Livestock Traceability in New Zealand: Using blockchain to address current challenges in the industry

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I. ABSTRACT

The existing livestock traceability system in New Zealand hardly achieves the general goals of a traceability system such as managing disease outbreaks and tracking animal-based products from farm to fork. Further, users often complain that the New Zealand system is difficult to use. To overcome such issues in other parts of the world, blockchain-based traceability systems have been suggested. However, there is little research in the New Zealand context. This study aims to fill that gap by identifying challenges in the existing livestock traceability system in New Zealand, then evaluating if blockchain technology can address those challenges. The applicability of a blockchain-based livestock traceability system to New Zealand is discussed.

Existing literature is used to understand the potential use of blockchain technology to address livestock traceability challenges relating to the themes of data management, relationships (among supply chain partners), transparency, compliance, and visibility. To understand the New Zealand context, participants in the New Zealand livestock supply chain are interviewed. Interview data is analysed using the themes listed above. Challenges gathered from the interviews are then compared with the challenges and solutions found in literature to evaluate if a blockchain-based traceability system would suit the New Zealand context.

The results suggest that a blockchain-based traceability system supported by the Internet of Things (IoT) and smart contracts can dramatically improve the livestock traceability system in New Zealand by addressing many of the country's traceability challenges. However, implementing such a system could initially involve a significant cost and necessitate changes to existing organisational practices. Further, workarounds should be sought for implementation barriers such as low network connectivity in rural New Zealand. Although expensive to implement, eventually, a blockchain-based traceability system could help industry manage otherwise expensive occurrences, such as food recalls, with less effort. Therefore, spending resources to implement a blockchain-based traceability system today can be a worthwhile investment for the future.

II. ACKNOWLEDGEMENTS

Without the support of Cecile L'hermitte, this project would never have seen the light of day. Thank you, Dr. Cecile, for playing many roles throughout the research. You've been a supervisor, a friend, and an emotional support person during this endeavour. Your guidance and the ability to motivate me when I felt lost is appreciated.

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Being a part-time student, I hardly visited the university but thanks to the amazing team at the Management School and the Library, I was able to get virtual help whenever I needed it. Thank you, Lori Jervis, Amanda Sircombe, Paresha Sinha, Nat Enright, and the IT support team for helping to make this project a reality.

Kushan, thank you for motivating me to take up this challenge. Scooby and Snowy thank you for never leaving me alone and reminding me that playing is an important part of life. You've made me smile during the stressful days of my life.

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1 INTRODUCTION

The purpose of this study is to evaluate if a blockchain system can address existing livestock traceability challenges in New Zealand. The research is important because the existing traceability system has already proven to be ineffective in manging industry disruptions such as animal disease outbreaks and tracking animal-based food products from farm to fork. For instance, about $349 million dollars have already been spent to control the MBovis outbreak (Kelly, 2020). If livestock were easily traceable, the cost could have been lower (O'Connor, 2017a).

Having an effective and efficient traceability system is a key factor in managing such situations, ensuring food safety, public health and safeguarding the livelihood of those who work in the industry (Canadian Cattle Identification Agency, 2020; Caporale et al., 2001; Cooke & Hawkins, 2005; Ministry for Primary Industries, 2021; Searle, 2020). When comparing the New Zealand livestock traceability system with those in the rest of the world, the New Zealand system has much room for improvement (Charlebois et al., 2014; Cooke & Hawkins, 2005; Stone, 2021). However, upgrading a system in a multi-billion-dollar industry (Dairy Companies Association of New Zealand, n.d.; *Meat Industry Association*, 2021) that is used by many different parties such as farmers, those in the livestock industry, and policymakers should not be taken lightly. The system should be easy to use and ensure that accurate traceability data is securely available for every party to use when needed. Blockchain seems to be a promising technology to achieve those goals – mainly because it can gather and store verified tamperproof data automatically and make them securely available to every user of the system (Bumblauskas et al., 2020; Sander et al., 2018). In other countries, blockchain systems are being studied and trialled (MLA, 2021; Mutua et al., 2020; Picchi et al., 2019) to upgrade existing traceability systems. However, the technology has not been considered in New Zealand. This study summarises how blockchain can be used to address livestock traceability challenges via a systematic literature review, identifies traceability challenges in New Zealand using semi-structured interviews and then evaluates if blockchain technology can address them. The research contributes to knowledge and the industry by analysing blockchain technology in the context of New Zealand livestock traceability.

This dissertation is organised into eight chapters – see Figure 1. Chapter 1 introduces the study. Chapter 2 provides an overview of livestock traceability in New Zealand and blockchain technology in a traceability context. The chapter also identifies gaps in current research, leading to the research purpose and the three research questions. Chapter 3 explains the research philosophy and the systematic processes employed to answer the research questions. Chapter 4 highlights insights from the systematic literature review and the semi-structured interviews. Findings are analysed in detail in Chapter 5 leading to the limitations of the study and future research opportunities in Chapter 6. Chapter 7 highlights the dissertation's contribution to knowledge and the industry and Chapter 8 holds concluding remarks. The Appendix contains supporting details, and the References section lists the sources used throughout the study.

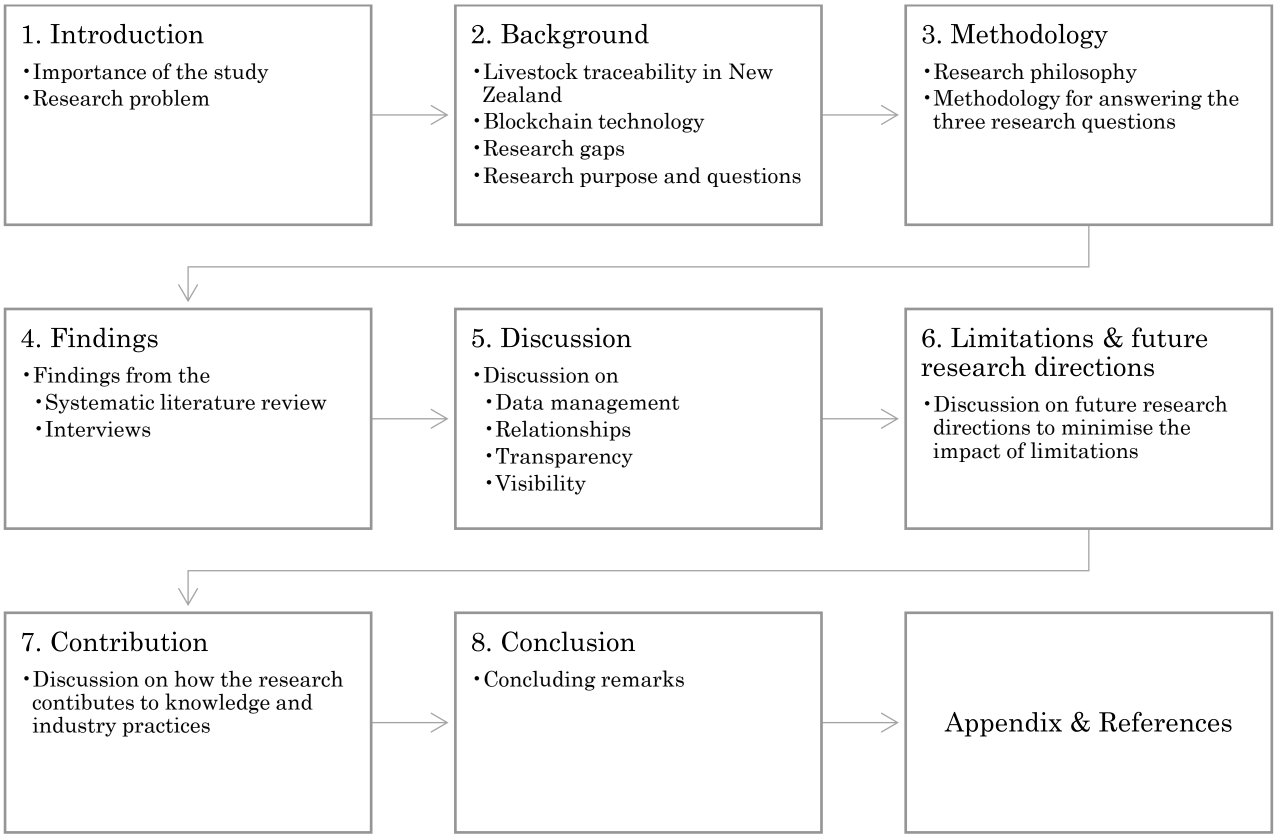

Figure 1: Structure of the dissertation

2 RESEARCH BACKGROUND

This chapter introduces the main concepts related to the research; livestock traceability and blockchain technology. It also identifies gaps in the current research that led to the research questions.

2.1 LIVESTOCK TRACEABILITY

There is no consensus on the definition of traceability (Cooke & Hawkins, 2005; Hobbs, 2003; Souali et al., 2016). After analysing numerous definitions, Olsen & Borit (2013) argue that traceability means the ability to access recorded information on the life cycle of a product. Livestock traceability is the ability to follow an animal or a group of animals from one point in the supply chain to the other (Canadian Food Inspection Agency, 2021; Cooke & Hawkins, 2005; Hobbs, 2003). The main objectives of livestock traceability are: to track origin, ensure food safety, support efficient disease control, assist food recalls, and to promote sustainability and animal welfare (Astill et al., 2019; Bai et al., 2017; Hobbs, 2003; Mutua et al., 2020; Opara & Mazaud, 2001; Tripoli & Schmidhuber, 2020). Animals can become value-added products such as meat, milk, eggs, fur, or wool along the supply chain but for this dissertation, only the traceability of meat and dairy products is considered because they have the highest economic impact for New Zealand. Dairy is the largest goods export sector (Dairy Companies Association of New Zealand, n.d.) and meat industry is the second largest (*Meat Industry Association*, 2021), generating nearly $30 billion combined revenue.

To achieve traceability objectives, careful quality control and data recording is required at all stages of the value chain. As illustrated in Figure 2, inputs, production, processing/distribution, and retail elements add value to the final product. A mistake in any element could lead to fatalities. In 2008, Chinese infant milk was found to be contaminated with melamine and resulted in over fifty thousand child hospitalisations and six deaths (Behnke & Janssen, 2020; Iftekhar et al., 2020).

