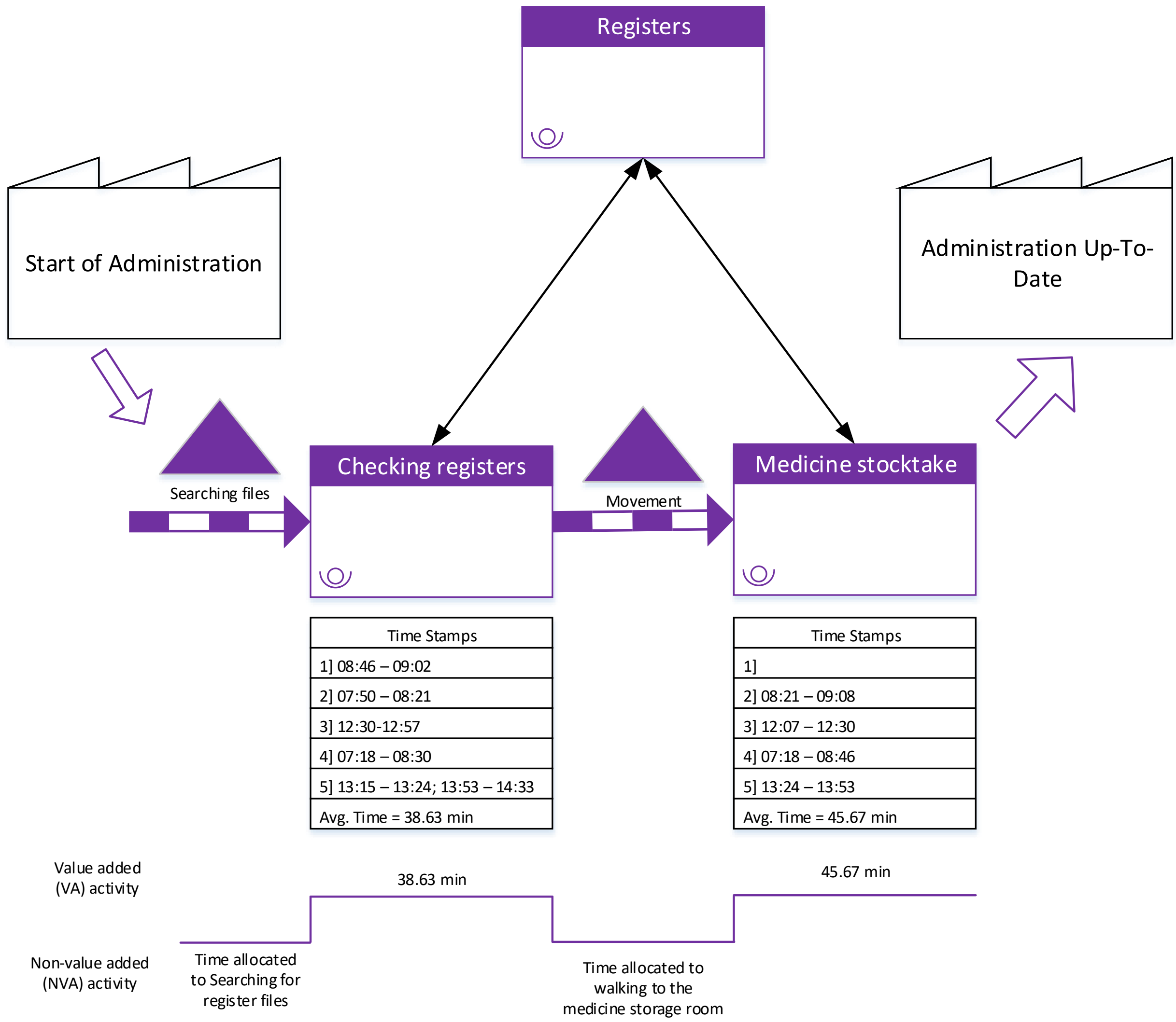

Figure 16. Value Stream Map of weekly administration

The time stamps included in Figure 16 indicate that time measured for each time study (refer to section 5.1.4.). For the checking registers activity, the 5th time study indicates two measured time periods. This is due to the farm manager first attending to registers, then medicine stock take, and then returned to checking registers. Moreover, one can notice that for the 4th time study the time stamps for both activities start at the same time. In this case, whilst the manager was checking registers, an assistant was doing the medicine stock take. The times measured were added together in Table 19 to maintain standardisation of analysing the time it takes to complete weekly administration for a single operator.

Brief descriptions of value adding and non-value adding activities are indicated on the lead time ladder in Figure 16. Notice Figure 16 does not include a time value for searching files and movement activities. While undergoing time studies, two farm managers were observed. Although both farmers participated in the weekly administration process, Manager A's medicine storage was quite a distance from the office whereas Manager B's wasn't. Moreover, Manager A's files were well structured and quick to find whereas Manager B's wasn't.

Literature shows that when deciding which work activities to study one should consider factors that can cause high variability in captured data (Brady and Drury, 1968). To mitigate this, work measuring methods such as "single duration measurement" or "milestones timing" are considered (Lopetegui et al., 2014). These methods incorporate the studying of specific activities within a process to accompany process unpredictability. Following this literature, searching files and movement activities weren't measured due to the major differences in process designs outside the scope of the value adding activities i.e., location of medicine stockroom and filing structure, and focused on the administrative process. Moreover, a prerequisite to make use of Niebel's Time study methods is that the method of operations must be standardized (Freivalds and Niebel, 2009, Jacobs and Chase, 2018). In noticing these differences, a potentially beneficial aspect of administration processes can be good housekeeping.

5.1.4. Time studies on weekly administration

Time study is defined as the procedure of establishing standards using stopwatch timing (Freivalds and Niebel, 2009). In this research the time study values aren't used to establish standards but quantify efforts to comply with established standards.

Table 19 includes five time-studies. Because the weekly administration process (refer to Figure 15) only occurred once a week, each study included only one cycle. Freivalds and Niebel (2009) suggests that if a cycle takes longer than 40 minutes then a minimum of 3 cycles are required (as defined earlier in Table 2). Therefore, to adhere to this, 5-time studies were conducted.

Table 19. Time study values

Study no.	Checking of registers	Medicine stock take	Total cycle time
1 (Manager A)	15.1 min		15.1 min
2 (Manager A)	30.38 min	44.53 min	1 hour 14.91 min
3 (Manager B)	26.33 min	23 min	49.33 min
4 (Manager A)	72.15 min	86.72 min	2 hours 38.87 min
5 (Manager B)	49.17 min	28.42 min	1 hour 17.59 min
Average	38.63 min	45.67 min	1 hour 15.16 min
Standard deviation	22.4 min	28.86 min	53.12 min

Notice in Table 19 there are two major outliers namely, study number 1 and study number 4. Time study number 1 occurred after Manager A completed a medicine stock take earlier that same week. Time study number 4 included the checking of Standard Operating Procedure registers, which usually occurs once a year (refer to Table 18).

Table 19 illustrates a high variation in time values captured in all areas showcasing an inconsistency in followed administration processes, or disruptions while participating in the administration processes.

Figure 17 illustrates a box plot of conducted time study values making use of the exclusive median method to determine its Q1 and Q3 values. Figure 17 communicates that for Checking of Registers study no. 2,3, and 5 results lie within the interquartile range where-as study no. 1 and 4 are considered as outliers. For Medicine stock take, study no. 1,3, and 5 are considered outliers and study no. 2,4 are within the interquartile range. Moreover, the interquartile range for Medicine Stock Take is greater than Checking of Registers.

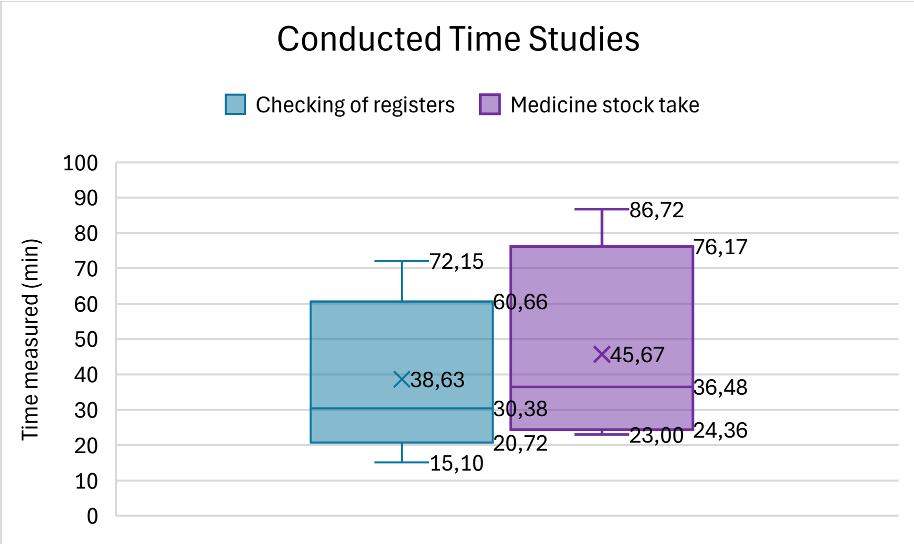

Figure 17. Box plot of conducted time studies

5.2. Findings

While undertaking time studies, the researcher observed that each manager had a non-standardised unique approach to the administration process. The niche process followed is illustrated in the Value Stream Map, but filing, stock take, and reconciliation methods differed. The different methods used influenced the administration process time and the effectiveness of the administration done. There were observed instances where not all registers were checked because the manager was either unaware of the register to be checked, or the manager could not find the file that needed to be checked.

During this exercise, it came to light that managers do not check the Pork 360 standards often. This can be attributed to a lack of clear SOPs and administrative processes and makes the challenge of remembering all the registers to be checked understandable. Moreover, Chapter 1 mentions the challenge farmers have with completing paperwork. Bearing the burden of determining an administration process as a manager may add to the reluctance of paperwork.

The researcher observed that registering work done is embedded in farm operations and serves as evidence that the specific tasks are completed and up to date. Furthermore, the register enables the manager to hold employees accountable, depending on whether the manager's administration is up to date. The managers are tasked to complete the administration process (refer to Figure 15) on a weekly basis, which doesn't occur as often as it should due to farm operational disruptions. This suggests that the manager prioritizes farm work over paperwork as elucidated in chapter 1. If farm operation disruptions occur on a regular basis, paperwork is neglected, the farm manager falls behind on administrative tasks, is unable to ensure that employees register tasks done on farm and bears the risk of medicine out-of-stock events.

5.2.4. Chapter Summary

This chapter addresses the current state of administrative processes using several methods. Porter's value chain and BPMN reveals the embeddedness of these standards in the day-to-day operations of the pig farm. Furthermore, VSM and Time studies reveal the current time and efforts required from farmers to participate in the administrative processes. Interestingly, the chapter suggests that Quality standards cannot be separated from practice, but instead, when standards are practiced, could improve overall farm production. This then raises the question of what causes the separation or reluctance of paperwork amidst pig farming operations.

CHAPTER 6 QUALITY STANDARDS ANALYSIS

This chapter provides analysis and results from a focus group discussion which investigated the participant's perspectives on Pork360 administration. The chapter accompanies thematic analysis methods and software to identify the theme of the focus group discussion. The chapter includes a consolidated analysis and an analysis per question. Results from these analyses are discussed wherein the theme of the focus group is identified for design requirement consideration.

6.1. Introduction

To analyse Pork 360 quality standards, participants who participate in Pork 360 standard compliance on a regular basis were invited to a focus group. Discussions held at the focus group undergo a thematic analysis to reveal discussion themes and sentiments towards Pork 360 quality standards.

6.2. Quality Standards

Quality management systems specify production standards, whereas certification indicates the degree of conformance to the standards. The South African Pork Producers Organisation has its own certification to maintain best practices throughout the pork chain called Pork 360 (Pork360, 2023). Pork 360 includes traceability as a standard that should be complied with resulting in registering activity for several operational areas within a piggery. The current registering method used by the farm entails both paperwork and an IoT system.

The aim of the focus group is to investigate and identify themes from the participant's perspectives with regards to Pork360 administration. Furthermore, the research hopes to determine whether themes from the discussion coincide with challenges expressed in Chapter 1, and to provide insight on the challenging aspects of paperwork in farm operations. It is worth noting that only the researcher participated as the focus group facilitator and data collector, therefore there is a possibility for bias in data collection and analysis.

6.2.1. Existing standards

The Quality Standards being investigated are the Pork 360 Consumer Assurance and Traceability Standards (C.A.T) for Farms (refer to Appendix A.2.). This certification entails a total of 56 Standards which are divided under 13 Objectives. Table 20 includes the 13 objectives. For a list and description of the standards refer to Appendix A.2.

Table 20. List of Pork 360 C.A.T for farms objectives

Objective number	Objective
0	Administration of C.A.T Program
1	Access Control
2	Employees
3	Pest Control
4	Feeding and Feed Quality
5	Housing
6	Management and Care
7	Sanitary and Hygiene Requirements
8	Medication and vaccines management
9	Waste Management
10	Transport

11	Maintenance
12	Measuring and monitoring

The objectives are presented to the reader to provide terminology reference for the focus group discussion analysis section. The first of version of the Pork 360 standards listed in Table 20 were compiled on 1 March 2013. The aim of the standards, as described by Pork 360, "…is to ensure the production of high-quality pork on welfare-friendly farms, with good biosecurity, environmental stewardship, and minimal antimicrobial usage". Moreover, the purpose of the objectives "is to ensure a consistent production system that supplies healthy and traceable pigs under good animal welfare practices to the abattoir" (Pork360).

6.3. Method of Analysis and Results

The research method described in Section 3.1. was followed for data collection, recording, and analysis. It is worth noting that one focus group was held which included 7 participants. The expertise distribution of the participants is illustrated in Table 21.

Table 21. Participant expertise distribution

No.	Participant role	Description	Level of expertise (Score out of 7)
1	Farm Veterinarian	Experienced veterinarian that has conducted Pork360 audits and understands the farm's process of operations.	3
2	External Veterinarian	Experienced veterinarian that has conducted Pork360 audits.	2
3	Assistant Farm Manager	Conducts farm activity registering tasks for Pork 360 compliance purposes.	2
4	Farm manager	Conducts all Pork 360 tasks.	4
5	Assistant Farm Manager	Conducts farm activity registering tasks for Pork 360 compliance purposes.	2
6	Farm Intern	Assists Participant 3 in activity registering tasks for Pork 360.	1
7	Farm Manager	An experienced farm manager that conducts Pork 360 tasks other than registering farm activities and maintains registered farm activities by participant 3 and 5.	5

The score given to each participant is determined by the number of years' experience, the degree of involvement at the specific farm, and theoretical knowledge of the Pork360 standards. A score of 1 indicates low experience, a low degree of involvement, and low theoretical knowledge of Pork360 standards where a 7 indicates high experience, high degree of involvement, and high theoretical knowledge. Participants are pseudo-anonymised and denoted P1 to P7 when making reference to discussion points in this chapter.

Figure 18 illustrates the focus group participants job profiling distribution and diversity. The percentage value is determined by the score out of 7 given to each participant in Table 21.

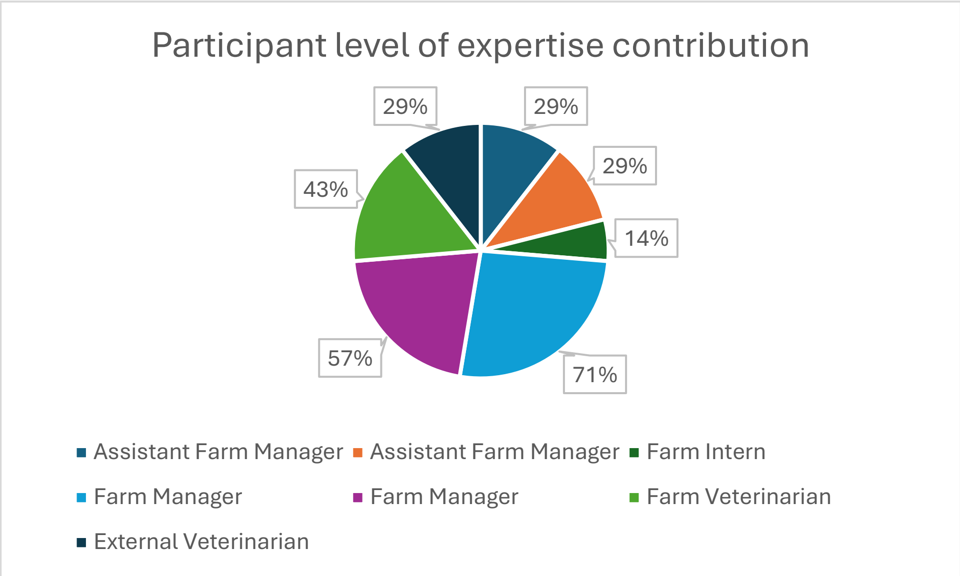

Figure 18. Participant level of expertise distribution

6.3.1. Categorisation

Categories, sub-categories, and codes were identified for analysis purposes (Nili et al., 2017). Figure 19 illustrates the category structure used for thematic analysis.

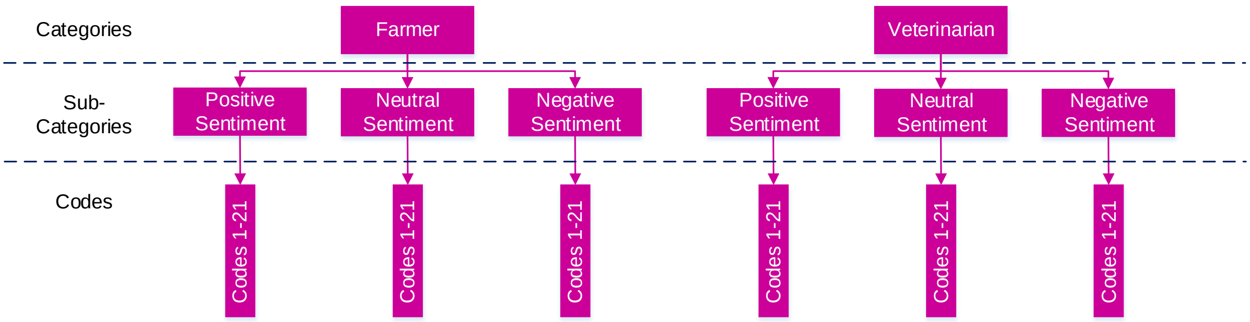

Figure 19. Category structure for thematic analysis adapted from (Nili et al., 2017)

Table 22 includes the list of codes to codify the transcript for analysis purposes.

Table 22. List of Codes

Code no.	Code name
1	A lot of paperwork
2	Adapting to changes isn't difficult
3	Administrative maintenance
4	Animal welfare
5	Bio-security

6	Difficult to manage all paperwork
7	Difficulty depends on administrative system used
8	Discipline
9	Don’t enjoy paperwork
10	Forced administrative system fails
11	Good record keeping
12	Healthy produce
13	Human access
14	Quality Standards are important
15	Responsible production
16	Sharing responsibility with employees
17	Technology is confusing
18	Technology is efficient for recording
19	Traceability
20	Treat environment responsibly
21	Understanding of technology and administration system

6.3.2. Consolidated co-occurrence analysis

The consolidated analysis involved codifying the focus group transcript and dividing the quotations (identified with codes) into the two relevant categories. Once the quotations have been divided accordingly, Atlas.ti’s web tool was used to perform a sentiment analysis which produces positive, neutral, and negative sentiments as codes for each paragraph of text using artificial intelligence models. After applying this tool, the researcher made minor changes to sentiment codes from discussion observations.

To accommodate sentiment codes the listed sub-categories, refer to Figure 19, are used as codes in the transcript and for the co-occurrence analysis. The co-occurrence analysis charts provided by Atlas.ti were used as a tool for thematic analysis. The purpose of the co-occurrence analysis was to identify and associate code occurrences with identified sentiments from both farmers and veterinarians. Codes that occurred less than 3 times with a sentiment were excluded from the consolidated analysis to present Figure 20 as less convoluted. This will assist the researcher to identify the theme or overall interpretation of all categories (Nili et al., 2017, Braun and Clarke, 2012).

