MOO-VING TOWARDS OPERATIONAL EFFICIENCY: A VENN DIAGRAM APPROACH TO FACILITY LAYOUT DESIGN AND CATTLE HANDLING PRINCIPLES

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ABSTRACT

In today's fast-paced and highly competitive industrial landscape, achieving optimal efficiency is the key to success. This review compares the fundamental facility layout design principles of industrial engineering with those of cattle handling facilities. This comparison is achieved through an integrative literature study on facility layout design principles, consisting of 1) a narrative literature review on industrial engineering principles and 2) a rapid systematic review of cattle handling facility design principles. By examining these principles side by side, we aim to identify the correlations and variations that exist and unearth opportunities for mutual enrichment and interaction between these seemingly disparate fields, to enhance both operational efficiency and improved production. A Venn diagram has been constructed to illustrate the relationship between these principles. This review offers valuable insights for industrial engineers, livestock managers, and researchers seeking innovative approaches to optimise operational performance and improve facility layout designs in diverse industrial and agricultural settings.

Keywords: cattle handling, facility, layout, design, principles, industrial engineering

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1 INTRODUCTION

The pursuit of operational excellence and efficiency is a constant challenge. Organisations are continually seeking innovative ways to streamline their operations and enhance productivity [1]. While many factors contribute to overall efficiency, one aspect with significant implications is the facility layout of such organisations. The importance of a well-designed facility layout cannot be overstated as it directly impacts the overall functioning of a physical workspace. This holds true not only in industrial settings but also in the intricate world of agriculture. It goes beyond mere aesthetics and holds the power to reshape workflows, reduce bottlenecks, and maximise resource utilisation [2].

Cattle feedlots are a specialised type of agriculture operation focusing on managing, raising, growing, and fattening cattle until they reach slaughter weight for meat production [3]. The advantage of feedlots is raising a large number of cattle on less land with fewer inputs, which results in maximum production at minimum cost. Feedlots strive for better productivity to drive profitability while ensuring animal welfare. Handling facilities are needed at feedlots to guide cattle in the desired direction for sorting, feeding, and handling. Cattle handling facilities demand a specialised set of design principles focussing on animal behaviour to ensure animal welfare, worker safety, optimised handling processes, and minimised stress on the cattle [4].

The heavier the cattle in weight, the better income they will receive if cattle are sold as beef. Thus, proper design, maintenance, and operation of these facilities can help minimise stress injury and improve the overall productivity and profitability of the livestock producers [5]. Therefore, it becomes imperative for feedlot operators to carefully consider the design and layout of their facilities, taking into consideration the unique needs of the cattle they handle.

Unfortunately, sometimes feedlot facilities fall short of meeting these objectives resulting in an inefficient facility layout that inhibits the flow of cattle. A poor facility layout causes bottlenecks to form in the corrals and cattle chutes leading to unnecessary stress on cattle. Elevated stress levels of cattle lead to increased rates of injury and a reduction in production (growth), leading to economic losses [6]. Furthermore, a poor facility layout will increase labour costs and increase the risk of potential safety hazards to workers [4].

In a similar vein, industrial engineering facility layout principles revolve around strategically organising machinery, workstations, people, and resources to achieve maximum operational efficiency. By applying these principles, industries have successfully improved workflows, reduced operational bottlenecks, and enhanced overall productivity [7].

Both the manufacturing industry and feedlots require proper facility layout to achieve operational excellence. However, there is a significant gap in research regarding the integration of industrial engineering and cattle-handling facility design principles.

By elucidating the parallels, industrial engineers can gain new perspectives on facility layout design by embracing the unique challenges and principles of cattle handling. The specialised considerations in cattle handling can offer novel insights into the design and optimisation of facility layouts in industrial settings. Simultaneously, it can demonstrate how the application of industrial engineering facility layout design principles can enhance cattle handling practices at feedlots.

The aim of this study is to investigate the relationship between industrial engineering facility design principles and cattle handling facility design principles. By comparing these principles, we can uncover the potential synergies, determining how they can mutually reinforce and contribute to one another, in the pursuit of better production and increased profitability.

The next section explains the method that was followed, while section 3 and 4 provide the findings and discussions. The review is concluded in section 5, with future research recommendations stated in section 6.

2 METHOD

An integrative literature review was utilised for this study as it is a method that seeks to summarise and synthesise existing knowledge and theories across literature to provide a comprehensive understanding of a topic [8]. It allows for generating new perspectives on a topic and resolving inconsistencies in literature by combining different literature review studies [9].

This method was followed to establish the possible correlations and variations between cattle handling and industrial engineering facility design principles. The findings of a 1) rapid systematic literature review and 2) a narrative literature review, were integrated to identify relationships concerning the respective principles.

2.1 Integrative literature review

The integrative literature review followed the 5-stage framework by Whittemore and Knafl [8] and is illustrated in Figure 1.

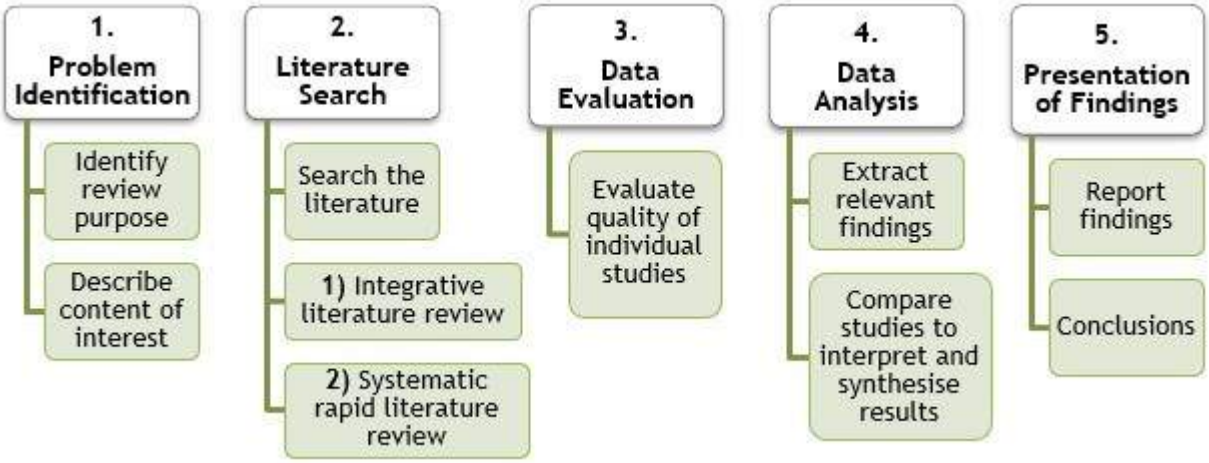

Figure 1:Integrative review methodology framework (Adapted from Whittemore and Knafl [8])

2.1.1 Stage 1: Problem identification

An integrative literature review was done to acquire practical insights into industrial engineering and cattle handling facility design principles. This review aimed to bridge the gap between these facility layout design principles. It has uncovered the correlations, explored the variations, and harnessed the collective wisdom of these domains to pave the way for a more efficient, sustainable, productive, and harmonious future.

2.1.2 Stage 2: Literature search

The literature review consisted of two separate literature reviews the findings of which were compared:

1) Since abundant information is available, a narrative literature review was conducted on Industrial Engineering facility design principles. (Detail of the method followed is discussed in Section 2.2)

2) A more specific systematic rapid literature review on cattle handling facility design principles was conducted. (Details of the method followed are discussed in Section 2.3.)

2.1.3 Stage 3: Data evaluation

Data evaluation entails the evaluation of the literature from each review based on their respective evaluation criteria, which can be found in Section 2.2 and Section 2.3.

2.1.4 Stage 4: Data analysis

Data analysis requires the extraction of key information from each study and comparison of the reviews to synthesise the results [9]. This will allow for the identification of the relationship between both reviews' findings where areas correlate and vary.

2.1.5 Stage 5: Presentation of findings

The key insights derived from the findings are effectively summarised and communicated. A Venn diagram allows for the representation of the research gaps and how the findings complement one another.

2.2 Narrative literature review - Engineering facility design principles

A general narrative literature review was conducted to extract information regarding facility layout design principles within the industrial engineering field. The purpose of this review was to synthesise and analyse a wide range of literature by combining various sources to construct a coherent narrative that highlights the current body of knowledge about industrial engineering facility layout design principles [10]. The following method of Green *et al*. [10] was adapted and followed for the review.

2.2.1 Objective

The industrial engineering facility design principles applicable to various industries were identified and established. The aim was to provide a comprehensive overview of the key principles contributing to efficient facility design and optimisation.

2.2.2 Search Strategy

Various electronic databases and books were searched to explore existing research that provided a comprehensive understanding of the topic [10]. The search terms used to obtain data were "industrial engineering" AND "facility layout design principles".

2.2.3 Inclusion and Exclusion Criteria

Sources were screened based on their relevance to industrial engineering facility design principles. Relevance refers to the degree to which the information provided by the source aligns with the research topic being investigated. Inclusion criteria included sources directly addressing these principles in an industrial engineering context. Sources that did not meet these criteria or were not specific to facility design principles were excluded.

2.2.4 Selection Process

Sources were reviewed to identify relevant studies. The full texts of the selected sources were thoroughly examined to extract pertinent information related to industrial engineering facility design principles.

2.2.5 Data Extraction

Relevant data were extracted from the selected sources. The information was organised in a structured manner to facilitate further analysis.

2.2.6 Synthesis of Findings

Recurring data and key findings were highlighted to provide a comprehensive overview of the principles. The findings are summarised and analysed in section 3.1 to compare them to the findings of the rapid systematic literature review (SLR).

2.2.7 Critical Evaluation

The findings were compared with existing knowledge to ensure a comprehensive and reliable representation of industrial engineering facility design principles.

2.3 Rapid systematic literature review - cattle handling facility design principles

A rapid SLR was conducted to explore cattle handling facility design principles. The review was accomplished by searching a specific database using predetermined keywords.

The reason for the rapid SLR is to extract as much information as was available on cattle handling facility design principles in a timely and comprehensive manner while still adhering to the rigorous methodology of a traditional systematic literature review [11].

Xiao and Watson [12] provide a methodological framework for conducting systematic reviews which is embedded with verification and validation within the steps to ensure rigour throughout the process. This framework was followed for the rapid SLR and is illustrated in Figure 2.

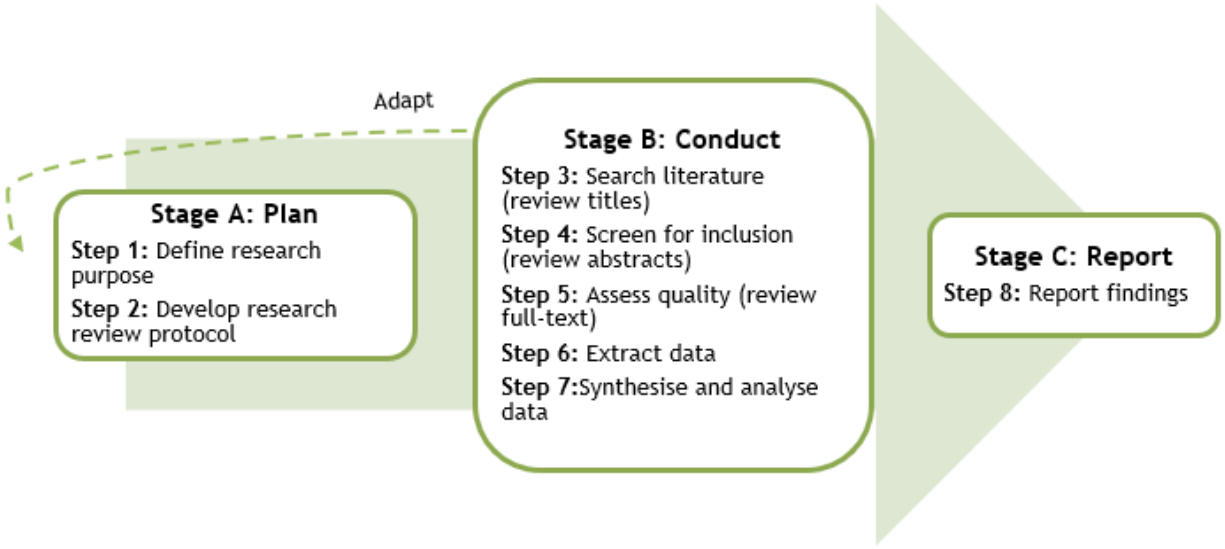

Figure 2: Method of Systematic Literature Review (Adapted from Xiao & Watson [12])

2.3.1 Step 1: Define research purpose

The purpose of the rapid SLR is to investigate the available literature on cattle handling facility layout design principles.