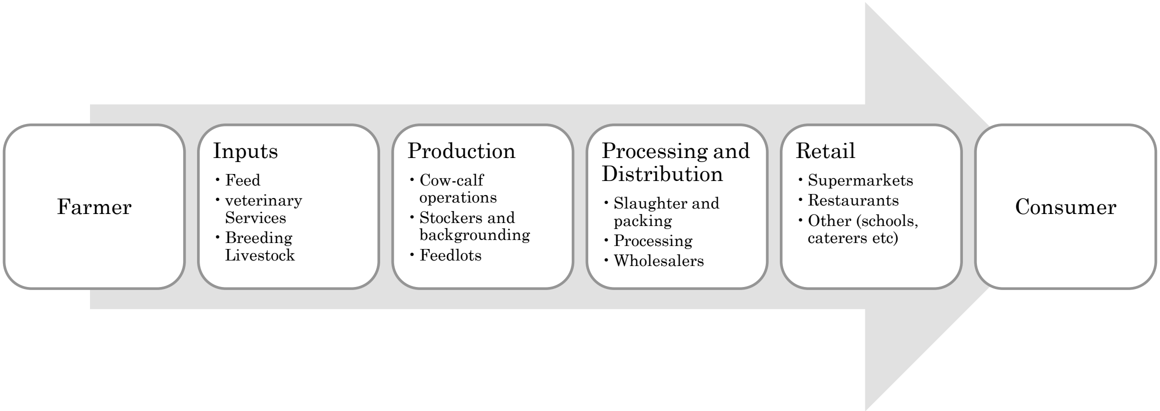

Figure 2: Elements of the livestock industry value chain (adapted from Lowe & Gereffi, (2009))

How the existing New Zealand traceability system works along the value chain is described in the next section.

2.2 LIVESTOCK TRACEABILITY IN NEW ZEALAND

The National Animal Identification and Tracing Act 2012 established a 'National Animal Identification and Tracing' (NAIT) organisation. NAIT is responsible for managing the animal traceability scheme in New Zealand (*National Animal Identification and Tracing Act 2012 No 2 (as at 01 December 2020), Public Act – New Zealand Legislation*, 2021). It is legally required to tag both cattle and deer with NAIT approved tags, register them in the NAIT system, record their movements between properties, and keep the contact details of the person in charge of animals up to date. The NAIT cloud database, which is centrally managed (OSPRI, 2021b), identifies animals individually via a tag system and supports the recording of movements, deaths and missing animals (Ministry for Primary Industries, 2021). When moving animals, it is mandatory to:

- complete either a digital or a paper-based Animal Status Declaration (ASD) containing information such as animal health, treatments, farming practices and Bovine Tuberculosis testing reports (OSPRI, 2021a) and
- record the animal movement in NAIT within 48 hours (OSPRI, 2021d)

As illustrated in Figure 3, NAIT covers the production and processing/distribution phases of the value chain.

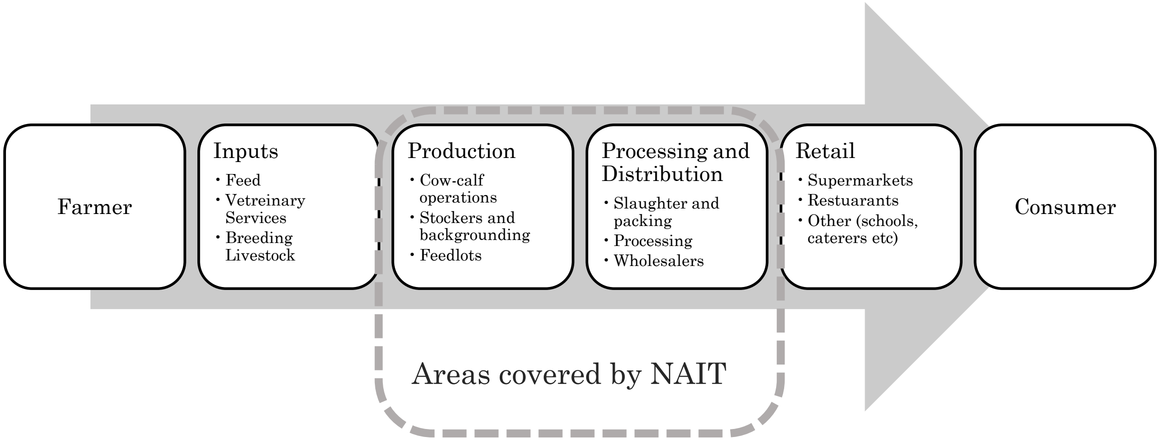

Figure 3: Livestock industry value chain: NAIT's area of influence

It is possible to record movements (OSPRI, 2021c) and register animals (OSPRI, 2021e) directly in NAIT. However, the industry prefers to use software provided by manufacturers of farming equipment (e.g., tag readers, weighing scales) because the data can directly be shared with NAIT (Gallgher, n.d.; Greathead, 2021). New Zealand also has many privately funded animal recording software programs (e.g., Datamars Livestock, FarmIQ, HerdMASTER, MINDA, DairyPlan C21, Halter) which can feed data into NAIT and record animal information such as weight and health treatments.

Despite all these systems, the country has faced difficulties due to ineffective traceability practices. The most recent incident is the Mycoplasma-Bovis outbreak in cattle (Biosecurity New Zealand, 2020; Laven, 2019; Neal, 2019). Ineffective traceability practices are reported as a contributing factor (Williams, 2019) to the spread of the disease. The eradication programme is budgeted at $870 million (O'Connor, 2020) and nearly $350 million has already been spent (Kelly, 2020). Similarly, in the 'whey protein concentrate contamination' incident in 2013, the tracing of the potentially contaminated products took a considerable amount of time due to inefficiencies in traceability mechanisms (Dairy Traceability Working Group, 2014).

Therefore it is evident that, in New Zealand, current traceability practices have some room for improvement (B+LNZ, 2020; Cooke & Hawkins, 2005; Irons, 2017; Livestock Improvement Corporation, 2020; O'Connor, 2017b; OSPRI, 2018). In 2018, NAIT was reviewed, and more than thirty recommendations were proposed to improve the NAIT infrastructure. The review, however, only looks at building on the existing NAIT infrastructure and does not explore the potential value of other technologies (Edge &

Kavalali, 2018). One option is blockchain, a technology that enables 'farm to fork' traceability (Alonso et al., 2020; Gaur & Gaiha, 2020; Marinello et al., 2017; Nestlé, 2019; Picchi et al., 2019; Team Ambrosus, 2018; Torky & Hassanein, 2020). Blockchain technology is explained in the next section.

2.3 WHAT IS BLOCKCHAIN TECHNOLOGY?

Blockchain is a distributed data storage mechanism (Garzik & Donnelly, 2018). Every record saved in a blockchain is cryptographically verified and therefore the system is considered highly secure and tamperproof (Baygin et al., 2019). Records in a blockchain system are linked to each other as in a chain using advanced cryptographic puzzles (Kshetri, 2018). Further, every participating stakeholder in the chain keeps a copy of the records in the chain. As shown in Figure 4, compared to centralised and decentralised systems, all participants in a distributed system are connected to each other (Christidis & Devetsikiotis, 2016; Hackius & Petersen, 2017; Subramanian et al., 2020).

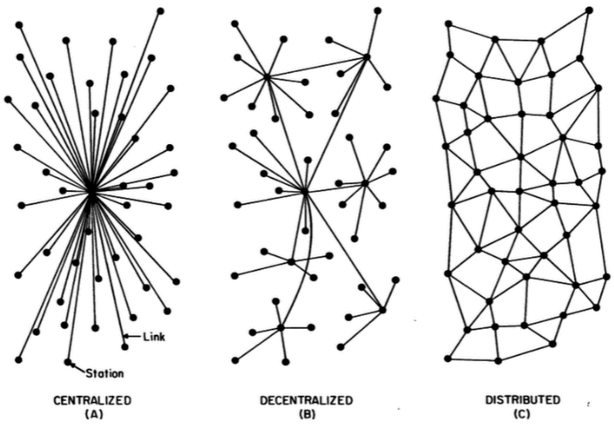

Figure 4: Centralised, decentralised, and distributed systems (Baran, 1964)

Therefore, it is unlikely that the records will be tampered with (Bacon et al., 2018; Drescher, 2017; Lee & Linda, 2018). When combined with 'smart contracts' (programs that run automatically when certain conditions are met) and Internet of Things (IoT) - various sensors/devices for data collection, blockchain-based systems can make intelligent decisions (Christidis & Devetsikiotis, 2016; Cong & He, 2019). For example, a 'grain control' system trialled in Brazil can automatically measure the quality of grain and pay a price to farmers based on the quality (Lucena et al., 2018).

Security concerns have resulted in public and private blockchains. Public or permissionless blockchain systems are open for anyone to join. Private or permissioned systems can only be accessed by safe-listed participants (Guegan, 2017; Lai & Chuen, 2018). An example of a widely used public blockchain system is the Bitcoin network. In contrast, permissioned blockchain systems such as IBM (*IBM Blockchain*, 2020) can only be accessed by pre-authenticated users.

In supply chain management, blockchain is used for purposes such as anti-counterfeiting (Vey & Monari, 2018), ensuring food safety (IBM, 2020; Nestlé, 2019; Tian, 2017), enhancing traceability (Gaur & Gaiha, 2020; Rogerson & Parry, 2020) and provenance (Dutta et al., 2020; Project Provenance Ltd, 2016). Blockchain systems for livestock traceability are explored by academia as well as the industry.

Research suggests that blockchain technology can be used to improve trust, transparency, visibility, and food safety. Tamperproof records improve trust (Asfarian et al., 2020; Cao et al., 2021). When linked with automatic sensors, the life of the animal, as well as the journey of its products can easily be automatically recorded and made available to everyone involved in the supply chain, due to the distributed nature of the system (Feng et al., 2020; Shew et al., 2021). As the traceability data is readily available, events like food recalls can be managed efficiently (Bumblauskas et al., 2020; Rejeb, 2018). Most importantly, events causing recalls can even be detected early if frequent quality testing and evaluations are implemented with the support of IoT and smart contracts (Astill et al., 2019; Southall, 2019). However, expensive implementation efforts and the lack of experience with the technology are often identified as adoption barriers (Kamilaris et al., 2019; Patelli & Mandrioli, 2020). Despite such difficulties, the industry has already started to reap its benefits. The Mi-Corporation enables easy data input (using smartphones) and disease management using a blockchain based traceability system (Clary, 2017). Neogen supports the tracking of the genomic profile of animals including feed and medical history (Einstein-Curtis, 2020). NSF International automates the collection of data such as an animal's location - easing the workload of farmers. Data is then stored in a blockchain system with three factor authentication for high data security (NSF, 2021). 'Breedr' gathers animal data directly from farms and makes them available to supply chain partners so that the beef supply can easily be predicted (Peskett, 2019). 'Deloitte' has proposed the use of blockchain to improve traceability within the Irish Beef Industry (Deloitte, 2018). Zimbabwe already has a blockchain based traceability system

(Mastercard, 2021) and Australia is running a pilot for a similar system (Meat and Livestock Australia, 2021). As recommended by a research organisation (Agrosuisse Technical and Agricultural Services Ltd, 2020) Brazil too has implemented a blockchain traceability system to not only improve livestock traceability, but also to improve socioenvironmental compliance such as the use of labour and land (Ferrer, 2021; The Cattle Site, 2021).