Figure 20 illustrates a Sankey diagram produced in Atlas.ti desktop. Atlas.ti’s web tool sentiments are automatically generated using artificial intelligence models after naming and color-coding sentiments (ATLAS.ti, 2024). Two groups of sentiment naming conventions included Veterinarian Positive, Veterinarian Neutral, Veterinarian Negative, Farmer Positive, Farmer Neutral, Farmer Negative. Positive sentiments were allocated the colour green, Neutral sentiments were allocated the colour yellow, Negative sentiments were allocated the colour red. Six co-occurrence codes that showed strong co-occurrence (band width) with each sentiment were highlighted.

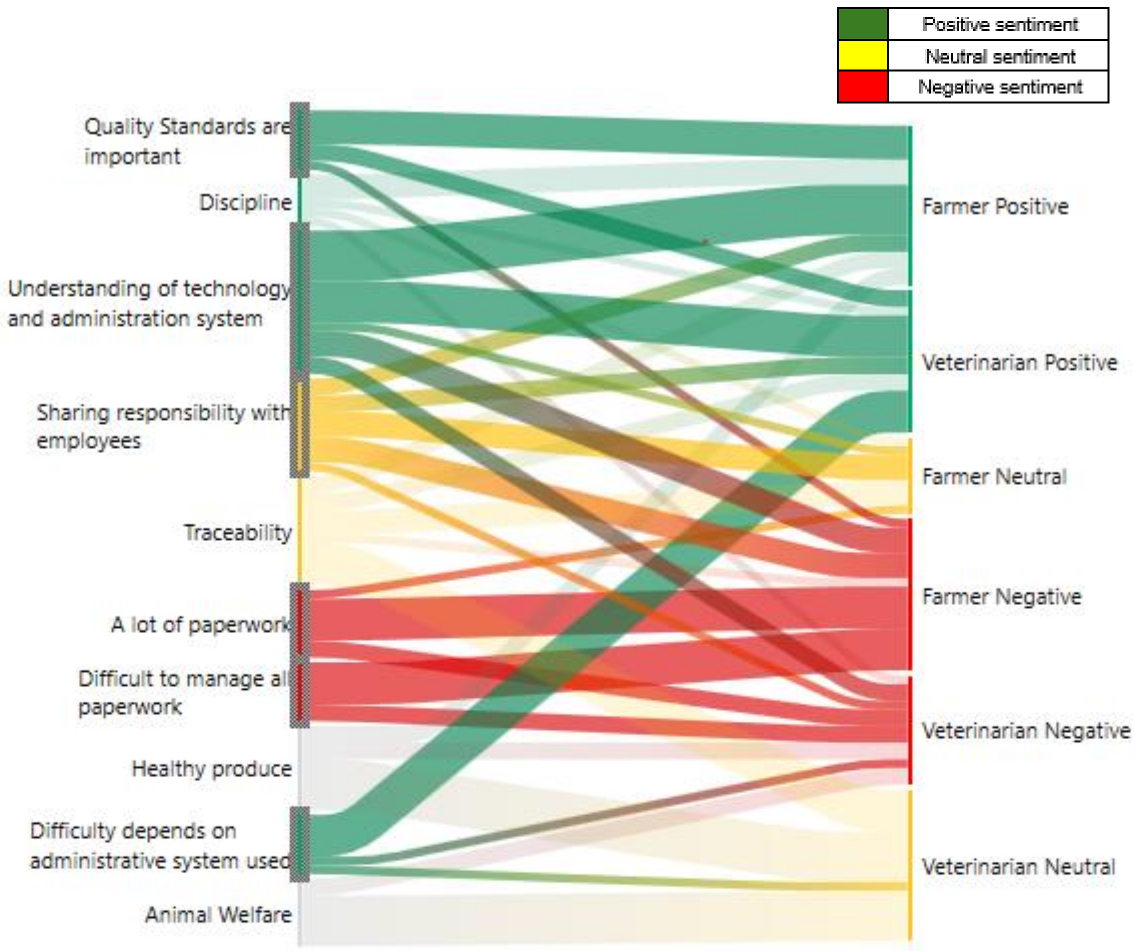

Figure 20. Sentiment vs Code co-occurrence Sankey diagram developed in Atlas.ti ver. 24.1.1

Figure 20 illustrates that both the farmer and veterinarian categories have strong negative sentiments towards paperwork but recognize that Quality Standards are important. Moreover, a strong neutral sentiment is evident for sharing administrative responsibility with employees. Lastly, there is a strong positive sentiment towards the understanding of technology and administration system, where the veterinarians show additional positive sentiment to the difficulty of administration depending on the administrative system used. Figure 20's illustrated associations provide insight in identifying the theme of the discussion on a categorical level due to the naming convention of sentiment codes i.e., Veterinarian Positive, Farmer Positive etc.

The six identified codes that displayed a strong sentiment association (illustrated in Figure 20) were then used in a second Sankey diagram where all other code occurrence associated to these six were investigated. Figure 21 illustrates the developed Sankey diagram where all code colours presented in Figure 21 were given their predominant sentiment colour.

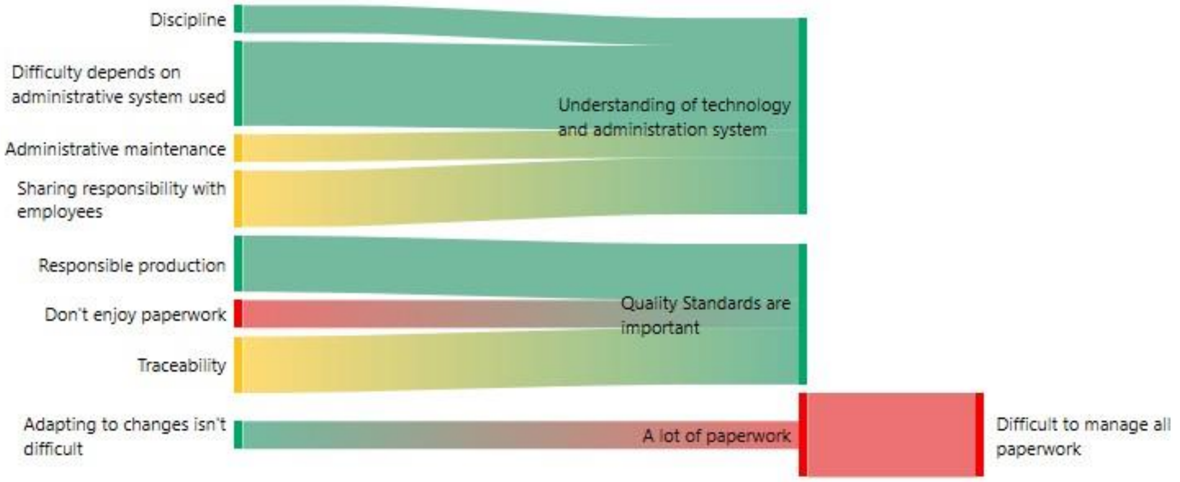

Figure 21. Identified codes from sentiment Sankey diagram vs all codes co-occurrence Sankey diagram developed in Atlas.ti ver. 24.1.1

Figure 21 showcases the code relationship in light of the predominant sentiment for each code. Figure 21's illustrated associations provide insight in identifying the theme of the discussion on a code level. The Sankey diagram illustrated in Figure 21 shows three separate streams, which occurred from the analysis provided from Atlas.ti.

Following the same approach as in Section 6.2.2, Section 6.2.3. – 6.2.9. makes use of a Sankey diagram to analyse the co-occurrence of codes and Participant sentiments per question. It is worth noting 3 additional questions were asked through the course of the discussion for discussion facilitation purposes.

6.3.3. Pork production quality standards awareness and top standards for compliance

Question 1 asked "What production Quality Standards are you aware of?" and Question 2 asked "What would you say are the three most important standards to comply with?". Questions 1 and 2 were asked simultaneously during the focus group and therefore responses were analysed accordingly. The discussions involved pork production quality standards awareness and top standards for compliance. Figure 22 illustrates a Sankey diagram analysis for Question 1 and 2. The diagram indicates sentiments towards specific codes in this discussion.

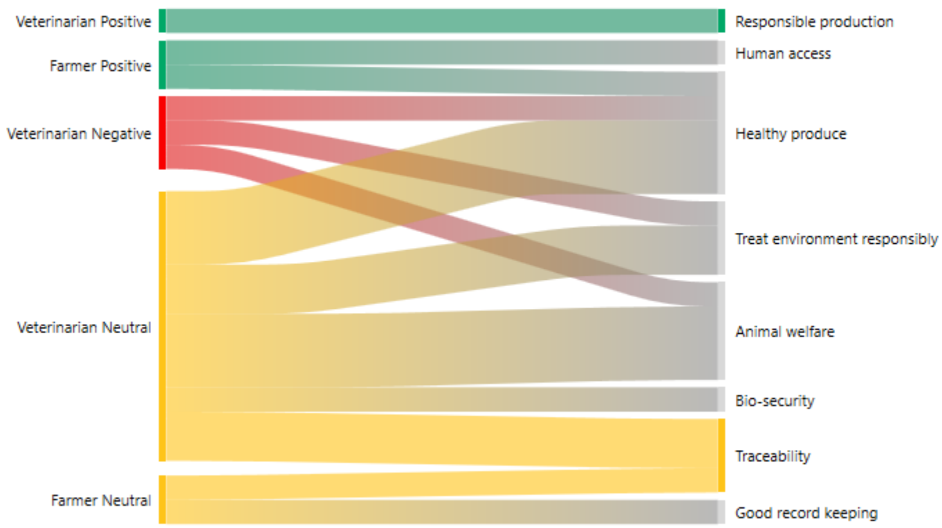

Figure 22. Sankey diagram for Question 1 and 2 developed in Atlas.ti ver. 24.1.1.

The farmer category shows positive sentiment towards Human access and Healthy produce whereas the veterinarian category shows positive sentiment only to responsible production. Overall, the discussion conveyed neutral sentiment where contribution mainly came from the veterinarian category.

The veterinarian category shows negative sentiment towards Healthy produce, Treat environment responsibly, and Animal welfare. The implications of antibiotic overuse were discussed by P1, stating that:

“We all know the risk of overusing the antibiotics, but animal welfare also plays a very, very important role. And if we want to keep our licence into producing pigs, we need to look after the environment.” – P1

This statement emphasises the importance of the standards discussed. Note this sentiment does not convey the dislike towards the codes itself, but rather the danger of the consequences.

6.3.4. Rating and reasoning the difficulty of Pork 360 administration

Question 3 asked “On a scale of 1 to 5, with 1 being strenuous and 5 being effortless, how difficult is it for you to comply with these standards and why?”. The discussions involved rating and reasoning the difficulty of Pork 360 administration. Figure 23 illustrates a Sankey diagram analysis for Question 3.

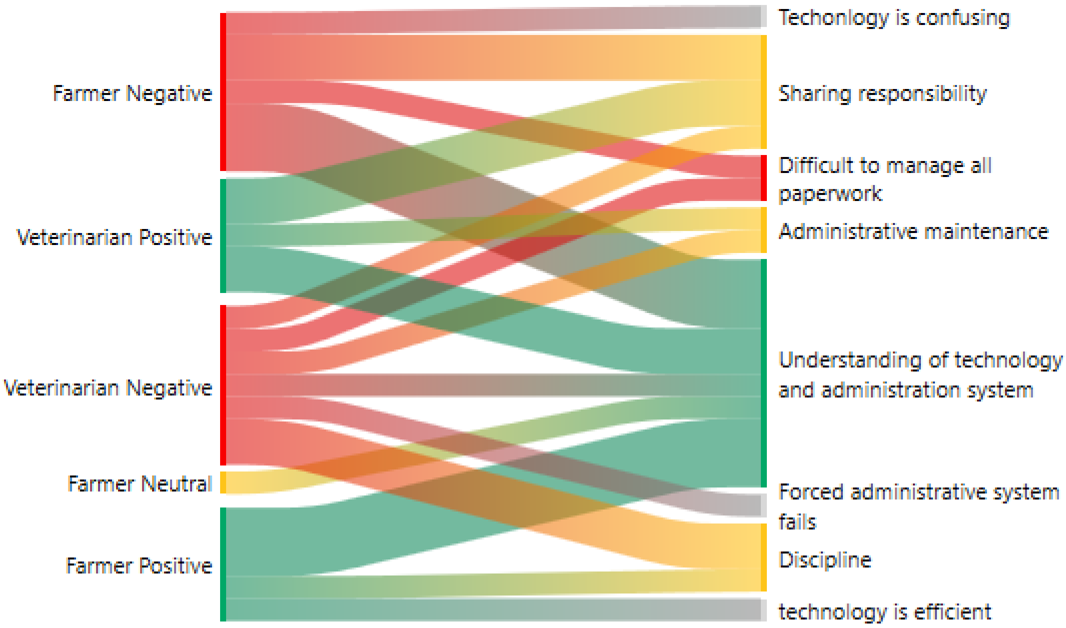

Figure 23. Sankey diagram for Question 3 developed in Atlas.ti ver. 24.1.1.

Figure 23 illustrates a strong positive sentiment is evident towards understanding the technology and administration system. Although Figure 23 showcases this there were mixed views in this discussion phase surrounding understanding the technology and administration system. While discussing technology P5 communicated the difficulty of making use of technology by stating:

"…I find it a bit more difficult and because those guys [farm workers] don't really understand how to enter the medication because those guys [farm workers] don't really understand how to enter the medication onto Cloudfarms [pig management software]" – P5

As a proposed solution, P3 added **"**so, we need people [farm workers] who are willing to do it on their own without being told." focusing on the willingness of individuals involved when working with technology.

Still on the discussion on technology's role in administration and the capability of complying with quality standards, P4 professed that:

"…I think complying with the standards is for myself personally is easy because we know it, we understand why and how…there is a barrier between them [farm workers] and using the app, recording medication and actually reconciling with what they have and what they must do…But complying and having everything in place at the end of the day is not difficult if you have people [farm workers] that understand what they are doing and why we're doing this." – P4

This revealed the significance of the relationship between people and technology when it comes to administrative tasks. Moreover, the discussion drew attention to a possible system design requirement being the understandability of the system.

Figure 23 illustrates a balanced sentiment towards sharing responsibilities with employees, administrative maintenance, and discipline. To clarify, discipline is described as consistently attending to the responsibility of weekly administration. P2 touches on discipline and the consequence of falling behind by stating:

“But I agree with Participant 1 that when it comes to reconciling things, that's usually where the operational issues come in and then forgetting to do things. And I think usually the forgetting happens when it's not practical… the system is not practical enough that it gets done as part of the run of the day and then it gets neglected.” – P2

Note, P2 suggests that paperwork neglect occurs when the system used isn’t practical emphasizing the importance of integrating administrative tasks with practical operations. P1 contributed by stating: “…if a system is forced upon a farm and it's not part of the farm, it fails”. This further emphasises the importance of administrative systems integrating with farm operations.

Lastly, Figure 23 illustrates a strong negative sentiment from both categories towards the difficulty of managing all paperwork.

6.3.5. The paper load for Pork 360 compliance and administration operations

Questions 4 asked “Does compliance require large amounts of paperwork, if so, why?” and Question 5 asked “What does the administration look like for compliance?”. Questions 4 and 5 were asked simultaneously during the focus group and therefore responses were analysed accordingly. The discussions involved the paper load for Pork 360 compliance and administration operations. Figure 24 illustrates a Sankey diagram analysis for Question 4 and 5.

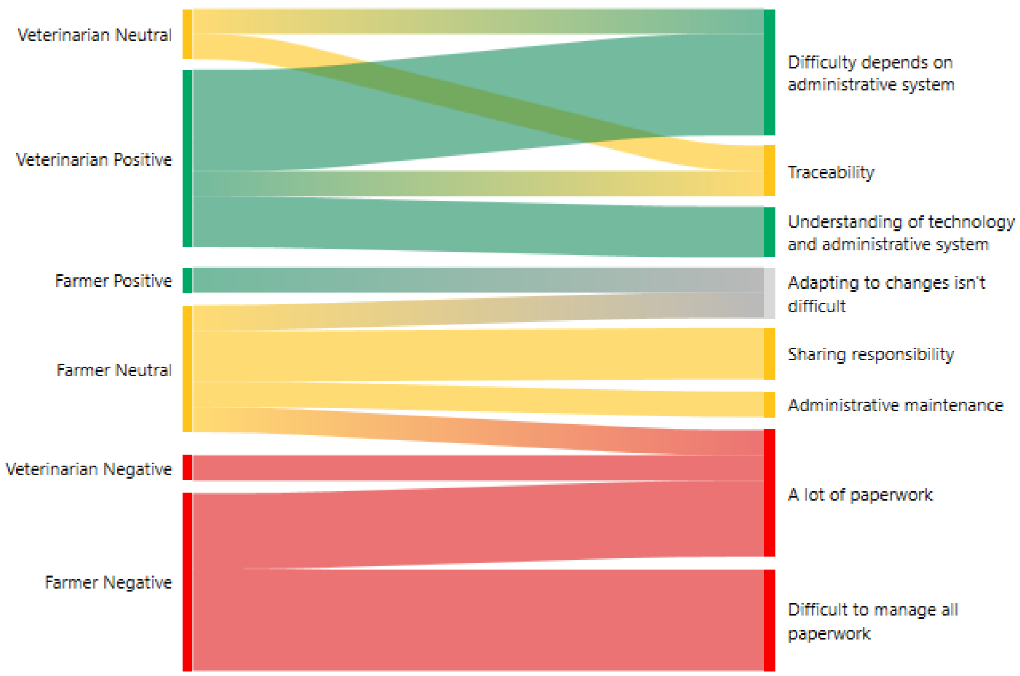

Figure 24. Sankey diagram for Question 4 and 5 developed in Atlas.ti ver.24.1.1.

A strong positive sentiment from the Veterinarian category is illustrated in Figure 24 towards the difficulty of paperwork being dependent on the administrative system used. P2 elaborates by stating that: “You can actually minimise a lot of the paper just by having it fit your system”. This statement is an echo from Section 6.3.4. where the notion of integrating administrative tasks with farm operations was introduced.

Figure 24 illustrates that neutral sentiments were conveyed in this discussion surrounding sharing the responsibility with farm workers and administrative maintenance.

Figure 24 illustrates a strong negative sentiment towards paperwork mostly from the farmer category. P5 shares the ramifications of neglecting or falling behind in paperwork by stating that: “If you skip one or a day, you are never returning to that.”. This relates as well to Section 6.3.4 echoing the significance of discipline. Furthermore, P7 suggests appointing someone to take the responsibility of paperwork as a proposition for the difficulty of maintaining paperwork by stating that: “…if you can appoint someone that's doing all the SOP’s and the registers and all those, then it makes sense”. This communicates the difficulties surrounding managing paperwork, so much so that appointing a person for the task may be needed.

6.3.6. The approximate time or percentage spent on administration per week

Question 6 asked “On average, what percentage of your time is spent on administration?”. The discussions involved the approximate time or percentage spent on administration per week.

This was a brief discussion with only neutral sentiments as the veterinarian participants could not answer this question. In summary the Head farm manager (P7) communicates that 70% of their time is spent on administration whereas the assistant manager spends approximately 2.5 hours a week on administration. Interestingly, P7 was previously an assistant manager and has experienced the difference in percentage of time spent on paperwork once promoted by sharing: "So, mine when I was a unit manager [assistant manager], I think it was 30 70 in, in the pig's favour [30% on paperwork]. But now it's the other way."

Noticeably, from the time studies discussed in Chapter 5 the observed average time spent on administration was 1 hour and 15.16 minutes which is more than an hour less than mentioned in the discussion.

