International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V72I5P120

Volume 72 Issue 5, 194-202, May 2024

Original Article

Knowledge-Based Decision Support System Framework for Swine Productive Management

Evelyn M. Baesa[1], Thelma D. Palaoag[2]

[1]*Institute of Computer Studies, Camarines Norte State College, Camarines Norte, Philippines.*
[2]*College of Information Technology and Computer Science, University of the Cordilleras, Baguio City, Philippines.*

[1]*Corresponding Author : evelynbaesa@cnsc.edu.ph*

Received: 26 December 2023 Revised: 02 April 2024 Accepted: 11 April 2024 Published: 26 May 2024

Abstract - *The swine industry plays a vital role in global food production, and efficient swine management is essential for ensuring sustainability and profitability. This research presents the design and development of a robust Decision Support System (DSS) framework tailored to the specific needs of swine productive management. The proposed framework integrates data analytics, predictive modeling, and expert knowledge to optimize breeding efficiency, minimize resource waste, and enhance overall farm productivity. This article discusses the theoretical foundations, architecture, and key components of the DSS framework, providing insights into its potential applications within the swine industry. The framework's adaptability and scalability make it a valuable tool for swine producers and researchers alike, offering a comprehensive solution to address the complex challenges of swine management. Furthermore, this provides to equip swine farmers technological advantage and enables strategic methods in managing their farms. Through trend analysis, recommendation models, and user feedback, the developed system empowers farmers with actionable insights to improve breeding efficiency and overall farm productivity.*

Keywords - *Decision Support System, Agriculture, Swine production, Farming, Technology.*

1. Introduction

The swine business is vital to ensuring food security and providing nutritional demands, as seen by the steady increase in demand for premium pork products around the world. The sustainability of swine farms, herd productivity, and breeding efficiency are all directly impacted by swine reproductive management techniques. For swine farmers, maximizing reproductive success and resource utilization is still a difficult task. Conventional approaches frequently rely on experience and intuition, which might result in less-than-ideal choices and possible inefficiencies in breeding procedures [1]. Pork farms and industry owners face significant difficulty in keeping an eye on farm operations, as well as the health and behavior of the swine herd. This is because the global pork market is growing to fulfill the demand for animal protein, which leads to larger swine farms. Along with effects on the environment, animal welfare, and human health, including zoonosis and antibiotic resistance, the expansion of swine production is also causing changes in the rhythm of the climate. The optimal growth and health of pigs are essential to swine farms' profitability, and contemporary farming techniques can guarantee the production of healthy pigs [2]. Furthermore, swine production contributes to several Sustainable Development Goals (SDGs), including Zero Hunger (SDG 2), Good Health and Well-being (SDG 3), and Responsible Consumption and Production (SDG 12). However, the industry faces significant challenges related to market volatility, disease outbreaks, and resource inefficiencies, which hinder its ability to contribute effectively to these goals. Moreover, the study aligns with SDG 9 (Industry, Innovation, and Infrastructure) by promoting the adoption of innovative technological solutions in the agriculture sector. By integrating machine learning into swine production forecasting, we aim to enhance the efficiency and productivity of the industry, reduce environmental impacts, and support sustainable economic growth. This, in turn, contributes to SDG 8 (Decent Work and Economic Growth) by fostering job creation and economic opportunities within the swine production value chain [3]. To solve these issues, ICT-based smart swine farming should be considered. To improve swine sector meat production, this plan should consider auto-identification, remote monitoring, feeding behavior, animal rights and welfare, zoonotic illnesses, nutrition and food quality, labor management, farm operations, etc. Modern swine husbandry uses technology for feeding plans, health and welfare monitoring, and herd reproduction [2]. The absence of dashboards in domains such as livestock management, aquaculture analysis, and others presents a notable research gap, suggesting an opportunity for the development of specialized decision-support tools tailored to these specific industries [4]. By addressing this gap and exploring the potential benefits of dashboards in these domains, future research can contribute to enhancing productivity, efficiency, and decision-making processes in agriculture and related sectors. To address the challenges in the demand for swine production and advance swine reproductive management practices, this research study focuses on developing and evaluating a state-of-the-art knowledge-based Decision Support System (DSS). The proposed DSS is envisioned as an intelligent tool that integrates genetic data, health, behavior, and reproductive performance monitoring to provide data-driven recommendations on critical breeding decisions. By leveraging advancements in technology and incorporating sustainable development principles, the DSS aims to revolutionize swine reproductive management, maximize breeding efficiency, and promote overall sustainability within the swine industry.

2. Literature Review

2.1. Agriculture 4.0

The so-called Agriculture 1.0 era used animal traction and basic equipment in the past, which required human labor and produced low production. Following industrial growth, the agricultural sector implemented new production techniques known as "Agriculture 2.0," which increased crop output and efficiency by using chemicals and machines. When the first computer programs were developed, new options for enhancing agro-industrial systems and productivity were made possible. Among them was the Global Positioning System (GPS), which is still in use today to help with satellite management and usher in the "Agriculture 3.0" era. The advent of Industry 4.0 brought digital technologies to the agricultural sector, ushering in a new era of technology and fostering open innovation in agribusiness, which is known as Agriculture 4.0. Precision agriculture, also known as agriculture 4.0, is a logical advancement of current food production systems that uses embedded technologies and remote sensing techniques to monitor and regulate the overall systemic performance [5].