Thus, around the world, blockchain-based livestock traceability systems are being researched and trialled. The technology may also be suitable to improve livestock traceability in New Zealand but the topic has not yet been explored in the New Zealand context. This opens some research gaps which will be discussed in the next section.

2.4 GAPS IN CURRENT RESEARCH

As explained above, blockchain technology can improve livestock traceability systems in numerous ways. Firstly, given that New Zealand's traceability system is due for an upgrade, it is worthwhile to consider if the technology suits the New Zealand context. However, there is little research on the topic. To understand if blockchain technology will benefit New Zealand, it is vital to understand the existing challenges in New Zealand. However, hardly any recent study explores the challenges in using the existing traceability system in New Zealand and if blockchain can address those challenges.

Secondly, many existing research combining blockchain technology and the livestock industry take a blockchain-centric view. They explain the benefits of using (or challenges in implementing) blockchain systems for the livestock industry (Azzi et al., 2019; Creydt & Fischer, 2019). The focus of the analysis is either on highlighting features of blockchain technology or improving traceability in general, rather than analysing how the technology can address existing livestock traceability challenges.

This study aims to fill these gaps. It is the first stage of a larger project (including a PhD thesis) that aims to investigate how to improve livestock traceability in New Zealand.

2.5 RESEARCH PURPOSE AND QUESTIONS

The overarching context for this research is the use of blockchain technology for livestock traceability in New Zealand. As there is little research in this area, it is vital to understand the value of a blockchain based traceability system for New Zealand. The following three research questions (RQs) will be addressed.

- Main RQ: Can a blockchain-based system address existing livestock traceability challenges in New Zealand?
- Sub RQ1: What livestock traceability challenges can be addressed using blockchain technology?
- Sub RQ2: What are the challenges associated with current livestock traceability system in New Zealand?

The three questions serve distinct purposes as explained in Figure 5. The next chapter illustrates how the study is designed to answer the three research questions.

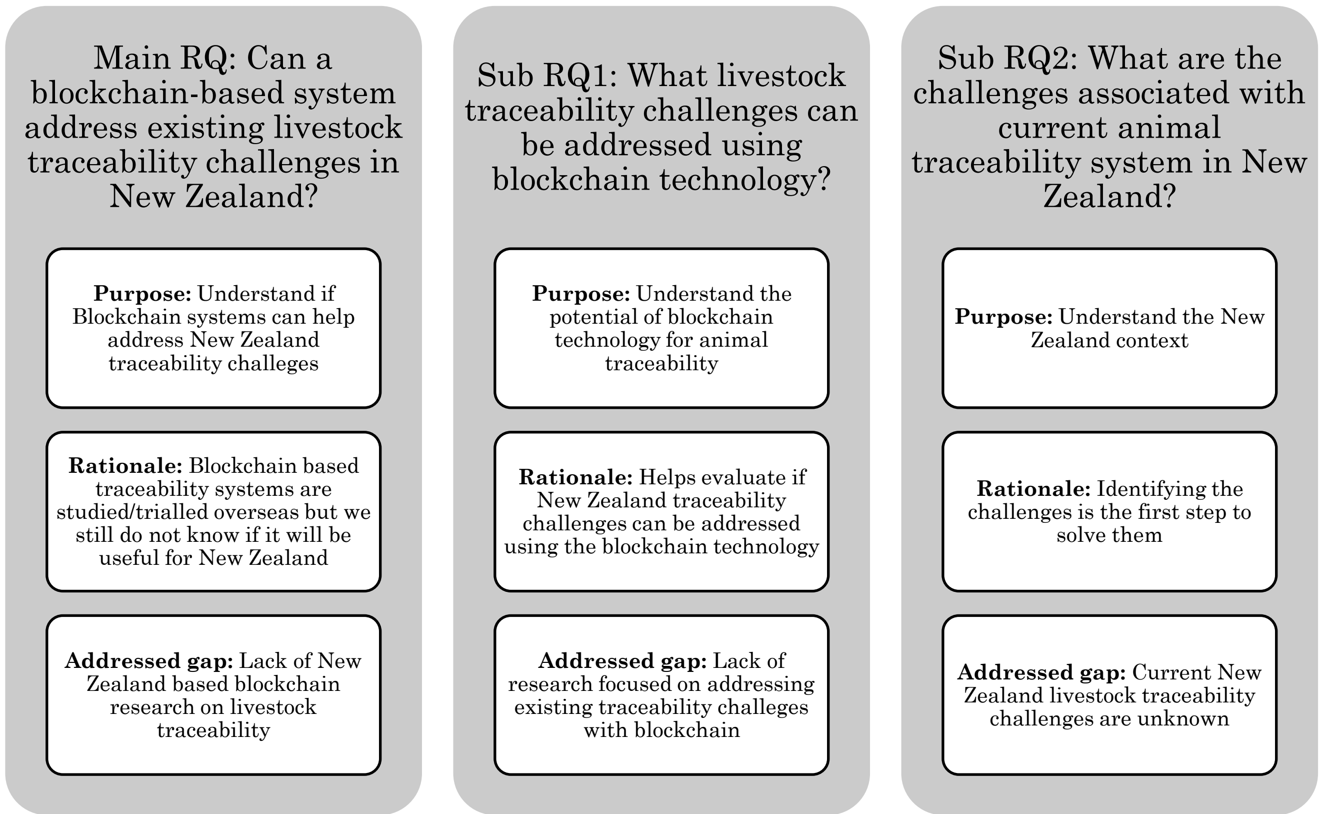

Figure 5: Purpose and the rationale for the research questions

3 METHODOLOGY

This chapter presents the rationale behind the selected research methods used to address the research questions identified in the previous chapter.

3.1 RESEARCH PHILOSOPHY

This study presents applied research. Studies that focus on better understanding a business problem with practical relevance are classified as applied research (Saunders et al., 2015). This research is classed as applied because it aims to better understand livestock traceability challenges in New Zealand and to evaluate blockchain technology as a potential response to those challenges by addressing three research questions. The findings are expected to be valuable for the New Zealand livestock industry as they can help resolve existing challenges and inform future business decisions.

The researcher adopted an exploratory qualitative approach. Exploratory research is conducted to gain greater familiarity with the topic (Saunders et al., 2015; Stablein & Anthony, 2017; Stebbins, 2001) when the topic is relatively new (Babbie, 2021). Data for exploratory studies are often collected using qualitative methods (Saunders et al., 2015). A qualitative approach complements an exploratory study as it uses rich, non-numerical data to gain insights (Dickinger, 2007; Saunders et al., 2015). Qualitative research often takes an interpretivist approach. Interpretivists believe that realities experienced by various groups of people vary, and therefore, explore research concepts from different perspectives (Saunders et al., 2015). This research takes an interpretive approach by selecting interview participants from various stages of the meat supply chain to understand challenges faced by each of them. The next section explains how the research questions are answered based on the above philosophical underpinnings.

3.2 METHODS AND MATERIALS

This research answers the three RQs in three stages. This section justifies the methods selected to answer the questions in each stage.

3.2.1 Stage 1: Identify how blockchain can address livestock traceability challenges

This stage addresses Sub RQ1 (What livestock traceability challenges can be addressed using blockchain technology?) through a systematic review of the literature.

3.2.1.1 Data collection

Systematic review of the literature is “a systematic, explicit, [comprehensive,] and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work” (Fink, 2005, p. 3). Blockchain is a new concept and the purpose of Sub RQ1 is to understand its potential in the livestock traceability context. A systematic literature review is an efficient way to rigorously summarise existing studies (Littell et al., 2008; Mulrow, 1994; Peričić & Tanveer, 2019; Petticrew, 2001) even for relatively new subjects (Petticrew, 2001; Queiroz et al., 2019). Therefore, it is the best option to address Sub RQ1.

ProQuest, Science Direct, Scopus, and Web of Science databases were queried with the syntax "(block chain* OR blockchain*) AND (animal* OR livestock OR agri*)" to select articles for the study. Those databases were selected because they returned the most relevant articles and are considered trustworthy in the subject area. The results were further filtered on the basis of duplicates, written in languages other than English, for being a thesis, dissertation, a conference proceeding, or research in progress. After the first level of filtration, as shown in Figure 6, 195 papers remained in the selection. Next, papers that listed blockchain as a technology without analysing it in detail, focused more on complementary technologies to blockchain, described potential use cases of blockchain for general traceability or technical papers presenting a possible blockchain-based animal traceability system without focusing on the advantages of the technology, were ignored. Fifteen papers (See section 9.1) describing how blockchain-based systems can improve livestock traceability remained.

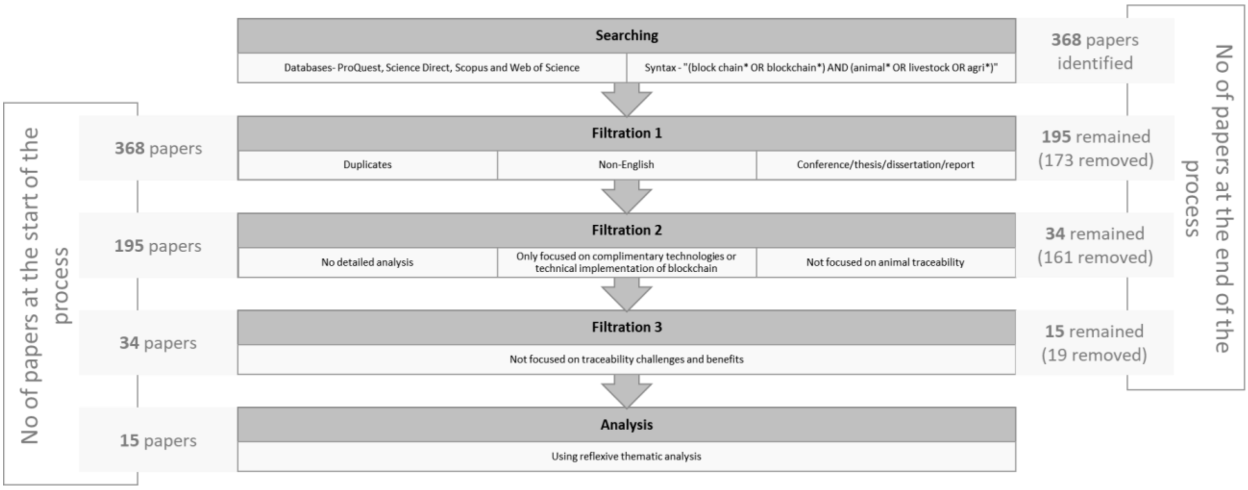

Figure 6: Selecting papers for the systematic literature review

3.2.1.2 Data analysis

The selected papers were reviewed to understand how blockchain technology has been used or proposed to be used to address traceability challenges.