6.3.7. Additional insights surrounding administration

Question 7 asked "Do you have any other insights surrounding administration?". The discussions involved additional insights surrounding administration. Figure 25 illustrates a Sankey diagram analysis for Question 7.

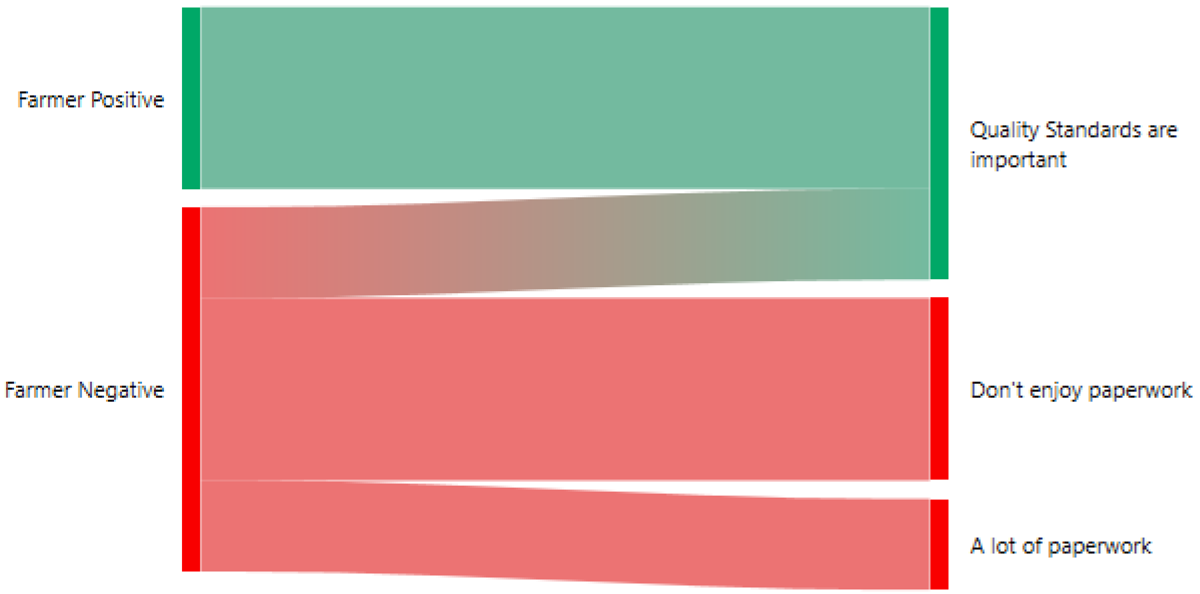

Figure 25. Sankey diagram for Question 7 developed in Atlas.ti ver.24.1.1.

Figure 25 illustrates that there is no neutral sentiment during this discussion. Moreover, although there is a lot of paperwork and the farmers don't enjoy it, the farmers recognise that Pork 360 Quality Standards are important. P4 encapsulates this sentiment by stating:

"It's irritating for everyone to go in and fill in a clipboard every time you walk the fence…Pork 360 plays such a huge role in the pork production in South Africa that we can't go without these standards…So at the end of the day, I would recommend any pig farmer to be part of Pork360, even though it can be a slep [burden] sometimes, but it's protecting you and it's protecting your employees and their jobs." – P4.

Significantly, P4 communicates that the quality standards protect the managers and employees. This could communicate that quality standards participate in value-adding activities (refer to section 5.1.1.), but aid in managers and employee's safety, and their job security.

6.3.8. The value of paperwork for farm operations despite disliking it

Question 8 asked "Is paperwork valuable for farm operations despite disliking the task?". The discussions involved the value of paperwork for farm operations despite disliking it. Figure 26 illustrates a Sankey diagram analysis for Question 8.

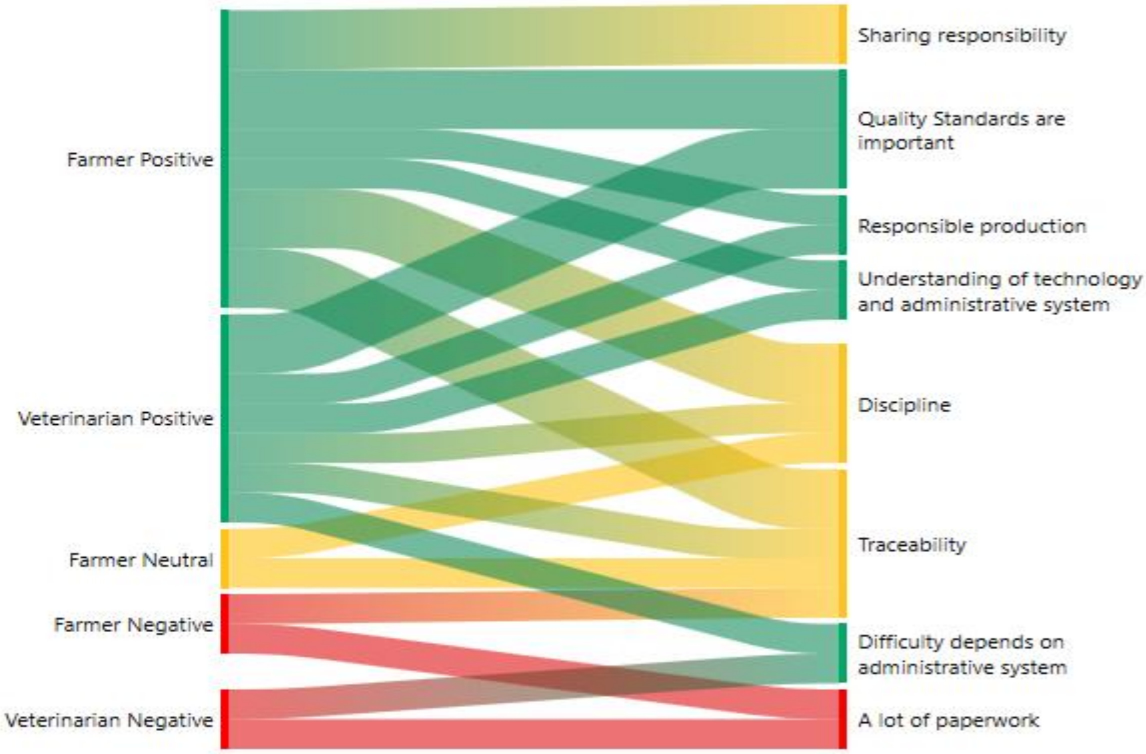

Figure 26. Sankey diagram for Question 8 developed in Atlas.ti ver. 24.1.1.

Figure 26 illustrates largely positive sentiments from both categories where responsible production, as a consequence of efficient paperwork, is recognised. P6 shares this sentiment by stating that: "… it's assurance that you are farming quality pork, you know, that you know what you're doing with, with your animals and that you know where it comes from and possibly where it's going, you know?". This reveals the value and contribution traceability has to responsible farm production.

P2 continues: "And I think that value, the value that it brings is traceability as part of the intrinsic idea of the scheme, both control on the farm and enabling better management and you know human resource management.".

Lastly, P2 elaborates further by stating that if the administrative system is used well, the farmer will be able to attain a lot more value from it than merely a certification: "So I do think you can, if the farm adopts the scheme as their own and makes the SOP'S and systems work for them, they can actually get a lot more value from it than just the certificate on the wall and the licence to sell". This contributes to the theme of integrating systems with farm operations.

6.3.9. Administration methods that were helpful and unhelpful

Question 9 asked "What administrative methods have you observed as solutions or failures?". The discussions involved administration methods that were helpful and unhelpful. Figure 27 illustrates a Sankey diagram analysis for Question 9.

Figure 27. Sankey diagram for Question 9 developed in Atlas.ti ver. 24.1.1.

As Figure 27 illustrates, the discussion points echoed from section 6.2.4. highlighting that when there is an understanding of the technology and administrative system the method works, where if responsibility is shared without understanding the method fails. P3 describes their own experience by sharing:

"So on my side, what really worked for me is the way I designed my medication on how to record a medication that is coming in and then the usage of medication. So what failed there is when I was doing it alone because I would do it, and then when someone does it, it's back to square one…" – P3

This statement reveals the significance of standardization of administrative processes and the importance of system understandability for delegation purposes.

6.4. Discussion of results

6.4.1. Consolidated analysis discussion

Figure 20 in Section 6.2.2. presents a triangulation of sentiment per category and identified codes in the discussion. Figure 20 conveys that understanding the technology used for administrative purposes and the administrative system will result in making the completion and maintenance of paperwork less difficult and by extension Pork 360 standards will be complied with. The Veterinarian category added to this by highlighting the design of the administrative system and that this design contributes significantly to the difficulty of managing paperwork pertaining to Pork 360 standards. Although both the Farmer and the Veterinarian category displayed strong negative sentiments to paperwork, the latter showed a stronger positive sentiment towards paperwork if the system used integrates sufficiently with farm operations.

Figure 21 shows that when it comes to understanding the technology and administrative system used, discipline, administrative maintenance, and sharing the responsibility are associated with it. Moreover, and more significantly, the design of the administrative system has a strong association to it. These associations reveal that when embarking on training participants in an administrative system, the design should be prioritized, discipline and by extension administrative maintenance is a requirement, and farm workers' collaboration should be practiced diligently.

Although Figure 20 portrays that understanding the administrative system as useful, sharing responsibility with employees (farm workers) had a more neutral sentiment. There is a positive sentiment towards collaborating with farm workers to maintain the administrative work. Moreover, it is understood that sharing administration responsibility with farm workers will ease the load and time spent on paperwork and as a result be helpful, but imparting the understanding of the administrative system remains a difficulty. Furthermore, once mistakes occur or paperwork isn't done the trust in sharing this responsibility fractures making it less likely that responsibility will be shared again.

Figure 21 indicates that adapting paperwork to changes made in quality standards isn't difficult. Although this may be the case, Figure 20 confirms the negative sentiment towards paperwork as described in Chapter 1 due to the amount of paperwork required and the difficulty of managing it amidst other operations and responsibilities.

Interestingly, Figure 21 indicates a balanced sentiment, leaning to positive, towards the importance of quality standards. This conveys that although the farmer participants don't enjoy paperwork and feel that it is too much, the farmers recognize that quality standards play an important role in their operations.

6.4.2. Questions analysis discussion

Figure 22 in section 6.2.3. largely portrays a neutral sentiment which is a result of the discussion mostly entailing a listing and reasoning of quality standards. Significantly, while discussing the top-quality standards, emphasis was placed on the usefulness of compliance and the risks involved when not adhering to or not having quality standards. Lastly, the value of having quality standards in farming was well communicated in the discussion pertaining to quality standard awareness. From this discussion the identified top categories were animal welfare, biosecurity, and treating the environment responsibly. Moreover, the veterinarian category contributed the most to this discussion suggesting that the farmer category awareness of Pork 360 standards was less than the veterinarian category.

The discussion on rating and reasoning the difficulty of paperwork, in section 6.2.4., showed both positive and negative sentiments, illustrated in Figure 23. It is evident that there was an agreed negative sentiment towards the difficulty of managing paperwork. A proposition of sharing the responsibility with the farm workers was brought up in the discussion. This proposition received mixed sentiments as it was perceived as a useful method for managing paperwork but only works if the workers are trained. Evidently, this is associated with the significance of understanding the technology and administrative system. In other words, it is difficult to get all administrative participants to understand the system, but once there is an understanding it is proven effective. Lastly, it was highlighted that if the administrative system doesn't integrate with the farm's method of operations, it fails. Therefore, a stakeholder engagement method of design should be used when formulating an administrative system for a farm. Making use of the CAM as the research design for this study shows its relevance and appropriateness for it incorporates stakeholder engagement.

Section 6.2.5. shows results of discussions on the paper load for Pork 360 compliance and admin operations. It can be deduced from Figure 24 that there is an agreement from both categories that there is a lot of paperwork which makes it difficult to manage. Furthermore, the farmer category communicated that they run the risk of 'falling behind', and if this occurs, they cannot recover. Although the veterinarian category agreed that there is a lot of paperwork involved for Pork360 compliance, they described the problem of paperwork as depending on the administrative system used.

Section 6.2.6. included results on a brief discussion surrounding time spent on Pork 360 related paperwork. It was revealed in this discussion that once an employee is promoted, the time or effort spent on paperwork increases. This suggests that as the responsibility increases, administrative tasks might increase, which will increase paperwork.

Section 6.2.7. dealt with additional insights surrounding administration. Figure 25 illustrates that despite not enjoying the large amounts of paperwork the farmer category acknowledges the importance of having quality standards. This recognition relates to the discussions on quality standard awareness in section 6.2.3.

Building on the acknowledgement of Quality Standard importance, section 6.2.8. dealt with the perceived value of paperwork. The discussion entailed benefits of having Pork 360 Standards such as the benefit of traceability for responsible production, but in general how the standards ensure that a farmer can produce responsibly. Furthermore, approaches of effective administration surfaced with a steady reminder that quality compliance involves a lot of paperwork.

Section 6.2.9. dealt with helpful and unhelpful methods of administration. The brief discussion summarized the agreed upon farmer category theme. This theme being that when there is an understanding of the technology and administrative system used amidst all participants, the sharing responsibility is possible, and by extension, the paperwork for Pork 360 compliance becomes easier.

6.4.3. Discussion summary

In summary, the farmer category described the solution to paperwork as sharing the responsibility with farm workers and training them such that they understand the technology and administrative system. The veterinarian category describes the solution to paperwork as designing the administrative system such that it integrates with farm operations. Moreover, training participants in understanding the technology and administrative system was also mentioned by the veterinarian category.

Both categories have communicated that paperwork is a lot and difficult to manage, but this difficulty depends on the understanding of the people involved and the design of the administrative system being used.

To showcase associations between sentiments and all 21 codes for system design requirements identification, Figure 28 illustrates an Excel table. The table showcases the co-occurrence of the codes and the sentiment categories. The conditional formatting Excel tool is used to colorize the sentiment weight value which is a percentage point of the total occurrence of a code. In doing this, a summarized analysis of the codes is possible allowing the formulation of the umbrella theme and the system design requirements.

Code number	Code	Farmer Negative	Farmer Neutral	Farmer Positive	Vet. Negative	Vet. Neutral	Vet. Positive	% Negative	% Neutral	% Positive
1	A lot of paperwork	5	1	0	2	0	0	88%	13%	0%
2	Adapting to changes isn't difficult	0	1	1	0	0	0	0%	50%	50%
3	Administrative maintenance	0	1	0	1	0	1	33%	33%	33%
4	Animal Welfare	0	0	0	2	6	0	25%	75%	0%
5	Bio-security	0	0	0	0	2	0	0%	100%	0%
6	Difficult to manage all paperwork	5	0	0	2	0	0	100%	0%	0%
7	Difficulty depends on administrative system used	0	0	0	1	1	5	14%	14%	71%
8	Discipline	0	1	3	1	0	1	17%	17%	67%
9	Don't enjoy paperwork	2	0	0	0	0	0	100%	0%	0%
10	Forced administrative system fails	0	0	0	1	0	0	100%	0%	0%
11	Good record keeping	0	2	0	0	0	0	0%	100%	0%
12	Healthy produce	0	0	2	2	6	0	20%	60%	20%
13	Human access	0	0	2	0	0	0	0%	0%	100%
14	Quality Standards are important	1	0	4	0	0	2	14%	0%	86%
15	Responsible production	0	0	1	0	0	3	0%	0%	100%
16	Sharing responsibility with employees	3	3	2	1	0	2	36%	27%	36%
17	Technology is confusing	1	0	0	0	0	0	100%	0%	0%
18	Technology is efficient for recording	0	0	1	0	0	0	0%	0%	100%
19	Traceability	1	3	2	0	5	2	8%	62%	31%
20	Treat environment responsibly	0	0	0	2	4	0	33%	67%	0%
21	Understanding of technology and administration system	3	1	6	2	0	5	29%	6%	65%

Figure 28. Co-occurrence table for all codes according category sentiment

In Figure 28, codes that show a dominant positive sentiment are code numbers 7,8,13,14,15,18, and 21. Identified positive themes are administrative system design and understanding, and management practices. Codes that show a dominant neutral sentiment are code numbers 4,5,11,12,19 and 20. Identified neutral themes are animal and environmental care, and data management. Codes that show a dominant negative sentiment are code numbers 1,6,9,10, and 17. Identified negative themes are paperwork management, forced administrative systems, and confusing technology. Merging the identified positive, neutral, and negative themes to aa central theme for the focus group discussion will enable the formulation of system design requirements.

6.5. Formulated central theme

Considering the several positive, neutral, and negative themes, the formulated umbrella theme is that paperwork is a lot and difficult to manage, but this difficulty depends on the involved people's understanding and the design of the administrative system being used. Moreover, technology usage can be confusing which can influence data management. Other themes such as management practice, animal and environment care fall outside of the scope of the research and isn't considered but are recommended for further research.

This theme communicates that an administrative system that is understandable and integrates with farm operations may resolve the challenge of the piggery experiencing long administration processing times for quality compliance. If a technology is considered as a deliverable, the user interface should be considered as a system design requirement to avoid confusion. These factors will then be considered as design requirements further discussed in Chapter 7.

6.6. Chapter summary

This chapter discusses the methods, analysis and results that pertain to focus group participant's perspectives with regards to Pork360 administration. Section 6.1 discusses the context and reasoning for conducting the focus group. Moreover, the aim and a list of objectives are provided in this section. Section 6.2. delved into the method of analysis, and results of the focus group discussions. Section 6.3. discusses the displayed results and identified key themes. Section 6.4. highlights the identified theme from the focus group for design requirement consideration in Chapter 7.

CHAPTER 7 SYSTEM DESIGN

This chapter provides a re-examination of the problem introduced in Chapter 1. The research followed the Critical Artefact Methodology (CAM) including the designing and processing of CA1, CA2, and CA3 to develop understanding of FA1. From the conducted SLR (CA1), Current State analysis (CA2), and Quality Standards analysis (CA3), the chapter identified requirements for the development of a system. Moreover, a discussion on the system architecture and detail design for the development of the system is discussed. Lastly, the chapter provides discussions on the developed FA1.

7.1. Re-examination of Problem and Prototype design method

Chapter 1 introduces the problem for this research namely that the piggery is experiencing long administration times for quality compliance. The chapter elaborated by discussing research that indicates farmers are frustrated by paperwork and tend to neglect it because paperwork requires hours and effort. Time studies and observations discussed in Chapter 5 confirm this by identifying that farm operations disrupt administrative processes and therefore take priority over paperwork. Moreover, the observed farmers have the responsibility of determining their own administrative process.

However, in neglecting paperwork, farmers risk not complying with quality standards for paperwork serves as evidence for quality operational activity. The consequence of non-compliance can mean substantial fines, or imprisonment. Furthermore, it can risk the inability to mitigate disease outbreaks and its effect on the customer community.

As discussed in Chapter 3, the advanced V-model method is followed for the development of a prototype. Figure 29 illustrates the advanced V-model and the chapter sections that address each layer. The model building takes place throughout sections 7.2 – 7.4. Testing layers are discussed in Chapter 8.