The increasing global food demand, driven by a growing population, places immense pressure on agriculture and the environment. Agriculture 4.0, the latest evolution in farming technology, focuses on boosting productivity, efficient resource allocation, climate resilience, and reducing food waste. Leveraging advanced information systems and the internet, Agriculture 4.0 collects and analyzes vast farming data like weather, soil conditions, market demands, and land use to help farmers make informed decisions and increase profitability. Four main requirements were identified as goals in Agriculture 4.0: increasing productivity, allocating resources reasonably, adapting to climate change, and avoiding food waste [6]. Additionally, these revolutions, like smart and precision tools for enhancing the agriculture industry, are very much welcomed, especially with the growing concern on the global issue of diminishing resources and food security. Therefore, these developments are key towards progressing and energizing the agricultural sectors all over the world.

Furthermore, the inclusion of Agriculture 4.0 has been the focus of many researchers around the world with the mind of integrating agriculture with technology and finding several opportunities which can be explored to be implemented in the agricultural sectors [7]. One of these is the growing concern about food security, especially worsened during the COVID-19 period and the growing conflicts and wars. The growing population, the reduction of available agricultural areas for cultivation, and increasing problems with flu viruses like the African Swine Flu (ASF) have further challenged the agricultural sectors. This predicament can somehow be amended by having the right strategies and leveraging modern tools and technologies that Agriculture 4.0 can provide.

However, although Agriculture 4.0 has made increased recognition, especially in the implementation of the technologies that are mostly in the Internet of Things (IoT), there are many barriers to its development. Some of these are the users' need for more knowledge and advanced skills, which requires more trained operators. Furthermore, other barriers include basic structures, control of technology, and communications between systems. A need for more developed devices, tools, systems, software, and machines is essential to further improve the development of Agriculture 4.0 across the different fields and disciplines. In the meantime, it is expected that alternatives could still provide some short solutions to these barriers [5]. According to some research, the most frequently cited and significant obstacles cited by farmers were age group danger, inadequate data on the rural environment, lack of infrastructure, inaccessibility of solutions for farmers, and the necessity of promoting R&D and creative business models. With this knowledge, a framework that aims to remove these obstacles from the way may be built, which will help spread agricultural 4.0. [8].

Moreover, by incorporating features from digital transformation processes already in place in other industries, including the automotive sector, digital technology can promote social and economic advancement. Attaining and preserving a proactive interaction between developing technology and industrial processes, as well as society, requires digital strategies. Digital transformation processes are dynamic and ongoing. An example of an imbricated situation is Industry 4.0, which introduces disruptive applications of digital technology to the industry, considerably advancing it. The main technology used by Industry 4.0 is digital, which facilitates decision-making and allows for enhanced operations. Some of these technologies are big data analytics, smart sensors, cloud computing, system integration, cyber-physical systems, autonomous and collaborative robots, Internet of Things (IoT), mobile systems and devices, artificial intelligence, digitalization and virtualization, simulation, industrial internet, additive manufacturing, cybersecurity, and augmented and virtual reality [9].

2.2. Swine Productive Management

Reproductive management is crucial for maintaining efficient breeding programs in the swine industry. Literature has extensively covered various aspects of swine reproductive management, including estrus detection, artificial insemination, reproductive cycle synchronization, and herd health monitoring. These studies provide valuable insights into the challenges and opportunities for improving reproductive performance. The concept of sustainable development is gaining increasing importance in the swine industry. Researchers have emphasized the need for integrating sustainability principles into livestock production systems to reduce environmental impacts, conserve resources, and ensure long-term viability.

Studies have explored strategies like optimizing feed efficiency, reducing waste generation, implementing manure management techniques, and adopting renewable energy sources in swine production. Some studies emphasize the multifaceted nature of swine reproductive management and the critical role of both developmental and functional components in optimizing reproductive performance. The findings shed light on challenges faced by replacement boars and sows during their developmental phase and highlight key management strategies that can positively impact their adult reproductive performance [10]. Furthermore, Boyd et al. highlights significant milestone technologies applied by the North American pork industry over the past decade through several innovations such as improved or resolved production limitations, practice and integration of new technologies, including gene editing technologies to control reproductive and respiratory syndrome and identify piglet genome. Furthermore, precision nutrition for pigs was developed, as well as other technologies for the timely detection of potential pathogens that may contribute to possible economic loss [11]. These innovations have played a pivotal role in shaping the trajectory of improvement and addressing production limitations within the swine sector. Each milestone technology has been integrated into practice, with some already revolutionizing swine management while others are on the brink of transforming the industry pending federal approval.