2.3.2 Step 2: Develop research protocol

Table 1 represents the research review protocol followed to guide the search and assess its quality. Following the protocol inclusion and exclusion criteria will remove research bias. For the rapid SLR only one scientific database will be utilised - Scopus.

Table 1: Research review protocol

Purpose of the study	To establish cattle handling facility layout design principles
Keywords	"Cattle handling" AND "facility" OR "layout" AND "design" OR "principles"
Inclusion criteria	• Literature on design principles for cattle handling facilities. • Literature on behaviour principles affecting design principles. • Literature on cattle handling facility layouts.
Exclusion criteria	• Literature that is not in English. • Cattle handling facility design literature about transportation or slaughter/abattoir. • Literature on Edu game. • Literature on dairy cattle handling. • Literature on diseases and reproductive performance. • Literature related to the biology of animals. • Literature on nutrients in animal feed.
Search databases	• Scopus
Quality assessment criteria	• Literature that provides reliable and valid information related to cattle handling principles. • The use of correct scientific methods during the research study.

2.3.3 Steps 3 to 5: Selection process

The search yielded 57 sources using the database and keywords mentioned in the review protocol. The titles of the sources were reviewed, and the inclusion and exclusion protocols were applied.

Thereafter, the abstracts of the sources were screened for inclusion using the criteria stated in the review protocol. It was determined that ten sources met the criteria after the screening of the abstracts. It was assessed based on the sources' correct interpretation of the keywords and checking the sources against the exclusion criteria. The literature that was discarded had no relevance relating to the design of cattle handling facilities. The focus of these studies relates to factors affecting bruises on carcasses, cattle behaviour during transport and slaughter and dairy cattle handling practices.

The full text of the ten sources was reviewed to determine the quality and reliability of the literature. Finally, seven sources were deemed eligible for use after quality assessment. The excluded literature was invalid and not related to cattle handling facility design principles. The literature was on an experiment conducted on designing and assessing animal welfare rather than focussing on facility layout design principles. Moreover, the literature was about the effect of stockperson handling on cattle behaviour. The process for selecting relevant sources on cattle handling facility design principles is depicted in Figure 3. It displays the different processes of the search, the number of sources found, and how this number decreased through the different selection processes.

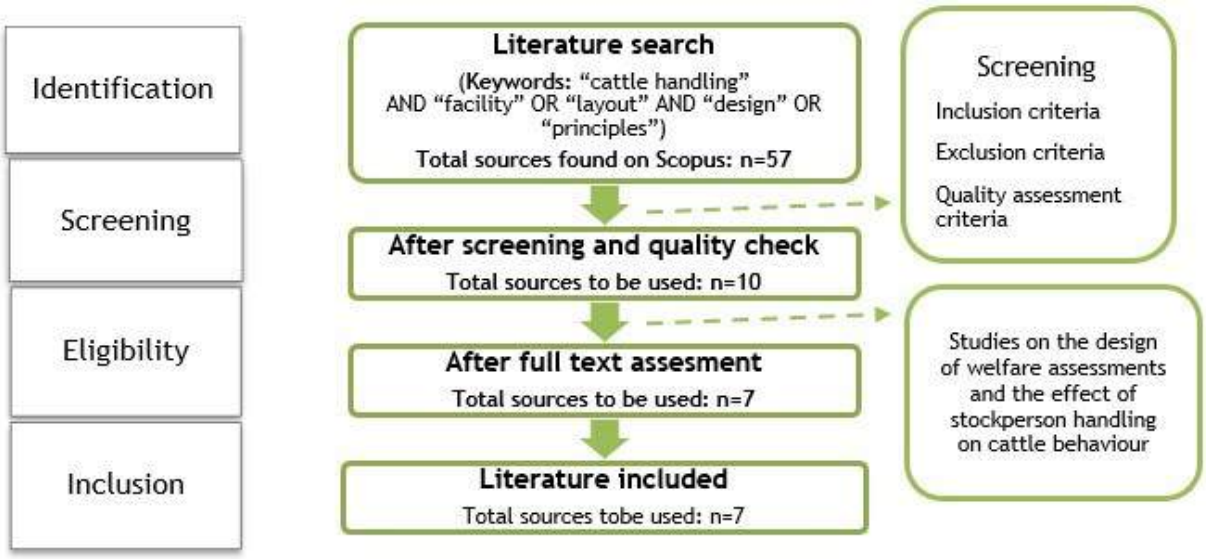

Figure 3: Selection process chart

2.3.4 Step 6: Data extraction

After the selection process, seven sources met the criteria and were eligible to be included in the study. The applicable literature on cattle handling facility design principles is presented in Table 2.

Table 2: Data extracted from applicable literature

#	Author(s)	Year	Title	Type	Ref
1	T. Grandin	1997	The design and construction of facilities for handling cattle	Journal article	[13]
2	T. Grandin	1977	Cattle handling systems for ranches, feedlots, meat packaging plants and auction yards, utilising curved and diagonal lanes	Journal article	[14]
3	D. Scott-Harp, C. Peek-Asa, D. S. Rohlman, B. Janssen	2019	More than time and money: A mixed-method study of the barriers to safer cattle handling practices	Journal article	[15]
4	T. Grandin	2014	A whole systems approach to assessing animal welfare during handling and restraint	Book chapter	[16]
5	T. Grandin	2018	Cattle welfare and principles of handling facility design	Book chapter	[17]
6	T Grandin	1980	Observations of cattle behaviour applied to the design of cattle-handling facilities	Journal article	[18]
7	T. Grandin	1998	Reducing Handling Stress Improves Both Productivity and Welfare	Journal article	[19]

2.3.5 Steps 7 to 8: Data analysis and report findings

The findings of the sources listed in Table 2 are analysed and summarised in section 3.2 so that they can be compared to the findings of the narrative literature review.

3 FINDINGS

The findings from each literature review are represented in separate tables to provide a summary and overview of the literature extracted from 1) the narrative literature review on industrial engineering facility design principles and 2) the rapid systematic literature review on cattle handling facility design principles.

3.1 Narrative literature review

Table 3 presents the findings of the narrative literature review conducted on industrial engineering facility design principles. It provides a summary of each principle, highlighting the core focus and objectives within the context of facility design.

Table 3: Industrial engineering facility design principles

Design Principles	Summary
Workflow optimisation	Optimising the flow of materials, information, and people within the facility. Designed to avoid bottlenecks and interruptions. Emphasises minimising waste and maximising productivity [20].
Operation efficiency	Related processes, inventory and equipment should be located near each other to minimise movement but also to facilitate material handling and process efficiency [20].
Lean manufacturing	Incorporate lean manufacturing principles. Focus on minimising inventory storage, creating clear visual cues, and facilitating smooth material flow [21].
Ergonomics	Considers the design of workstations and equipment to ensure optimal human performance and safety. Emphasises ergonomic principles to reduce strain and enhance worker comfort [22].
Space utilisation	Maximises the efficient utilisation of available space within the facility, ensuring optimal placement of equipment and resources. Aims to minimise empty or unused spaces and maximise storage capacity [20].
Safety	Incorporates safety measures to create a secure working environment, preventing accidents and promoting employee well-being [22].
Management	Apply supply chain principles to optimise the flow of materials, information, and resources across the facility and its external partners [21].
Flexibility	Enables easy modifications. Changes should be made with minimal interruption to production. Allows for future expansion or reconfiguration to accommodate evolving needs [20].
Accessibility	Considers the ease of movement and accessibility for personnel, equipment, and materials. Ensures efficient flow and reduces travel distances within the facility [22].

Design Principles	Summary
Visibility	Focuses on adequate ability for supervision with clear lines of sight, foot access and visibility across the facility to enhance monitoring and control [22].
Sustainability	Consider energy-efficient design principles to minimise environmental impact and reduce operating costs [22].
Economic feasibility	Finding the right balance between cost and efficiency that will contribute to overall profitability and long-term sustainability [22].
Technology utilisation	Incorporates advanced technologies, automation, and digital systems to enhance operational efficiency and streamline processes [20].
Regulatory Compliance	Adhere to industry regulations, safety standards, and building codes [22].

3.2 Rapid systematic literature review

Table 4 presents the findings of the rapid systematic review on cattle handling facility layout design principles. It summarises each principle, outlining its focus and objectives within the context of cattle handling.

Table 4: Facility design principles for cattle handling

Principles	Summary
Reduce distractions	Design facility with solid walls and floors, avoiding bright lights and shadows, helps maintain their focus and reduces anxiety during handling [13].
Reduce obstructions	Ensuring that the facility design does not include sharp edges, protrusions, or objects that could potentially harm cattle. Clear path with minimal obstructions ensures the safety of cattle [13].
Cattle flow	Visual barriers, non-slip flooring, and gradual slopes to facilitate smooth and efficient movement of cattle for handling operations. Minimises congestion, reduces handling time, and optimises the overall workflow [18].
Prioritise animal welfare	Gentle handling to reduce stress and improve the overall well-being, safety, and comfort of the cattle. It includes investing in the necessary infrastructure and resources. Providing shaded areas, proper ventilation, and non-slip flooring can further enhance animal welfare [17].
Sufficient Space	Providing enough space for cattle to move freely to allow cattle to move comfortably and avoid overcrowding, which can lead to stress and injury [14].
Adequate infrastructure	Ensure a robust and durable system capable of efficiently handling a large number of cattle, minimising the risk of breakdowns or frequent

Principles	Summary
	replacements, thereby maximising productivity and reducing long-term maintenance costs [15].
Efficient handling operations	Selection and placement of equipment. Enables efficient and safe handling, sorting, and containment of cattle. Consider resource placement to optimise the flow of handling operations while minimising unnecessary movement and resource wastage [19].
Safety	Use safety measures and protocols to minimise risks and injuries to both cattle and handlers. Ensure secure and controlled handling environments to prevent accidents or escapes [15].
Worker efficiency	Optimise layout to enhance worker efficiency during cattle handling tasks, reduce fatigue, and streamline processes. Consider factors like access to tools and clear communication [19].
Ease of cleaning	Facilitate easy cleaning and maintenance of the facility to maintain hygiene and reduce the risk of diseases. Efficient removal of waste to promote a healthy environment for cattle [14].
Low-Stress Handling Techniques	Implementing low-stress handling methods, adopting modern, humane handling practices such as calm and patient approaches, minimising loud noises, and avoiding abrupt movements helps maintain a relaxed environment for the cattle and encourages cooperative behaviour [19].
Cattle Behaviour	Incorporating an understanding of cattle behaviour into the facility design, considering their natural instincts, social hierarchy, and movement patterns [16].
Flexibility	Design for adaptability to accommodate different sizes and various types of cattle [13].
Accessibility & visibility	Workstations, equipment, and pathways designed to provide clear visibility and easy access for personnel, allowing for efficient monitoring and handling of the cattle [18].
Welfare regulations	Comply with animal welfare regulations and guidelines [16].
Training workers	Train workers to handle livestock, considering cattle flight zones, thereby minimising stress effectively and ensuring the safety of the cattle and maximising operational efficiency [19].

4 DISCUSSION

The exploration of cattle handling and industrial engineering facility design principles reveals an overlap and shared principles between the two domains. A closer examination reveals that both domains recognise the importance of layout optimisation, workflow analysis, and safety considerations.

There are notable similarities between these design principles. However, there are also variations since industrial engineering principles provide a more comprehensive approach to

facility design across various industries, while cattle handling principles offer specialised insights specific to the unique challenges and requirements of handling livestock, which may not be fully captured by general industrial engineering design principles.

A visual representation of the correlations and variations amongst the respective principles is depicted in a Venn diagram (Fig 4). The correlations are further discussed in Section 4.1 and the variations in Section 4.2.