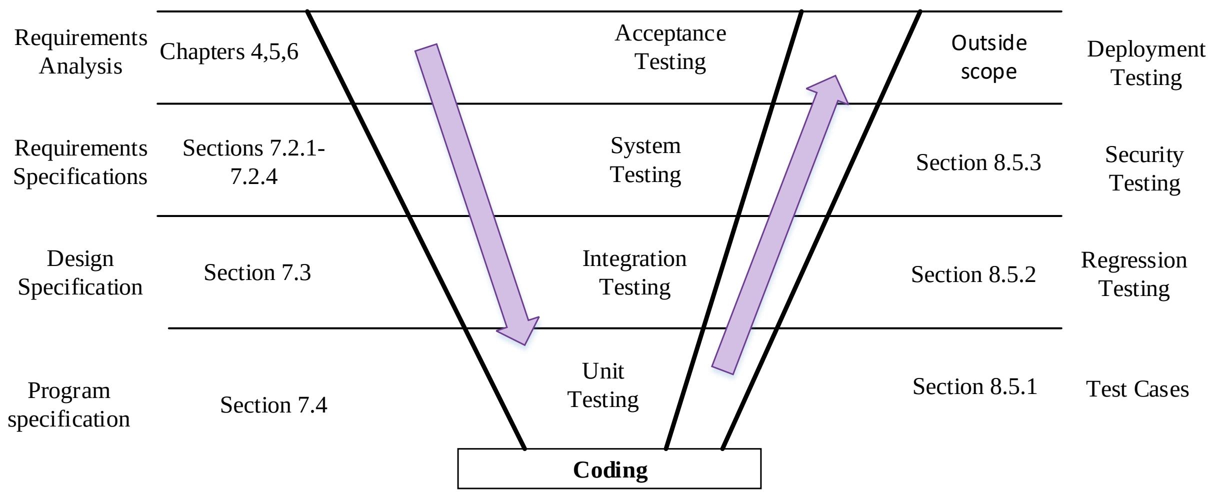

Figure 29. Advanced V- Model method with related sections

The scope of the research does not include the deployment of a system, but the design of a prototype therefore Deployment and Acceptance testing were not included in this research.

7.2. System Requirements

This section investigates design requirements from the conducted critical artefacts discussed in Chapters 4,5, and 6. The critical artefacts are a systematic literature review, current state analysis, and investigation of Quality Standards.

7.2.1.Systematic literature review

The purpose of the systematic literature review (SLR) was to investigate studies that pertain to precision agriculture applied in the swine industry. The scope of the identified problem considers the administrative space which indicates that results from the SLR are worth investigating and considering for system design requirements.

In Chapter 4, Figure 4 includes the identified enablers of pig precision agriculture, and barriers that pertain to the adoption of these technologies. To identify system design requirements this section will list the identified barriers. Table 23 includes the listed barriers identified in Chapter 4 and the associated system design requirements.

Table 23. Identified system requirements from the SLR

Code	Barriers	Identified system design requirements
DR1	Data inaccuracies	Captured data should be accurate
DR2	Impractical technology	The technology should be practical
DR3	Different software	A central software platform should be used
DR4	Maintenance of complex technology	The technology should be simple to maintain
DR5	Data capture inconsistency	The system should allow consistent data capture.

Table 23 includes design requirements that pertain mainly to the technological aspect of the design. This coincides with the sentiment discussed in Chapter 6 where a negative sentiment was observed towards confusing technology (refer to Figure 28).

7.2.2.Current State Analysis

The aim of the current state analysis was to make use of tools, described in Chapter 5, to formulate a context to the described problem and identify design requirements. Focusing on the findings of this chapter will be done to identify the determined system design requirements from the current state analysis. Table 24 includes a list of findings mentioned in Chapter 5 and the associated identified system design requirements.

Table 24. Identified system design requirements from the current state analysis

Code	Findings	Identified system design requirements
DR6	It was found that managers use a non-standardized unique approach to weekly administration (Section 5.1.3.).	The system should introduce a standardization to weekly administration.

DR7	It was found that not all registers are checked when conducting weekly administration (Section 5.1.2.).	The system should assist users in ensuring all registers are checked for compliance purposes.
DR8	It was found manager do not often check Pork360 quality standards (Section 5.1.2.).	The system should enable users to check Pork360 quality standards for compliance purposes.
DR9	It was found that farm managers bear the responsibility of developing their own administrative process (Section 5.1.3.).	The system should assist the user in developing an efficient administrative process.

Table 24 includes design requirements that take standardising weekly administration into consideration. Moreover, awareness of Pork 360 quality standards and registers to be checked are also considered. Lastly, the design requirements pertain mainly to how the system design should integrate with processes.

7.2.3. Quality Standards Analysis

Chapter 6 set out to analyse Pork 360 quality standards by conducting a focus group. The aim of the focus group was to investigate and identify themes from the participants' perspectives with regards to Pork 360 administration.

The chapter set out to identify a single theme of the discussion for system design requirement purposes. The identified theme was that although paperwork is a lot and difficult to manage, the difficulty depends on the understanding of the people involved and the design of the administration system. This indicated that:

- the system should be understandable (DR10) and
- the system should be integrable with farm operations (DR11).

7.2.4. System Design Requirements

System design requirements identified in Sections 7.2.1-7.2.3. are summarized in Table 25.

Table 25. System Design Requirements summary

System Design Requirements	
Systematic Literature Review (CA1)	
DR1	Captured data should be accurate
DR2	The technology should be practical

DR3	A central software platform should be used
DR4	The technology should be simple to maintain
DR5	The system should allow consistent data capture
Current State Analysis (CA2)	
DR6	The system should introduce a standardization to weekly administration
DR7	The system should assist users in ensuring all registers are checked for compliance purposes.
DR8	The system should enable users to check Pork 360 quality standards for compliance purposes.
DR9	The system should assist the user in developing an efficient administrative process.
Quality Standards Analysis (CA3)	
DR10	The system should be understandable
DR11	The system should be integrable with farm operations

Table 25 lists technology-oriented design requirements from CA1, process-oriented design requirements from CA 2, and process and user interaction design requirements from CA3. The listed system design requirements in Table 25 will be used to design the system architecture.

7.3. System Architecture

The system architecture sets out defining the structure, behaviour, and other relevant characteristics of the final artefact system. This is done by formulating a service-oriented system architecture, illustrated in Figure 30, and making use of an entity resource diagram to indicate system element relationships, illustrated in Figure 31.

For formulating the systems architecture, the service-oriented architecture (SOA) method is used due to the several layers it incorporates for defining the elements within the system. Moreover, literature reveals several uses of this method for designing data-oriented systems. (Refer to Section 2.3.2). Defining the elements within a system assists in determining system specifications on several layers of development which can be depended on throughout the development process. Moreover, defining users of the system allows the developer to design and develop the system around the defined users to increase the adoptability of the technology.

Figure 30 illustrates in the perception layer that Microsoft PowerApps as an application development software will be used. Currently the farm already makes use of applications created in Microsoft PowerApps resulting in PowerApps being considered for the development of the final artefact. Therefore, to maintain technology standardization specific to the farm and user familiarity

(Chi-Ju Woo, 2023), the researcher will make use of the Microsoft PowerApps platform. For the same reason, Microsoft SharePoint will be used as a database for the final artefact.

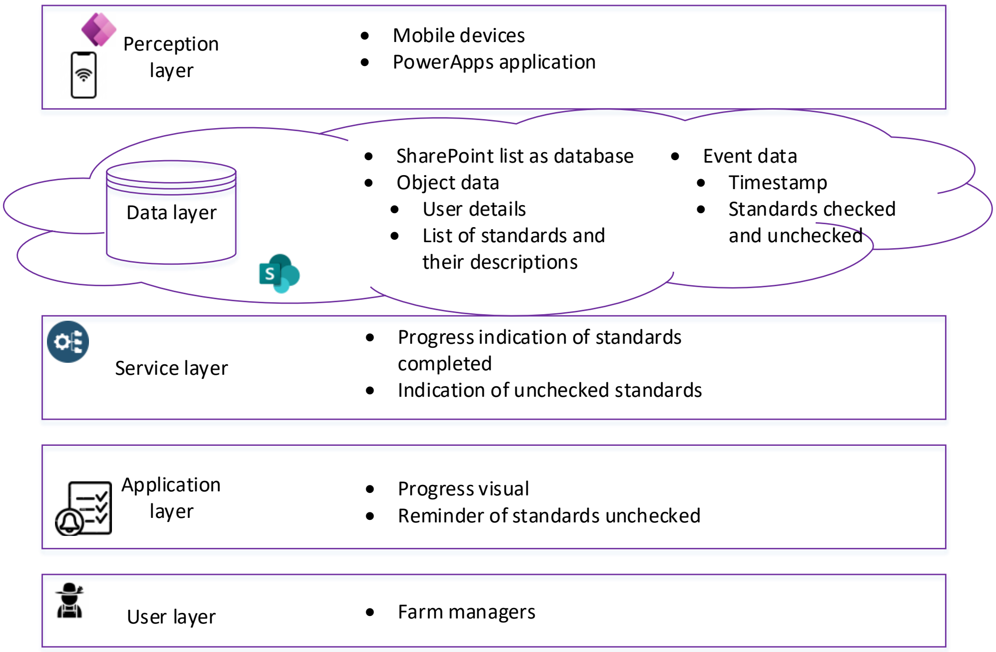

Figure 30. Service-oriented system architecture

Figure 31 illustrates the entity relationship diagram (ERD) showcasing the relationships between layers of the system. Furthermore, the ERD introduces attributes/elements of entities within the system. The details of these elements will be discussed in Section 7.4.

The perception layer includes screens that the user interacts with, and attributes or data points the user enters. The service and application layer includes data feedback operations such as updating the progress bar and notifying unchecked standards.

The data layer includes a temporary database and a SharePoint consisting of two databases. The temporary database acts as a temporary application database created on the mobile device which the user can add to and manage data. Upon submission, the data stored in the temporary database is transferred to the Checklist database found in SharePoint. On SharePoint the Checklist database and the Quality Standards database are located. The Checklist database includes the historical register of checklists submitted, and the Quality Standards database includes list if the quality standards and its descriptions.

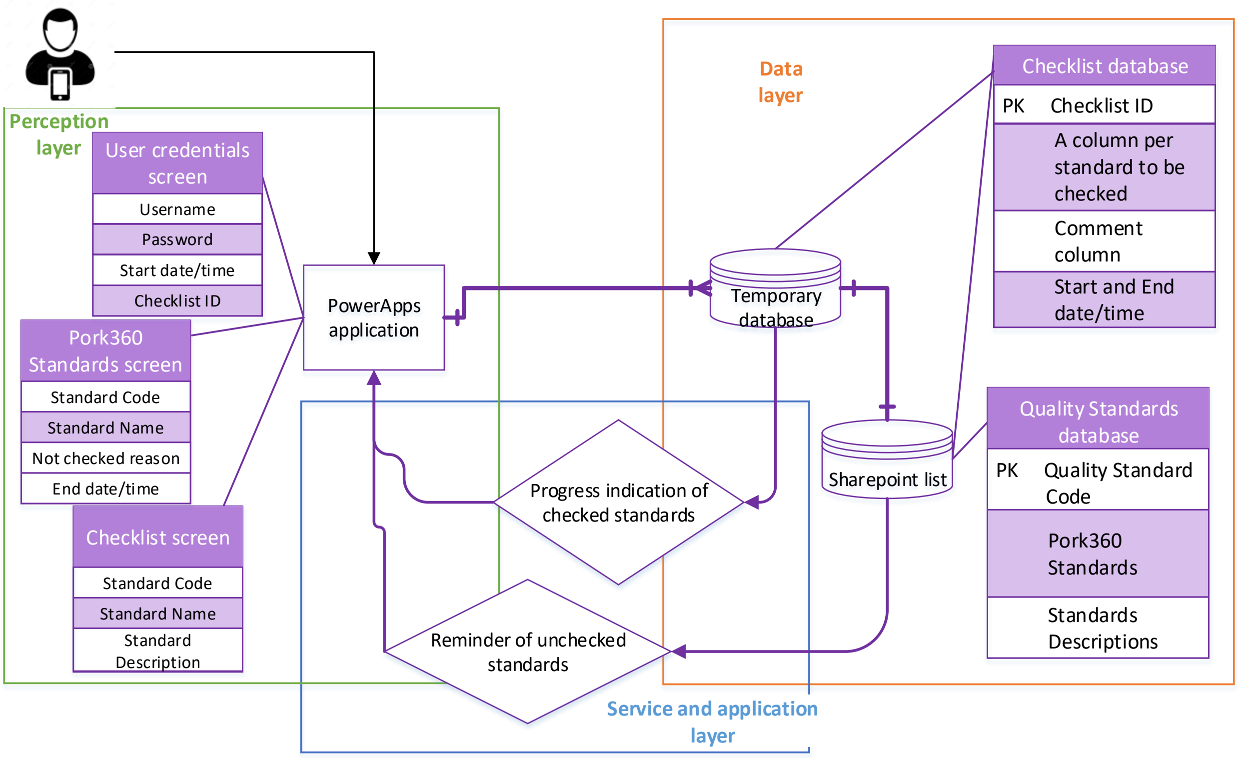

Figure 31. System Entity Relationship Diagram

The User Credentials screen checks the entered username and password with existing data for security purposes. Moreover, upon login the start date/time and unique Checklist ID is generated. The Pork360 Standards screen includes the codes, and names of standards. Furthermore, upon submission reasons for not checking standards can be entered and the End date/time of the session is captured. The Checklist screen includes the code, name, and description of the selected standard called from the Quality Standards database.

In Figure 31, the data in the temporary database updates the user's progress while checking the standards. It was found that this operation processed slower without a temporary database during the integration testing phase, therefore the decision was made to make use of a temporary database for application speed purposes.

7.4. Detail Design

This section aims to provide pseudo-code logic, decision logic, and user interface graphic design for the user credentials, Pork 360 standards, checklist interfaces, progress indication, and reminder of unchecked standards. The Pork 360 standard that will be considered for this system design are those that relate to the weekly administration process (refer to Figure 15 in Chapter 5).

7.4.1. User login

This interface is for user login purposes and serves as a security measure for the usage of the application. Table 26 includes the pseudo code and decision logic for the user login screen.

Table 26. Pseudo code and decision logic for user login screen

Pseudo code and decision logic

START Pork 360 weekly administration
// OnVisible event
OnVisible:
    // Set text for TextLabel 1
    TextLabel1.Text = "Pork 360 weekly administration"
 	
    // Set hint for username input
    username.TextInput.Hint = "Enter username"
 	
    // Set hint for password input
    password.TextInput.Hint = "Enter password"
 	
// On login button selected event
LoginButton.OnSelect:
    // Check if username or password is empty
    If(Or(IsBlank(username.Text), IsBlank(password.Text)),
        Notify("Username or password empty", NotificationType.Error),
 	
        // Check for valid username and password
        If(Or(
            And(username.Text = "User1", password.Text = "1234"),
            And(username.Text = "User2", password.Text = "1235")),
 	
            // Navigate if credentials are valid
            Navigate(Pork360Standards, ScreenTransition.Fade),
 	
            // Notify if credentials are invalid
            Notify("Invalid username or password", NotificationType.Error)
)

```
);

// Patch operation to update the administration record
Patch('Pork 360 weekly administration',
    Defaults('Pork 360 weekly administration'),
    {
        Title: Last('Pork 360 weekly administration').Title + 1,
        'Start Time': Text(Now(), "dd/mm/yyyy HH:mm")
    }
);

// Clear collection for TempData
ClearCollect(TempData, Last('Pork 360 weekly administration'));
```

Figure 32 illustrates the login screen design using a context diagram which will be developed in Microsoft PowerApps.

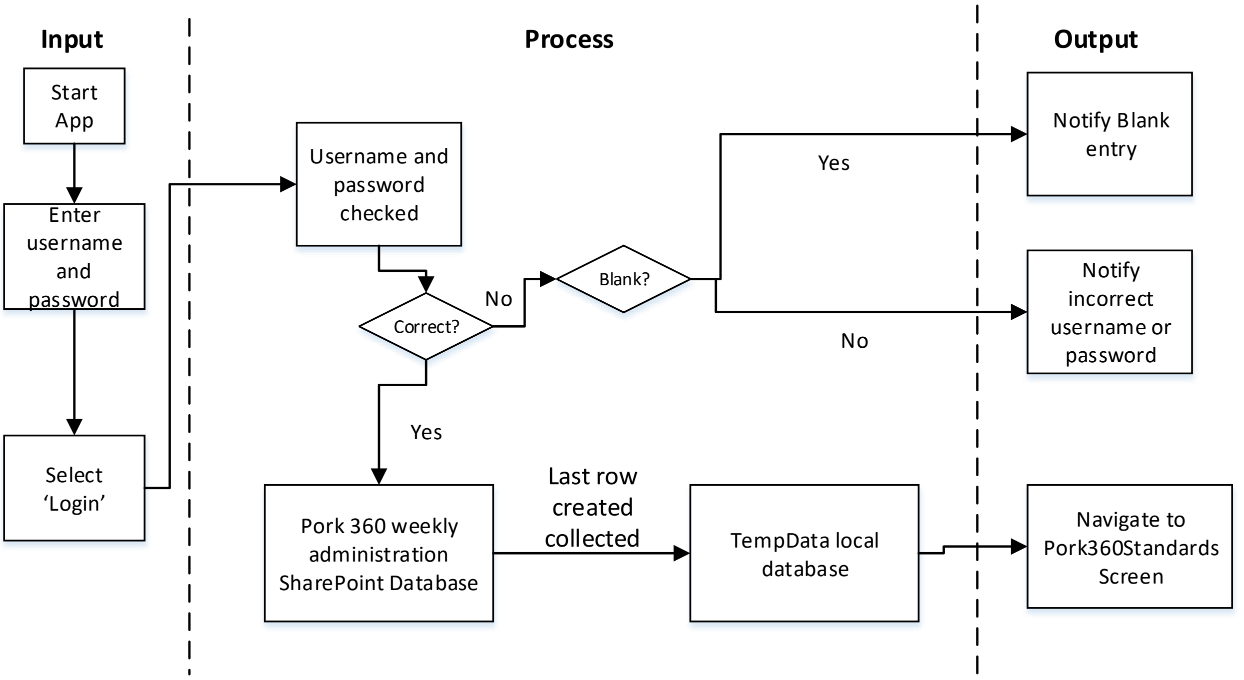

Figure 32. Context diagram of the user login screen

The user login screen operates by requesting the user to enter the username and password. If either entry is blank or incorrect, the user will be notified accordingly. If the entered details are correct, the last Checklist ID recorded in the Pork 360 weekly administration database (Checklist database) is called and incremented by 1 to create a new row wherein data can be entered. This new row is created in the TempData local database (temporary database). The user is then navigated to the Pork360Standards Screen.

7.4.2.Pork 360 Standards Screen

This interface is for displaying relevant quality standards to weekly Pork 360 related administration. Table 27 revisits these standards.

Table 27. List of Quality Standards related to weekly administration

Code	Quality Standard task	Code	Quality Standard task
1.5	Internal movement register	**7.2**	Cleaning of pens register
1.6	Delivery vehicle access register	**8.2**	Medicine Stocktake
2.1	Cleaning Schedule	**8.3**	Treatment Stocktake
2.2	PPE register	**8.6**	Needles Reconciliation
3.2	Pest Control register	**11.2**	Maintenance Register
4.2	Feed ordered and delivered reconciliation		

Table 28 includes the pseudo code and decision logic for the Pork 360 Standards Screen. The screen is prompted with a reminder of unchecked tasks from the previous login event. The Screen includes a Progress Bar which depicts the number of items that have been checked and a vertical gallery which provides a list of Pork 360 Standards to be checked. Once a checklist is complete and the user wants to submit the checked list, a prompt is presented to the user wherein a comment field is available for notes.