Nowadays, precision pig farming systems using sensors, cameras, and radio frequencies supplemented by AI with computer vision are adopted as key indicators of pig health and welfare. The use of artificial intelligence technologies to detect, track, and recognize the behavior and sound recognition of pigs is both an opportunity and a challenge for the pig farming industry [12]. Others utilize integrating cloud platforms with decision support systems to optimize models and make other devices accessible and more robust, making planning and decision-making optimal, especially on large-scale pig farms [13]. These technology integrations allow better market decisions for pig farmers. Having data accessible and readily available to them would enable them to be easily updated with their farm information through requests from different devices and make sensible information from the visualized display obtained from this technology-enabled systems.

2.3. Decision Support Systems

Decision Support Systems (DSSs) help organizations make decisions that require judgment, determination, and a series of actions. The information system analyzes massive amounts of unstructured data to help mid- and high-level management solve problems and make decisions. DSSs can be human-powered, automated, or both [14]. Decision Support Systems (DSS) have evolved from analysis to intelligent automation. The prominence of recommendation systems in recent years shows how DSS can improve performance [15]. There are many successful examples. The importance of recommendation systems in agriculture systems to improve productivity and management, which includes the aspects of interoperability, scalability, accessibility, and usability, has provided important improvements along these dimensions, which will undoubtedly be growing in the next few years. A model-driven DSS allows access to and the management of financial, organizational, and statistical models. Data is collected, and parameters are determined using the information provided by users. The information is created into a decision-making model to analyze situations [21]. There are even some published studies, including research about rule-based systems as decision-support analyzing people during a pandemic [16], resource allocation [17], smart decision-support systems designed for pig farming with real-time data, and intelligent analysis reports for decision-making [18]. Even behavior and physiology-based decision support tool to predict comfort and stress in non-pregnant, mid-gestation, and late-gestation sows [19]. These studies provide important concepts regarding the development of decision support systems and provide baseline information towards their practical applications, especially in modern swine farming and management.

Strategic decisions at the individual and organizational levels are designed and implemented with the assistance of Decision Support Systems (DSS), which are advanced technologies that increasingly leverage big data. Nevertheless, using these technologies excessively can lead to poor decision-making in businesses, especially when they are used in stressful and high-pressure situations. It is possible to avoid learning from mistakes by having limited comprehension and interpreting things one way [20]. However, no matter how perfectly planned a decision support system is, it still encounters possible failures, most of which are because of the situated nature and affordances of decision-making, the distributed nature of cognition in decision-making, and the performance of the DSS itself.

Looking into these factors may improve its development and delivery for optimum use. This learning provided insights towards the development of the framework for the knowledge-based decision support system for swine productivity management. The important considerations and elements towards its successful development are provided, recognizing the complexity of the processes required [22].

3. The Knowledge-Driven Framework

The development of the knowledge-driven DSS framework for swine productive management involved various steps that led to its creation. A needs assessment was conducted to identify specific requirements and challenges within the swine productive management domain.

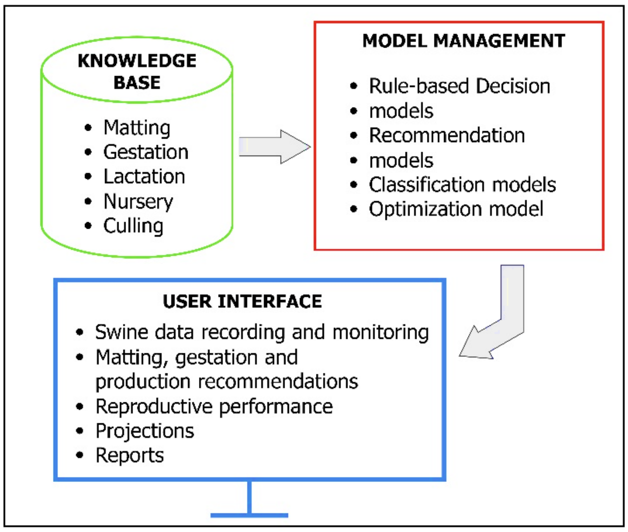

Fig. 1 The DSS framework

This process is important to understand to needs of swine farmers and the industry to inform the development process. A comprehensive literature review was conducted to explore existing decision support systems, technologies, and methodologies related to swine farming and agriculture. The insights from the literature review informed the design decisions and features integrated into the framework.

Given that this study proposes a knowledge-driven DSS, the formulation of rules would require experts in the said domain, which included the backyard, medium-scale and big swine farmers, agriculturists from the Department of Agriculture and researchers in the agriculture domain. Once the rules were established, the framework involved the selection and integration of the models into the framework. Lastly, the system features were conceptualized to tailor to the needs and preferences of swine farmers.

The three main components of a DSS framework are the knowledge base, model management system, and user interface. Figure 1 shows the DSS Framework for Swine Productivity Management which captured the aforementioned components of a DSS. Each component in the DSS framework played a crucial role in supporting swine farmers and managers in optimizing their swine production processes. The knowledge base provides the necessary expertise, model management offers data-driven insights, and the user interface ensures accessibility and ease of use for those working in swine farming.