Reflexive Thematic Analysis with an inductive approach was used as the data analysis method. Thematic Analysis is an umbrella term which refers to a group of methods which focus on summarising data based on themes or codes. Patterned meanings across datasets are then identified. (Braun & Clarke, 2012; Fugard & Potts, 2015; The University of Auckland, 2019). In Reflexive Thematic Analysis, data is first coded and then themes are derived from the codes (Braun & Clarke, 2021). When coding and theme development are guided by the content of the data, the analysis is inductive. This approach suits Sub RQ1 because the goal was to identify common animal traceability themes mentioned in the existing blockchain literature. nVivo software was used to conduct the analysis.

Ten subthemes were identified in the data, and they were grouped into four themes as presented in Table 1. The four themes formed the basis of coding the 15 articles in NVivo. The same themes will be used to analyse interview data and guide the discussion in Chapter 5.

Table 1: Data analysis framework and the coding scheme

Themes (Codes in NVivo)	Includes information related to	Sub themes
Data Management	Recording, storage and sharing of data	• Data recording • Data stored in - independent systems and - centralised systems
Relationships	The interactions of supply chain partners with each other	• Participants' varying attitudes • Verifications by third parties • Privacy concerns
Transparency & compliance	Ability to gain insights on what participants do along the supply chain	• Transparency of participants' actions • Validation of recorded data • Tracking law abidance
Visibility	The tracking of products along the supply chain	• Food safety and quality • Origin of food products

3.2.2 Stage 2: Identify livestock traceability challenges in New Zealand

This stage addresses Sub RQ2 (What are the challenges associated with current livestock traceability system in New Zealand?) through semi-structured interviews.

3.2.2.1 Data collection

Semi-structured interviews were used as the data collection method to understand the challenges in using existing animal traceability systems in New Zealand. This method was chosen because it allows researchers to provide a direction for discussions while allowing the narrative to unfold more information (Galletta & Cross, 2013). To prevent bias, questions were designed as open ended (Reja et al., 2003) and the interview data were triangulated (Mathison, 1988) with the findings of the systematic literature review.

Purposive sampling was used to select participants for the study. Purposive sampling focuses on selecting participants based on their availability and ability to provide the most relevant insights for the research (Etikan et al., 2016; Sharma, 2017; Tongco, 2007). An input–process–output IPO model (Curry et al., 2006; Goel, 2010; Grady, 1995) was used as a guideline to categorise participants. The IPO model describes the basic structure of an information system; input-process-output. The process was also inspired by the interpretivist belief that every human lives in their reality and that each reality can add valuable insights to a study (Saunders et al., 2015). For this research, each component of the IPO model was considered a 'reality'. People who interact with traceability systems in each 'reality,' as illustrated in Figure 7, were invited to take part in interviews.

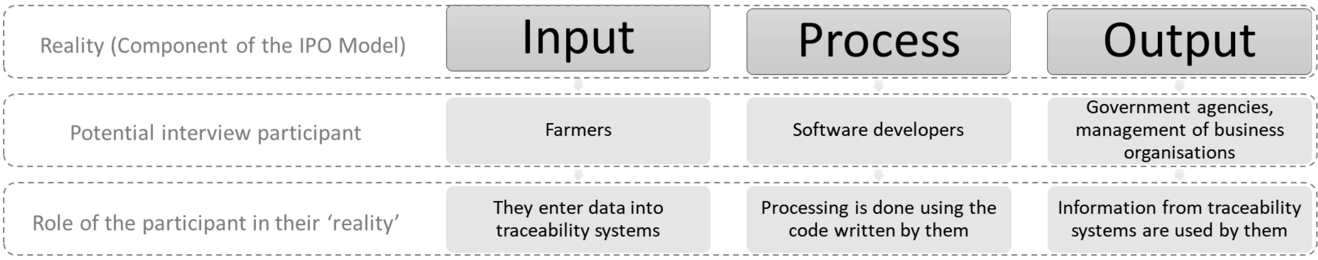

Figure 7: Selection of interview participants based on the IPO model

Interviews took place via digital video conferencing. The average interview time was 35 minutes.

A total of 22 email and social media messages were sent out to potential participants identified based on their job and organisational descriptions. Thirteen responses were received, which resulted in eight interviews. A breakdown of the interview participants is shown in Table 2.

Table 2: Breakdown of interview participants

Category	**Participant code**	**Participant description**
1 (Input)	F1	Farmer owning a sheep, bull & cow operation
	F2	
2 (Process)	SD1	Software developer in a reputed software development company
	SD2	
3 (Output)	U1	Traceability expert working with the government
	U2	Manager of a meat supply farm
	U3	Manager of a meat processing company
	U4	Manager of a dairy systems operation

The interviews comprised three levels of discussion:

1. How the participant interacts with the traceability system.
2. Their level of satisfaction in using the system.
3. The challenges met when using the system.

As shown in Table 3, the questions were slightly adjusted to suit the participant's nature of work.

Table 3: Format of the interview questions

Format of the interviews			
Common questions	1. Respondent's profile: How/why do you use an animal traceability system(s)?		
	2. Are you satisfied with the current traceability system(s)? Why?		
Slightly varied questions	3. Challenges in using animal traceability systems		
	Input component: e.g., Farmers	*Processing component: e.g., Software Developers*	*Output component: E.g. Managers*
	• What is your biggest challenge when using existing traceability system(s)? • What other difficulties have you encountered when using them? • Have you ever found yourself not able to provide/acquire/record some data that you/another party wanted due to limitations in the existing traceability system(s)?	• What is your biggest challenge when developing/maintaining existing traceability system(s)? • What other difficulties have you encountered when working with them? • Have you ever found yourself technologically limited so that you could not design/develop a system feature that a client wanted?	• What is your biggest challenge when using existing traceability system(s)? • What other difficulties have you encountered when using them? • Have you ever found yourself not being able to provide/acquire some data that you/another party wanted due to limitations in the existing traceability system(s)?

All the interviews took place via Microsoft Teams or Zoom and were video recorded with the participants' consent. Recorded interviews were transcribed verbatim. The next section explains how the transcribed interview data was analysed.

3.2.2.2 Data analysis

Framework Analysis was used for the interview data. Framework Analysis begins with coding of data, but its defining feature is a matrix summarising the codes and the cases (Gale et al., 2013; Mason et al., 2021). When coding and theme development are directed by existing concepts, the analysis is deductive (Braun & Clarke, 2006). As the themes derived from Sub RQ1 guided the coding, the approach can be classified as deductive. This approach allowed better organisation of data and some triangulation between literature and the empirical data.

Transcriptions were imported into NVivo for coding. The codes from the literature review were used as the base codes. Interesting points to note were coded into new nodes for further analysis.

Coded interview data were organised into a framework matrix where one axis contained identified themes and the other, the interview participants. The cell where the two axes meet contained what the interview participant said about the specific theme. This allowed easy identification of New Zealand traceability challenges that can be solved using blockchain technology. The output of this stage was used as an input in the third stage, as explained below.

3.2.3 Stage 3: Identify if blockchain can address traceability challenges in New Zealand

This stage addresses the main research question by comparing the output of stage two, livestock traceability challenges in New Zealand, with the outputs of stage one, how blockchain can address traceability challenges.

3.2.3.1 Data collection

As shown in Figure 8, outputs of the sub research questions were used as inputs for the main research question. Hence, no further data collection was necessary.

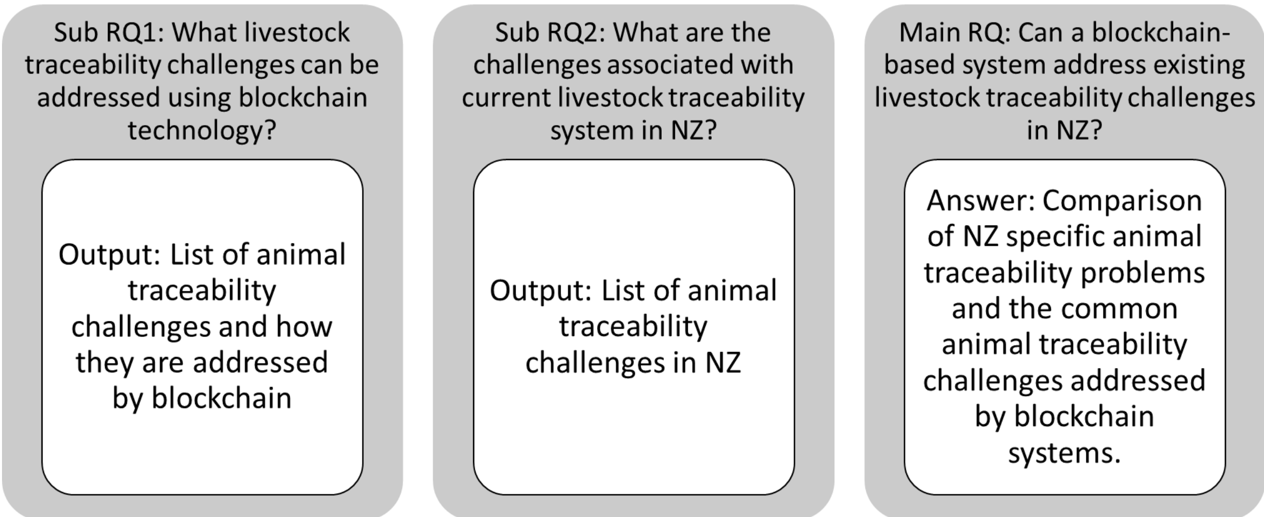

Figure 8: Outputs of the sub RQs help address the main question

3.2.3.2 Data analysis

Comparative analysis was used to analyse data. Comparative analysis requires multiple commensurable items for analysis, and the goal of the comparison is to identify the similarities and differences between the compared items (Adiyia & Ashton (Bill), 2017; Esser & Vliegenthart, 2017; Pickvance, 2001). For this study, the commensurable items are the outputs of Sub RQ1 and Sub RQ 2.