Figure 4: Venn diagram of correlations and variations between industrial engineering- and cattle handling facility design principles

4.1 Correlations

The correlations between cattle handling facility design principles and industrial engineering design principles are captured in a comparison table (Table 5). These correlations highlight the distinct objectives and considerations that shape the design principles in cattle handling facilities and industrial engineering, reflecting the specific needs and challenges of each industry.

Table 5: Correlation between facility layout design principles in Industrial Engineering and Cattle handling

Principle	Cattle handling	Industrial engineering
Safety	Incorporation of safety measures and low-stress animal handling techniques to minimise injury of both cattle and workers. Ensuring a safe working environment.	Implementing ergonomic workstations and safety measures to create a safe and comfortable working environment for employees.
Flow	*Cattle flow* - Attention to animal behaviour, cattle movement and	*Workflow* - Analysing material flow and movement patterns to minimise

Principle	Cattle handling	Industrial engineering
	designing chutes, gates, and alleys to facilitate smooth and controlled movement of livestock. (Minimise stress and congestion).	bottlenecks and streamline workflow. (Optimise process and remove waste).
Efficiency	*Handling and worker operations* - Appropriate equipment and resource placement to optimise the flow of handling operations while minimising unnecessary movement and resource wastage. (Improve livestock handling efficiency)	*Operation efficiency* - Related processes, inventory and equipment should be located near each other to minimise movement but also to facilitate material handling and process efficiency.
Space	Sufficient space - Provide enough space for cattle to move freely and comfortably to avoid overcrowding, which can lead to stress and injury.	Space utilisation - Efficiently utilise space to optimise workflow and productivity.
Regulations	Compliance with animal welfare regulations and guidelines to ensure humane treatment.	Compliance with relevant industry regulations, safety standards, and building codes.
Accessibility & visibility	Proper positioning of the equipment, infrastructure, and pathways to maximise operator visibility and accessibility while minimising distractions for livestock. (Efficient monitoring and handling of the cattle).	Considers the ease of movement and accessibility for personnel, equipment, and materials. Consideration of operator visibility to maximise productivity and minimise errors.
Flexibility	Design facilities that can handle different sizes and types of cattle.	Design for adaptability to accommodate changes in production demands.

4.2 Variations

The variations between cattle handling - and industrial engineering facility layout design principles occur due to the nature of the industries they serve and the specific objectives they aim to achieve. While both share the goal of improving operational efficiency, they differ in their primary focus areas. Cattle handling principles strongly stress the importance of animal welfare, cattle behaviour and the reduction of stress (for the animal) during handling processes. On the other hand, industrial engineering principles prioritise factors such as worker (human) ergonomics, automation and technology integration, and lean manufacturing within industrial settings. These differences stem from the distinct challenges and requirements of each industry, revealing the need for tailored approaches to facility design to meet specific objectives effectively.

4.2.1 Cattle handling principles

The literature reviews showed that cattle handling facilities employ principles in their layout design that are distinct from industrial engineering design principles. However, industries can learn from these principles:

4.2.1.1 Training Workers:

Providing proper training programmes to handlers will ensure that they have the necessary skills and knowledge to handle cattle safely and effectively. The training includes teaching workers proper handling techniques, understanding cattle behaviour, and promoting gentle and humane handling practices.

Implementing training programmes for workers in industrial settings can enhance safety protocols, reduce the risk of accidents or injuries, and improve overall operational efficiency. Well-trained workers are better equipped to handle machinery, follow procedures accurately, and make informed decisions, thereby reducing human error and optimising productivity. Moreover, training programs can foster a culture of continuous improvement, where workers are encouraged to share their knowledge, learn from each other's experiences, and contribute to the overall growth and success of the organisation. Investing in worker training in an industrial setting will enhance employee morale.

4.2.1.2 Ease of Cleaning:

The principle will permit the maintenance of hygiene and prevent disease transmission. The design includes easy access to all areas, including chutes, pens and alleys, to facilitate thorough cleaning and disinfection. Proper drainage systems and smooth surfaces will also aid in efficient cleaning processes.

The principle can be applied to various industries by ensuring hygienic and easily maintainable environments. Industries can improve cleanliness standards and maintain a safe and healthy working environment for employees.

4.2.1.3 Cattle behaviour principles:

Feedlots showcase a diverse range of physical and behavioural variations among cattle, reflecting differences in breeds, growth rates, temperaments and responses to the feedlot environment. Therefore, it is imperative to understand and account for cattle behaviour. The facility layout should align with natural cattle movement patterns to facilitate smooth flow and minimise sudden visual barriers that may cause distress to the animals.

Industries can leverage insights from cattle behaviour principles observed at feedlots to implement efficient processes within their own operations.

4.2.1.4 Adequate Handling Equipment and Infrastructure:

In cattle handling facilities, well-designed chutes, gates, and pens are necessary to facilitate smooth movement and sorting of cattle. Sturdy infrastructure is needed to ensure the safety of both animals and handlers, reducing the risk of accidents or injuries during handling.

Having adequate infrastructure and equipment in an industrial organisation is crucial to ensure the safety of employees by providing them with reliable and well-maintained machinery and facilities. It enables efficient and smooth operations, reducing downtime and maximising productivity.

4.2.1.5 Prioritise Animal Welfare:

Gentle handling is utilised to reduce stress and improve the overall well-being, safety, and comfort of the cattle. Providing shaded areas, proper ventilation and non-slip flooring can further enhance animal welfare.

Industries can learn from the animal handling environment by prioritising human welfare in an organisation. Prioritising the safety and comfort of workers will lead to improved operational efficiency and worker satisfaction.

4.2.1.6 Low-Stress Handling Techniques:

Gentle handling methods will minimise stress in cattle and encourage calm and cooperative behaviour. Minimising loud noises, sudden movements and other potential stressors are also important to keep cattle calm during handling operations.

Cattle handling principles offer unique insights into promoting animal welfare and ensuring safe and stress-free handling procedures. Industries can learn from these techniques and apply them to enhance worker safety and reduce stress in the workplace.

4.2.1.7 Reduce Obstructions:

Clear pathways, well-placed gates, and adequately designed alleys in cattle handling facilities ensure smooth and unobstructed cattle flow and the safety of cattle.

4.2.1.8 Reduce Distractions:

Avoiding visual distractions and reducing noise levels in cattle handling facilities will maintain cattle cooperation and focus during handling. Minimal distractions will result in stress free handling operations.

Creating layouts in the industry that align with natural movement patterns, minimal distractions, and obstructions can lead to improved operational efficiency.

4.2.2 Industrial engineering principles

Industrial engineers utilise principles that are distinct from cattle handling principles when designing facilities. However, these principles could be used to improve cattle handling facilities:

4.2.2.1 Principles of Ergonomics:

Ergonomics refers to designing workstations and equipment layouts that promote worker safety, comfort, and productivity. The principles of ergonomics involve accounting for factors such as proper lighting, ventilation, noise control, and ergonomic design of tools and equipment.

In the feedlot environment, cattle handlers would compromise their own comfort to prioritise the welfare of the cattle. This contrast underscores the intricate balance that must be struck between human comfort and animal welfare within the context of cattle feedlots, to ensure both human and animal needs are met effectively.

Principles of ergonomics can be adapted to design layouts that also prioritise the comfort of workers (not just animals) during handling operations. Applying ergonomic principles to cattle handling systems could reduce fatigue, injury and improve production efficiency.

4.2.2.2 Supply chain management principles:

Supply chain management principles optimise the flow of materials, information, and resources across the facility and its external partners. The principles include inventory management, supplier collaboration, and demand forecasting to enhance overall supply chain efficiency.

These principles can be applied at cattle feedlots by implementing effective inventory management systems, collaborating with suppliers to ensure timely delivery of feed and other resources, and utilising demand forecasting techniques to enhance overall efficiency and minimise disruptions.

4.2.2.3 Principles of lean manufacturing:

Lean manufacturing requires eliminating waste, reducing variability, and streamlining processes. Lean manufacturing involves techniques such as value stream mapping, just-in-time production, and continuous improvement to maximise efficiency.

In the feedlot environment these principles could be utilised to optimise workflow and minimise unnecessary movement of cattle and workers.

4.2.2.4 Sustainability and environmental factors:

Sustainability and environmental factors incorporate energy efficiency and waste reduction measures into facility designs. It involves implementing energy-saving measures, recycling programmes, and sustainable material selection.

These factors can be integrated into the design of feedlot facilities to minimise the environmental impact of livestock operations.

4.2.2.5 Principles of economic feasibility:

Economic feasibility studies focus on balancing cost-effectiveness with operational efficiency by considering factors such as resource utilisation, space optimisation, equipment selection, and labour allocation. The aim is to create facility layouts that minimise unnecessary expenses while maximising productivity and profitability and to create sustainable and financially viable solutions that optimise resource utilisation and contribute to long-term success.

These principles can be applied in the feedlot environment by optimising resource utilisation and minimising unnecessary expenses. Feedlots could invest in durable equipment and infrastructure to reduce maintenance costs and the need for frequent replacements. By making this investment, feedlots could save money in the long run and improve their overall financial stability. An economical and efficient facility layout can contribute to cost savings by optimising labour utilisation and maximising the output per worker.

4.2.2.6 Automation and technology integration:

Integrating automation and technology improves productivity and efficiency and reduces human error. The integration can include the use of robotics, automated material handling systems, and data-driven decision-making tools.

In the feedlot environment, utilising technology and automation will improve productivity. Implementing robotics and automated material handling systems could enhance the speed and precision of cattle movement and sorting. Additionally, technology integration for tracking, identification and data analysis could optimise handling processes.

5 CONCLUSIONS

This review has examined the fundamental design principles of industrial engineering facility layouts and compared them with the design principles applied in cattle handling facilities. The intricate puzzle of merging these distinct fields, emphasises the comforting truth that solutions exist even in complex integrations. This review visually mirrors the convergence through a Venn diagram, elucidating the overlapping puzzle pieces where these principles offer potential mutual enrichment and interaction. Furthermore, to the researcher's knowledge at the time of publication, it is believed that this study is the first comparison concerning these distinct facility design principles.

The overlap between industrial engineering principles and cattle handling principles lies in the shared goals of operation efficiency, productivity and safety. Both fields recognise the importance of eliminating waste, reducing variability and streamlining processes. Integrating best practices from both domains will enhance facility layout designs, improve production, and increase profitability in both industry and agriculture settings.

The similarities between these principles underscore the critical importance of a well-designed facility layout. The shared emphasis on creating efficient and effective facility layouts highlights the universal need for thoughtful design considerations and their influence on overall operational success.

The divide between industrial engineering facility design principles and cattle handling facility design principles is rooted in the distinct nature of these domains. The disparity is particularly evident in the realm of ergonomics, where a notable contradiction arises. Industrial ergonomics is primarily driven by optimising human comfort, while cattle handlers compromise their own comfort to prioritise the well-being of the cattle.

Despite their apparent differences, there exists a connection that remains largely unexplored. The knowledge and insights to be gained from this exploration can lead to transformative advances in operational efficiency and hold value for professionals in both industry and livestock sectors.

6 FUTURE RESEARCH

Future research should explore the potential for further integration between industrial engineering principles and cattle handling principles to continue to explore relationships between these principles, facilitate knowledge exchange, and foster collaboration to unlock new possibilities for operational excellence.

By leveraging these design principles, it will become possible to enhance cattle handling facility layouts through insights and strategies derived from industrial engineering, ultimately leading to improved productivity, safety, and economic feasibility.

Further research should also address the specific challenges faced by different sectors within the livestock industry and explore tailored solutions to optimise operational performance and animal welfare.

Additionally, there is a need to bridge the gap in research between theoretical principles and practical implementation. Future research could conduct field studies to assess the real-world effectiveness of different facility layout designs. By closely examining how these designs function in practical scenarios, researchers can gain valuable insights into their actual performance and identify areas for improvement. Moreover, future research could conduct field studies to evaluate real-world challenges. This would entail observing and analysing the current issues and obstacles encountered at feedlots, enabling researchers to develop more informed and effective solutions that align theory with practical application.