- Front-end server: The user interface displays swine data recording and monitoring, mating, gestation, production recommendations, reproductive performance, projections, and reports.
- Back-end server: Processes front-end requests and provides the most relevant response. Utilizes an inference engine to evaluate guidelines and provide output. It also sends guidelines to the database via controllers [23]. Model management control encompasses rule-based decision models, recommendation models, categorization models, and optimization on the back end.
- The back-end controllers are responsible for creating and sending guidelines, and the database is for storing those guidelines. The data management subsystem consists of a database containing relevant data for the scenario and a Database Management System (DBMS) that is administered by software. The data management subsystem can be linked to the corporate data warehouse, which is a storehouse for data relevant to corporate decision-making. This part contains needed information on the knowledge-based component which is on mating, gestation, lactation, nursery, and culling of swine.

A data management subsystem, a model management subsystem, a user interface subsystem, and a knowledge-based management subsystem can all be found in a DSS application. A Database Management System (DBMS) keeps the user away from the physical features of the database structure and processing. It also provides logical data structures (as opposed to physical data structures) and informs users about the different types of data accessible and how to access them. A DBMS's functions include database creation and reorganization, database updating (adds, deletes, edits, and changes), data retrieval for queries and report production, and complicated data manipulation tasks. The model management subsystem is a software package that incorporates financial, statistical, management science, or other quantitative models that provide analytical capabilities to the system as well as proper software administration. A modeling language is also offered for creating bespoke models. This program is commonly referred to as a Model Base Management System (MBMS).

This component can be linked to a corporate or external model repository. The user interface subsystem allows the user to communicate with and command the DSS. The user is regarded as a component of the system. Some of the unique benefits of DSS, according to researchers, are obtained from the intensive interaction between the computer and the decision-maker. For most DSS, the web browser provides a familiar, consistent Graphical User Interface (GUI) framework.

The knowledge-based management subsystem can supplement or replace any of the other subsystems. It supplies intelligence to supplement that of the decision-maker. It can be linked to the organization's knowledge repository, also known as the organizational knowledge base. Web servers can supply knowledge. Many artificial intelligence approaches have been incorporated into web development tools such as Java, making them simple to combine with the other DSS components.

4. The Case Study

In order to illustrate the practical utility of the proposed framework in managing swine operations, this section showcases a case study in which the framework was implemented. Specifically, a prototype of a web-based system was constructed according to the outlined DSS framework.

```
if age_of_sow >= 8 months and
   estrus_of_sow == "yes" and (timing >= 24 hours and
   timing <= 36 hours after onset_of_estrus)
then
   allow_mating
else
   not_allow_mating
```

Fig. 2 Pseudocode for the mating procedure in swine

4.1. The Knowledge Base

The Knowledge Base serves as the repository of domain-specific information and expertise crucial for making informed decisions in swine productive management. Swine farmers, agriculturists and researchers in Camarines Norte, Philippines were interviewed to determine the procedures for each of the phases in swine productive management. This encompasses comprehensive knowledge related to various aspects of swine farming, including mating, breed compatibility, gestation, lactation, nursery management, and culling criteria. This component provides the essential foundation of expertise that informs and guides the recommendations and decisions generated by the DSS. The specific steps for the different parameters based on swine productive management are shown in the algorithms as follows:

- Mating

This procedure contains domain-specific information related to the mating process in swine. It includes guidelines on when and how to mate boars and gilts, the importance of estrus detection, and factors affecting successful mating.

- Boar Selection

Thorough deliberation is imperative during the pivotal phase of boar selection for swine reproduction in order to guarantee maximum reproductive efficacy and genetic variety among the herd. This section examines crucial elements in the process of selecting studs, with an emphasis on the fundamental importance of virility and the distinct factors that must be taken into account when selecting junior and senior boars. An investigation into the coupling frequencies of boars according to age yields significant knowledge regarding the intricate administration of these animals, thereby aiding in the overarching objective of improving the effectiveness and durability of swine breeding initiatives.

- Gestation

During the gestation stage of swine farming, a decision support system can provide valuable assistance to farmers in optimizing the management of pregnant sows and ensuring the well-being of both sows and piglets. A gestation period forecasting will be developed for this component. Given that the gestation period for swine is typically 110-118 days, according to interviewed swine farmers, the process focuses on gestation period forecasting can help farmers plan and prepare for the arrival of piglets. An alert system will be implemented to notify users when a sow's expected farrowing date is approaching. This helps with timely preparations for farrowing.

```
for each boar in allBoars:
   // Check for masculinity
   if boar.characteristics.masculinityScore >
   thresholdMasculinity:
      // Check for preferred age category
      if boar.age >= juniorBoarMinAge and boar.age <
   seniorBoarMinAge:
         matingFrequency = if boar.age <
   seniorBoarMinAge then juniorBoarMatingFrequency
   else seniorBoarMatingFrequency
         // Check if mating frequency meets the minimum
   requirement
         if matingFrequency >= if boar.age <
   seniorBoarMinAge then
   juniorBoarMinMatingFrequency else
   seniorBoarMinMatingFrequency:
            // Boar meets all criteria, add to selected studs
            selectedStuds.append(boar)
// Result: selectedStuds now contains the boars selected
   for breeding
```