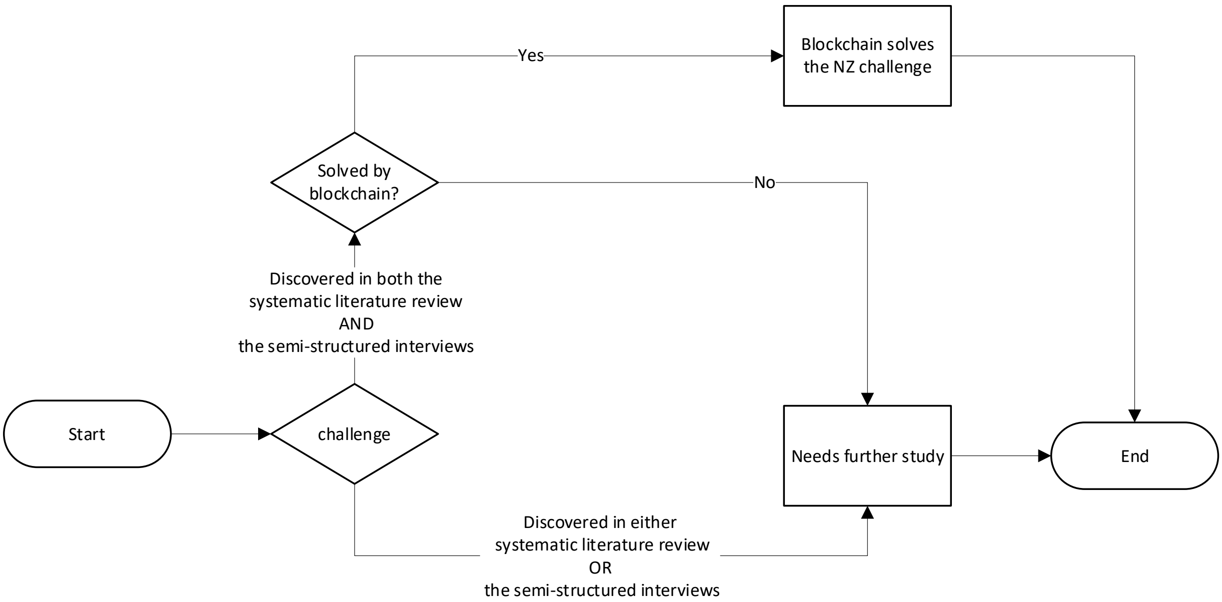

Figure 9: Logic for answering the research questions

As illustrated in Figure 9, if a challenge discovered during both stage 1 and 2 is addressed by blockchain it is considered that blockchain can help address that New Zealand challenge. If not, further study is suggested to find ways to address such challenges. If a challenge is found either in the systematic literature review or the semi-structured interviews, the same recommendation is made due to the reasons illustrated in Figure 10.

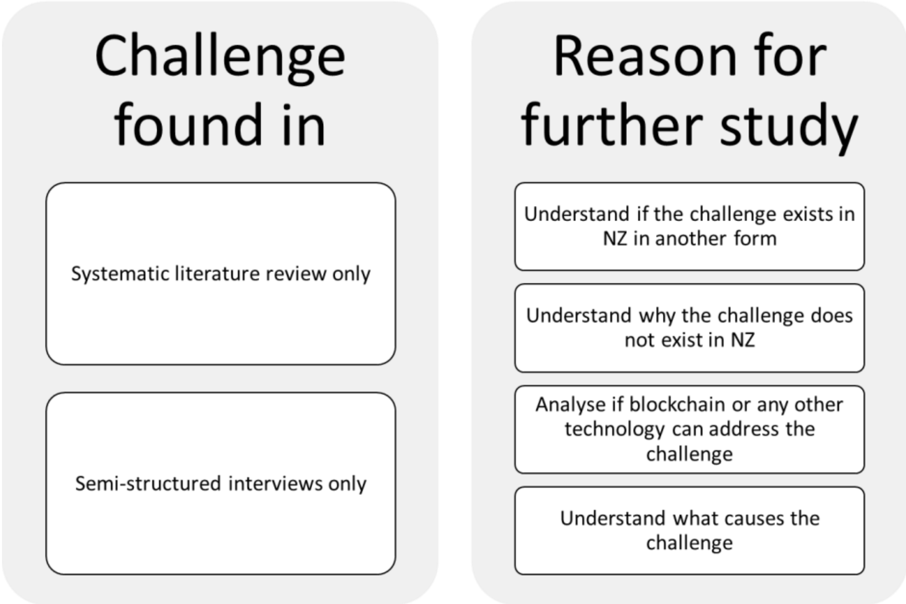

Figure 10: Reasons for further studying challenges found in just one stage

A table summarising the traceability challenges and blockchain benefits discovered during the literature review and the New Zealand challenges discovered via the interviews was developed to facilitate the comparison.

The three-stage process discussed so far is summarised in Figure 11.

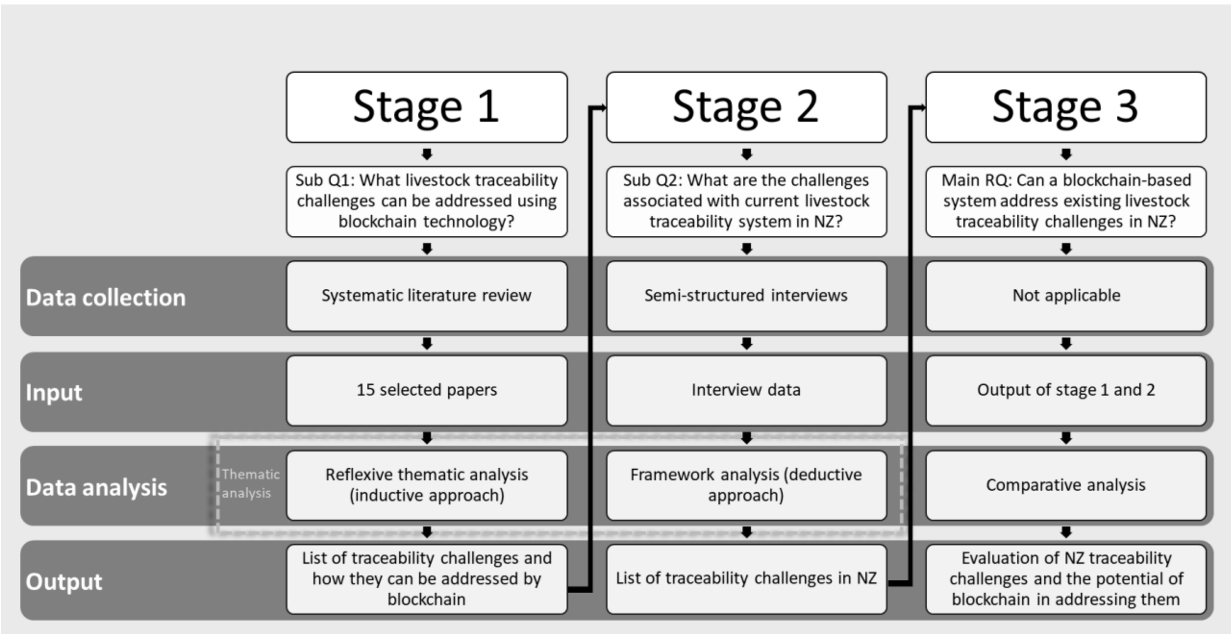

Figure 11: Three stage process used to answer research questions

The Findings section addresses the Sub RQs by summarising the outputs of stages one and two. The output of stage three is presented in the Discussion section and addresses the Main RQ. The process is illustrated in Figure 12.

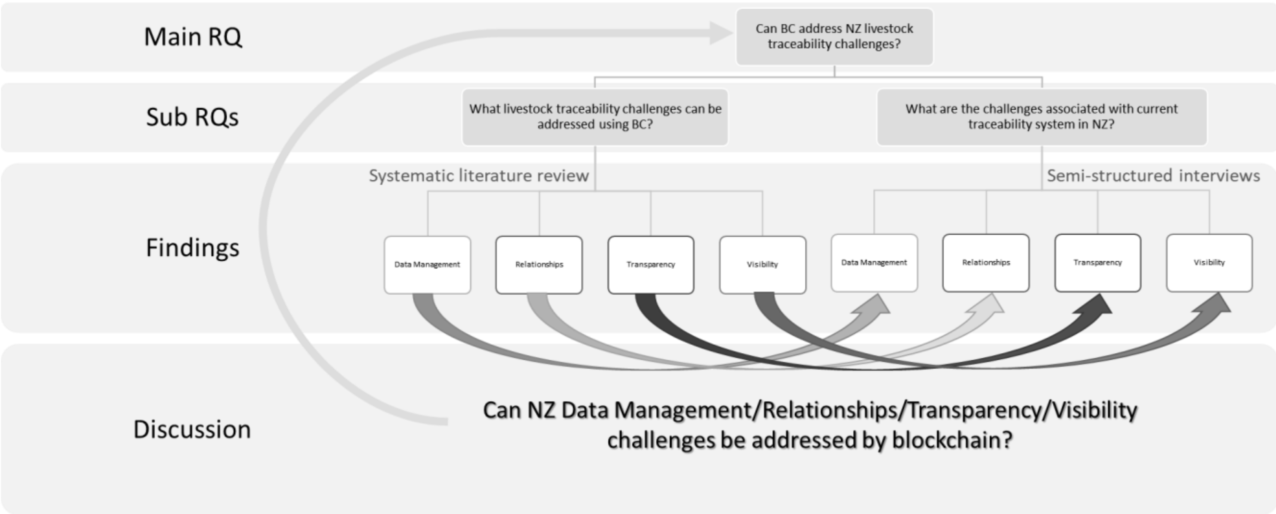

Figure 12: Findings and discussion sections address all the RQs

4 FINDINGS

This section presents a summary of the outputs of stages one and two as explained above.

4.1 REFLEXIVE ANALYSIS OF THE LITERATURE

The purpose of literature review was to identify the livestock traceability challenges that can potentially be addressed using blockchain technology. In this section, the challenges are organised by themes and sub themes that were presented earlier in Table 1. Later in the research, the same themes and sub themes were used to analyse the interview data.