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INVESTIGATING THE CONTRIBUTION OF ORGANISATIONAL STRUCTURE AND CULTURE FACTORS IN THE ADOPTION OF AGILE METHODOLOGY IN FINANCIAL INSTITUTIONS

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ABSTRACT

Financial institutions are rapidly adopting Agile to speed up the development of products and services. In such a highly regulated industry the adoption of a Software Development Life Cycle (SDLC) is hampered by the organisation's existing structure and culture. This paper investigates how a financial institution's organisational structure and culture influence its SDLC decision-making process to ensure that Agile is accepted by the organisation. A survey of 80 project practitioners in various South African financial institutions and hypothesis testing revealed that the organisational structure factors of management style and work ways and the organisational culture factor of work style have a significant positive influence on SDLC decision-making in a financial institution. The research indicates that the way the organisation approaches decision-making influences the perceived acceptance of agile. Financial institutions are encouraged to regularly review their organisational structure, culture, and decision-making to ensure that it is aligned with their development strategy.

Keywords: Organisational culture, organisational structure, agile, financial institutions, South Africa

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1. INTRODUCTION

Financial institutions operate in a very competitive environment to produce innovative products and services for their customers [1]. In South Africa, financial institutions are known for being very innovative and providing solutions that cater to their customers' needs. South African banks are ranked amongst the top 15 banks on the African continent with Standard Bank, First National Bank (FNB), Amalgamated Bank of South Africa (Absa), and Nedbank holding the Top 4 positions [2]. The solutions financial institutions develop are dependent on information technology (IT) infrastructure and require a software development approach. The rapid evolution of technology is forcing the financial industry to embrace digitisation, which requires this industry to align its business with information technology (IT). Various competitive factors have created a strategic need for financial institutions to be more agile, so that they can respond quickly and adapt faster while delivering greater value and keeping their existing market share [1]. This is the reason why most financial institutions are transitioning from a traditional waterfall methodology to an agile methodology as their preferred Software Development Life Cycle (SDLC). An SDLC is the framework that is used to plan, manage, and control the process of developing an information system (Bassil, 2012). There are seven different SDLC methodologies namely agile, lean, waterfall, iterative, spiral and dev-ops. This paper investigates how an organisation goes about adopting a new SDLC methodology such as agile based on its existing organisational culture and structure.

Agile methodology is based on the agile manifesto, which is a set of guiding principles of practice. The agile manifesto promotes values of collaboration over contract negotiations, adapting to change over following a specific plan, having a working solution over comprehensive documentation, and finally, human interactions over tools and processes [3]. These values speak to an organisation's culture and structure.

Many studies have investigated agile and agile adoption in organisations [4]. However there has been a much more limited focus on agile studies in financial institutions [5]. Financial institutions differ from the software development industry, where agile is very prevalent. Financial institutions are more traditional and have a lot more regulations, policies, and procedures that they need to comply with. This highly regulated environment provides a level of complexity when implementing an agile methodology. Failing to adhere to these regulations can result in (a) the institutions being fined; (b) reputational damage, and the most serious consequence which is (c) having their financial license revoked. It is due to operating in such a highly regulated environment that financial institutions seemingly have stringent and bureaucratic decision-making processes and have taken a conservative approach to adopting agile [6]. It is therefore important to investigate the factors/dimensions that are unique to the financial industry that determine the successful adoption of agile.

It has been shown that an agile methodology provides a workable solution much faster than when a traditional methodology is used, although organisations often struggle to adapt to agile [7]. Past research shows that software development process changes trigger complex organisational changes and that these changes cannot be accomplished by merely replacing current tools and technologies with new ones [8]. When an organisation decides to adopt an agile methodology it should review its entire structure, management practice, and culture.

The aim of this study is to investigate the organisational structure and culture factors that contribute to a financial institution successfully adopting an agile methodology for its projects.

The objective is to identify the factors relating to an organisation's structure and culture that contribute to the successful adoption of agile methodology in the financial industry.

Given the objectives, the research questions are:

1. How does the organisational structure in the financial industry play a role in the acceptance of an agile methodology?

2. What organisational culture factors ensure a perfect culture for agile adoption in the financial industry?

2. LITERATURE REVIEW

2.1. Organisational culture

Organisational culture is a shared belief system that infuses an organisation or sub-unit and ultimately influences the actions of people and workgroups [9]. Understanding the culture of an organisation ensures that an organisation and its project office choose a software development method that suits the organisational culture irrespective of software development evolution [10]. The culture of an organisation can be categorised according to various typologies. Burns [11] uses the Hofstede dimension framework to measure the culture in an organisation. Organisational culture studies tend to evaluate individualism vs collectivism; power distance; uncertainty avoidance; and masculinity vs. femininity in the organisation [11]. In contrast, Livari and Huisman [12] use a competing value framework (CVM) to determine the organisational culture based on the organisation's value system. The culture types that be identified based on the CVM framework [12] include:

- The group culture - This culture is concerned with morale and human relations. This type of culture values collaboration and the distribution of decision making.
- The development culture – Describes a culture that emphasises growth and the willingness to adapt. This type of culture values communication that is horizontal, and informal coordination.
- The rational culture – This culture focuses on efficiency, productivity, and the achievement of goals. The culture prefers centralised decision making with formal control systems.
- The hierarchical culture - This culture is concerned with control, stability, and efficiency by following formal rules and regulations.

Each culture type mentioned above has its drawbacks which highlights the inherent dilemmas an organisation might have. An organisation may consist of more than one type of culture based on the size and structure of the organisation.

Although organisational culture may be interpreted in various ways, previous studies emphasize that organisational culture influences the adoption of a software development methodology [13], [14].

Moreover, organisational culture or the organisational climate has a significant impact on the work style exhibited by individuals in an organisation [15]. Work style is defined as the appropriate skills and abilities that an individual possesses to be able to do their job [15]. The literature states that work style, management style, communication, and knowledge sharing processes are all important cultural factors that influence the implementation of agile in an organisation [9].

By knowing which factors are indicative of the organisational culture and therefore determine the different culture types, the study aims to establish the organisational culture factors that can influence the acceptance of an agile methodology.

2.2. Agile culture

Agile is defined as "a network of teams within a people-centred culture that operates in rapid learning and fast decision cycles which are enabled by technology, and that is guided by a powerful common purpose to co-create value for all stakeholders" [14]. To determine the quality of agile, one needs to understand agile development from a human and cultural perspective [13]. By knowing the type of culture inherent in an organisation one can gain

insight into how that organisation will embrace an agile culture which is part and parcel of adopting an agile methodology. An agile culture encompasses factors that influence the decision-making process in an organisation. Depending on how decision-making power is distributed in the organisation, the organisation and its management can either empower their employees to be self-sufficient and creative or the employees can be disempowered which results in them doing just the bare minimum of what is required. The latter will limit the benefits of adopting an agile methodology in an organisation.

An agile culture changes the way employees coordinate, communicate, and collaborate [16]. Furthermore, there should be alignment between product and project decision making and the organisation's business strategy to ensure the success of the agile strategy in the organisation [16]. An agile culture requires a shared decision-making model to empower the team to not be confined to a specialised role. This implies that decision-making power should not only be vested in the project managers and management of the organisation but also in the team [16]. Moreover, the involvement of team members in the decision-making process may even change based on the phase of the development cycle the team finds itself in. An example of this is that when the team is collaborating, the decision making process should include the input of various stakeholders even though they may have different goals and backgrounds [16].

2.3. Organisational Structure

Organisational structure is defined "as the formal system of task and reporting relationships that controls, coordinates, and motivates employees so that they cooperate to achieve an organisation's goal" [Ajagbe (2017) in 17]. The structure of the organisation determines how tasks are executed which in turn has implications for the performance of that organisation.

Karpik [14] describes the functional structure as a "hierarchical structure where each department consist of employees who report to the functional manager and where the functional manager reports to the head of department who oversees the overall performance of the department" [14].

One of the oldest organisational structures is the hierarchical structure also commonly known as the traditional organisational structure. Burns [18] describes the hierarchical structure as a structure where decision making power is centralised towards the top of the organisation and cascades down. This provides managers with the confidence that they have the authority to manage their units [18]. Funminiyi [19] found that the decision-making process in a hierarchical structure may have a negative impact on the organisation if management is ineffective in motivating employees and providing them with training [19].

A second type of organisational structure is the matrix structure where the organisation is more project-oriented and where teamwork between departments is required. The matrix structure tends to be flexible, but it requires interactions and communication amongst the employees. The level of authority in the matrix structure may not be equally shared between the functional and project managers as it depends on the balance of power in the organisation [14]. One of the organisational benefits of the matrix structure is motivated employees. Motivated employees perform at a high level as they have some sense of autonomy and don't always need to wait for top management to make decisions. The mindset of people working in the matrix structure tends to be more strategic and receptive to new ideas [20].

The third organisational structure is called the flat structure. This type of structure is the opposite of the hierarchical structure in that it typically has few to no management levels [21]. The organisation of the flat structure can be based on projects, production, geography, or division. Funminiyi [19] suggests that the flat structure allows employees to be more creative which increases their productivity as they are more satisfied with their work [19].This

is because decision making power is distributed to the employees and everyone is seen as equals.

Based on the literature above how managers manage and direct their employees and how these employees respond to their manager's direction is an important factor that determines the organisation's structure. Olmedo-Cifuentes and Martínez-León [22] named this factor management style. They further suggest that management style can assist in the organisation's brand identity. Management style is described as the manner in which managers of an organisation control and manage their employees [22]. The management style of an organisation also influences how the employees respond to the method of management which then determines employees' work ways.

The literature review indicates that an institution's organisational culture and structure may influence its SDLC decision-making and adoption process with reference to the adoption of agile. However, few studies have investigated these factors in the financial institution context, this is the gap we hope to address with this study.

3. CONCEPTUAL MODEL

The conceptual model shown in Figure 1 below is derived from Chan and Thong's [23] framework for studying agile adoption by reviewing various factors in an organisation that contribute to knowledge management outcomes which will in turn ensure that an agile methodology is successful in an organisation. The conceptual model indicates the organisational structure and culture factors that will be covered in this study. This study will be make use of the organisational culture types identified by Iivari and Huisman [12] namely group culture, developmental culture, hierarchical culture, and rational culture. By identifying the existing culture type(s) in a financial institution one can determine if that culture supports an agile culture which the institution requires to be able to successfully adopt agile.

To identify the organisational structure of a financial institution we will be using the structures identified by Funminiyi, Taylor and Karpik [14], [19], [21] namely the functional, hierarchical, flat and matrix structure.

3.1. Organisational structure factors

The organisational structure factors (See Figure 1) refer to how the organisation is structured in terms of the level and type of hierarchy and the decision-making authority. The management style is indicative of the style of the management that is followed. The style will either be one of mentor and leader where the employees are provided with autonomy and support, or the style can be authoritative and dictating. The work ways factor refers to how the employees perform their duties in relation to management giving them more accountability and responsibility to make decisions and carry out work. These factors have been derived from the literature and are based on studies that determine how the structure of an organisation impacts how decisions are made in an organisation [14], [19], [21].

3.2. Organisational culture factors

Organisation culture factors (see Figure 1) refer to the employees' behaviour in the organisation. These factors provide insight on how the employees perform their duties and to what extent they are involved in decision making in the organisation. Work style refers to the extent to which the organisation encourages teamwork and collaboration from their employees. How the organisation reacts to uncertainty and the distribution of power (power distance) provides more insight on the flexibility of the organisation.

3.3. Agile culture factors

Agile culture factors refer to those factors that need to be considered when an organisation wants to adopt an agile SDLC to be able to deal more effectively with change and uncertainty. Agile culture factors take into consideration the structure that is necessary to be able to follow an agile methodology as well as the culture that needs to be in place for these practices to be successful. The decision-making variable for agile is given to employees as it is not a 'top management only' function. The team is provided with autonomy and flexibility to deliver what is required without the need to get approval from management [14]. By using decision making as an agile culture factor, it becomes apparent that the management style suited for agile is one of mentoring and leadership instead of demand and control [9]. Communication methods focuses on collaboration, cooperation, and consultation to ensure that the team is working towards a common goal and sharing knowledge [24]. By doing a comparison between the existing organisational structure, culture factors and agile culture factors it will become clear whether the organisation is ready to embark on an agile transformation journey and what changes will be required to make the adoption successful.