Fig. 3 Pseudocode for the boars selection process in swine

```
currentDate = getCurrentDate()
for each sow in swineHerd:
   estimatedFarrowingDate = sow.breedingDate + 110
   daysToFarrowing = estimatedFarrowingDate -
currentDate
   if daysToFarrowing >= 0 and daysToFarrowing <= 8:
      alertMessage = "Sow #" + sow.id + " is
approaching farrowing in " + daysToFarrowing + "
days."
      sendAlert(alertMessage)
function sendAlert(message):
   //Send the message to the farm manager or relevant
personnel
```

Fig. 4 Pseudocode for the boars selection process in swine

- Lactation

The lactation period typically lasts up to 30 days, but it can vary. Decision support can help determine the optimal duration for each sow based on her and her piglets' health and growth. Decide on the appropriate time for weaning piglets. Decision support can consider factors such as piglet weight, health, and sow condition to recommend the best time for weaning.

- Nursery

The nursery is a phase in the production cycle that follows the farrowing (birth) stage and precedes the grower/finisher stages. The nursery phase focuses on the care and management of piglets after they have been weaned from their mother's milk until they reach a certain age or weight.

This phase is critical for the successful transition of piglets from a diet based on their mother's milk to solid feed and for the development of good health and growth. As shown in Table 1, the procedures in the nursery phase of swine production are crucial for the successful growth and development of piglets after weaning.

Table 1. Swine nursery phases and development

Duration	Procedure
After 3 days from birth	inject Iron medicine
After 5 days	guide the piglets to eat a booster feed
After 7 days	inject Respisure for anti-pneumonia
After 10 days, follow up	inject Iron and vitamins
After 12-15 days	castration for male piglets

```
function makeCullingDecision(animal):
   if isLowFertility(animal) or
hasReproductiveIssues(animal):
       return "Cull due to reproductive issues"
       if hasChronicIllness(animal) or
carriesGeneticDisorders(animal):
       return "Cull due to health concerns"
       if isOld(animal) or
showsDeclineInProductivity(animal):
       return "Cull due to age or decline in productivity"
       if hasAggressiveBehavior(animal) or
displaysAbnormalBehavior(animal):
       return "Cull due to behavioral concerns"
       if hasStructuralDefects(animal) or
doesNotConformToStandards(animal):
       return "Cull due to physical conformation issues"
       if isExpensiveToMaintain(animal) or
marketConditionsDemandCulling(animal):
       return "Cull for economic reasons"
   if isEnvironmentalConsideration(animal):
       return "Cull based on environmental
considerations."
   return "No culling decision"
```

Fig. 5 Pseudocode for the boars selection process in swine

- Culling

Culling in swine farming involves the removal of animals from the herd based on certain criteria. The specific criteria for culling can vary depending on the goals and priorities of the swine operation.

4.2. Model Management

Model Management is the analytical powerhouse of the DSS, housing a variety of models and algorithms that process data and knowledge from the Knowledge Base. These models included rule-based decision models and recommendation models. Each model played a distinct role in analyzing data and knowledge to provide practical recommendations, classify swine, and optimize resource allocation, thereby facilitating data-driven decision-making.

- Rule-Based Decision Models

Rule-based decision models are a type of decision-making approach that relies on a set of predefined rules or conditions to guide actions or outcomes. The procedures identified in each of the phases of swine productive management were translated into rules that were implementing decisions given identified variables. In the trend analysis for the breeding, pregnancy and birthing that was created in the DSS dashboard, rule-based decision models were employed to interpret patterns and trends observed in the swine data.

- Recommendation Models

In determining swine that needed to be culled due to poor reproductive performance, recommendation models played a crucial role. These models leverage data on various reproductive metrics such as breeding success, pregnancy rates, birthing outcomes, and mortality rates to make informed recommendations on which swine should be culled from the herd.

4.3. User Interface

The User Interface serves as the bridge between the DSS and the swine farmers and managers. It provides an accessible and user-friendly platform for recording and monitoring swine data. Additionally, the User Interface presents recommendations related to mating, gestation, and overall swine production. Users can monitor the reproductive performance of the herd and generate projections and reports that offer valuable insights into future production estimates, resource usage forecasts, and overall performance summaries.

Figure 6 shows the diagram of the knowledge-based DSS for swine farmers, promoting user interactivity with the different models for effective management and decision support. This maximizes the capabilities of the farmers in managing their farms, enabling them to be more responsive to the needs of their farms and establishing real-time management support and efficient delivery of necessary services. As shown, the system is divided into three important key modules for the author with access towards the development environment for the improvement of rule-based processes. The database as the main back-end holding most of the repositories for the data needed, and the front-end or the interface for the users of the system. The DSS allows swine business owners to maintain and fine-tune knowledge-based rules that impact the application behavior while reducing other costs. It also provides a wide range of intuitive and domain-specific interfaces with natural language for rule authoring, hence making it more manageable and controlled [23].