Table 28. Pseudocode and decision logic of Pork 360 Standards Screen

Pseudo code and decision logic

// OnVisible event
OnVisible:
    // Calculate the progress count
    Set(var_progress,
        CountIf(TempData, 'Internal movement register' = true) +
        CountIf(TempData, 'Delivery vehicle access register' = true) +
        CountIf(TempData, 'Cleaning Schedule' = true) +
        CountIf(TempData, 'PPE register' = true) +
        CountIf(TempData, 'Pest Control register' = true) +
        CountIf(TempData, 'Feed ordered and delivered reconciliation' = true) +
        CountIf(TempData, 'Cleaning of pens register' = true) +
        CountIf(TempData, 'Medicine stocktake' = true) +
        CountIf(TempData, 'Treatment stocktake' = true) +

```
        CountIf(TempData, 'Needles Stocktake' = true) +
        CountIf(TempData, 'Maintenance Register' = true)
    );

    // Set update variable and reminder prompt
    Set(var_update, false);
    Set(var_reminder, true); // Activate reminder prompt

    // Display reminder text label
    ReminderLabel.Text = "The following items haven't been checked previously: "

    // Build list of unchecked items from previous data
    UncheckedItemsLabel.Text =
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Internal movement register') = false, "1.5. Internal movement register", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Delivery vehicle access register') = false, "1.6. Delivery vehicle access register", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Cleaning Schedule') = false, "2.1. Cleaning Schedule", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'PPE register') = false, "2.2. PPE register", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Pest Control register') = false, "3.2. Pest Control register", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Feed ordered and delivered reconciliation') = false, "4.2. Feed Monitoring", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Cleaning of pens register') = false, "7.2. Cleaning of pens register", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Medicine stocktake') = false, "8.2. Medicine Stocktake", " ") & "
```

```
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Treatment stocktake') = false, "8.3. Treatment Stocktake", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Needles Stocktake') = false, "8.6. Needles Stocktake", " ") & "
" &
        If(LookUp('Pork 360 weekly administration', Title = Text(Last(TempData).Title - 1), 'Maintenance Register') = false, "11.2. Maintenance Register", " ")

    // "Continue" button action
    ContinueButton.OnSelect:
        Set(var_reminder, false);

    // Set button properties for progress display
    ProgressButton.Width = (var_progress / 11) * 591
    ProgressButton.Text = Round(var_progress / 11, 2) * 100 & "%"

    // Set default fill color for labels
    For each label in Labels:
        Label.Fill = If(Last(TempData).'Related item' = true, RGBA(21, 125, 2, 1), RGBA(202, 202, 202, 1));

    // Set up vertical gallery to navigate to checklist screen
    VerticalGallery.Items = 'Pork360 Quality Standards'
    For each item in VerticalGallery:
        item.NavigateIcon.OnSelect = Navigate('Checklist screen', ScreenTransition.Fade);


// On "Select to Complete check" button selected event
SelectToCompleteButton.OnSelect:
    Set(var_update, true);

    // Display prompt for unchecked records
    If(var_progress < 11 And var_update = true,
        DisplayText = "There are " &
```

```
        CountIf(TempData, 'Internal movement register' = false) +
        CountIf(TempData, 'Delivery vehicle access register' = false) +
        CountIf(TempData, 'Cleaning Schedule' = false) +
        CountIf(TempData, 'PPE register' = false) +
        CountIf(TempData, 'Pest Control register' = false) +
        CountIf(TempData, 'Feed ordered and delivered reconciliation' = false) +
        CountIf(TempData, 'Cleaning of pens register' = false) +
        CountIf(TempData, 'Medicine stocktake' = false) +
        CountIf(TempData, 'Treatment stocktake' = false) +
        CountIf(TempData, 'Needles Stocktake' = false) +
        CountIf(TempData, 'Maintenance Register' = false) &
        " unchecked records. Are you sure you want to submit?"
  );

  If(var_progress = 11 And var_update = true,
     DisplayText = "Would you like to submit your checklist?"
  );

// Multiline text input for comments
CommentInput.Hint = "Comment?";

// On Submit button selected event
SubmitButton.OnSelect:
  // Patch TempData with comments and end time
  Patch(TempData, LookUp(TempData, Title = Last(TempData).Title),
     {
        Comment: TextInput2.Text,
        'End Time': Text(Now(), "dd/mm/yyyy HH:mm")
     }
  );

  // Reset update variable and navigate
  Set(var_update, false);
  Navigate(LoginScreen, ScreenTransition.Fade);

  // Patch updates to weekly administration
```

```
    Patch('Pork 360 weekly administration', TempData);

    // Reset comment input field
    Reset(TextInput2);


// On Cancel button selected event
CancelButton.OnSelect:
    Set(var_update, false);
```

Figure 33 includes a context diagram of the Pork 360 Standards Screen functionality. In the process phase the list of standards in the SharePoint database is included in a vertical Gallery List view and the progress of the progress bar is populated by the number of true values associated to the current Login ID. When a standard, located in the vertical gallery, is selected then the user is navigated to the Checklist Screen (refer to Section 7.4.3.). Upon submission, data in the TempData local database is sent to the Pork 360 weekly administration as a new entry.

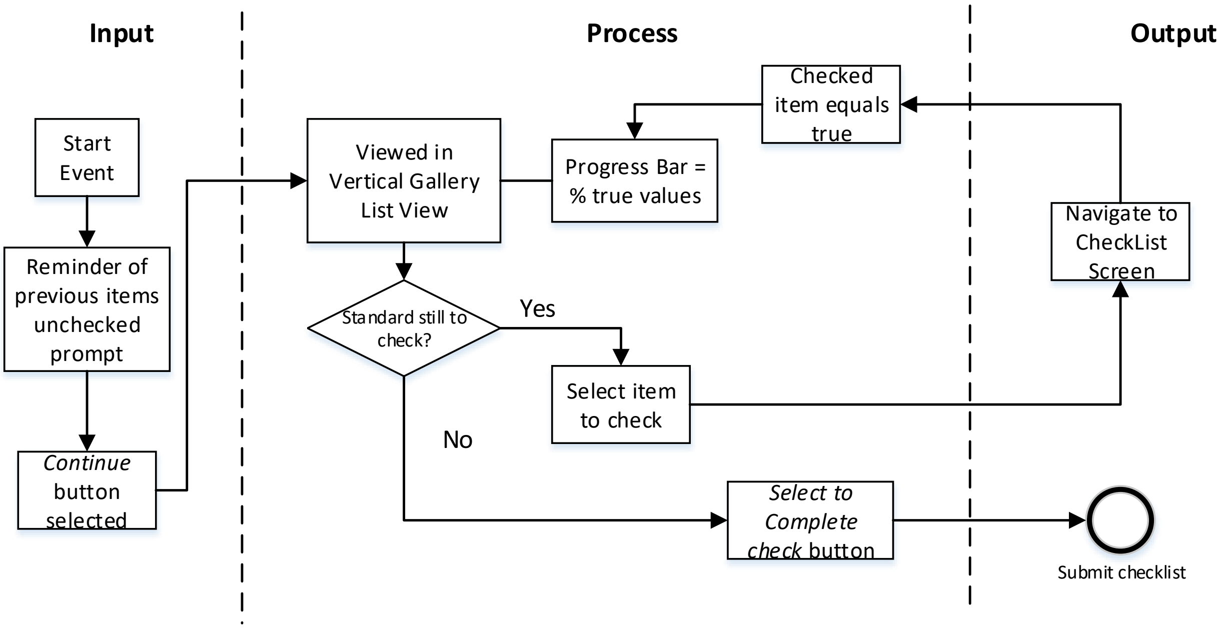

Figure 33. Context Diagram for Pork 360 Standards Screen

7.4.3.Checklist Screen

The purpose of the checklist screen is to provide the Pork 360 quality standard details of a selected item to be checked. Table 29 includes the pseudo code and decision logic of the Checklist screen. The screen includes three text labels and one check icon that acts as a button.

Table 29. Pseudo code and decision logic of Checklist Screen

Pseudo code and decision logic

// OnVisible event
OnVisible:
    // Set for Text Label 1
    TextLabel1.Text =
        LookUp('Pork360 Quality Standards', Title = Gallery1.Selected.Title).Title & " " &
        LookUp('Pork360 Quality Standards', Title = Gallery1.Selected.Title).'Item name'
 	
    // Set for Text Label 2
    TextLabel2.Text = "Item description"
 	
    // Set for Text Label 3
    TextLabel3.Text =
        LookUp('Pork360 Quality Standards', Title = Gallery1.Selected.Title).'Item Description'
 	
// On check icon selected event
CheckIcon.OnSelect:
    If(Gallery1.Selected.Title = "1.5.",
        Patch(TempData, Last(TempData), {'Internal movement register': true}),
    If(Gallery1.Selected.Title = "1.6.",
        Patch(TempData, Last(TempData), {'Delivery vehicle access register': true}),
    If(Gallery1.Selected.Title = "2.1.",
        Patch(TempData, Last(TempData), {'Cleaning Schedule': true}),
    If(Gallery1.Selected.Title = "2.2.",
        Patch(TempData, Last(TempData), {'PPE register': true}),
    If(Gallery1.Selected.Title = "3.2.",
        Patch(TempData, Last(TempData), {'Pest Control register': true}),
    If(Gallery1.Selected.Title = "4.2.",
        Patch(TempData, Last(TempData), {'Feed ordered and delivered reconciliation': true}),
    If(Gallery1.Selected.Title = "7.2.",
        Patch(TempData, Last(TempData), {'Cleaning of pens register': true}),
    If(Gallery1.Selected.Title = "8.2.",
        Patch(TempData, Last(TempData), {'Medicine stocktake': true}),
    If(Gallery1.Selected.Title = "8.3.",

```
    Patch(TempData, Last(TempData), {'Treatment stocktake': true}),
If(Gallery1.Selected.Title = "8.6.",
    Patch(TempData, Last(TempData), {'Needles Stocktake': true}),
If(Gallery1.Selected.Title = "11.2.",
    Patch(TempData, Last(TempData), {'Maintenance Register': true}),
    " "
))))))))

// Navigate to the Pork360Standards screen
        Navigate(Pork360Standards, ScreenTransition.Fade)
        Notify("Item checked successfully", NotificationType.Success)
```

Figure 34 includes a context diagram of the input, process, and output of the Checklist screen. TempData is a local database store on the user's device which is useful as connection to this database isn't dependent on the internet.

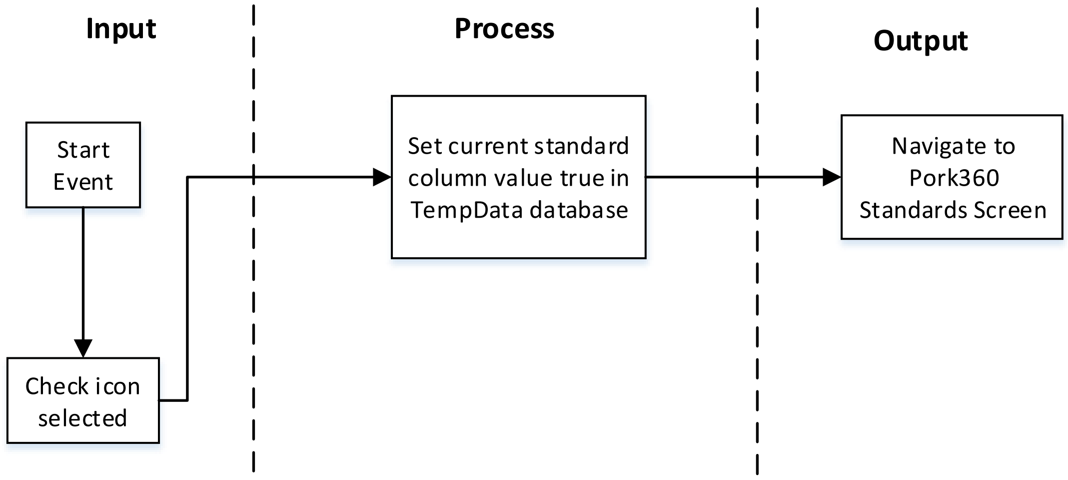

Figure 34. Context Diagram for Checklist Screen

7.5. Developed Final Artefact

This section introduces and illustrates the developed screen discussed in Section 7.4. The purpose of this development is to determine whether the design requirements identified in Section 7.2. can be developed. Microsoft PowerApps software is used for the development of the app, moreover Microsoft PowerApps' virtual mobile emulator is used. Microsoft PowerApps is used due to its accessibility and familiarity for the farm currently makes use of Microsoft PowerApps applications. In addition, the database for the captured data is stored in Microsoft SharePoint list for similar reasons. Note, the developed final artefact serves as a pilot artefact for testing purposes in accordance with the advanced V-model.

7.5.1. User login Screen

The developed User login screen consists of a text label, two text inputs, and a button. The purpose of this screen is to ensure security for App users. Upon selecting Login, the user navigates to the Pork 360 Standards screen. Figure 35 illustrates the user interface of the user login screen.

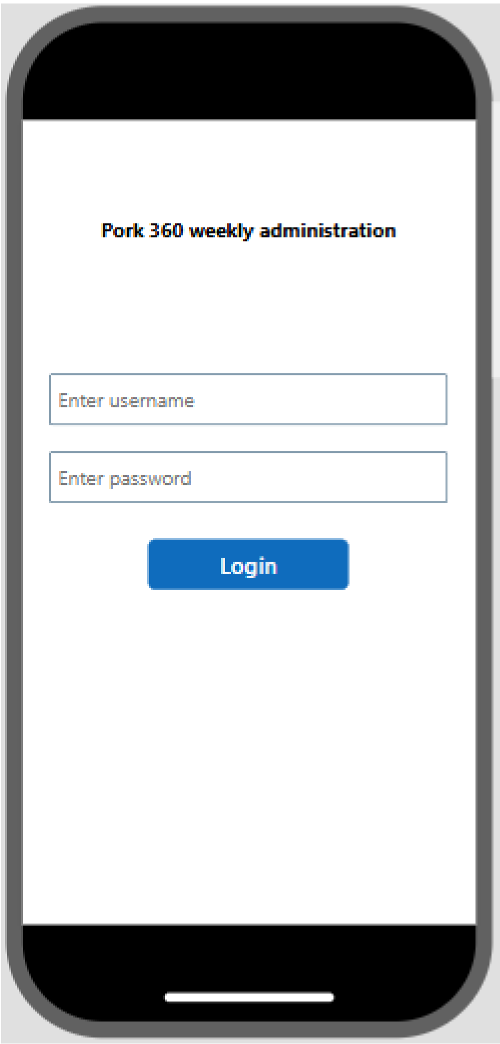

Figure 35. User login screen

7.5.2. Pork 360 Standards Screen

There are several prompts and functions involved in the Pork 360 Standards Screen. The screen accompanies a reminder prompt, a progress bar, a list of standards, and a submission prompt.

Once the user has logged in, the reminder prompt, illustrated in Figure 36, presents the user a list of items/standards that haven't been checked previously. The list included in the prompt corresponds with the Pork 360 Q.A.T codes and the title of the item/standard.

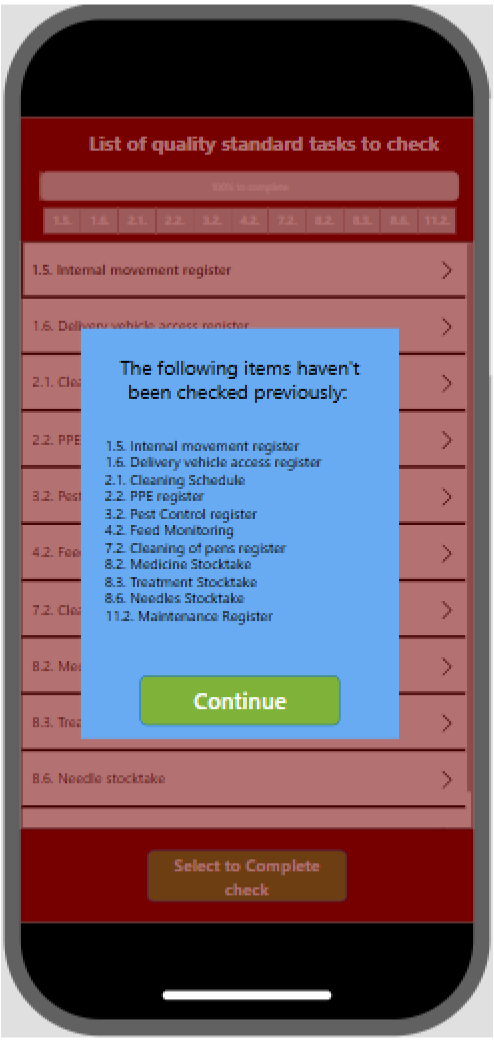

Figure 36. Screenshot of Pork 360 Standards screen reminder prompt

Once the user selects Continue the prompt is no longer visible and the user can continue with the weekly administration.

The primary user interface of the Pork 360 Standards screen consists of two progress bars and a vertical gallery list. The topmost progress bar indicates the percentage of items/standards checked, and the second progress bar indicates the items that have been checked. Figure 37 illustrates a screenshot of the main Pork 360 Standards screen and includes labels discussing parts of the application interface.

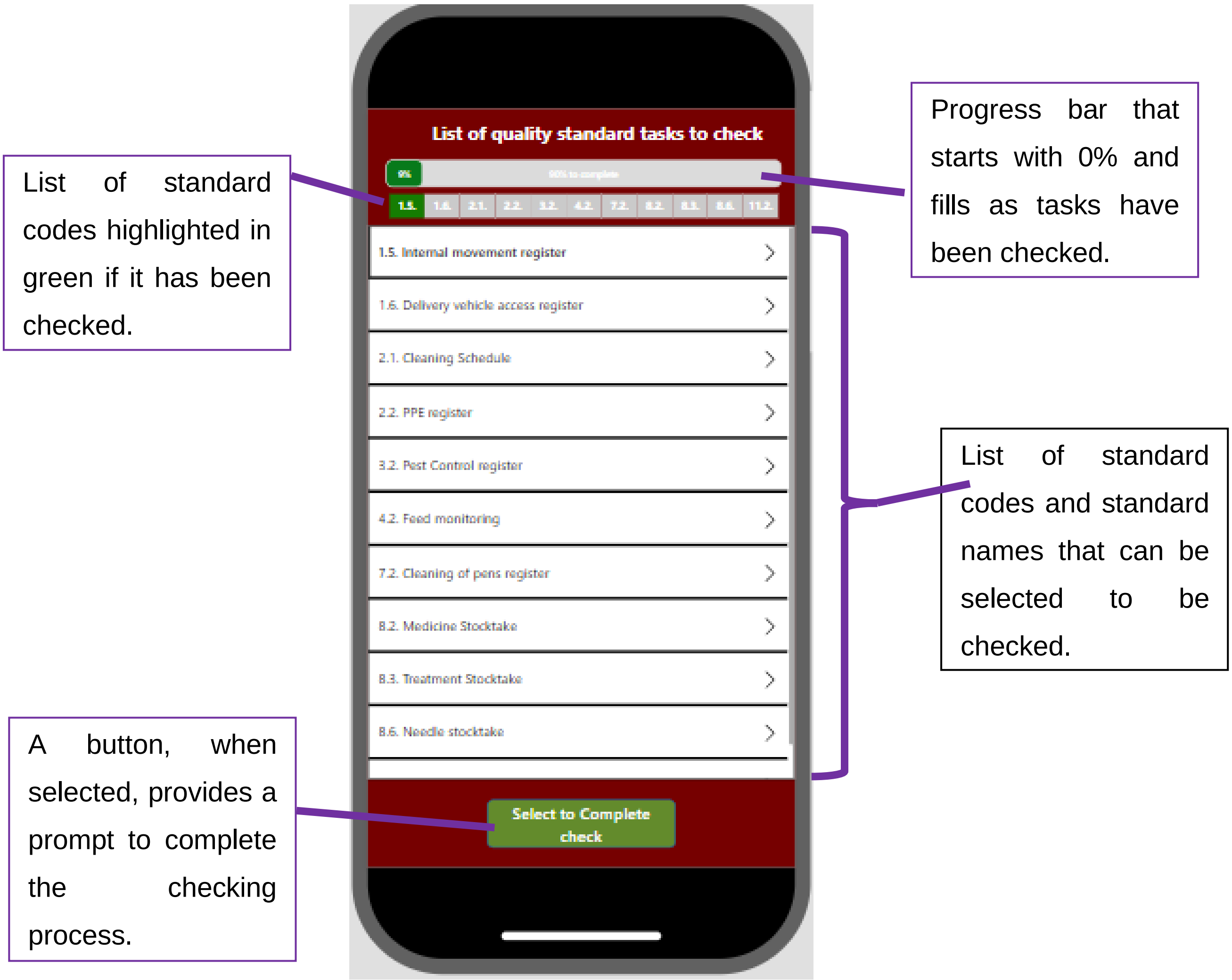

Figure 37. Screenshot of Pork 360 Standards main screen

The vertical gallery includes 11 rows including the item code which corresponds with the Pork 360 Q.A.T codes, the title of the item/standard, and an arrow. The correspondence of item codes is incorporated for standardisation purposes. When a user selects the arrow in a specific row, the user is navigated to the checklist screen.