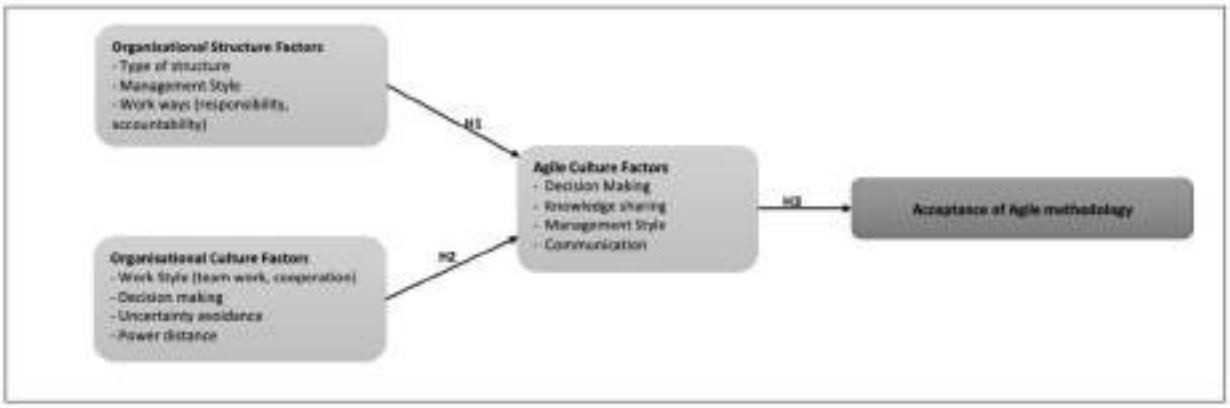

Figure 1: Research Conceptual Framework derived from [23]

The hypotheses derived from the conceptual model, to be tested in this study are set out below:

H1: Organisational structure has an influence on decision-making regarding the choice of the software development life cycle methodology used in the financial industry.

H2: Organisational culture has an influence on decision-making regarding the choice of the software development life cycle methodology used in the financial industry.

H3: The approach towards decision-making regarding the choice of the software development life cycle methodology has an influence on the acceptance of an agile methodology in the financial industry.

4. RESEARCH DESIGN AND METHODOLOGY

A quantitative method was used to gather data for this study and to test the hypotheses that were derived from the conceptual model. A questionnaire containing both open and closed, likert type questions, was distributed amongst a purposive sample of participants working in a project environment.

4.1. Population and sample

Respondents from all four major commercial banks and the central bank of South Africa participated in the study. The participants were selected because of their involvement in the Business Analysis Book Of Work (BABOK) and/or the Project Management Office (PMO)

community in the financial institutions. Using these communities of practice in the financial sector ensured that the participants provided accurate information regarding the decision-making process which is used to choose the software development life cycle methodology for their financial institution. Incomplete responses and responses from participants that did not work in the financial industry were excluded. Eighty complete responses were received and analysed as part of the study. Statistical methods were used to analyse the data derived from the survey. Descriptive statistics were used to summarise the data and to be able to perform complex analysis [25]. Inferential statistics consisting of scatter plots, regression analysis, and Pearson correlation analysis were done to test the study hypotheses.

4.2. Data collection

Out of the 82 responses received for the questionnaire, only 80 were found to be suitable for data analysis as 2 participants did not work for a financial institution, so these responses were excluded. Due to limitations imposed by the COVID19 pandemic the low number of responses and limited data was insufficient to measure all the factors contained in the original conceptual model. The conceptual model was revised to accommodate this limitation. The conceptual model shown in Figure 2 was used to test the hypotheses.

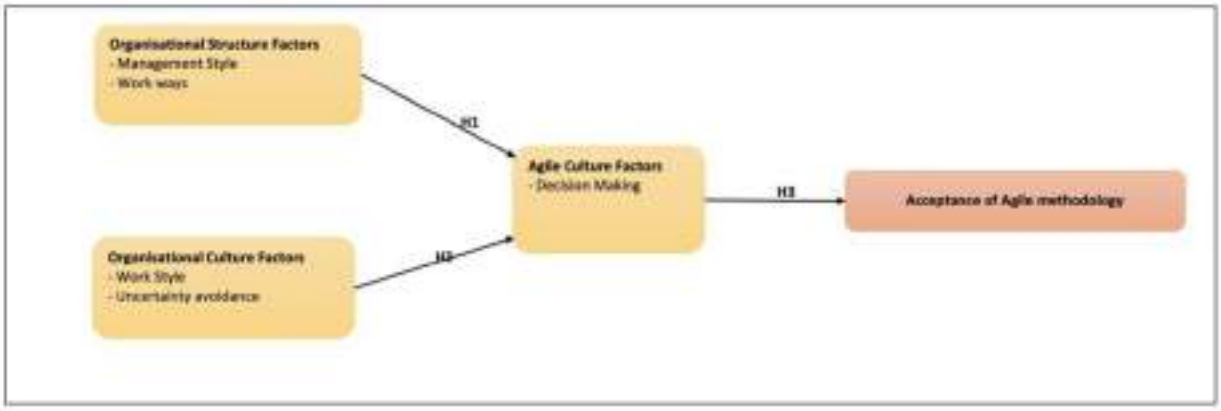

Figure 2: Revised conceptual model

4.3. Data analysis and reliability

The 23 likert scale questions items were analysed to determine the measure of internal consistency. Internal consistency was measured using the Cronbach alpha coefficient, where the overall reliability of $\alpha = 0.91$ is regarded to be very good [26], [27]. All the dimensions (agile methodology, decision making, work ways, management style, work style) were reliable except uncertainty avoidance with a Cronbach alpha coefficient higher than 0.6, the rest were all within the range $\alpha = 0.636 - 0.865$. These alpha values are within the acceptable range of 0.6 – 0.7 and very good reliability levels of greater than 0.8 [26]. As the reliability of uncertainty avoidance was questionable, this dimension was removed from the study.

Table 1: Reliability of the dimensions

Dimension	Number of items in a scale	Items	Cronbach alpha (α)
Agile methodology	3	Q10, Q18, Q19	0.8654
Decision making	4	Q13, Q26, Q27, Q28	0.6404
Work ways	4	Q14, Q20, Q31, Q32	0.6364
Management style	4	Q11, Q12, Q29, Q30	0.7139
Uncertainty avoidance	2	Q15, Q21	0,4227
Work style	6	Q16, Q17, Q22, Q23, Q24, Q5	0.6573
Overall	23		0.9118

4.4. Hypothesis testing

To test the hypothesis, scatter plots, correlation, and regression analysis were used. The scatter plot was used to determine the extent of the correlation between variables for organisational structure factors [28]. The Pearson correlation analysis was used to determine the statistical significance between the variables whilst regression analysis was used to determine the impact of the variables. Further tests were done to determine the regression model correlation using multicollinearity [29] along with the variability of variables using the heteroskedasticity method with the variables [30].

5. RESULTS & DISCUSSION

5.1. Methodology used in the respondent institutions.

Results from the survey showed that the South African financial institutions use several SDLC methodologies. The dominant methodology was agile (53%) followed by waterfall/predictive/traditional (36%) and then hybrid (12%). Of the 38 respondents who indicated that their organisations were using other SDLC methodologies, 92% indicated that their organisation was thinking about using an agile methodology. This meant that more than 95% of the organisations were either using the agile methodology or were thinking of migrating to agile methodology. For the organisations that were using agile, 5% indicated that it was not working, while most respondents did not answer this question (84%). We speculate that this could be because the respondents were unsure of how to determine if agile was working or not working in their organisation.

5.1.1 Organisational structure factors

Organisational structure is a formal system that contributes to the performance of an organisation and how tasks can be performed. The organisation's structure promotes a management style which influences the work ways of the employees. Most financial institutions still use the functional structure (44.3%) followed by the hierarchical (26.6%), matrix(20.3%) and flat(5.1%) structure. The financial industry with its mainly functional structure may not be a good fit for agile based on the literature [14]. The reason for this is that the decision-making authority is centralised at the top of the organisation which can result in silos in an organisation and its departments. However, when taking a closer look at the factors within organisational structure, the results contradict the literature.

The first hypothesis consisted of:

H10: Organisational structure has no influence on decision-making regarding the choice of the software development life cycle methodology used in the financial industry.

H1A: Organisational structure has an influence on decision-making regarding the choice of the software development life cycle methodology used in the financial industry.

Table 2: Correlation between organisational structure variables and decision making.

	Decision making	Management style	Work ways
Decision making	1		
Management style	0.604***	1	
Work ways	0.553***	0.560***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results show that an organisational structure with management style and work ways as variables has an influence on the decision making of which software development life cycle to use. The results showed a positive correlation of r = 0.604, p < 0.001 between management style and decision making, and positive correlation of r = 0.553, p < 0.001 between work ways and decision making as shown in Table 2. The regression results also revealed positive relationship with ß = 0.307 (3.00), p < 0.001 with good r-squared value of 0.4318 indicating that management style and work ways are predictors of decision making in an agile culture.

The management style of the financial institutions in terms of decision-making show that the financial industry still has high levels of bureaucracy (54.3%). This corresponds with the nature of the organisation, as financial institutions are risk averse, burdened by regulations, policy driven and conservative. Therefore, the management style tends to be concerned with reducing any uncertainty and job security [22]. Upon assessing the productivity and quality of work within the financial institution, the results showed a high level of productivity and quality with 74.1% and 81.5% respectively. This shows that the management style in the financial industry is also one that fosters productivity and innovation although the decision making might not be shared at all levels and at all times, amongst the employees.

Results pertaining to the work ways of the financial institutions revealed that 76.5% of these institutions ways of work is still driven from top management downwards, which correlates with the existing organisational structures ie. functional. The respondents indicated that financial institutions value their clients (82.7%) and focus on their clients' needs (71.6%). With 70.7% stating that the chosen methodology fosters a focus on client requirements. This client centric approach supports an agile culture as the purpose of agile is to co-create value and be people centred [14]. Organisational structure factors form part of the organisational identity and the way in which the organisation chooses to distribute the decision-making power. It should be aligned to the structure of the organisation especially when adopting an agile methodology.

All the three factors that were used to measure the organisational structure and agile culture yielded a positive relationship, therefore accepting the alternative hypothesis being that the organisational structure with management style and work ways as variables has an influence on the decision making of software development life cycle used in the financial industry.

5.1.2 Organisational culture factors

The respondents were also asked to describe the culture of their organisation. These questions analysed the shared belief and practice systems that inform all team members' actions. The most dominant culture within these organisations was group culture (46.8%), which is characterised by collaboration and the distribution of decision-making[12]. This was followed

by the hierarchical culture (26.6%), which is concerned with control, stability and efficiency by following rules and regulations. The least dominant culture in the SA financial industry was the development culture (15.2%) and rational culture (11.4%), which prefers centralised decision-making with formal control systems. This means that the dominant culture in financial institutions (group culture) supports the findings of Siakas and Siakas [13]. This culture is suitable for agile since the employees' values collaboration and management also values distribution of decision making with their employees. However, there are still some financial institutions that are still conservative and prefers formal decision-making processes and regulations which is why there is still centralised decision making and formal control systems in place[12].

The second hypothesis was that organisational culture has an influence on the decision-making regarding the choice of the software development life cycle methodology used in the financial industry. The variable of organisational culture was work style. Where work style describes employees working attributes, based on their environmental exposure [15]. The second hypothesis can be recapped as follows:

H20: Organisational Culture has no influence on the decision-making regarding the choice of the software development life cycle methodology used in the financial industry.

H2A: Organisational Culture has an influence regarding the decision-making regarding the choice of the software development life cycle methodology used in the financial industry.

Table 3: Correlation between organisational culture variables and decision making

	Decision making	Work style
Decision making	1	
Work style	0.543^{***}	1

$^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$

The results show that organisational culture has an influence on the decision making of software development life cycle. A positive correlation of r = 0.543, p < 0.001 between work style and decision making is shown in Table 3. The regression results also reveal a positive relationship with β = 0.528 (5,67), p < 0.001 with r-squared value of 0.295 indicating that work style is regarded as a predictor of decision making in agile culture.