The proposed DSS framework became the basis for the development of the prototype of the swine productive operations management system. Some of the essential features of the system that was developed could be included:

- Swine Data Recording and Monitoring: This is the recording and monitoring features of the user interface. This component allows users to input and track critical data related to swine, such as health records, growth measurements, and breeding history. It should be user-friendly and accessible.
- Matting, Gestation, and Production Recommendations: This component could facilitate the presentation of recommendations related to the mating process, gestation, and overall production. Users should have a clear view of suggested actions and their rationale.

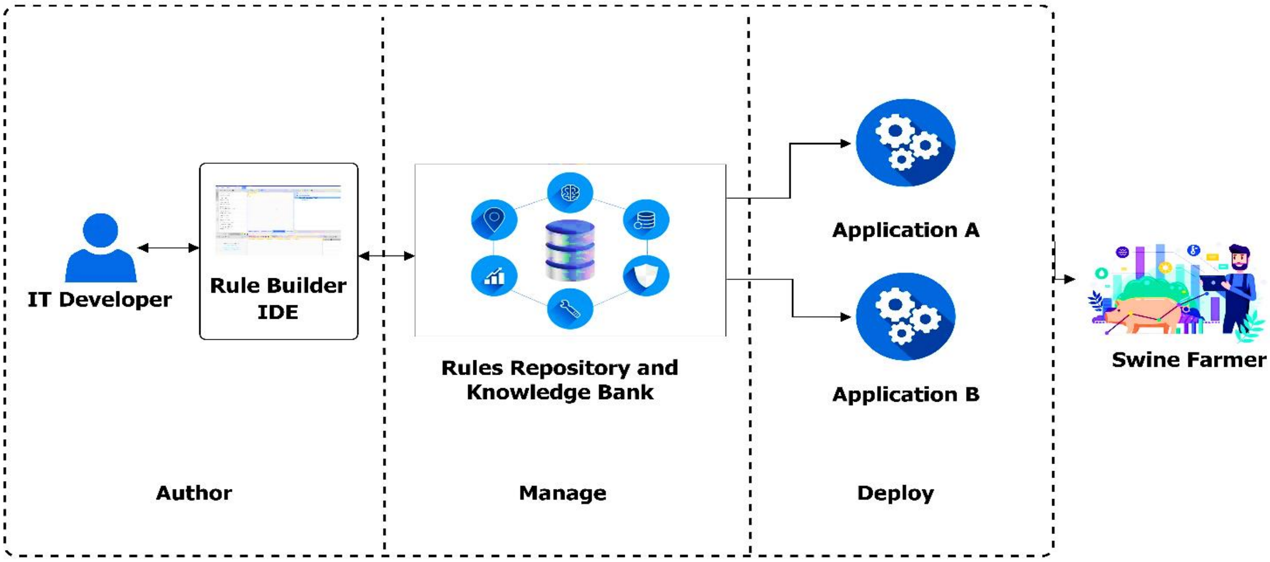

Fig. 6 The Knowledge-based decision support system for optimized swine farmer productivity

- Reproductive Performance: This feature provides an interface that enables users to monitor and assess the reproductive performance of the swine herd. This includes features for tracking fertility rates, litter sizes, farrowing intervals, and other key performance indicators.
- Trend Analysis, Projections and Reports: This component provides a user interface that generates projections and reports. These reports provide valuable insights into future production estimates, resource usage forecasts, and overall performance summaries, allowing users to make data-driven decisions.

The knowledge-based structure, model, and the user-interface provided the framework that would help in the development of the system with the potential of improving swine farm management and enhancing the decision-making process of the farmers. Taking these considerations, some important steps are needed to ensure that the development is easily implemented; hence, the collective information from experts like the Department of Agriculture and other large-scale swine farmers and operators is best to be consulted, ensuring the success rate that which the framework can be deployed. The innovation provides an addition to the development of agriculture and is believed to help boost swine production within the locality.

The potential implication of the implementation would accomplish to ensure short and long-term solutions towards livestock production, improving food security and sustainability. This significant framework could also establish critical policies that will help ensure food security and allowing key administrative officials, especially the Local Government Units (LGUs) make strategic plans towards its full adoption. These indicators and other various future inclusions would provide further applications to validate this claim. Hence, the framework would be a significant step towards contributing to the success of the agricultural sectors, especially in swine production.

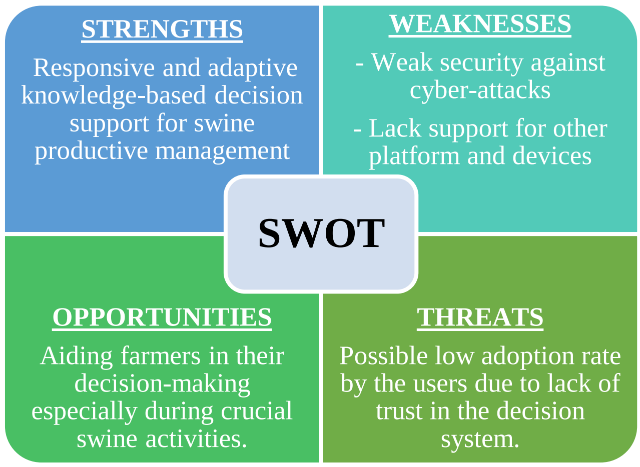

Fig. 7 SWOT analysis

5. Evaluation

Various evaluation measures were conducted to measure the effectiveness of the proposed DSS framework. These measures include SWOT Analysis, Usability Testing and Functional Testing.