The user then selects Select to Complete check button, once the user has completed the administration and would like to submit the checked list. Upon selecting the button, a submission prompt is presented to the user where the user can decide whether to submit the checklist or return to the main screen. Figure 38 illustrates a screenshot of the Pork 360 Standards submission prompt screen.

The submission prompt includes an indication to the user on how many items haven't been checked and a multi-line text input field for comments. The user can select the Cancel button, if the user decides to return to the main screen.

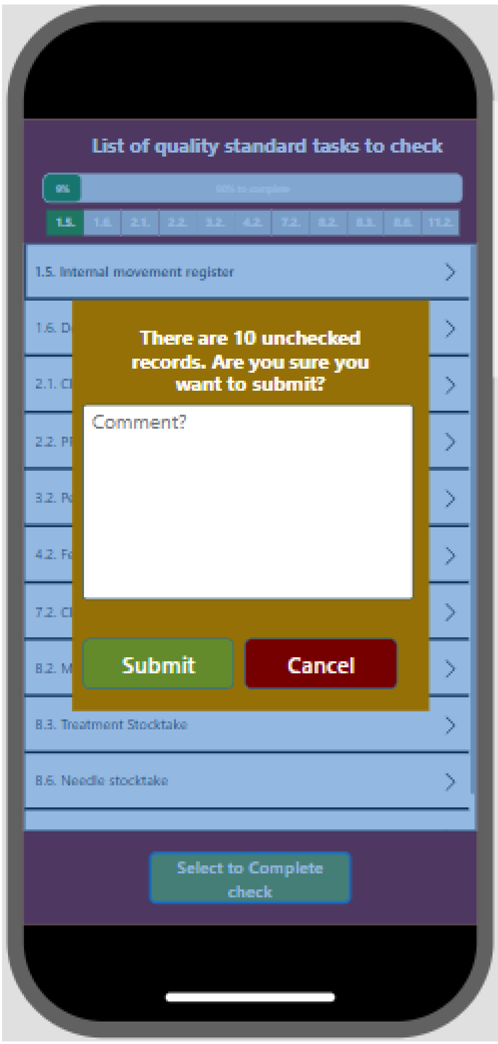

Figure 38. Screenshot of Pork 360 Standards submission prompt

Once the user selects the Submit button, the following data will be stored in the SharePoint list:

- items/standards that have been checked or unchecked
- Start and End timestamps
- Comments
- Session/Checklist ID

7.5.3. Checklist Screen

The Checklist screen includes 3 text label fields where in the standard title and description can be found. The descriptions included in this screen correspond to the Pork 360 Q.A.T document and presents the user details of the quality standard to be complied with. Figure 39 includes a screenshot of the Checklist screen.

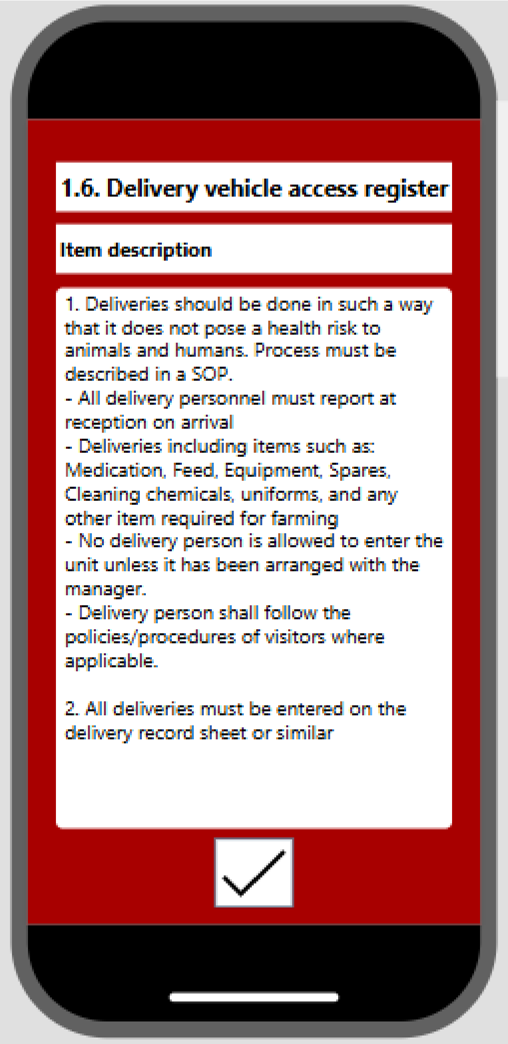

Figure 39. Screenshot of Checklist Screen

The Checklist screen includes a check icon which acts as a button. Once the check icon is selected the item/standard is recorded as 'checked', and the user is navigated to the Pork 360 Standards screen.

7.6. Chapter Summary

This chapter provided a re-examination of the problem introduced in Chapter 1. From the conducted SLR, Current State analysis, and Quality Standards analysis, the chapter identified requirements for the development of a system. In the design phase of development, this chapter discussed the system architecture and detail design. Lastly, the chapter provided discussions on the developed final artefact. The verification and validation of the system is further discussed in Chapter 8.

CHAPTER 8
VERIFICATION AND VALIDATION

This chapter discusses the verification and validation of critical artefacts and the final artefact. The chapter first introduces definitions and descriptions of the terms verification and validation. Once described, verification and validation for the SLR, Current State Analysis, Quality Standard analysis, and Checklist application are discussed. Moreover, methods of verification and validation for each section are introduced and discussed.

8.1. Verification and Validation

The Critical Artefact Method (CAM) contains continuous verification and validation. In this research this occurs at each critical artefact in various ways. This chapter aims to provide a discussion on the verification and validation methods used for the Systematic Literature Review (Chapter 4), Current State Analysis (Chapter 5), Quality Standard Analysis (Chapter 6) and the development of the final artefact (Chapter 7).

The oxford dictionary defines verification as the act of showing or checking that something is true or accurate, and validation as the act of proving that something is true or correct (Press, 2024). From a model design perspective, verification is described as the substantiation of a model or framework which is designed and executed according to design requirements or specifications (Balci, 1998). Validation is described as substantiating a model based on its applicability with its domain and its satisfactory with set objectives (Balci, 1998).

8.2. Systematic Literature Review (CA1)

While completing the systematic literature review a selection process was followed discussed in Chapter 4. The selection process entailed searching research articles while following a defined research protocol. Search results were exported into a Comma Separated Value (CSV) file which were then consolidated into master Excel spreadsheet. Both the exported csv files, and excel spreadsheet included the title, keywords, journal name, abstract, and year of publication for each article. The identification of duplicates procedure involved an Excel VLOOKUP function using the title of the paper as the look up value. Once duplicates were removed, the eligibility screening procedure involved searching exclusion terms, defined in the exclusion criteria within the articles.

The systematic literature review (SLR) results were included in a manuscript that was submitted to a conference which included a double-blind review. Upon first submission the manuscript is communicated to two anonymous manuscript reviewers. The task of the review is to place the manuscript and its content under verification and validity critique. The reviewers then provided feedback giving indication on the degree of manuscript changes and upon changes made, the manuscript can be accepted in the conference proceedings. Table 30 includes the requested changes which involved further clarification on specific themes in the document and improving the document quality amidst other criteria.

Table 30. Reviewers' responses for SLR manuscript

	Review 1	Review 2
Contribution	3: (significant and important contribution) Should not have references in the abstract.	1: (marginal contribution)

Method/Approach	3: (well-reasoned and convincing method/approach)	1: (Some flaws but can be considered after addressing the issues/concerns)
Clarity	3: (excellent)	1: (needs improvement - some rework required)
Quality	2: (minor issues)	2: (minor issues)
Conference theme	2: (clearly related to the conference theme)	1: (somewhat related to the conference theme) The puzzle concept brought in your conclusion is, "The study contributes one piece to the puzzle of the implementation of precision agriculture techniques". This can be taken further by clarifying the piece of the puzzle you have brought and which other known issues still exist not covered in your study.

The researcher applied the requested clarifications and changes to the manuscript and re-submitted the changed manuscript. Upon re-submission the manuscript passed the double-blind review, was accepted in the conference proceedings, and presented at the ISEM2023 conference in Somerset West, South Africa between the 2nd and 4th October 2024.

8.3. Current State Analysis (CA2)

Several approaches were used to analyse the current state of the farm that served as a case study for this dissertation. One approach was to conduct time studies which is discussed in Chapter 5. To verify the time studies, a survey was developed where the survey questions were formulated from findings in Chapter 5. Seven questions were included in the survey and a 5-point Importance Likert scale approach was used to record participant responses, 1 being Very Low (Very Unimportant) and 5 being Very High (Very Important). Upon receiving ethical approval to conduct the survey (ethics number NWU-00498-24-A3), the survey was communicated to 5 different managers at the specific farm (refer to Section A.3.). The survey received 3 responses, illustrated in Table 31, including the mean and standard deviation (Boone Jr and Boone, 2012).

Table 31. Survey responses

Code	Motive for survey question	Question	Mean	Standard deviation
Q1	To prove that managers have a non-standardised unique approach to filing, stock take, and reconciliation	Is having a standardized administration process important?	4.667	0.577

Code	Motive for survey question	Question	Mean	Standard deviation
Q2	To prove that managers spending too much time on administrative tasks could be because of a lack of clear SOP's and administration processes.	To what degree of an affect would a standardized administration process have on the time spent on administrative tasks?	3.667	1.155
Q3	To prove farm operational disruptions, cause paperwork neglect.	To what degree do farm operations take priority over administrative tasks?	4	1
Q4	To check the usefulness of technology used for stock take during administration.	To what degree are you confident in the accuracy of data recorded on technological devices?	3.333	0.577
Q5	To check the awareness of registers and the importance thereof	To what degree is checking registers important?	4	1
Q6	To check the significance of technology used for medicine stock take.	To what degree is medicine stock take important?	4.667	0.577
Q7	To prove that technology is a useful solution to administrative tasks	To what degree do you think technology can help with administrative tasks?	4.333	0.577
		Grand mean	4.1	0.780

Based on the survey results, it can be deduced that consensus was reached amongst participants (with an average of greater than 3 on each of the survey statements), thereby verifying and validating the application.

The responses for the first two questions convey an interesting view of standardization. There is consensus (low variance) on the importance of standardization, but not on its impact on administration time.

For the prioritization of farm operations and paperwork question, it received an Important score in the farm operations favour, but there is high variation in responses. The variation in responses indicates that some participants view administrative tasks as significant in comparison to farm operations.

Responses related to the usage of technology received a Neutral score in data accuracy with low variance, but the view of technology being a helpful method of administration received an important score also with low variance. This suggests that most participants are not very confident in the accuracy of data captured with technology but recognize the usefulness technology has for administrative tasks.

In Table 31, Q4, Q5, and Q6 are linked to verifying the current state analysis whereas Q1, Q2, Q3, and Q7 are linked to validation. The survey attempts to verify that managers make use of technology for medicine stock take and check registers (refer to Figure 15). The survey does this by checking the managers perceived importance on the usefulness and significance of technology and checking the manager's perceived importance of registers in the administrative context.

The survey attempts to validate findings in Chapter 5 from observations made while conducting time studies. More specifically, the survey set out to prove that managers make use of non-standardized unique approaches to administration (Q1) which could cause spending too much time on administrative tasks (Q2). Therefore, technology as a viable solution could be considered (Q7). Lasty, farm operational disruptions cause paperwork neglect (Q3).

The survey set out to prove Q1 by revealing the perceived importance of standardized administrative processes. Moreover, Q2 sets out to prove a relationship between time spent on administration and standardized administrative processes. Q7 set out to prove that managers consider technology a useful solution to administrative tasks. Lastly, Q3 set out to prove that managers perceive farm operations more important than paperwork.

8.4. Quality Standards Analysis (CA3)

The approach taken to analyse Pork 360 quality standards was to conduct a focus group. Upon receiving ethical approval, an invitational poster was communicated to pre-selected potential participants where in a detail of the focus group discussion is included. Following the snowball method, the potential participants could then share it with other individuals they felt could contribute to the discussion. Before the focus group was held, an informed consent form was shared with each participant to maintain ethical procedure. Participants were informed that discussions were recorded for data analysis purposes. Several questions were asked during the focus group to facilitate the group discussions and to clarify discussed points. Recorded discussions were then transcribed and analysed in Atlas.ti which is discussed in Chapter 6.

To maintain rigor during the focus group, questions were formulated such that it aligns with the inquiry purpose (Ryan et al., 2014). Meaning, aligning the focus group questions with the piggery experiencing long administration processing times for quality compliance. Credibility of the focus group is considered to convey the validity of the focus group (Chism et al., 2008). (Chism et al., 2008) shares steps to assure methodological soundness and recommends to of the steps to be employed. The two steps that have been employed are triangulation and reflexivity. Moreover, triangulation is considered as an approach of giving evidence for credibility (Chism et al., 2008).

Triangulation includes capturing multiple points of view to look for patterns illuminating themes in the discussion. This was evident in the analysis of focus group discussions in Chapter 6 by triangulating identified codes with observed attitudes. This assisted in identifying what attitude participants conveyed in specific discussion themes. Reflexivity was shown by communicating possible researcher bias in section 6.2 and the last paragraph of section 6.3.2. Possible bias included the researcher being the only focus group facilitator, and three additional questions being asked to facilitate the focus group discussions.

The performed sentiment analysis reveals the negative sentiment farmers have towards paperwork which proves identified challenges discussed in Chapter 1. Moreover, the analysis showcased administrative difficulties are dependent on the administrative system used. In light of this, the found sentiment managers have towards paperwork is understandable due to the evident challenges the current administrative system has (refer to Chapter 5).

8.5. Checklist application (FA1)

For evidence of verification and validation, the developed application in Chapter 7 will undergo several tests as described by the advanced V-Model methodology.

8.5.1. White box testing using Unit testing/Test Cases

As described in Chapter 2, white box testing involves testing individual units of a system. This can be small units of code or classes. The developed application was verified by testing logic, boundaries, error handling, and object orientation. This was performed by including a prompt or notification that signifies the tester whether the unit of code works as intended. Moreover, to ensure no errors occur upon initialization of the code. Table 32 includes the checklist of sample codes that were tested for errors, logic and boundaries. To maintain brevity, not all code is included in Table 32.

Table 32. White box testing of developed application

Screen	Sample code to be tested	
Login screen	**/*If input is blank or is incorrect return prompt indicating blank or invalid entry*/** If(Or(IsBlank(username.Text),IsBlank(password.Text)),Notify("Username or password empty", NotificationType.Error), If(Or(And(username.Text = "User1", password.Text = "1234"), And(username.Text = "User2", password.Text = "1235")), Navigate(Pork360Standards, ScreenTransition.Fade), Notify("Invalid username or password", NotificationType.Error)));	✓
	/*If there is an error creating a new row after login, return prompt indicating an error*/ IfError(Patch('Pork 360 weekly administration', Defaults('Pork 360 weekly administration'), {Title: Last('Pork 360 weekly administration').Title + 1 ,'Start Time': Text(Now(), "dd/mm/yyyy HH:mm")}), Notify("An error occured please try again", NotificationType.Error);	✓
Pork360 Standards screen	**/*Check if reminder prompt visibility is set to false once Continue is selected*/** IfError(Set(var_reminder,false),Notify("Prompt visibility could not be set to false", NotificationType.Error))	✓
	/*Check if there is an error when capturing the entered comment and the current date and time*/ IfError(Patch(TempData, LookUp(TempData, Title = Last(TempData).Title), {Comment: TextInput2.Text, 'End Time': Text(Now(), "dd/mm/yyyy HH:mmotify("Could not capture the comment or date", NotificationType.Error);	✓
	/*Check if the upload prompt visibility is set to false*/ IfError(Set(var_update, false),Notify("prompt could not be set to false", NotificationType.Error));	✓
	/*Check if the navigation path is correct*/ IfError(Navigate(LoginScreen,ScreenTransition.Fade), Notify("Could not navigate to the login screen", NotificationType.Error));	✓
	/*Check if there is an error when uploading data*/ IfError(Patch('Pork 360 weekly administration', TempData),Notify("Could not upload data", Notify("Upload failed", NotificationType.Error)));	✓
	Check if the item checked function works as intended	✓

Checklist Screen	After checking the item, does the progress bar update with 1 item?	✓

Table 32 illustrates that the developed application is verified and completes the first phase of testing.

8.5.2. Black box testing using Regression and Integration testing

Black box testing involves functional testing which solely focuses on outputs generated from selected inputs and end execution conditions. Regression and Integration testing are the two types of testing considered for verifying the functionality of the developed application. Regression testing involves retesting previously tested functionalities to verify code changes that have affected the existing features. Integration testing tests the interface functionality between software units of the application.

Table 33 includes a checklist for both regression and integration testing. The regression testing tasks focus on checking object and calculation changes while the application is in use. These tasks pertain to the progress bars, the reminder prompt, and submit prompt as all of them are susceptible to changes while the application is in use.

The integration testing tasks focus on application navigation, in other words, user navigation while using the application. These tasks include navigating the user from the login screen to the Pork360 standards screen, navigating from the Pork360 standards screen to the checklist screen, navigating the user to the Pork360 standards screen after checking an item, and navigating the user to the login screen upon submission.

Table 33. Regression and Integration testing checklist

Test type	Task	Check
Regression	Do both progress bars update appropriately once an item is checked?	✓
	Does the reminder prompt include items previously unchecked?	✓
	Does the submit prompt include the number of items that haven't been checked accurately?	✓
Integration	Is the user navigated successfully to the Pork360 Standards screen after login?	✓
	When selecting an item to check, is the user navigated to the Checklist screen with the correct item name and description?	✓
	Once the item is checked, is the user navigated to the Pork360 Standards screen?	✓

	After the user has submitted the checklist, is the user logged out?	✓

8.5.3. System testing

System testing revisits the system requirements defined in Chapter 7, and checks if the developed application addresses these requirements. Table 34 includes a checklist of system requirements and the approach taken by the developed system to address the requirement.

Table 34. System requirements checklist

Code	System Design Requirements	Check	Reason
Systematic Literature Review			
DR1	Captured data should be accurate	✓	The application does not require complex data entries which ensures accurate data.
DR2	The technology should be practical	✓	The application is usable on a mobile device or tablet.
DR3	A central software platform should be used	✓	The Microsoft Power Platform is used.
DR4	The technology should be simple to maintain	✓	The database for captured data is accessible to users, if data needs to be corrected.
DR5	The system should allow consistent data capture	✓	The system maintains simplicity therefore ensures consistent data capture.
Current State Analysis			
DR6	The system should introduce a standardization to weekly administration	✓	The system includes names and descriptions of quality items/standards which introduces a standardization to items addressed.
DR7	The system should assist users in ensuring all registers are checked	✓	The system includes names and descriptions of quality items/standards.
DR8	The system should enable users to check Pork 360 quality standards	✓	The system includes names and descriptions of quality items/standards.

DR9	The system should assist the user in developing an efficient administrative process.	✓	The system provides awareness of quality standards to be checked providing an opportunity for the user to develop an efficient administrative process.
Quality Standards Analysis			
DR10	The system should be understandable	✓	The system's usability isn't complex with a helpful user interface.
DR11	The system should be integrable with farm operations	✓	The system incorporates integrability ensuring the application is available on a mobile phone and showcasing the quality standard names and descriptions.