4.1.1 Data management

As mentioned earlier, data management refers to the recording, storage and the sharing of data.

4.1.1.1 Data recording

Farmers record data, such as animal movements, via handwritten notes, later converting them to a digital format. However, this process is prone to error, inefficient and time-consuming, with a risk of tampering (Bumblauskas et al., 2020; Park & Sung, 2020; Shahid et al., 2020). Consequently, estimated, incorrectly processed, and unreliable data could enter the supply chain and later be used for decision making (Muganda et al., 2020).

Blockchain systems improve data collection by integrating with IoT for automatic data collection. The process involves less human interaction and less manual recording (Creydt & Fischer, 2019; Feng et al., 2020; Iftekhar et al., 2020; Park & Sung, 2020; Rejeb, 2018). Therefore, the system is more efficient and less error-prone (Azzi et al., 2019; Bumblauskas et al., 2020). Collected data is then stored in the blockchain after being validated through consensus mechanisms or smart contracts (Feng et al., 2020; Iftekhar et al., 2020). Feng et al (2020) provide an interesting example on how the process works in a chicken farm in China.

> *Every chicken wears a chicken card from farming, slaughtering, refrigeration, packaging, transportation and reaching the consumers, which*

can automatically collect the location and movement data of chickens and upload them to the blockchain in real time. The traceability information includes breed of chicken seedlings, environmental sensors data (temperature, RH, air, light, etc.), weigh, health, growth cycle, slaughtering data, quarantine, sales information etc… (p.10)

4.1.1.2 Data stored in independent systems

It is common for organisations to store livestock data in private repositories (Feng et al., 2020; Ferdousi et al., 2020; Fortuna & Risso, 2019; Iftekhar et al., 2020; Muganda et al., 2020; Rejeb et al., 2020). It makes tracing the journey of the animal along the supply chain challenging (Iftekhar et al., 2020; Muganda et al., 2020), makes informed decisions almost impossible (Makkar & Costa, 2020; Muganda et al., 2020), and leaves consumers vulnerable to fraudulent information (Shahid et al., 2020). Further, the lack of common data standards and formats cause interoperability issues when transferring data between various traceability systems (Bumblauskas et al., 2020; Sander et al., 2018).

Blockchain systems address the problem of siloed data by storing all the data in a decentralised platform which can be accessed by all the participants (Azzi et al., 2019; Feng et al., 2020; Fortuna & Risso, 2019; Prashar et al., 2020; Rejeb, 2018; Sander et al., 2018). Thus, a shared view of the truth is available in real-time to all the stakeholders (Bumblauskas et al., 2020; Ferdousi et al., 2020; Iftekhar et al., 2020; Muganda et al., 2020). Data integrity and quality is not lost and interoperability issues are almost non-existent as unnecessary copying and processing are not needed to transfer data between various systems (Bumblauskas et al., 2020). Participants can make informed decisions (Azzi et al., 2019; Creydt & Fischer, 2019; Makkar & Costa, 2020; Park & Sung, 2020) based on the same data, which streamlines supply chain operations.

4.1.1.3 Data stored in centralised systems

Many existing traceability systems are centralised (Feng et al., 2020). Centralised systems have a single point for data storage and control which exposes supply chains to various challenges (Baran, 1964). Data stored in a single location is prone to tampering which leads to fraudulent and corrupted data (Azzi et al., 2019; Rejeb, 2018; Sander et al., 2018; Shahid et al., 2020). Further, a failure in the system impacts all the supply chain participants. Accessibility of the data is also under risk as bottlenecks could form when multiple parties attempt to access the same data at the same time (Shahid et al., 2020). In other words, data integrity, security, resilience, and accessibility are easily compromised in a centralised system.

Blockchain systems, on the other hand, are distributed and therefore address the risks posed by centralised systems. Firstly, data is duplicated in the nodes of all the participants, avoiding risks such as a single point of failure (Ferdousi et al., 2020; Fortuna & Risso, 2019; Park & Sung, 2020; Shahid et al., 2020). Secondly, data in a blockchain is immutable, protecting it against tampering and increasing the integrity of the data (Azzi et al., 2019; Creydt & Fischer, 2019; Feng et al., 2020; Fortuna & Risso, 2019; Iftekhar et al., 2020; Makkar & Costa, 2020; Muganda et al., 2020; Rejeb, 2018; Shahid et al., 2020). All nodes should consent cryptographically before saving data permanently in the chain (Azzi et al., 2019; Creydt & Fischer, 2019; Fortuna & Risso, 2019; Sander et al., 2018). This makes all the information in the system trusted and verified. Speed is improved as bottlenecks no longer occur (Muganda et al., 2020). As a copy data is available at every participant, denial of service (DoS) attacks, which prevent legitimate users from accessing the system, are almost impossible (Shahid et al., 2020). Also, it is easy to push data to other analytical tools for improved decision making (Muganda et al., 2020).

4.1.2 Relationships

As mentioned in Table 1, relationships refer to the interactions between the supply chain partners. This section explores how blockchain technology can address challenges relating to relationships.

4.1.2.1 Participants' varying attitudes

Participants attitudes toward traceability vary. Some believe that traceability is critical in the supply chain, while others consider it to be a mere window-dressing activity (Sander et al., 2018). For instance, in a 2018 study conducted in the Netherlands, meat suppliers declared that they believe consumers do not care about traceability, while customers responded that traceability data impacted their purchase decisions (Sander et al., 2018). Due to not understanding the traceability needs of the downstream stakeholders in the supply chain, there is a risk of the relevant data not being collected further up the chain.

Even if the data is collected, some farmers do not realise the importance of individual contributions to traceability of the whole supply chain (Iftekhar et al., 2020; Muganda et al., 2020; Rejeb, 2018). Therefore, their data never leaves their internal systems. Integration issues as described in the data management section further exacerbates this problem as farmers do not make the extra effort required to sync their data with external systems.

The automation of verifications, approvals, and trading implemented in a blockchain system, can help participants understand the needs of the stakeholders throughout the supply chain. Further, not having the relevant data recorded may financially affect suppliers. For instance, if a smart contract decides that a pack of meat does not meet the quality standards due to a lack of data, the supplier may receive no or a lower payment (Creydt & Fischer, 2019; Rejeb, 2018; Shahid et al., 2020). Thus, the participants are informed of the traceability needs downstream. Therefore, participants will have a shared understanding of the traceability needs in the supply chain, which may result in the recording of the required data upstream.

4.1.2.2 Verifications by third parties

A livestock supply chain employs third parties for label verifications (e.g. antibiotic-free, cruelty-free), export approvals, and animal trading (Azzi et al., 2019; Creydt & Fischer, 2019; Shahid et al., 2020). Verification incurs costs to participants (Bumblauskas et al., 2020; Creydt & Fischer, 2019) and can also slow the flow of animal goods in the chain (Creydt & Fischer, 2019).

Blockchain-based systems can reduce the involvement of third parties for verifications by using smart contracts and verified sensors (Creydt & Fischer, 2019). For instance, a smart contract can help automate processes such as custom clearances for exported animal products without the involvement of a third-party. (Creydt & Fischer, 2019; Fortuna & Risso, 2019). A sensor automatically checks the quality and the smart contract ensures that payments are only approved if goods meet the agreed quality (Creydt & Fischer, 2019; Rejeb, 2018; Shahid et al., 2020). In a blockchain system, every saved record is cryptographically verified. In other words, all the participants act as verifying authorities. Therefore, third party involvement in verifications is minimised, saving costs and improving efficiencies (Bumblauskas et al., 2020; Creydt & Fischer, 2019; Feng et al., 2020; Makkar & Costa, 2020; Park & Sung, 2020; Prashar et al., 2020). Further, the risk of malicious actions by third parties is significantly reduced (Shahid et al., 2020).

4.1.2.3 Privacy concerns

Having all the participants record data in a traceability system is critical for traceability and transparency. However, businesses may hesitate to share data due to confidentiality concerns. Some fear data being accessed by competitors and insist that only specifically allowed parties should access their data (Creydt & Fischer, 2019; Ferdousi et al., 2020; Iftekhar et al., 2020; Sander et al., 2018). Further, when stored in a central location, any party who has access to the database could easily access confidential data. In consequence, some data may never be uploaded to centralised traceability systems making the information flow fragmented and inaccurate.

Blockchain systems offer two levels of protection against privacy concerns. At the system level, private/permissioned-blockchains can protect participants' data by only allowing trusted parties to access data (Creydt & Fischer, 2019; Ferdousi et al., 2020; Fortuna & Risso, 2019; Iftekhar et al., 2020; Park & Sung, 2020; Prashar et al., 2020; Rejeb, 2018; Shahid et al., 2020). At the data level, smart contracts can granularly manage data access permissions or share anonymised aggregated data with other parties given the data owners agree (Ferdousi et al., 2020; Shahid et al., 2020). Further, some proposed systems allow participants to store their data locally and save only a hash – a string of characters generated by passing the original data through a formula (Taub, 2017), in the blockchain, which further enhances data privacy and control (Ferdousi et al., 2020). In summary, blockchain systems allow fine-grained access control and better privacy compared to traditional systems (Bumblauskas et al., 2020; Feng et al., 2020).

4.1.3 Transparency and compliance

Transparency and compliance, as mentioned in Table 1, refer to the ability to gain insights on what participants do along the supply chain. This section explores how blockchain technology can help improve transparency and compliance in livestock supply chains.

4.1.3.1 Transparency of participants' actions

Consumer (and other stakeholder) trust can easily be built if the full life cycle of a product is transparent However, existing food traceability systems are not very effective in presenting that data in a transparent manner (Feng et al., 2020; Iftekhar et al., 2020). Therefore, those who are near the end of the chain cannot see the actions of the participants upstream. For instance, a meat packet may be labelled 'antibiotic-free,' but consumers have no way to confirm that the animal was not given antibiotics.

Blockchain systems help alleviate the problem by recording every transaction that happens along the supply chain in real-time (Azzi et al., 2019). When all the collected data is accessible to all the participants in the chain, transparency is improved (Azzi et al., 2019; Bumblauskas et al., 2020; Feng et al., 2020). The actions of each participant such as medical treatments, feeding (and the feed used); and the farm conditions such as the nature of animal shelter are then available to the end consumer (in the form of a Q.R. or an RFID code) to aid their purchase decision (Iftekhar et al., 2020; Makkar & Costa, 2020; Rejeb, 2018). Availability of such information can help stakeholders take actions to improve each step in the livestock supply chain (Fortuna & Risso, 2019). In summary, the availability of such data helps build consumer trust in the animal products they consume.