5.1. SWOT Analysis

To evaluate the viability of the knowledge-driven DSS for swine productive management, internal and external factors were identified. These are basically divided into Strengths, Weaknesses, Opportunities, and Threats, providing possible key issues and deployment considerations. The analysis provided a clear identification of various capabilities as well as shortcomings that the system may encounter during the process. One of the key elements in the SWOT analysis is the strengths, which pointed out the designed frameworks' responsiveness and adaptive quality of the decision support systems in providing optimized support for swine farmers, allowing competitiveness and management easy. It is important to consider the quick responsiveness to external business factors and environmental variants of the framework.

On the other hand, weaknesses are factors and internal capabilities that restrict the designed system from optimal performance. An anticipated vulnerability of the system is its inadequate protection against cyber-attacks and its failure to function on alternative platforms and devices. This is one of the limitations of the system as it is designed initially for functionality first and later, the system will be making improvements as scalability increases. Likewise, other platforms may not at present be included as further testing of the system stability needs to be studied first before increasing the platforms included.

The opportunities that can be taken advantage of with the design of the decision support system would be in aiding the swine farmers in making informed decisions which could help in the management of their farm. The adoption of the system would be beneficial in the different aspects of their swine farming, from mating to culling, while being equipped with the model management system and increasing its optimized service once used. Another element in the SWOT analysis is the threat, which is both a challenge and an opportunity for the swine farmers. It is actually anticipated that most swine farmers would be adamant about using the system, which potentially reduces its usefulness; however, providing accurate information on critical farm activities would help them realize that more benefits are acquired than potential losses. Furthermore, at this point in time where issues of ASF and problems of inflation, the use of technology that might aid them in making their lives easier would be the deciding factor for them to utilize the system for their benefit.

5.2. Usability Testing

The user acceptance evaluation gathered feedback from 30 respondents, including swine farmers, farm owners, and agriculturists from Daet, Camarines Norte, Philippines, on SwineTech's usability, functionality, and satisfaction. The survey utilized a 5-point Likert Scale to gauge respondents' agreement on various indicators such as Ease of Use, Dashboard Features, Record Management, and System Performance. SwineTech offers a significant advancement in swine farm management. It provides a user-friendly interface and comprehensive features tailored to farmers' needs, including record management, reproductive management, and data-driven decision-making through its dashboard. The platform enables users to optimize breeding outcomes and enhance overall farm efficiency through informed decision-making.

Table 2. User acceptance evaluation result

Indicator	Score
Ease of Use	4.28
Dashboard and Features	4.45
Swine Record Management	4.34
Pigpen Utilization Monitoring	4.39
Reproductive Management	4.48
System Performance	4.41
Likelihood of continued use	4.33
Overall Satisfaction	4.40
Average	**4.385**

Table 3. Effectiveness evaluation result

Indicator	Score
Usefulness	4.37
Functionality	4.54
Reliability	4.44
Impact of the DSS dashboard	4.65
Average	**4.50**

Table 2 presents the result of the user acceptance evaluation, which is an average of 4.385. The positive feedback from users, as indicated by the high average score of 4.385 in the user acceptance evaluation, underscores the system's effectiveness and potential to revolutionize swine production management.

5.3. Functional Testing

Evaluating the efficacy of decision support involves determining how the Decision Support System (DSS) dashboard contributes to more informed decision-making in the context of swine husbandry. A questionnaire assessing the efficacy, functionality, dependability, and consequences of the DSS interface was distributed to stakeholders—farmers, labourers, and agriculturists—in order to gather insights. The results, as presented in Table 3, indicate that the DSS interface was rated an average of 4.5, which signifies the extent to which it was regarded as effective and beneficial in assisting with rational decision-making.

6. Conclusion and Future Work

This paper demonstrates a significant advancement in swine farm management, offering a comprehensive solution for improving breeding and farrowing management. By integrating a Knowledge-based DSS framework with advanced analytics and recommendation models, the system enables farmers to make informed decisions based on data-driven insights. The user acceptance evaluation demonstrates the platform's usability, functionality, and overall satisfaction among swine farmers and industry stakeholders.

Moving forward, further research and development efforts can focus on enhancing the system's capabilities, expanding its applicability to other areas of swine production, and addressing emerging challenges in the industry. With its innovative features and user-centric design, SwineTech Precision stands poised to revolutionize swine farming practices and contribute to the sustainable growth of the swine industry. For future work, an integrated system which is easily scalable and manageable with a user-friendly interface could be provided with real-time access and monitoring of the swine farmers, investors, the government, and other concerned agencies ensuring the quality of meat products of each swine investor.