In summary, the developed Checklist application (FA1) suffered three levels of testing (Sections 8.5.1. – 8.5.3.). As defined in the introduction of this chapter, validating a model is described as substantiating a model based on its applicability with its domain and its satisfactory with set objectives. The developed application has satisfied set objectives (design requirements) within the domain defined by the methods of testing at the unit testing, integration and regression testing, and system testing levels. It is worth reminding the reader, the scope of the research does not include the deployment of a system, but the design of a prototype therefore Deployment and Acceptance testing were not included in this research.

8.6. Chapter summary

This chapter discussed the verification and validation of critical artefacts and the final artefact. The chapter first introduced definitions and descriptions of the terms verification and validation. Once described, verification and validation for the SLR, Current State Analysis, Quality Standard analysis, and Checklist application were discussed. In summary, the SLR was verified via a double-blind peer review, and the Current State Analysis was verified using a Survey. Moreover, the Quality Standard analysis was verified through triangulation, reflexivity and procedural description, and the Checklist application was verified using white box/black box testing and a system requirement checklist.

CHAPTER 9 CONCLUSION AND RECOMMENDATIONS

This chapter concludes the dissertation by revisiting the problems discussed in Chapter 1 and artefacts discussed in Chapter 4,5,6, and 7. The chapter continues by providing concluding remarks, the novelty of the dissertation, and recommendations for further research.

9.1. Revisiting the problem

Problems described in Chapter 1 discuss the difficulty farmers have to accommodate paperwork or administration whilst performing farm operations. In some cases, farmers react by neglecting Quality Management System (QMS) related administration which results in severe penalties. The identified problem statement was that the piggery is experiencing long administration processing times for quality compliance.

The presented opportunity is the combination of QMS and information technologies to significantly reduce processing times of quality compliance.

9.2. Revisiting the artefacts

The research made use of the Critical Artefact Methodology including three critical artefacts (Objectives 1-3), and a final artefact (Objectives 4-6). The objectives of the study are:

- O1 Perform a systematic literature review (SLR) to identify current uses of Internet of Things systems in agriculture.
- O2 Determine the current state of the piggery, using Time studies, value stream mapping, and other tools.
- O3 Accumulate quality standards provided by partners in the value stream.
- O4 Collate System Design requirements from SLR, time studies, and quality standards.
- O5 Design a prototype system
- O6 Test the developed prototype system.

The Systematic Literature Review (Chapter 4) investigated literature on Internet of Things systems and other information technologies in pig farming globally over the past 5 years. The Systematic Literature Review (SLR) showcased the stages of implementing Information and Communication Technologies (ICT). These stages included the installation of hardware and/or software, the management and analysis of acquired data, and the visualization of analysed data for decision-making purposes. The SLR found that advanced technologies are applicable in pig farming among other enablers, but the adoptability of these technologies remains a barrier for several reasons.

The Current State Analysis (Chapter 5) utilised several methods for the analysis of the piggery's administrative process such as Porter's value chain, time studies, and value stream mapping. The Current State Analysis made use of several tools to formulate a context to the described problem at the specific farm which served as a case study. It found that QMS related administration, in this case Pork 360, adds value for the pig farm. When investigating the weekly administration processes, it found that some QMS related activities are unaccounted for and observed manager's administrative systems differed due to medicine stock location and filing methods. Moreover, the conducted time studies indicated a high variability resembling inconsistencies in followed administration processes. From this, it can be understood that due to managers having to decide their own administrative system, managers struggle to integrate their administrative processes with farm operations and lose the potential value it can contribute.

The Quality Standards evaluation (Chapter 6) critical artefact made use of a focus group to accumulate quality standards provided by partners in the value stream. Moreover, Chapter 6 provided an analysis of perspectives provided by partners in the value stream about these quality standards. For the evaluation of Quality Standards, a focus group was performed where individuals who participate in Pork 360 standard compliance on a regular basis were invited. The aim of the focus group was to investigate and identify themes from the participant's perspective with regard to Pork 360 administration. The problems discussed in Chapter 1 were confirmed in the analysis by the evident sentiment shown towards discussions pertaining to paperwork. An interesting discussion point was that the difficulty of paperwork depends on the administrative system used. Moreover, understanding the technology and administrative system seemed a solution to the predicament of paperwork from the participant's perspectives.

The final artefact was a prototype system design (Chapter 7) developed by collating system design requirements from the conducted critical artefacts. Moreover, a prototype system was designed and developed. A prototype system was designed and developed following the system design requirements provided by the performed critical artefacts. The system, or checklist application, was developed including the list of standards and descriptions to be checked on a weekly basis. Testing the developed prototype system was completed in Chapter 8 satisfying the final objective of the investigation. This system underwent white box testing, black box testing, and system testing to ensure design requirements were met.

9.3. Concluding remarks

Identified barriers to technology adoptions discussed in Chapter 4, speak to technology requiring additional work within process of operations. This is evident in Chapter 5 where it has been found that the current process makes use of technology for administrative purposes, but as an additional activity. Interestingly, focus group participants indicate that understanding the technology used is a considered solution to the additional activities, and perhaps an approach to overcome the barrier of technology adoption.

Chapter 5 revealed that manager's struggle to integrate their administrative processes with farm operations and lose the potential value it can contribute. In agreement with this, in Chapter 6 a discussion point was expressed about the difficulty of paperwork depending on the administrative system used. In the same discussion, it was mentioned that a potential solution to this can be assisting the participants in the administrative system in their understanding of the system.

Chapter 6 found that amidst sharing administrative responsibilities, once mistakes occur or paperwork isn't done, the trust in sharing this responsibility fractures making it less likely that responsibility will be shared again. This finding showcases that if the paperwork load is to be delegated then consideration should be given to the significance and efficiency of sharing understanding of the technology used, and the administrative system or process followed.

The research set out to investigate long processing times for paperwork at a specific piggery. It found that technology is only useful if it substitutes process activities, but if the users of that technology do not understand it, the technology becomes an additional process activity which affects process times. In the case of the piggery, the technology contributed to long processing times. Furthermore, the research found that the design of an administrative system and its integrability with farm operations plays a significant role in the difficulty of paperwork. In the case of the piggery, the analysed administrative system does not integrate well with farm operations and contributes to the difficulty and long processing times of paperwork.

The designed and developed prototype system satisfied the listed system design requirements and in doing so facilitates the streamlining of administrative work with farm operations by using technology. Moreover, the prototype system encourages better housekeeping. Therefore, the prototype system presents itself as a possible solution to the found difficulties of technology and administrative systems the piggery faces.

9.4. Novelty

Although the prototype system might not satisfy the found difficulties the piggery faces, the researcher appeals to the reader to consider the novelty of the research and its findings. The novelty of this research can be found in its identified system requirements. The system design requirements encapsulate all critical artefact findings to be used in a practical setting specifically for the pig farming industry. The identified barriers of technology, the factors to consider for administrative processes, and the human interface attributes are what the research contributes to the endeavour of finding a solution to integrating Quality Management Systems with pig farm operations while using Information and Communication Technologies.

9.5. Research Implications

The novelty of the research reveals the contribution of the research, but connected to the mentioned contributions are potential implications of the research.

The research investigated and discussed regulations (refer to Chapter 5 and 6), specifically Pork 360 regulations, and reveals that regulations do add value to farm operations but need to be flexible enough to adapt to the current farm operations. The implication of this could be formulating regulations that are scalable or introducing and basic regulation implementation and maintenance plan for pig farmers.

The research unveiled challenges farmers experience to comply with quality standards, moreover the research revealed the involvement the quality standards have in farm operations (refer to Chapter 5). This could indicate to policy makers the significance and sensitivity of policy changes to farm operations, and factors that need to be taken into consideration before changes are approved.

The research investigated and discussed Pork 360 standards in a focus group format. The discussions provided insight in the importance of having quality standards to comply with, one of which being biosecurity and health (refer to Chapter 6). This reveals that quality standards in the health and food industry are prevalent and necessary to ensure good quality food.

The research showcased the usefulness of data technologies for administrative processes. Furthermore, the research provided insight in the prerequisites of successful technological adoption (refer to Chapter 4). Data technologies for administrative purposes could alter the development of administrative processes, and the usefulness of data captured during administration.

9.6. Recommendations

In this research, several recommendations have been identified for further research. It is recommended to investigate an effective method to train individuals to make use of technologies within their processes. Moreover, it is recommended to investigate efficient methods of designing administrative systems suitable for specific operations. It is recommended to investigate the effect of understood technologies and efficient administrative systems on time spent on administration or paperwork. It is recommended to investigate time spent on non-value adding activities and its impact on completing administrative activities.

In investigating the current state of administrative processes, it found technologies being used for administrative purposes. Therefore, it is recommended to investigate IoT as a solution to integrating QMS with farm operations. Furthermore, it is recommended to include implementation and training material in this investigation. Knowledge management systems can also be considered for future research.

Johann Wolfgang van Goethe once said: “By seeking and blundering we learn”. This research set out with investigating precision farming administrative processes. Seeking characteristics from completed artefacts with the agenda to formulate a practical solution. In doing so, it learned the complexity and value of administrative processes. It learned the difficulties of adopting technologies and that human interaction with technologies play a significant role.

There is a cliché phrase “It is not the destination that matters, but the journey” and in some sense this is what the research experienced. A practical solution was formulated, but the research found more value in what was learned. Moreover, during the journey, new connections were made directing the investigation into finding a solution of integrating Quality Management Systems with pig farm operations while using Information and Communication Technologies.

Finally, if a system is created to bridge the gap between standards and practice, more elegant implementation of researched standards could be possible. Furthermore, the elegant streamlining of researched standards and industry practice could bring theory into reality more efficiently benefitting businesses, supply chains, and communities. After all, isn’t research for the betterment of society?

“The Road goes ever on and on,

Down from the door where it began.

Now far ahead the Road has gone,

And I must follow, if I can,

Pursuing it with eager feet,

Until it joins some larger way

Where many paths and errands meet.

And whither then? I cannot say.”

– J.R.R Tolkien, Lord of the Rings

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Appendix

A.1. Ethics letter (1)

Private Bag X1290, Potchefstroom
South Africa 2520

North-West University Engineering Research Ethics Committee (NWU-ENG-REC)

Tel: 018 299-1575
Email: ENG-REC@nwu.ac.za

16 October 2023

ETHICS APPROVAL LETTER OF STUDY - PHASE ONE

Based on approval by the North-West University Engineering Research Ethics Committee (NWU-ENG-REC) on 16 October 2023, the NWU-ENG-REC hereby approves your study as indicated below. This implies that the NWU-ENG-REC grants its permission that, provided the general and specific conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Investigating precision farming administrative processes at a South African Swine farm

Meelan Roopa and Dr Mia Mangaroo_Pillay
Chris van Dyk
Ethics number: NWU-00222-23-A3

Institution Study Number Year Status

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Single
Approval date:16 October -2023
Expiry date: 16 February 2024

Risk: Low Risk

Approval of the study is provided for four months, after which continuation of the study is dependent on receipt and review of annual monitoring report and the concomitant issuing continuation.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The principal investigator/study supervisor/researcher must report in the prescribed format to the NWU-ENG-REC:*
  - *Annually on the monitoring of the study, whereby a letter of continuation will be provided annually, and upon completion of the study; and*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the principal investigator/study supervisor/researcher must apply for approval of these amendments at the NWU-ENG-REC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for active monitoring.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-ENG-REC reserves the right to:*

9.1.5.4.2 Ethics Approval Letter of Approval 1

- request access to any information or data at any time during the course or after completion of the study;
- to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;
- withdraw or postpone approval if:
  - any unethical principles or practices of the study are revealed or suspected;
  - it becomes apparent that any relevant information was withheld from the NWU-ENG-REC or that information has been false or misrepresented;
  - submission of the annual monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and/or
  - new institutional rules, national legislation or international conventions deem it necessary.

- *NWU-ENG-REC can be contacted for further information via ENG-REC@nwu.ac.za or 018 299 2645*

Special conditions of the research approval (if applicable): NA

Special in process conditions of the research for approval (if applicable): NA

The NWU-ENG-REC would like to remain at your service and wishes you well with your study. Please do not hesitate to contact the NWU-ENG-REC for any further enquiries or requests for assistance.

Yours sincerely,

Prof. P. Van Vuuren
Chair NWU-ENG-REC

Current details: [illegible]

File Reference: 9.1.5.4.2

A.2. PORK 360 Consumer Assurance and Traceability Standards for Farms

PORK 360 CONSUMER ASSURANCE AND TRACEABILITY STANDARDS FOR FARMS			
Document No:	**HO 02**	**Version Number:**	011
Created By:	Pork 360	**Date revised:**	2024 04 01
Initial Issue Date:	2013-03-01	**Page/s:**	1 of 18

CONSUMER ASSURANCE AND TRACEABILITY STANDARDS

VERSION: 2024 Version 011
NAME: Pork 360 Farm Standards
Effective: 1st April 2024

Approved:

Contents

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Significant Changes in this document compared to HO 02 QA Standard 2023 -04 -01 Ver010:
Additions & Changes in bold & red.

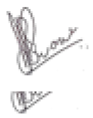
Approved:

		0.5.2 It is recommended that a plan is in place for outbreak of notifiable disease. 0.5.3 The SOP must include contact persons and contact details in case of emergency
0.6	Training	0.6.1 The responsible person must also ensure that all employees have the necessary training to implement SOPs. A schedule of training shall be available for inspection. 0.6.2 A register and proof of training and/or annual verification (by a responsible person and records of verification must be kept). The following minimum aspects shall be included: - • Animal handling • Cleaning and sanitation • Euthanasia • Feed monitoring • Medicine, needle and syringe control & recording • Personal hygiene • Pest control (including the handling of poisons) • Routine maintenance & filling in checklists • Post-mortem training

Objective 1 : - Access Control

Item	C.A.T. Standard	Compliance Criteria
1.1	Fencing	1.1.1 All pig production units must be totally and effectively fenced (pig proof) with a fence that is a minimum of 1.8m high. All access gates must be closed and locked at all times. Access shall be limited. It is recommended that a concrete or similar base be used to secure bottom of the fence and to prevent animals burrowing under fence. 1.1.2 An SOP is required detailing when and who checks the fence. This shall be done at least weekly, and a register shall be kept detailing any faults and corrective actions. (Note: Photographic registers are acceptable)
1.2	Signage	Clear signage at all entrances indicating: • Bio-secure area. • Unauthorised access prohibited.
1.3	Visitor Access	1.3.1 Access of visitors must be described in an SOP and shall take place as follows:

Approved:



		• It is a pre-requisite that under all circumstances, persons entering the unit shall shower into the unit and be provided with clean clothing on the other side of the shower • Cross contamination between own clothing and the piggery's clothing must be prevented. • When leaving the unit again persons shall shower out and change back into original (own) clothing. All clothing worn inside the piggery remains in the changing area. 1.3.2 The visitor changing facilities must be maintained in a tidy and clean manner. The changing facilities must be cleaned daily and disinfected with a registered disinfectant weekly at a minimum. Records of cleaning scheduled must be kept. Free access to all visitors is strictly prohibited. 1.3.3 A detailed visitors' register shall be kept
1.4	Vehicle Access	No unauthorised vehicle shall enter the fenced pig farming area. 1.4.1 An SOP describing authorised and unauthorised vehicles must be in place. All vehicles authorised to enter shall have their tyres and undercarriages washed and disinfected before entering the production unit. 1.4.2 A detailed register of all vehicles entering the unit must be kept
1.5	Animal Access & traceability	1.5.1 No domestic animals shall be allowed inside the fenced area of a piggery. 1.5.2 A register/record of all pigs entering and leaving the unit must be kept. The register/record must indicate: - • Source • Contact details • Age at arrival • Treatment on arrival 1.5.3 All pigs entering the unit shall come from a Pork 360 certified unit. 1.5.4 **All pigs leaving the unit shall be logged as a movement on the World of Pork platform.**
1.6	Deliveries	1.6.1 Deliveries should be done in such a way that it does not pose a health risk to animals and humans. Process must be described in a SOP. • All delivery personnel must report at reception on arrival.

Approved:

		• Deliveries including items such as: Medication, Feed, Equipment, Spares, Cleaning chemicals, uniforms, and any other item required for farming • No delivery person is allowed to enter the unit unless it has been arranged with the manager. • Delivery person shall follow the policies/procedures of visitors where applicable 1.6.2 All deliveries must be entered on the delivery record sheet or similar.

Objective 2 : - Employees

Item	C.A.T. Standard	Compliance Criteria
2.1	Worker facilities	2.1.1 A SOP regulating employee access shall be in place 2.1.2 All employees shall shower into the unit • All employees must change into the provided overalls. Each employee has at least two sets of overalls • When leaving the unit employees must change into their own clothes. Under no circumstances are employees allowed to remove any clothing from the unit. 2.1.3 Hygienic ablution facilities shall be provided • A minimum of 1 toilet per 12 Employees • Wash Hand basins and soap must be provided at toilets and canteen 2.1.4 A canteen (if meals are consumed within the biosecurity area), shall be provided, and all food must be taken directly to the designated eating facility. • No pork, pork products or raw meat is allowed in the unit/canteen. • Employees are only allowed to eat in the designated eating facility, no food shall be taken into pig housing 2.1.5 The change room and eating facility shall be kept neat and clean at all times. A responsible person must be assigned to ensure that these facilities are kept clean and. These facilities must be washed daily and a register must be kept of when cleaning took place. 2.1.6 All clothes and towels are to be washed on-farm or contracted out to an approved contractor
2.2 **MAJOR**	Worker Health	2.2.1 Employees must be provided with necessary & appropriate safety equipment which must be in good repair A register of PPE issued must be maintained

Approved:

		2.2.2 Employees who pose a zoonotic health risk shall not be allowed to have contact with pigs Employees with respiratory symptoms or chronic gastro-enteritis symptoms must be examined by a medical doctor. The doctor should be given a copy of Pork 360 medical letter to medical practitioners. If the medical doctor states that the worker is suffering from a suspected Zoonosis the worker should not come into contact with pigs until he/she has recovered. 2.2.3 A register must be kept of all absentees that include the reasons for absenteeism and doctor's letters if appropriate. NOTE: It is recommended that Employees should undergo a medical examination prior to appointment and on leaving employment.

Objective 3 : - Pest Control

Item	C.A.T. Standard	Compliance Criteria
3.1	Pests Plan	3.1.1 A SOP shall be in place for the control and extermination of vectors (rats/ mice/ flies / insects, feral cats) where necessary. A contract shall be in place when using external contractors. 3.1.2 A responsible person must be identified and trained as pest control officer. 3.1.3 All pest control stations, if used, must be clearly indicated on the farm plan
3.2	Records	Records shall be kept on the usage of all substances, and indicate where they were used
3.3	Substances	3.3.1 All substances must be registered in terms of Act 36 (1947). 3.3.2 All substances shall be securely stored.

Approved:

Objective 4 : - Feeding and Feed Quality

Item	C.A.T. Standard	Compliance Criteria
4.1 **MAJOR**	Feed quality	4.1.1.1 Home-mixers: Refer current Pork 360 HO 02A Feed Mill standard. 4.1.1.2 Third-party Feed supplier: Food safety system Certification for the supplier must be kept on file and available for inspection. 4.1.2 A sample of every ration (home mixed and /or purchased) type must be taken weekly and stored for 3 months. Each sample must be clearly marked, indicating ration type and week number/date mixed.
4.2 **MAJOR**	Feed monitoring	4.2.1 A monitoring system described in a SOP must be in place that ensures correct delivery of rations to the correct animals. 4.2.2 Reconciliation between feed ordered (from own feed mill or bought feed) and delivered should be done at least weekly and recorded on a register. 4.2.3 All feed ration types shall be identified.
4.3 **MAJOR**	In-feed medication	Only medicines that have been prescribed by a SAVC registered consulting veterinarian may be used on Pork 360 farms. Antimicrobial growth promoters (AGPs) may only be used if prescribed by piggery's consulting veterinarian in line with the PVS of SAVA's current Antibiotic Guidelines for the Pig Industry. 4.3.1 Medicated feed may only be used in accordance with Veterinarians instructions /script. 4.3.2 Samples of Rations fed to pigs destined for market (cull sows and growers) in next 30 days must be collected at point of use and tested for antimicrobials using a SANAS accredited screening test. Sampling must be done quarterly – either collected by the internal auditor or his/her assignee. 4.3.3 Any positive antibiotic results shall be immediately communicated to Pork 360 office by the responsible person (appointed in 0.1.1). The Pork 360 unit must then test rations monthly for three consecutive months. Should antimicrobials be found within this period the farm may be deregistered. 4.3.4 The withdrawal period, as stated on product label or in the product literature for all registered (Act 36 /Act 101) anti-microbials administered via feed or water, must be adhered to. Compounded products may only be used if a valid prescription is on record which must

Approved:

<table>
<tr><td></td><td></td><td>clearly state the withdrawal period for the compounded medication.</td></tr>
<tr><td>4.4

MAJOR</td><td>Animal By-products</td><td>Any animal by-product included in feed shall be purchased from a registered (Act 36 of 1947) source. Only sterilized products are permitted.