The working style factor for financial institutions in projects show that the team members collaborate to execute project related work though they also have a sense of individual accountability in the delivery. 58% Of the respondents say that they are solely responsible for the deliverable and with 95.1% of respondents say that they work together with their team members to execute project work. This finding supports a group culture which is characterised by collaboration [12].

56.8% Of the respondents indicated that there is a knowledge management process in place in the financial institutions. Only 43.2% say that the knowledge management process in place is effective and 31% feel that the knowledge management process can be improved. These results suggest that there is room for improvement when it comes to the work style factor in the financial institutions though the culture has facets of agile culture in place. When the work style factor was compared to the decision-making factor for an agile culture, the findings revealed a strong relationship with a correlation of 0.543. Based on these results, it can be concluded that the null hypothesis is rejected, and the alternative hypothesis is accepted. As such, organisational culture has an influence on the decision-making of software development life cycle methodology in the financial industry.

5.1.3 Agile culture factors

The results showed that 64.1% of the participants are using agile methodology in their organisation and 35.9% uses waterfall methodology. The respondents indicated that there was no dominant group that makes project-related decisions in the organisation within the financial industry. 34.2% Indicated that it was the project sponsor, 32.9% the project team and 30.4% the project owner, respectively that made project related decisions. This data highlights the divergence in terms of where the decision making resides in financial organisations. An agile methodology requires an agile culture that has shared decision-making power to empower their employees [14] [16] whilst the findings of this study shows that only 32.9% are allowed to make decisions as a project team.

The third hypothesis focused on the influence of the approach to decision-making on the acceptance of agile methodology. This hypothesis can be recapped as follows:

H30: The approach to the decision-making regarding the choice of the software development life cycle methodology has an influence on acceptance of agile methodology in the financial industry.

H3A: The approach to the decision-making regarding the choice of the software development life cycle methodology has an influence on acceptance of agile methodology in the financial industry.

Table 4: Correlation between decision making and acceptance of agile methodology.

	Agile methodology	Decision making
Agile methodology	1	
Decision making	0.5221^{***}	1

$^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$

The results show that the approach to decision making of software development life cycle has an influence on the acceptance of agile methodology in the financial industry. The results showed a strong and positive correlation of r = 0.5221, p < 0.001 between agile methodology and decision making as shown in Table 4. The regression results also reveal a positive relationship with ß = 0.590 (5,37), p < 0.001with r-squared value of 0.272. indicating that the approach to decision making is a statistically significant positive predictor of acceptance of agile methodology for projects undertaken in the financial industry. Based on these results, it can be concluded that the null hypothesis is rejected, and the alternative hypothesis is accepted. As such, the approach to decision-making of software development life cycle methodology has an influence on the acceptance of agile methodology in the financial industry.

When reviewing the factor of agile culture in terms of collaborative work in the financial institution, the findings showed that 84% perform collaborative work in their financial organisations which would support an agile culture [13].

When determining the level of understanding of agile in the financial institution, 51.85% agreed that the entire organisation knows what agile involves, while 25.93% disagree with this statement. When determining the suitability of agile in the organisation, 49.4% agreed with the agile approach while 25.9% disagreed with the statement. Finally, when determining the success of agile in the organisation, 55.6% believed that agile is a success while 21% disagreed.

These results indicate that financial institutions are moving towards an agile culture with shared decision making though this is still in the early stages as only 32.91% of respondents stated that decision making is shared amongst the project team.

6. CONCLUSIONS AND RECOMMENDATIONS

This paper investigates how a financial institution's organisational structure and culture influence its SDLC decision-making process to ensure that Agile is accepted by the organisation. Most organisations adopt an agile methodology by migrating from the traditional methodology i.e., moving from waterfall to agile. This migration tends to introduce various people related challenges [8]. Identifying and addressing those challenges should theoretically increase the adoption of agile in an organisation. From the literature it was evident that amongst others, organisational structure and culture are key factors that contribute to an organisation successfully adopting an agile methodology.

The results of a survey with 80 respondents showed that there is a positive relationship between organisational structure and agile culture in terms of decision making. As well as a positive relationship between organisational culture and agile culture in terms of decision making. The research also found that management style and work ways as organisational structure factors; and work style as organisational culture factor do have an influence on the decision of which SDLC is used in the financial industry. Moreover, the research indicates that in the financial industry the way an organisation approaches decision making can influence the acceptance of agile methodology.

Financial institutions need to review their structures and align it to their business and information strategy. This means that an organisation should change their structure to fit their strategy. An agile methodology requires a structure that is flexible and quick to adapt therefore, having a functional structure or hierarchical structure adds a level of complexity in the acceptance of the agile methodology.

The second recommendation involves the decision-making process within a financial institution's organisational structure. Adoption of an agile methodology requires a management style that motivates, builds a positive team, and most importantly empowers employees to make work-related decisions. When looking at the organisational structure factors of management style and work ways, it was found that the financial industry still has high levels (54.3%) of bureaucracy and 76.5% of the 'way of work' in this industry is still driven by top management. By addressing these issues organisations will ensure the acceptance of agile increases, as it will empower the employees to self-manage and be more accountable for their work output without the need to get approval from top management.

Organisational culture forms part of the organisation's identity. Having a culture that is conducive to creativity, and high productivity requires financial institutions to occasionally assess their culture to ensure that it is aligned to what the organisation is trying to achieve. An agile culture is centred on decision making and people. Therefore, having a culture that allows for shared decision making and transparency in the knowledge sharing process will ensure that the success of the methodology is not short lived. The findings showed that there are employees who are still undecided regarding the adoption of agile in the SA financial industry. It is important that organisations address these findings if they desire to effectively implement agile and build an agile culture in the organisation.

6.1. Theoretical contribution and managerial implications

The findings of the study contribute to the limited research on software development life cycle selection in the financial institution industry. The results indicate that financial institutions are different from the typical software industries that use agile methodology and decision making is important to ensure agile adoption is successful. The relevance of the organisational factors suggests that financial institutions need to perform due diligence before deciding on a development methodology to ensure that the entire organisation is on board with the change and is equipped to exploit the methodology.

6.2. Limitations and recommendations

The study was limited to South African financial institutions. The scope of this study was limited to a few selected organisational factors and this list was reduced further based on the low number of complete responses received. Therefore, it is recommended that future studies include the agile culture factors of knowledge sharing, management style and communication that could not be investigated in detail this study. Finally, the respondents were not distributed equally across the financial institutions therefore the findings may not be consistent across the financial institutions investigated.

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EXPLORING THE TANGIBLE AND INTANGIBLE RESOURCES OF THE SOUTH AFRICAN SAWMILLS: A RESOURCE-BASED VIEW APPROACH

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ABSTRACT

In the era of globalised trade, abundant forest resources are no longer the primary source of sustainable competitiveness for sawmills but rather a primary resource owned by most sawmills. Strategies applied in sawmilling firms have been approached generally, whereas the role of intangible and tangible resources in constructing firm-level success has received less concentration in the literature. Although vital insights can be derived from the business economic literature on other industries, comprehensive research is required to explain the resource-based view of the firm and identify resources that can contribute to sustainable competitive advantage in sawmills. The resource-based view was used as the base theory to examine the South African sawmill industry firms in this study. A desktop study on the available resources was conducted to determine the resources within the sawmills. The results will help guide what resources have benefits to firms.

Keywords: resources, resource-based view, strategy, sustainable competitive advantage, sawmill industry

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1 INTRODUCTION

The sawmill industry is a significant source of employment and is vital for sustaining global economic development [1]. Establishing a competitive advantage in this industry can be seen as a challenging puzzle worth solving to promote environmental and social sustainability. In the era of globalised trade and increased trade, ample forest resources are no longer the primary source of sustainable competitiveness [2]; however, the raw material (logs) is crucial and can be regarded as a primary resource for all sawmills [3], [4]. Past research on forestry prioritised the influence of external factors compared to internal factors when evaluating a sawmill's ability to establish a sustainable competitive advantage [2]. According to Lähtinen [2], there is a lot of technology study being done on the sawmilling sector, but not much business economics research. Though important knowledge may be gained from the business and economic literature on other sectors, it is essential to examine South African enterprises' competitiveness and the variables that influence their competitive advantages in light of their resources. Extensive study is needed to explain the resource-based vision of the company and discover resources that might help it achieve sustained competitive advantage in the sawmilling industry. [1]. An official investigation of the physical characteristics and geographic location of land is necessary for the study of manufacturing economics. [5]. The study's objective is to evaluate the resources that lead to competitive advantage in the sawmilling industry internationally and locally by applying the resource-based view of the firm theory. The results will be used to understand the overall available resources in the South African sawmill industry and how they compare with resources in global sawmill industries.

2 LITERATURE REVIEW

2.1 Strategy

Strategic decisions inside sawmills have been essential to maintain competitiveness in the rapidly evolving business environment [3]. Its history and strategy determine any company's resource mix and how well the resources integrate with the external business environment [2], [6]. Strategic decisions significantly influence the value of a company's resources and capabilities with the opportunities present in the market [3]. The structural strategy of a company is based on its assets, capacities, core competencies, and interactions with the external business environment [2]. Core competencies refer to what a firm does particularly well compared to competitors [7]. Business performance measures are pointers for a firm's success in reaching its strategies, goals, and key performance indicators [3]. For example, a strength, weaknesses, opportunity and threats (SWOT) analysis could produce valuable knowledge [8]. Resource-based theorists believe a sustainable strategy should be based on the firm's resources and competencies [7]. Resources are strengths that may be leveraged to implement corporate plans by managing valuable, scarce, and unique resources to obtain a sustained competitive advantage [9].

2.2 Resource-Based

The resource-based view of the firm can be used to evaluate a company's strategic resources. It suggests that company managers may develop a plan to establish a sustained competitive advantage in markets and sectors by utilising their internal resource base and core skills [4] [10]. Penrose 1959 established the resource-based viewpoint [10]. Some critics of the resource-based view argue that it places too much emphasis on firm [11]. According to the resource-based perspective, capabilities and resources must be valuable and scarce to give firms a competitive advantage. To provide a durable competitive advantage, they must be challenging to copy, substitute, and trade [1], [12]. Li [13] discussed value, rarity, imitability, and organisation within firms.

A corporation cannot adopt strategies that take advantage of environmental possibilities if the resources or capabilities it controls have no value.

Competitive parity will result through exploiting resources or talents that are valued yet in abundant supply.

A corporation will temporarily gain a competitive edge if it can use resources or talents that are valuable, scarce, and inexpensive to copy.

Exploiting precious resources, hard to come by and expensive to copy, will provide a persistent competitive edge.

From a resource-based view, each firm is a distinctive collection of resources [9], [13] that determines which external conditions offer opportunities and which cause threats [6]. The resource-based view of the firm is based on two main assumptions, which are that firms within an industry may be heterogeneous concerning the strategic resources they control, e.g., though wood is the standard input raw material used, the resources of various firms are not the same. The second assumption is that resources may not seamlessly move across firms, and heterogeneity can be permanent [1]. These assumptions signify that every firm has unique resources that others cannot easily copy.

2.3 Resources

Firms comprise resources from ongoing organisational activity and external opportunities and threats [12]. The term "resources" refers to a collection of tangible and intangible assets, capabilities, organisational processes, company characteristics, information, and knowledge [7], [8]. Firm resources must be diversified in character and permanently immobile to transition from a short-term competitive advantage to a sustained competitive advantage [14]. Large-scale forest sector enterprises have enough resources for expanding and sustaining their service offerings, according to research by Mattila [9] on the Finnish sawmill industry. According to Bonsi [1], many businesses are failing or have ceased operations due to increased international competition, partly due to a focus on external variables over which firms have little or no control instead of emphasising internal resources and capabilities. When organisations create uncommon and valuable resources due to their 'unique historical route,' they may exploit them in ways rival enterprises cannot [8].

Resources are usually categorised as either tangible or intangible. Tangible resources comprise only assets, while intangible resources include assets and capabilities [2]. According to Mattila [9], tangible and intangible resources may be classified as operand (manufacturing elements) and operant (knowledge and information). Capabilities refer to this knowledge and information. Intangible assets have no physical form and frequently exist in people's thoughts and minds. Firm resources become valuable if utilised resourcefully [1]. Firms will achieve long-term competitive advantage if the resource and capability requirements (valuable, uncommon, imperfectly imitable, and non-substitutable) are met [4]. Both assets and capabilities must be the foundation for long-term planning since they give the principal direction for a company's business strategy and financial success [2].