4.1.3.2 Validation of recorded data

Traditional traceability systems act as a storage location for supply chain transaction data, but it is challenging to identify whether the recorded data is accurate (Azzi et al., 2019; Feng et al., 2020; Fortuna & Risso, 2019). For instance, there have been incidences where horse meat has been labelled as beef (Iftekhar et al., 2020; Sander et al., 2018). Some traceability information such as production method (e.g., organic, antibiotic-free) has a direct relationship with the product's price. Therefore, it is tempting for fraudsters to manipulate supply chain data to secure higher prices. The consequences, however, can be serious (Creydt & Fischer, 2019; Iftekhar et al., 2020; Makkar & Costa, 2020). For instance, if all the ingredients of a product are not listed, allergies to the unlisted ingredients can cause severe illness to those affected. The European Union's answer to the issue is labels, but consumers, regulatory authorities and other stakeholders cannot access the data to support certification/ quality claims that appear on food labels (Azzi et al., 2019; Bumblauskas et al., 2020; Iftekhar et al., 2020; Rejeb, 2018). Another dangerous scenario is the issuance of labels by illegal institutes (Prashar et al., 2020). Communication using labels becomes further complicated if the supply chain spans across several countries, as consumers as well as the suppliers in each country are subjected to different laws and regulations (Creydt & Fischer, 2019).

Blockchain systems perform better in this aspect compared to traditional systems due to their technical features (Shahid et al., 2020). As records in blockchain systems are unalterable (Azzi et al., 2019; Creydt & Fischer, 2019; Feng et al., 2020; Fortuna & Risso, 2019), verified by all the participants with various consensus mechanisms (Bumblauskas et al., 2020; Feng et al., 2020; Ferdousi et al., 2020) and linked to the previous record (Azzi et al., 2019; Feng et al., 2020), the ability to alter the quality, origin or ingredient information for a product is limited (Makkar & Costa, 2020). Any alteration to a previous record or an attempt to enter counterfeit products will be instantaneously and effortlessly detected (Azzi et al., 2019; Ferdousi et al., 2020; Park & Sung, 2020; Rejeb, 2018). By combining with IoT, data to support certification/quality claims can easily be collected automatically (Creydt & Fischer, 2019; Makkar & Costa, 2020). Smart contracts can be used to certify products based on the collected supportive data (Creydt & Fischer, 2019) and to ensure that only data from trusted sources is saved in the blockchain (Ferdousi et al., 2020). As the data is available to all the participants in the chain, it is easy for them to analyse the chain of records to verify the certification claims (Feng et al., 2020).

4.1.3.3 Tracking law abidance

Supply chains spread across the globe, so animal products pass through various countries/states with varying rules and regulations. Some authors suggest global level agreements on regulations (Creydt & Fischer, 2019), but that would be challenging to achieve. For instance, the legal definition of 'organic' can differ from country to country. Traditional systems simply record that a product is organic. There is no way to find out why the product was labelled as organic. Therefore, when meat travels around the world, the word 'organic' becomes meaningless. Sometimes, the law requires producers to meet specific environmental conditions, such as temperature for meat. These environmental conditions can also vary from country to country. Therefore, simply recording that the temperature requirements have been met may not be specific enough for exported products (Bumblauskas et al., 2020). Thus, even if laws and regulations exist, consumers have no means to know if they are adhered to (Park & Sung, 2020; Rejeb et al., 2020; Sander et al., 2018).

The solution offered by blockchain systems to this problem has two aspects. Firstly, actual data rather than the states are recorded. For instance, a blockchain based system will record the exact storage temperature of a meat pack rather than recording that the temperature requirements are met (Iftekhar et al., 2020). Secondly, as explained above, a blockchain system makes the collection and sharing of data easy, thereby improving the transparency of data in the livestock supply chain. Therefore, each participant in the supply chain can decide if the animal products meet their legislative body's requirements (Park & Sung, 2020) based on verified factual data.

4.1.4 Visibility

As mentioned in Table 1, visibility relates to the tracking of products in the supply chain. This section explores how blockchain technology can address visibility challenges in livestock supply chains.

4.1.4.1 Food safety and quality

A food recall is often the result of a food safety or a quality issue. Recalls happen more frequently these days due to complex supply chains, increasing interest in food safety, quality issues, and the discovery of various animal diseases (Park & Sung, 2020). Animal products can deteriorate during distribution and processing due to temperature differences and inadvertent contamination with bacteria/viruses or residue from medicines (Bumblauskas et al., 2020; Feng et al., 2020; Park & Sung, 2020). Identifying these issues before the product reaches the consumer involves rigorous testing and monitoring. However, current supply chains do not facilitate the rapid identification of contamination, resulting in expensive food recalls, a loss in trust of brands, and sometimes, sick consumers (Azzi et al., 2019; Creydt & Fischer, 2019). In a recall, if all the traceability data is easily accessible, the recall process can become more efficient. However, such traceability data is not always available (Creydt & Fischer, 2019).

The challenge is also partly due to the lack of appropriate infrastructure to record the relevant information. Rejeb (2010) illustrates this through the tilapia supply chain in

Ghana. Due to supply chain complexity, fish from farmers who use safe feed and correct refrigeration practices, as well as fish from farmers who cannot afford high quality feed and refrigeration, end up in the same supply chain. Thus, the quality of the fish and their feed cannot be assured.

Blockchain addresses contamination and other quality issues using sensors and smart contracts. Azzi et el (2019) describe an analytical sensor called 'Biosensor' which can monitor the biological content of food products and record the data gathered during the monitoring process in a blockchain system. If the sensor notes anything unexpected, stakeholders can be notified. Such implementations allow supply chain partners to proactively manage food contamination and quality issues rather than waiting for a report of a sick individual or a lab test to start investigations (Azzi et al., 2019; Fortuna & Risso, 2019). Thus, tracing the cause of the problem in the event of a food recall is more efficient and less costly (Fortuna & Risso, 2019; Makkar & Costa, 2020; Prashar et al., 2020).

4.1.4.2 Origin of food products

There is an increasing demand for provenance data (Bumblauskas et al., 2020) as the origin of food products is often linked to higher prices. However, origin tracing and verification is reported to be challenging in current traceability systems (Azzi et al., 2019; Creydt & Fischer, 2019; Feng et al., 2020; Fortuna & Risso, 2019). The journey of the product is either recorded in fragments, open to manipulation, or not recorded at all (Creydt & Fischer, 2019; Ferdousi et al., 2020).

Combined with GPS and other sensor data, blockchain technology can support origin claims (Bumblauskas et al., 2020; Feng et al., 2020). If data generated from approved/verified sensors is saved directly in the blockchain, there is little opportunity to tamper with that data, and as they come directly from verified sensors, the data can be trusted. Further, using smart contracts, automated certificates of origin can be generated. When origin data is saved permanently in a blockchain, consumers can, on their own, trace the origin of meat or any other livestock product they purchase, thereby increasing the trust element in the supply chain (Prashar et al., 2020; Rejeb, 2018; Sander et al., 2018).

4.2 FRAMEWORK ANALYSIS OF THE INTERVIEWS

This section presents a summary of interviews conducted to identify livestock traceability challenges in New Zealand. The same themes and subthemes in the literature review are used to structure the section. The reference attached to each quotation reflects the three categories of participants. F1-2 for farmers, SD1-2 for software developers and U1-4 for others. See section 9.2 for more quotes.

4.2.1 Data management

4.2.1.1 Data recording

Every interview participant mentioned data collection as a challenge. Lack of trained staff and time to record traceability data was the main problem. As mentioned by F1, *"…you can't just get a guy off the street to record data…"*

Infrastructure issues such as the lack of data connectivity and power sources to charge recording devices on backcountry farms were also often mentioned. While farmers struggle to get data collected using the limited resources available, other stakeholders commented that farmers have very little idea of how real-life actions on the farm can be transformed to digital records via apps. The knowledge gap impacts the quality of the data, but farmers do not have time to invest in learning how various apps work. Instead, they try to record animal data with as minimal effort as possible to comply with the laws and regulations. For instance, SD1 mentioned,

> *"…a big problem is the quality of the data; it stems from primarily the fact that these systems are imposed on farmers with little thought given to the fact that they are time poor…"*

All the farmers interviewed felt that the process should involve better technological solutions. Some felt that the existing applications are not user friendly and offer little flexibility. This resonates with the comments made by some software developers that they had very little knowledge of animal husbandry when starting their careers as software developers in agriculture. Some even remarked that involving farmers early in the design process could have resulted in more user-friendly traceability applications. One farmer developed his own data recording application to be used on the farm.

In addition, many participants mentioned that tags falling off the animals is a major issue that directly affects traceability. When animals lose tags, all the data saved against those tags become meaningless, unless the farmer places a new tag on the animal, identifies the tag it replaces, and transfers the data from the lost tag to the new one. However, farmers revealed that they rarely follow those steps meticulously.

Quite a few interviewees mentioned either the lack of incentives to record or penalties for not recording animal traceability data. Participants generally agreed that the lack of both made farmers feel relaxed about recording.

4.2.1.2 Data stored in independent systems

Participants complained about having to record data in various applications. Some reported using a different app to record various types of data such as medication administered, weights, and movements. According to F1, they use *"…three applications, basically because they don't integrate properly…"* Some even reported using both digital and manual systems.

Commenting on the scenario, SD1 mentioned that it is difficult to get insights about animals in one place as the data is spread across various applications which are not compatible. Farmers also complained of having to manually edit data before sending to another application. Although farmers wished for an eco-system of applications that are interconnected and compatible with each other, software development agencies stated that it is a difficult feat to achieve. A few years ago, such a project was initiated but SD2 declared that the initiative was not successful due to lack of profitability. According to SD2, the priority for technology companies is to build an application that will be widely used in the industry and profitable. Supporting interoperability is a lower priority. Therefore, the underlying data structures of each application are quite different. This was confirmed by farmers who explained that sending data from one application to another or sending movement-related data (such as the originating and destination farm of recently bought/sold animals) from their farm recording system to NAIT is always cumbersome. At the national level, due to the non-integration of animal movements and animal disease management systems, officials reported facing difficulties in managing the MBovis spread.

4.2.1.3 Data stored in centralised systems

None of the farmers or other stakeholders mentioned this topic as a challenge but one interview participant commented that storing data in central locations is common practice these days and that hardly anyone sees it as a challenge.