Registration certificates of sterilizing/rendering plant and products shall be available for inspection.</td></tr>
<tr><td>4.5
MAJOR</td><td>Swill</td><td>Under no circumstances is kitchen-, ship-, hospital-, canteen-, restaurant-, or any other swill to be fed to pigs.</td></tr>
<tr><td>4.6

MAJOR</td><td>Water</td><td>4.6.1 An adequate supply of water that is fit for use for animal watering must be available to all pigs every day. (Adequate is considered to be 8 percent of body mass per day)

4.6.2 **Water usage shall be measured, and monthly records kept. This only applies to incoming fresh water and not water recycled on-farm.**

4.6.3 Fitness for use must be assessed on an annual basis using the Department of Water Affairs and Forestry: South African Water Quality Guidelines, Volume 5 Agricultural Use: Livestock Watering (1996).

If the concentration of heavy metals (below) in drinking water exceeds the following limits, samples of masseter muscle, kidney and liver must be analysed to ensure that levels are within the Maximum Acceptable Levels for human consumption thereof:
- Cadmium: 0.05 mg/l
- Lead: 0.30 mg/l

4.6.4 Microbiological Indicator Organism tests shall be conducted bi-annually, for Total Coliform Counts, Faecal Coliform Counts and E. coli (as counts/100 ml) and classed as follows:
<table>
<tr><th>Indicator</th><th>Good</th><th>Marginal</th><th>Poor</th></tr>
<tr><td>Total Coliform Counts:</td><td>< 10</td><td>10 – 100</td><td>>100</td></tr>
<tr><td>Faecal Coliform Counts:</td><td><1</td><td>1 - 10</td><td>>10</td></tr>
<tr><td>E.coli: counts:</td><td><1</td><td></td><td></td></tr>
</table>
Total Coliform Counts and Faecal Coliform Counts should be within the "Marginal" classification.

E. coli counts should remain undetected (<1 count/100ml).</td></tr>
</table>

Approved:

		Samples should be obtained from the drinker lines providing pig houses and tested using an accredited SANAS method. Exceedance of the Marginal Classification should trigger retesting to confirm the result and in the event of non-conformance, testing must be conducted on a monthly basis until such time as it complies. 4.6.5 If disinfection is practiced, residual (free) chlorine should be tested weekly and be at <1.5 ppm (Dept Water and Sanitation: Water Quality Guidelines, Livestock Watering) at the Point of Use, and due cognizance of the potential for disinfection by-product formation should be taken.

Objective 5 : - Housing

Item	C.A.T. Standard	Compliance Criteria
5.1	Farm Plan	Each farm must have a plan indicating building layout, post mortem area, location of the loading ramps, manure dams and area where dead pigs are disposed of. On the plan the number of pens/crates, the area of pens/ size of crates, area per pen, maximum number of pigs per pen and the number of pigs that can be housed in each and every building. (NB if pens of differing sizes are present in a house the information on area, space allowed and max. animals/pen must be reflected for the different size pens)
5.2	Building Identification	All buildings must be clearly identified.
5.3 **MAJOR**	Housing	5.3.1 Housing shall make provision for good control and management of differences in class and age of pigs. Housing shall provide sufficient protection, safety and comfort to pigs. It should aim to provide pigs a good quality of life. Housing shall be arranged to provide sufficient ventilation, allowance of movement, access to water and food and rest to pigs. 5.3.2 Mechanically ventilated buildings must have alarm systems fitted to alert personnel of system failures and/ temperature extremes. 5.3.3 The minimum floor space allowances for post-wean pigs shall be adhered to: Weight category | Minimum Space (m^2 /pig)

Approved:

	Solid	Partly or fully slatted
< 35 kg	0.35	0.30
< 50 kg	0.50	0.46
< 80 kg	0.69	0.62
<110 kg	0.85	0.77
<130 kg	0.95	0.86

(Based on Canadian Welfare Code Standards, calculated as 0.0335 X metabolic weight)

NB: where no slats are provided, the open s drainage/dunging area may not be included in the calculated area to determine whether space is adequate

5.3.4 Sow stalls must be constructed so that

- They are free of any objects/projections which could cause injury to the sow
- When standing the sow's back must not touch the top bars of the crate, nor should her sides be in contact simultaneously with both sides of the crate
- When standing a sow's snout and hindquarters must not simultaneously be in contact with the front and rear of the crate

NOTE: Recommended crate size is greater than or equal to 2,3m long and greater than or equal to 60cm internal width = approx. 1,4 m^2 per sow

5.3.5 Group Housing Gestating Sows & Gilts

- 2.25 m^2 per sow on solid floors and for groups of 10 or less.
- For Groups larger than 10 sows or smaller groups on partially slatted floors minimum space is 2,03m^2 per sow.
- 1.75 m^2 per gilt on solid floors and for groups of 10 or less.
- For Groups larger than 10 gilts or smaller groups on partially slatted floors minimum space is 1,53m^2 per gilt.

5.3.6 Boar housing

- Individual boar pens 5,6m^2 per boar and shortest side of 2,35m long.

Teaser boars may be housed in groups provided that they are carefully mixed to prevent aggressive behaviour. The shortest side of a group pen should be 2.35m and all the boars in the pen should simultaneously be able to lie down comfortably.

Approved:

5.4	Stormwater	A stormwater management plan must be in place to ensure that stormwater leaving the site does not contain any unwanted substances and should be kept separate from the biodegradable industrial wastewater.
5.5	Water	Measures to ensure efficient water use shall be in place.

Objective 6 : - Management and Care

Item	C.A.T. Standard	Compliance Criteria
6.1 **MAJOR**	Care	6.1.1 Visual health inspection of all animals must take place on a daily basis by a suitably trained person/s. 6.1.2 All aspects, except space requirements detailed in Objective 5.3, must comply with SAPPO welfare code.
6.2 **MAJOR**	Health Planning & surveillance	6.2.1 A current health plan (revised at least annually) approved by a pig veterinary consultant shall be in place. The plan must describe the following: • vaccination policy • **needle policy** • routine medication • piglet processing • basic housing • internal pig movements 6.2.2 **Surveillance for disease by a consulting veterinarian must be recorded on a quarterly basis on the World of Pork platform.**
6.3 **MAJOR**	Animal Identification	6.3.1 The following is necessary with regards to marking of pigs: • All pigs must be tattooed with a registered tattoo mark by the time they are weaned. 6.3.2 A copy of the Registration certificate must be available in SOP master file 6.3.3 Age identification 6.3.3.1 All pigs must be marked with their ISO week of birth by means of a tattoo or ear notch. 6.3.3.2 All personnel responsible for marking pigs with age of birth need to be trained annually *Note: - Week one of eaoh year is the first 4 day week of the year and day one is a Monday*
6.4 **MAJOR**	Age at marketing	Entire boars must be marketed by end of their 22nd week of age (i.e. maximum of 154 days old) Immuno-castrated male animals will be deemed = castrates

Approved:

6.5	Sick Pigs	Provision must be made for the correct handling and isolation of chronically sick pigs. Designated hospital pens shall be available. No systemically ill pigs shall be marketed for slaughter
6.6 **MAJOR**	Euthanasia	Provision must be made for humane killing of casualty pigs. This must be described in a standard operating procedure.
6.7	Emergency Slaughter	Producers shall liaise with the relevant abattoir should they have a need for emergency slaughter No systemically ill pigs shall be marketed for slaughter.
6.8	Post mortem facilities	Provision shall be made where post mortem examination can take place. All waste from the post mortem area must be disposed of in a biosecure manner.
6.9	Post Mortem Records	All deaths of post-weaning animals and adult animals must be recorded in a register indicating suspected reasons.

Objective 7 : - Sanitary and Hygiene Requirements

Item	C.A.T. Standard	Compliance Criteria
7.1	House cleaning procedures	The correct procedures for washing and disinfecting shall be established. The procedures need to be developed in consultation with a pig veterinary consultant and include: • Physical cleaning • Washing and drying • Disinfecting • Rest period
7.2	Records & Products	7.2.1 Records shall be kept on the usage of all substances used in cleaning and disinfecting. Records should be reconciled monthly. The disinfectant must be used according to label instructions pertaining to the concentration and application rate. 7.2.2 Only SABS approved/ registered products are to be used • All products shall be kept under lock in appropriate storage area.

Approved:

Objective 8 : - Medication and vaccines management

Item	C.A.T. Standard	Compliance Criteria
8.1 **MAJOR**	Storing	All medication must be kept locked in a specific designated area. All medications must be stored under appropriate conditions as advised by manufacturer.
8.2 **MAJOR**	Records & reconciliation	8.2.1 No medicines / drugs, including compounded medicines, may be used on Pork 360 farms unless prescribed by a SAVC registered veterinarian. Any products that are administered to pigs, and not prescribed by the consulting veterinarian MUST be registered under Act 36 (1947) for use in pigs. 8.2.2 The person who issues the medication shall also be responsible for the weekly balancing of usage / purchases and stock. The process must be described in a standard operating procedure. 8.2.3 Detailed records on medication (parenteral and oral) stored in the storeroom should be kept for auditing purpose. The records should at minimum include: • **Total antibiotic usage per active ingredient and per antimicrobial class (monthly)** • Detailed inventory list • Date of issuing • Section dispatched to • Signature of responsible persons (issuing and receiving)
8.3 **MAJOR**	Treatment records	8.3.1 Detailed records of all finisher/grower pigs treated within 8 weeks of average marketing age shall be kept. This shall include date/s of treatment, ailment, drug used, dose used and date of earliest marketing / death. • Reconciliation on a per millilitre (ml) must be done for parenteral products at least monthly, with appropriate action taken in the case of not balancing. • Reconciliation per gram or ml for oral medications at least monthly, with appropriate action taken in the case of not balancing. • Rough reconciliation data shall be kept for 6 months.

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8.4 **MAJOR**	Withdrawal period	No treated pigs may be marketed sooner than withdrawal time advised by the consulting veterinarian to the farm or as stated in the literature of the product/s used. The withdrawal periods of any medication (in-feed / in-water / injected) shall be adhered to. 8.4.1 A list of medications used on the farm indicating the withdrawal period must be available for inspection. 8.4.2 Treated pigs must be identified in a manner that will be visible for the entire duration of the withdrawal period and taking into consideration earliest marketing age.
8.5 **MAJOR**	Injections	Needles used for injections should be changed between litters. One litter per needle maximum. **When injecting/vaccinating sows the number of sows that can be injected, before exchanging a needle for a new / disinfected needle must be described in the Health Plan (6.2)** When injecting sick pigs, a new/disinfected needle must be used per individual sick pig.
8.6 **MAJOR**	Needle control	A system must be in place whereby a certain number of needles are issued to persons responsible for injecting in the various sections of the farm. New needles may only be issued on receipt of old used needles 8.6.1 The number of needles in the sections must be reconciled weekly to ensure that none have gone missing /broken off in pigs. 8.6.2 Producers must liaise with the relevant abattoir before marketing a pig with a broken needle. Marketing shall be done with the appropriate identification.
8.7	Needle hygiene	Clean needles shall be kept in a separate clean container marked "clean needles" Used needles shall be kept in a separate container marked "used/dirty" needles Used re-usable needles may be disinfected and reused.
8.8	Syringe hygiene	Syringes must be rinsed and disinfected daily

Objective 9 : - Waste Management

Item	C.A.T. Standard	Compliance Criteria
9.1 **MAJOR**	Biodegradable Wastewater (BW)	9.1.1 BW generated on site and any subsequent fractions thereof (liquid and solid fractions) must be handled in compliance with the applicable Section 21 activities of

Approved:

		the National Water Act (Act 36 of 1998), applicable government notices and prescribed guidelines. 9.1.2 **Soil samples shall be analysed annually where BW is used on agricultural land for soil enrichment. Testing shall include heavy metals.**
9.2	Hazardous Waste	9.2.1 Empty containers, syringes and other bio-hazardous products must be placed in clearly marked bins and disposed according to current regulations. This includes pesticide packaging, medical packaging and disinfectant packaging. Needles and sharps must be collected in a separate container which can be sealed and be disposed of in a responsible manner. Records of disposal must be available for inspection
9.3	Animal disposal	Dead animals must be disposed of in an acceptable manner according to a standard operating procedure taking into consideration regulations pertaining to burial/disposal of animals, reducing risks of contaminating groundwater by ensuring the correct setback distances and preventing theft of the bodies.

Objective 10 : - Transport

Item	C.A.T. Standard	Compliance Criteria
10.1	Loading and transport	Aspects that need specific attention when loading and transporting animals include: 10.1.1 Loading ramps and platforms shall match vehicle height and loading gate. Inclines should not exceed 25° for loading onto trucks. Offloading ramps shall not exceed 20° (Meat Safety Act (40 of 2000)) 10.1.2 Loading and unloading must be done with minimum force. Under no circumstances may prodders of any type be used.

<table>
<tr><td>10.2

MAJOR if <90% of space provided</td><td>Vehicles</td><td>Vehicles shall make provision for:
10.2.1 Shading on the top deck
10.2.2 Partitioning to prevent crushing
10.2.3 Grids: to prevent sliding and injury

10.2.4 PIGS PER UNIT OF FLOOR SPACE:
<table>
<tr><th>Average live weight (kg /pig)</th><th>Space (m² /pig)</th><th>Space longer than 3,5 hrs (m² /pig)</th></tr>
<tr><td>6</td><td>0.07</td><td>0.08</td></tr>
<tr><td>25</td><td>0.18</td><td>0.21</td></tr>
<tr><td>50</td><td>0.22</td><td>0.25</td></tr>
<tr><td>75</td><td>0.29</td><td>0.34</td></tr>
<tr><td>85</td><td>0.31</td><td>0.36</td></tr>
<tr><td>95</td><td>0.34</td><td>0.39</td></tr>
<tr><td>105</td><td>0.36</td><td>0.41</td></tr>
<tr><td>125</td><td>0.42</td><td>0.48</td></tr>
<tr><td>150</td><td>0.48</td><td>0.55</td></tr>
<tr><td>175</td><td>0.55</td><td>0.63</td></tr>
<tr><td>200</td><td>0.61</td><td>0.70</td></tr>
</table>

Objective 0.5: - Contingency plan for emergencies such as breakdowns</td></tr>
<tr><td>10.3</td><td>Vehicle hygiene</td><td>All vehicles must be washed and disinfected to ensure that no pathogens are transmitted into the piggery from any other farm, feed mill, etc.
Vehicles transporting pigs to the abattoir, different pig flows, or different farms must be washed and disinfected between loads (records? At the abattoir?). A SOP must be in place describing decontamination procedures and register/s must be available proving that the vehicles have been decontaminated.
Water from wash bays must not flow into the piggery.</td></tr>
</table>

Objective 11 : - Maintenance

Item	C.A.T. Standard	Compliance Criteria
11.1	Routine	There must be a maintenance program which will include a SOP document addressing the routine maintenance of all equipment and structures.

Approved:

		A responsible person must be identified to ensure adherence to the routine maintenance schedule Routine maintenance checks must be performed on applicable points pertaining to welfare of pigs, preventing disease, preventing feed or water outages, preventing injury /harm to pigs and reducing environmental contamination accidents. Some aspects that should be addressed include: - • Fence & gates • Ablution facilities • Feeding systems • Watering systems • Ventilation equipment • Electrical equipment • Truck wash areas • Waste water handling facility • Pig transport vehicle
11.2	Emergency repairs	11.2.1 A SOP describing the action to be taken in case of breakdowns must be developed 11.2.2 A repairs worksheet must be completed whenever an emergency repair is lodged and kept on record

Objective 12 : – Measuring & monitoring

Item	C.A.T. Standard	Compliance Criteria
12.1	Verification	Any medication weighing equipment shall be verified quarterly

Approved:

A.3. Survey for Current State Analysis verification and validation

Survey on administration process

Please answer the question by giving a rating between *Very Low* and *Very High*

1.

	Very Low	Low	Medium	High	Very High
Is having a standardized administration process important?	○	○	○	○	○
To what degree of an affect would a standardized administration process have on the time spent on administrative tasks?	○	○	○	○	○
To what degree do farm operations take priority over adminstrative tasks?	○	○	○	○	○
To what degree are you confident in the accuracy of data recorded on technological devices?	○	○	○	○	○
To what degree is checking registers important?	○	○	○	○	○
To what degree is medicine stock take important?	○	○	○	○	○
To what degree do you think technology can help with administrative tasks?	○	○	○	○	○

A.4. Ethics letter (2)

Private Bag X1290, Potchefstroom
South Africa 2520

North-West University Engineering Research
Ethics Committee (NWU-ENG-REC)

Tel: 018 299-1575
Email: ENG-REC@nwu.ac.za

16 September 2024

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the North-West University Engineering Research Ethics Committee (NWU-ENG-REC) on 30 September 2024, the NWU-ENG-REC hereby approves your Research study as indicated below. This implies that the NWU-ENG-REC grants its permission that, provided the general and specific conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Investigating precision farming administrative processes at a South African Swine farm

Student : Chris Van Dyk
Study leader: Dr. Ockert Koekemoer, Dr. Mia Mangaroo Pillya and Meelan Roopa
Ethics number: NWU-00496-24-A3

Institution | Study Number | Year | Status

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Single
Approval date: 30 September 2024
Expiry date: 29 September 2025
Risk: Low Risk

Approval of the study is provided for a year, after which continuation of the research is dependent on receipt and review of annual monitoring report and the concomitant issuing of a letter of continuation.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The principal investigator/study supervisor/researcher must report in the prescribed format to the NWU-ENG-REC:*
  - *Annually on the monitoring of the study, whereby a letter of continuation will be provided annually, and upon completion of the study; and*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the principal investigator/study supervisor/researcher must apply for approval of these amendments at the NWU-ENG-REC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for active monitoring.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-ENG-REC reserves the right to:*

- *request access to any information or data at any time during the course or after completion of the study;*
- *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
- *withdraw or postpone approval if:*
  - *any unethical principles or practices of the study are revealed or suspected;*
  - *it becomes apparent that any relevant information was withheld from the NWU-ENG-REC or that information has been false or misrepresented;*
  - *submission of the annual monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and/or*
  - *new institutional rules, national legislation or international conventions deem it necessary.*
- *NWU-ENG-REC can be contacted for further information via ENG-REC@nwu.ac.za or 018 299 2645*

Special conditions of the research approval (if applicable): NA

Special in process conditions of the research for approval (if applicable): NA

The NWU-ENG-REC would like to remain at your service and wishes you well with your study. Please do not hesitate to contact the NWU-ENG-REC for any further enquiries or requests for assistance.

Yours sincerely,

Prof. P. Van Vuuren
Chair NWU-ENG-REC

Current details: (25767984) NWUNextCloud\ENG-REC\Letters sent\[Date]\9.1.5.4.3_NWU-ENG-REC_REC_EAL_[student surname_name]

File Reference: 9.1.5.4.2