2.4 Competitive advantage

The competitive environment of the sawmill sector is rapidly evolving, requiring managers to seek out fresh streams of competitive advantage and develop plans that exploit their fundamental strengths [10]. Firms geared to adapt can better preserve their competitive edge than those that are not, as management can renew and alter their resources and connections as time, rivalry, and shifts within a competitive environment diminish their value [14]. The sawmill sector must develop new value-creation strategies to maintain a sustained competitive edge [4]. The firm's long-term competitive advantage is based on its abundance of specialised resources. Firms that manage a niche through reduced prices or distinguishing

goods have a competitive edge [15]. Businesses that actively recognise and take advantage of environmental opportunities may experience sustainable and competitive advantages, resulting in competitive sustainability [12].

2.5 Competitiveness

A firm's capacity to acquire and use the right mix of resources determines its long-term competitiveness [4]. Tangible and intangible resources and capabilities are the foundation for competitiveness in today's fast-changing business environment [3]. In the forest products business, the capability to innovate significantly influences a firm's competitiveness. Firms in the wood products business are not uniform and might be productive depending on their own internal conditions [1]. The chance of a business maintaining its competitive edge increases with the heterogeneity of the resources on which that firm's competitiveness is built [2].

According to the resource-based theory, businesses in the sector differ in terms of competitiveness since each firm has a unique set of resources and capabilities [10]. The ability to develop value-added, make educated strategic decisions, and creatively employ intangible and tangible resources is critical for preserving sawmilling sector competitiveness in higher-cost nations [2], the capacity to produce value-added, make informed strategic decisions and creatively use intangible and tangible resources are essential to achieving sustainable competitiveness in higher-cost-level nations. Maintaining long-term competitiveness in the conventional sawmill sector has grown more complex than ever [4]. This is because competitiveness is resource-based and subject to variance [12].

3 METHODOLOGY

A systematic scoping review was selected for this study [16], [17]. This form of study ensures that the process of conducting the review is documented in enough detail to allow replicability of the study by other researchers. The scoping review framework entails establishing the research questions, sourcing relevant studies, selecting studies, mapping the data, and organising, summarising, and reporting the results [16].

3.1 Research questions

From the literature review, the following research questions were identified:

1. What tangible resources do international sawmills use to gain a competitive advantage?
2. What intangible resources do international sawmills use to gain a competitive advantage?
3. How do South African sawmills' typical tangible and intangible resources compare with international sawmills?
4. Which resources (strengths) can South African sawmills leverage to obtain a competitive advantage?
5. Which resources (weaknesses) can South African sawmills develop to increase competitiveness?

3.2 Inclusion and exclusion criteria

Scopus and Web of Science were used to find publications. The two databases were chosen since they are two of the three main bibliometric databases, along with Google Scholar [18], [19]. The initial step was to define the articles' inclusion and exclusion criteria. The search was restricted to articles:

- Published between 2002 and 2022.
- Only articles relevant to the research questions were used.

- Publications not written in English were excluded.

The search query and phrases used to search are shown in Table 1.

Table 1:Seach quarry search phrases used on Scopus and Web of Science

(TITLE-ABS-KEY (resource-based AND view AND sawmill AND industry)
OR TITLE-ABS-KEY (tangible AND intangible AND resource AND allocation)
OR TITLE-ABS-KEY (resource AND based AND view AND sawmill AND industry)
OR TITLE-ABS-KEY (resource AND utilisation AND in AND the AND sawmill AND industry)
OR TITLE-ABS-KEY (resources AND in AND sawmill)
OR TITLE-ABS-KEY (resources AND capabilities AND in AND the AND sawmill AND industry)
OR TITLE-ABS-KEY (innovation AND resources AND in AND the AND sawmill AND industry)
AND TITLE-ABS-KEY (resource)
AND TITLE-ABS-KEY (forestry)
AND TITLE-ABS-KEY (sawmill))
AND PUBYEAR > 2001 AND PUBYEAR < 2023

The number of articles obtained from applying the search query and inclusion and exclusion criteria in both Web of Science and Scopus is shown in Figure 1. The number of papers obtained from Web of Science was 617, and Scopus 161 from the search — 689 articles in total after removing duplicates. After the abstract and full-text screening, the articles relevant to the research questions were 21.

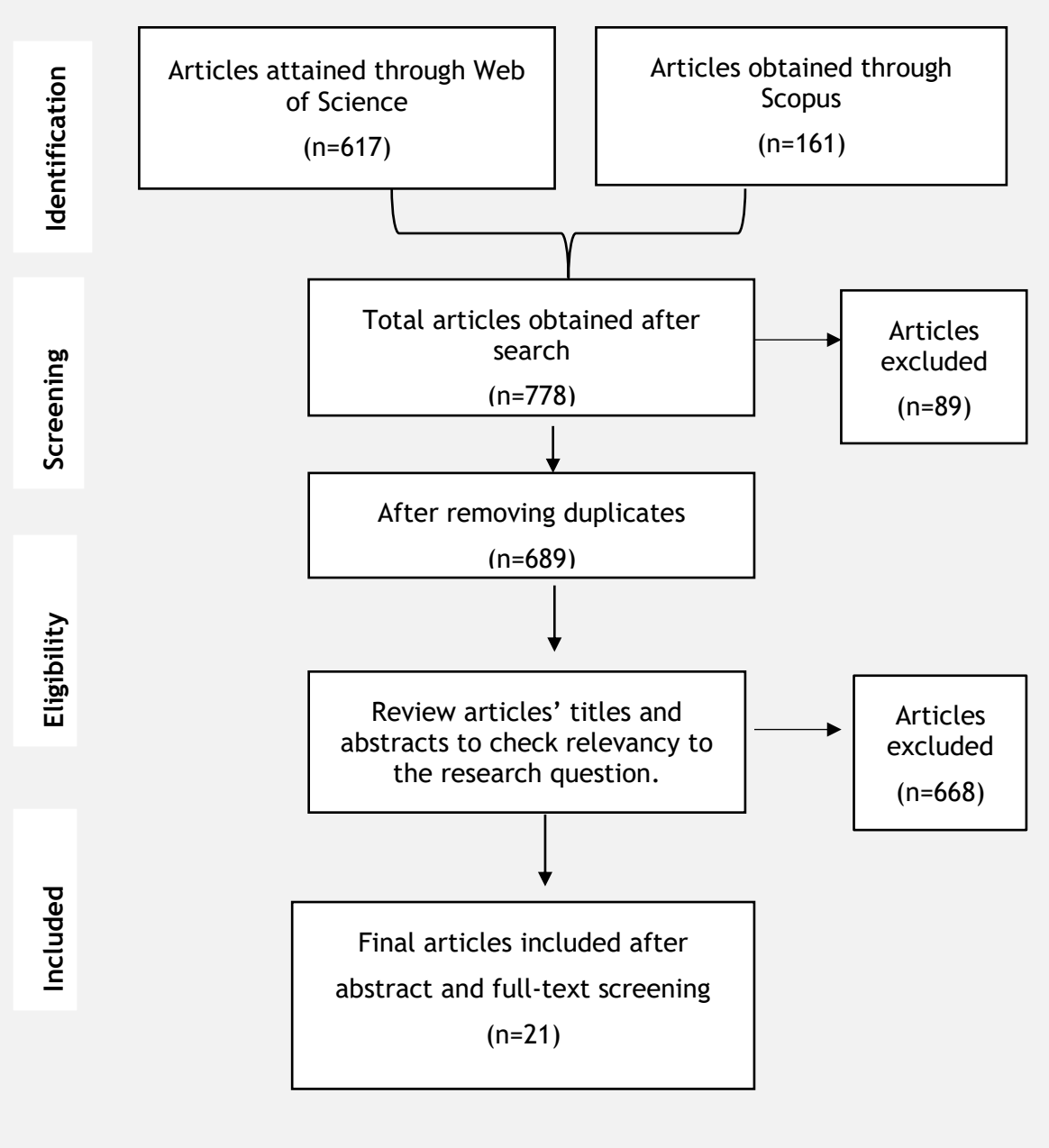

Figure 1: Steps followed to identify articles for the scoping review

3.3 Data analysis

The data was analysed using Atlas. ti, and information relevant to the research questions were extracted and used to answer the research questions. Some of the material utilised to answer the research questions was acquired through a desktop examination of published reports due to the limits of studies on resources and resource-based theory as it applies to the South African sawmill industry. Atlas.ti was used to generate a word cloud based on the most dominant topics in the identified included articles. The most occurring words were wood, forest, production, model, and resources. The highlighted words show the main themes of the articles used to answer the research questions.

Figure 2: Word cloud of the reviewed articles

4 RESULTS

The research aimed to determine which resources lead to a competitive advantage in the local and international sawmilling industries. The tangible and intangible resources in the sawmill industry, as found in the reviewed papers, are shown in Figure 3. The resources are grouped according to whether they are tangible or intangible. The tangible resources were the raw material, geographic location, finance, strategy machinery, and production technologies. The intangible resources highlighted from the studies were managerial expertise, human resources, employee know-how, operational reputation, technological know-how, organisational culture, and collaboration. Some of these resources offered competitive advantages in some international firms, while some resources still need to be fully utilised to create competitive advantages in some sawmills.

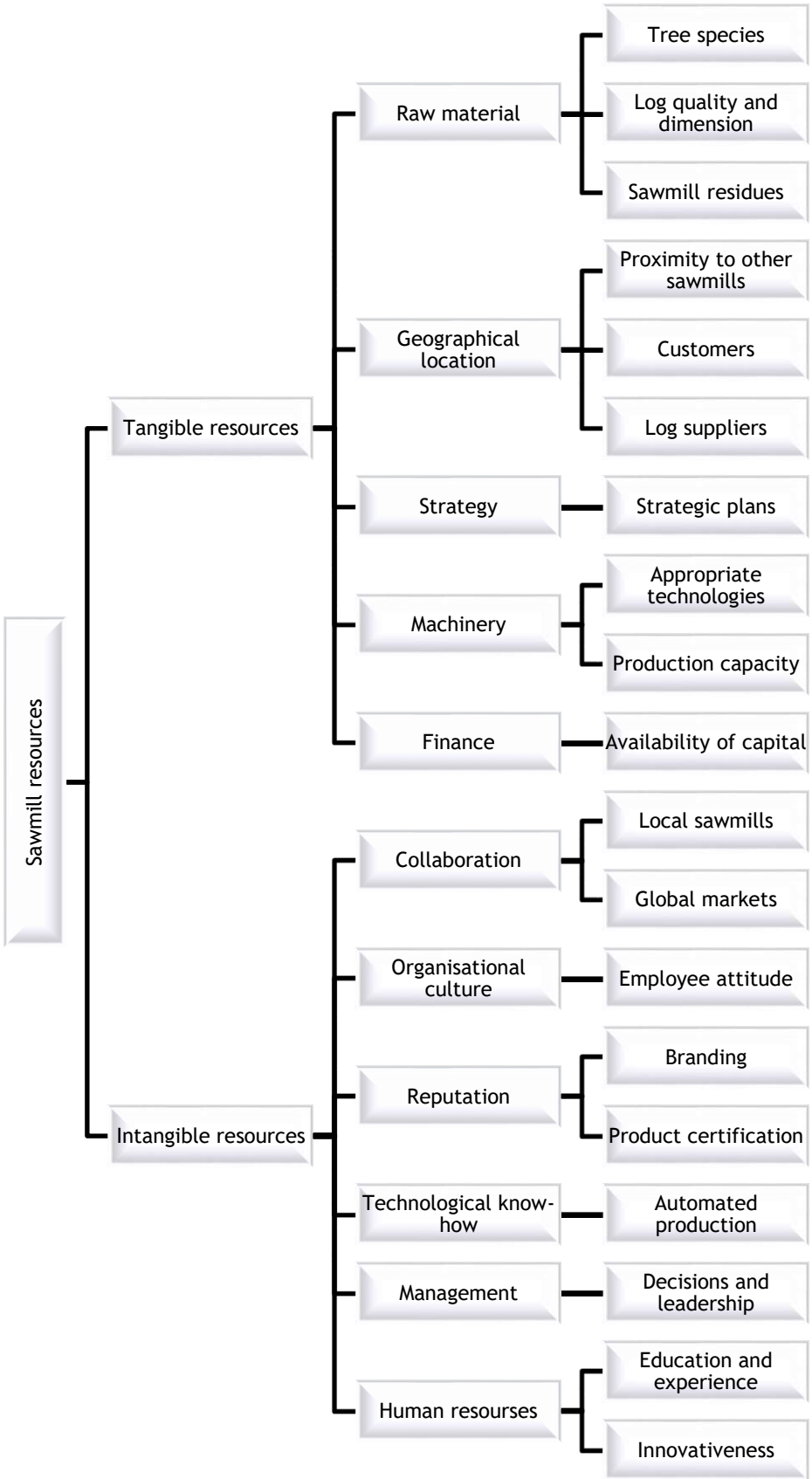

Figure3: Summary of the identified tangible and intangible resources used in the sawmill sector.