Acknowledgement

The authors express their appreciation and gratitude to the Camarines Norte State College, the University of the Cordilleras and the Commission on Higher Education Department for their support, which provided aid to this work.

References

[1] Food and Agriculture Organization, *World Food and Agriculture - Statistical Yearbook 2022*, FAO, pp. 1-382, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[2] Shad Mahfuz et al., "Applications of Smart Technology as a Sustainable Strategy in Modern Swine Farming," *Sustainability*, vol. 14, no. 5, pp. 1-15, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[3] Francisco Gutiérrez et al., "A Review of Visualisations in Agricultural Decision Support Systems: An HCI Perspective," *Computers and Electronics in Agriculture*, vol. 163, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[4] P. Boettcher et al., "World Livestock: Transforming the Livestock Sector through the Sustainable Development Goals," *Food and Agriculture Organization of the United Nations*, pp. 1-220, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[5] Francisco Tardelli da Silva et al., "Open Innovation in Agribusiness: Barriers and Challenges in the Transition to Agriculture 4.0," *Sustainability*, vol. 15, no. 11, pp. 1-14, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[6] Zhaoyu Zhai et al., "Decision Support Systems for Agriculture 4.0: Survey and Challenges," *Computers and Electronics in Agriculture*, vol. 170, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[7] Fahim Bin Alam et al., "Analysis of the Drivers of Agriculture 4.0 Implementation in the Emerging Economies: Implications towards Sustainability and Food Security," *Green Technologies and Sustainability*, vol. 1, no. 2, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[8] Franco da Silveira et al., "Farmers' Perception of the Barriers that Hinder the Implementation of Agriculture 4.0," *Agricultural Systems*, vol. 208, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[9] Charvi Arora et al., "Integrating Agriculture and Industry 4.0 under 'Agri-Food 4.0' to Analyze Suitable Technologies to Overcome Agronomical Barriers," *British Food Journal*, vol. 124, no. 7, pp. 2061-2095, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[10] William L. Flowers, "Reproductive Management of Swine," *Animal Agriculture*, pp. 283-297, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] R.D. Boyd et al., "Review: Innovation through Research in the North American Pork Industry," *Animal*, vol. 13, no. 12, pp. 2951-2966, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[12] Shunli Wang et al., "The Research Progress of Vision-Based Artificial Intelligence in Smart Pig Farming," *Sensors*, vol. 22, no. 17, pp. 1-23, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] Mireia Moix Atienza, "*eFat, a Prototype of a Cloud Decision Support System for Optimal Delivery of Fattened Pigs to the Abattoir*," University of Lleida, pp. 1-48, 2019. [Google Scholar] [Publisher Link]

[14] Margaret Rouse, What is a Decision Support System Mean?, Decision Support System, Techopedia, 2018. [Online]. Available: https://www.techopedia.com/definition/770/decision-support-system-dss

[15] Ting-Peng Liang, "Recommendation Systems for Decision Support: An Editorial Introduction," *Decision Support Systems*, vol. 45, no. 3, pp. 385-386, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[16] Henderi et al., "Covid-19 Series: A Rule-Based Decision Support System for Analysis Behavior of People while Working from Home," *IOP Conference Series: Materials Science and Engineering*, vol. 1007, pp. 1-7, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[17] Lea D. Austero, Michael Angelo D. Brogada, and Rommel Evan J. Paje, "Determining Resource Capacity in Disaster Relief through a Model-Driven Decision Support System," *2018 International Symposium on Computer, Consumer and Control (IS3C)*, Taichung, Taiwan, pp. 225-228, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[18] Hao Wang et al., "Smart Decision-Support System for Pig Farming," *Drones*, vol. 6, no. 12, pp. 1-13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[19] Betty R. McConn et al., "A Behavior and Physiology-Based Decision Support Tool to Predict Thermal Comfort and Stress in Non-Pregnant, Mid-Gestation, and Late-Gestation Sows," *Journal of Animal Science and Biotechnology*, vol. 13, no. 135, pp. 1-13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[20] Paolo Aversa, Laure Cabantous, and Stefan Haefliger, "When Decision Support Systems Fail: Insights for Strategic Information Systems from Formula 1," *The Journal of Strategic Information Systems*, vol. 27, no. 3, pp. 221-236, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[21] Sarah Tifany Silva, Francini Hak, and José Machado, "Rule-based Clinical Decision Support System using the OpenEHR Standard," *Procedia Computer Science*, vol. 201, pp. 726-731, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[22] 8 Decision Support System Examples to Guide Decision-Making, Indeed.com, 2023. [Online]. Available: https://www.indeed.com/career-advice/career-development/decision-support-system-examples

[23] Kwok W. Cheungl, and Mei-Peng Cheong, "Intelligent On-Line Decision Support Tools for Market Operators," *2007 International Conference on Intelligent Systems Applications to Power Systems*, Kaohsiung, Taiwan, pp. 1-6, 2007. [CrossRef] [Google Scholar] [Publisher Link]