4.1 Research question 1: What tangible resources do international sawmills use to build a competitive advantage?

In their study of Finnish medium- and large-sized-sized sawmills, Lähtinen and Toppinen [20] found that finance, strategy and personnel were highly valued, whereas factory and machinery attained were less of a priority. They also emphasised that while conventional techniques for manufacturing are not a unique resource, access to investors and specialised sawmilling skills is required to acquire a competitive edge.

Some authors highlighted the availability of raw materials as key to attaining competitive advantage. Luppold and Sendak [21] said that the availability of a wood resource in Maine, USA sets in motion a series of economic and technological instruments to utilise the resource and meet a present or future demand for a specific set of goods and services. This is why there is a need to establish additional forest areas that would act as resource-feed to sawmill industries [22]. A study conducted in Vietnam showed how policies are geared towards establishing planted forests and developing the wood processing industry to increase the timber resource's availability [23]. This is due to the need for the necessary technology and raw materials to develop higher-priced products and customised services in sawmilling [24].

With the changing global needs and operating environment, resources are no longer being seen only as logs but also the residues from the forest and sawmills. Sawmills typically produce at least one of these wood residues: chips, sawdust, wood shavings, and bark. This means that mills can use this biomass to introduce a new market for bioenergy, as some mills do not use the residues to dry their timber. Holm *et al* [25] highlighted how customers may be given access to more diverse wood assortments, as the sustainable potential of wood has yet to be realised in Switzerland.

In their study, Venn *et al*. [26] highlighted the importance of strategic decisions regarding the mill's location, production capacity, and level of value-adding. This was supported by Uusitalo and Lidelow [27], who said that firms must consider supply chain structures when making future strategies. This is because sawmills that can attain logs from closer locations would be advantageous over mills that transport much longer distances, saving them time and money [22].

The development, execution and control of an entire firm strategy entail reflective data and information basis [28]. Firms are also increasingly expected to invest in resource-efficient and clean technologies [29]. When resources are limited, it is required to transition from traditional technical innovation to green innovation [30]. This allows firms to explore innovative ways to use their available resources.

4.2 Research question 2: What intangible resources do international sawmills use to build a competitive advantage?

Sawmills with brilliant workforce and research and development departments benefit from employees' knowledge, such as specific understandings about the products or production process and companies' specific know-how and their patents [31]. Other mills that lack particular expertise capitalise on their relationships with others. Network-based business models (collaboration) present a novel angle for pursuing competitive advantage by exploiting international opportunities [32]. By taking firm-level collaboration into account as one of its strategic resources, a company can assess its present or potential partners [33]. Their study also revealed valuable collaborations in the Finnish sawmilling industry. Still, the sawmill managers do not believe these collaborations can be a strategic resource. In their study, Lahtinen *et al*. [24] showed that management was regarded highly as a resource but collaboration, reputation, and organisational culture were less valued. Silva and Oliveira [34] found a strong relationship between innovation, intellectual capital, human resources,

services facilities, results and procedures. Firms that advance innovation are said to promote their export visibility globally [34].

4.3 Research question 3: How do South African sawmills' typical tangible and intangible resources compare with international sawmills?

The sawmilling business in South Africa is based on timber from highly maintained plantations of exotic Pines and Eucalypts. Seventy-five per cent of those plantations are FSC certified (among the highest in the world) [35]. It is estimated that plantation areas globally will grow between 20 million and 40 million ha by 2050 [36]. Plantations cover 1.2 million hectares in South Africa [37]. This implies that South Africa has a small forested area compared to Sweden, Finland, the USA, Russia, etc.

Although some studies [33] suggested that wood raw material did not provide a foundation for long-term competitive advantage in other sawmills, having wood is vital for market share. South Africa is a predominantly dry country, and areas with sufficient rainfall for plantations are restricted to catchments in the southern (Western Cape, Eastern Cape, KwaZulu-Natal, Mpumalanga and Limpopo provinces) part of the country [37]. South African plantations mainly produce pine, eucalypt and wattle logs to be used by pulp mills, sawmills, pole treaters, mining timber manufacturers, and wattle tannin manufacturers [37]. Schwarzbauer and Stern [38] highlighted that international trade in industrial roundwood is essential to domestic supply.

A report by Crickmay and Associates [35] highlighted that Zimbabwe supplied ±85,000 m3 of sawn timber to South Africa annually. They also highlighted that geographically, Zimbabwe is the closest alternative resource if there is a shortage of wood. Charis *et al*. [39] mentioned the valorisation of biomass in Zimbabwe, specifically its residues and waste into bioenergy and engineered wood products, has been considered as a response to climate change issues; however, adoption of such practices has been limited in Zimbabwe, where most sawmills lack enough downstream industries to use waste.

According to their analysis FOA [36], engineered wood products and mass timber are the most promising wood products for replacing non-renewable resources on a broad scale. This could mean that South Africa could see an uptake in the use of wood in construction. Regarding employment, FAO [36] stated that the number of official and informal workers in the forest industry was anticipated to be 33.3 million in 2019, down from 39.5 million in 2013. According to Crickmay and Associates [35], the South African Lumber Miller's Association reported in 2001 that there were 113,000 direct employees in the sawmilling business from plantation to product. The number of direct employees continues to go down as sawmills are closing. It was reported that the number of direct employees in the industry in 2019 was 59 200 [40], a significant decrease from 113 000 in 2001.

The markets for sawn wood have seen several significant innovations in the form of improvement in glueing technology enabling exterior plywood use (the 1930s) and Oriented Strand Boards and Medium Density Fibreboard (1960s and 1970s); the emergence of pre-engineered woods (Cross Laminate Timber and glulam) and Modular prefabricated factory construction [41]. According to a study conducted in South Africa by Crafford and Wessels [42], green-glueing of eucalypt timber might enable manufacturing engineered structural lumber such as cross-laminated timber from rapidly grown pulp wood resources.

4.4 Research question 4: Which resources (strengths) can South African sawmills leverage to obtain a competitive advantage?

The balanced allocation of resources is necessary for distinctive competitive advantages, exceptional performance, and growth by reducing operation costs, improving capital utilisation efficiency, and corresponding the resource with operational needs [30]. Silva and

Oliveira [34] argue that the business climate in which companies operate is challenging, forcing managers to employ effective business tactics. This implies that South African sawmills can readjust their business strategies to respond to the changing business environment. They went on to say that to be competitive, businesses must prioritise market orientation, management expertise, and customer management relationships. South Africa's forest sector is regarded as a global pioneer in sustainable plantation forestry since it has the world's biggest area of endorsed exotic plantations and is one of the nations with the greatest FSC-certified wooded area [32]. The sawmilling industry could leverage this differentiator to gain a competitive advantage.

Coley *et al* [31] suggested that managers should strive to secure relationship-specific intangible resources partnerships, with a focus on ensuring equality in distributing intangible resources. Global demand for renewable energy sources is rising [43]. This is also evident in South Africa, which is facing a major energy crisis. Like the Contemporary Energy Policy of the European Union, which set an agenda for implementing the energy industry based on biomass [44], South Africa could follow suit by working with sawmills to generate electricity from wood biomass. Applying the solutions of biomass resource regionalisation reduces the cost of transport and energy consumption [44]. To achieve this, the industry will have to focus on innovation.

4.5 Research question 5: Which resources (weaknesses) can South African sawmills develop to increase competitiveness?

According to Silva and Oliveira [34], a particular market's crucial players are those with access to unique resources that are difficult to copy; hence, the technological boom was believed to be extremely important. This means that the sawmill industry in South Africa can work towards improving the technologies in their processing plant and investigate inventing new technologies.

The external business environment and internal strategic decisions made by a corporation are considered to impact its competitiveness [33]. One way of using strategy as a resource is for sawmills within an industry to align their overall strategy towards collaboration. South African enterprises should consider collaborating because it increases flexibility, economies of scale, effective risk management, and facilitates inter-firm learning [33].

Firms within the South African sawmill industry can also look for international partners. Hietala *et al*. [32] stressed the relevance of a firm's inter-organisational networks in producing new unique information and facilitating internationalisation in the network theory of internationalisation. Bioeconomy expansion will establish new prospects for firms functioning in the global wood marketplaces, and recognising and utilising these prospects is stressed as a key to achieving competitiveness. A study was conducted by Nwokolo *et al*. [45] to evaluate the performance of a Johansson biomass gasifier system, which utilises chunks of wood from a sawmill industry, for energy production in South Africa. This shows that the implementation of such systems can ease the energy crisis in South Africa. Still, in terms of renewable resources, there is a growing need for building goods that are environmentally friendly and have minimal embodied energy [26], [27].

5 DISCUSSIONS

Several types of resources were discussed as significant for firms to gain a competitive advantage. Each of these resources influences firm performance in its way. Employees are essential in developing and maintaining a firm’s competitive edge over rivals, as highlighted. The downside of human resources as a resource is that, unlike other organisational resources, employees can leave.

According to Mattila *et al*. [9], a customer, as a resource, develops value in collaboration with the firm that provides tangible and intangible resources for the value creation process.. They further emphasised that the firm must offer resources that enable or improve this process to add any additional weight to a client's value creation process. Technological know-how as a resource may aid in achieving a competitive advantage when combined tactically with other resources. Still, it is not a strategic resource for sawmills [3]. Strategic resources are said to be valuable, rare, inimitable and non-substitutable. Producing value-added products and improving customer service have been highlighted as critical strategic choices and vital for competitiveness.

Collaboration is a positive strategy that allows mills to expand their other resources. This is because sawmills benefit from collaborations, partnerships, and mergers by utilising each other's resources and focusing on their core strengths to grow their business. If individual sawmills would each specialise in a particular niche area in the wood value chain, it would influence other sawmills' willingness to collaborate and grow the sawmill industry as each one will be meeting a gap in the industry. This will also limit the need to compete as each mill will provide a niche product to the South African sawmill industry.

6 CONCLUSION

The assessment brought to light that a firm's resource attributes—which include tangible and intangible assets required to carry out selected strategies—determine its competitiveness. Firm resources include all assets, capacities, organisational processes, and insights within the jurisdiction of a business that enables it to carry out its strategies. Sawmill strategy ensures that the resources are acquired and allocated accordingly to carry out the mill's operations. This implies that the strategy of the individual firms on which resources to prioritise should all be geared towards attaining competitive advantage.

The study revealed that South African and international sawmills' primary tangible and intangible resources do not differ much; however, the strategies, policies and implementations differentiate them. The resource can supply logs to the sawmills; however, with the planted area's decline, the industry must look at different innovative ways to gain a competitive advantage. The industry could invest more towards using forest and mill residues in manufacturing composite products and bioenergy to maximise the value they get from the logs. International mills have demonstrated how sawmill residues are being utilised to generate energy that feeds into the grid and not just as fuel for the boilers in the mill. Sawmill managers should seek local and global strategic collaborations to achieve sustainable competitive advantage in sawmills. South Africa could look into expanding their use of timber as a construction material.

7 RECOMMENDATIONS

The study highlighted the primary resources firms and other sawmills use to gain a competitive advantage. A more in-depth analysis is necessary to understand the specific resources in the South African sawmill industry. Interviews or surveys with mill managers will highlight some of the strategies mill managers employ and the scope of resources in each sawmill.

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