4.2.2 Relationships

4.2.2.1 Participants' varying attitudes

Interviews revealed that traceability information recorded by farmers varies significantly. The reason for the differences included varying attitudes about traceability, commercial and/or legal reasons. For some farmers, recording traceability information is just a regulatory burden while for others, it is an absolutely necessity for the survival of the industry. U1 said, *"When we speak to farmers and industry and say, 'What value do you get from NAIT?' the answer is 'Nothing, it is a regulatory burden'."* U1 further continued, *"we couldn't have tackled the eradication of Mbovis, without NAIT"*

For instance, farmers who sign up for premium supply programmes such as organic or antibiotic-free meat are required by their contracts to record every medication they administer to animals. However, if the business does not trade as 'antibiotic-free', farmers would probably not record health data strictly. It was also revealed that convincing various stakeholders in the animal supply chain to record traceability data accurately is challenging. Farmers would sometimes choose to pay fines rather than painstakingly record traceability data. Haulage truck drivers do not believe that they should be involved in any traceability recording. According to SD1, farmers rarely update animal movements in NAIT at the right time. By the time the receiving property records that a herd of animals have arrived at their farm, if the sending property had not updated their systems to say that a herd has left their property, information discrepancies occur in NAIT which need manual intervention to resolve.

4.2.2.2 Verifications by third parties

Interview participants mentioned that verifications by third parties take place but none of them mentioned it as a challenge. Instead, they accepted it as the norm.

4.2.2.3 Privacy concerns

Privacy was a topic of interest for many interview participants. F2 said "*we have a stock agent in the middle and that's his or her interest to make sure that we don't develop a relationship with the purchaser – because you know, that's their livelihood*". F2 had requested health data for the animals they had recently bought but the other party had not responded to that request. F2 suspects that the other farmer does not want to share that information as it will reveal previous health problems of the animals.

ST1 added that farmers wish to see the traceability details of animals such as their previous movements even before buying but currently, it is not possible to do so as that information is kept private by the stock agents. U4 confirmed that sellers and stock agents prefer that arrangement as they seem to think that it is confidential information that could negatively affect sales. At the industry level, some companies have access to large pools of data thanks to the industry-wide use of their IT systems. Although the information they hold, especially trends and summaries of data, could be useful to everyone in the industry, it is not freely available outside their proprietary databases due to data privacy concerns. U3 had a specific legal problem. They collect animal carcass data, and they are happy for the industry to make use of that data but are hindered by the Privacy Act.

> *"…the challenge we've got in more recent times is the Privacy Act. So that information now is actually all over. That's all owned by the farmer, it's their information. So, if we want to make it available to the market, we have to get the farmer to sign a piece of paper releasing, you know, saying, Look, I'm happy to share that information…"*

Thus, privacy concerns hinder participants from accessing the data they want before making buying decisions.

4.2.3 Transparency and compliance

4.2.3.1 Transparency of participants' actions

Interview participants did not mention the transparency of actions by participants as a challenge.

4.2.3.2 Validation of recorded data

Many participants seemed to think that the industry relies on trust in many instances instead of the data recorded in the supply chains. For instance, farmers who have signed up for high-value labels such as 'organic' and 'antibiotic-free' mentioned that the validation of labels happens through random checks by the certification agency. It was also mentioned that once an agreement is signed, it is merely a matter of trust rather than facts that ensure the label claim is respected.

> *ST4: It is more of a declaration than any way and we can't be on the farm to watch what cows have been eaten. We audit those farms once a year…*

Interviews revealed that it is extremely easy to get wrong data recorded and, when that occurs, it is hard to detect. For instance, ST1 questioned the validity of weight data recorded as farm weighing systems are not certified. They suggested having a certification system around farms to validate the weights recorded. The suggestion was to certify the locations where the weighing scales were installed and then, every animal whose weight was recorded from that weighing scale can be recorded as having verified weight information.

Another interesting revelation was how incorrect data is treated when identified. ST1 mentioned that sometimes they identify incorrect data through animal tags. For instance, the animal tag may indicate that the animal is six years old, but the animal is recorded as two years old. When that happens, they just record it as an anomaly in the system and move on.

Together with the challenge of understanding if the recorded data is correct, interpreting the data that is not available is a challenge identified by the interview participants. For example, during the MBovis investigations, some farms were thought to be free from Mbovis as there was no record of it being exposed. However, the truth may mean that the farm was never tested for Mbovis.

> *F2: …they're only clear of Mbovis because they've never been tested…*

Farmers also mentioned scenarios where buyers challenged their animal data. One farmer mentioned a scenario where they weighed the animals before a sale but when the buyer weighed the animals after the sale, the weights had drastically changed. The buyer maintained that the weights were incorrectly recorded but the farmer had recorded weight correctly as far as they were aware.

4.2.3.3 Tracking law abidance

The interview participants did not discuss directly whether laws are followed but many talked about few or no repercussions or penalties for not recording animal data. Many commented that sometimes, recording is not given much attention because the adherence to laws is either not consistently audited or the penalties are not high.

4.2.4 Visibility

4.2.4.1 Food safety and quality

Interviewees revealed that current practices in both dairy and meat industries hider visibility and as a result, food safety and quality are affected. For instance, U2 explained that a batch of meat in slaughterhouses usually denotes a set of animals processed in a specific timeslot; sometimes, this may include animals from different farms. This increases the risk of contamination and if meat from a particular farm had to be recalled, makes the process tricky as the recording systems do not contain the individual tags of animals who were slaughtered within a specific timeslot. In the dairy industry, tankers collect milk from several farms and pour them into tanks at the processing facilities. If a lab finds an issue at the processing facility, the whole tank of milk is discarded for safety reasons. Thus, in order to maintain food safety and quality, dairy manufacturers incur losses.

Some recording practices such as recording animal health treatments at herd level are influenced by the business processes and the features available in the animal health recording applications. For instance, treatments such as drenching are carried out in herds or mobs. Recording such treatments at the herd/mob level is easy, close to the reality and is supported by animal health recording applications. However, from a food safety perspective, recording data per animal is preferred by some stakeholders due to food safety concerns. For instance, if a recall is activated for animals treated with a specific medication, herd/mob level recording prevents isolating such animals. The software developers acknowledge these requirements, but they warn that changing the existing practices can incur more costs and require training staff. SD1 said *"…that requires not just farmers doing a lot of traceability work, but that requires quite a big investment and process change…"*

In summary, many interviewees felt that the current processes need a drastic change, and that manual intervention is necessary to improve the food safety and quality.

4.2.4.2 Origin of food products

Several participants mentioned that the ideal traceability system would allow a piece of steak eaten at a restaurant to be traced back to the animal's farm. However, they all agreed that it is hard to achieve with the current systems. A slaughtered animal can be traced back to the abattoir and the animal's last farm but tracing an animal back to the farm where it was born is almost impossible.

One dairy industry interviewee mentioned that they have systems in place to track milk from a bottle to a farm where the animals are raised. However, they commented that it took a lot of time, money, effort, and drastic changes in their work processes to achieve that.

Apart from all the practical challenges, some felt that the challenges in the NAIT system make it difficult to track a piece of meat back to the farm where the animal was born. U3 said: *…we can't make a label claim in the market with absolute confidence 'back to farm' just because the NAIT system is still challenging…*

Further, animal behaviour can add complications. For example, some animals may jump into other paddocks where animals treated with specific medications are kept. When that happens, there is hardly any way for the farmer to know that an untreated animal has joined a treated group of animals. Another scenario is the mingling of stock during transport. Farmers noted that it is very easy to get animals mixed up and put into the wrong trucks.

However, successful attempts are being made to achieve at least regional traceability. One organisation claimed that they provide region traceability information for their meat products to a foreign market. They hope to gain more market share overseas by providing a mechanism for the consumers to know which farm or at least the region where the animal was raised.

In summary, interview participants expressed that achieving 100% visibility is challenging due to the existing systems and processes in place.

5 DISCUSSION

The purpose of this section is to address the main research question by comparing the findings of the literature analysis (Step 1) and the interviews (Step 2) summarised above. The section is organised by the four major themes identified in the Findings section (Chapter 4).

5.1 DATA MANAGEMENT

5.1.1 Data recording

Interview data supported the claims in the literature that data collection is highly challenging. A blockchain-based system integrated with smart contracts and IoT can address some of the New Zealand challenges related to data recording. For instance, the lack of time and trained staff can be addressed by automating the data collection using sensors (Feng et al., 2020; Rejeb, 2018). Smart contracts can help improve the accuracy of the data by warning users when the collected data seem inaccurate and incentivise data recording. However, blockchain technology does not yet offer substantial solutions to operational challenges such as animal tags falling off and the lack of data connectivity. However, it is promising to see that investigations have already started to find ways to use blockchain technology with poor network connections (Igboanusi et al., 2021; Nguyen et al., 2021). Using solar/wind energy as a power source is suggested by some authors but the initial set up cost will be very high (Bumblauskas et al., 2020).

In summary, blockchain technology can improve traceability data recording in New Zealand but to do so, operational challenges such as low network connectivity must be resolved first.

5.1.2 Data stored in independent systems

Interviews supported the claims in the literature that managing data in independent systems hinders traceability. The literature suggested that storing data in a distributed blockchain system would help address this problem. Theoretically, blockchain could be a solution but the interviews hinted that it could be challenging to motivate competing software platform developers to store data in the same distributed system. Software vendors are often motivated by profit, and without any financial benefits, they would not be interested in supporting an industry-wide traceability system. The literature suggests that individual software vendors can maintain their own data storage systems while the common traceability data is stored in a blockchain (Azzi et al., 2019). This requires every software package or system to use the same data format or "back end". As the first step, New Zealand already has started standardising agriculture data formats (AgriTech New Zealand, 2020). In summary, blockchain can be an effective solution for data that is stored in separate independent systems.

5.1.3 Data stored in centralised systems

Centralised systems were considered the norm by the interview participants and the ability to edit data and make them easily available to others was seen as an advantage. Although blockchain is designed to store data immutably, that requirement can be satisfied with systems that enable modifications of data through recomputed blockchain hashes if all the participants consent (Ferdousi et al., 2020). Alternatively, systems can use arbitrators who have the authority to remove or modify data in the event of a dispute (Shahid et al., 2020). Therefore, blockchain technology can satisfy New Zealand data sharing needs without using a centralised system.

A summary of the data management discussion is shown in Figure 13.

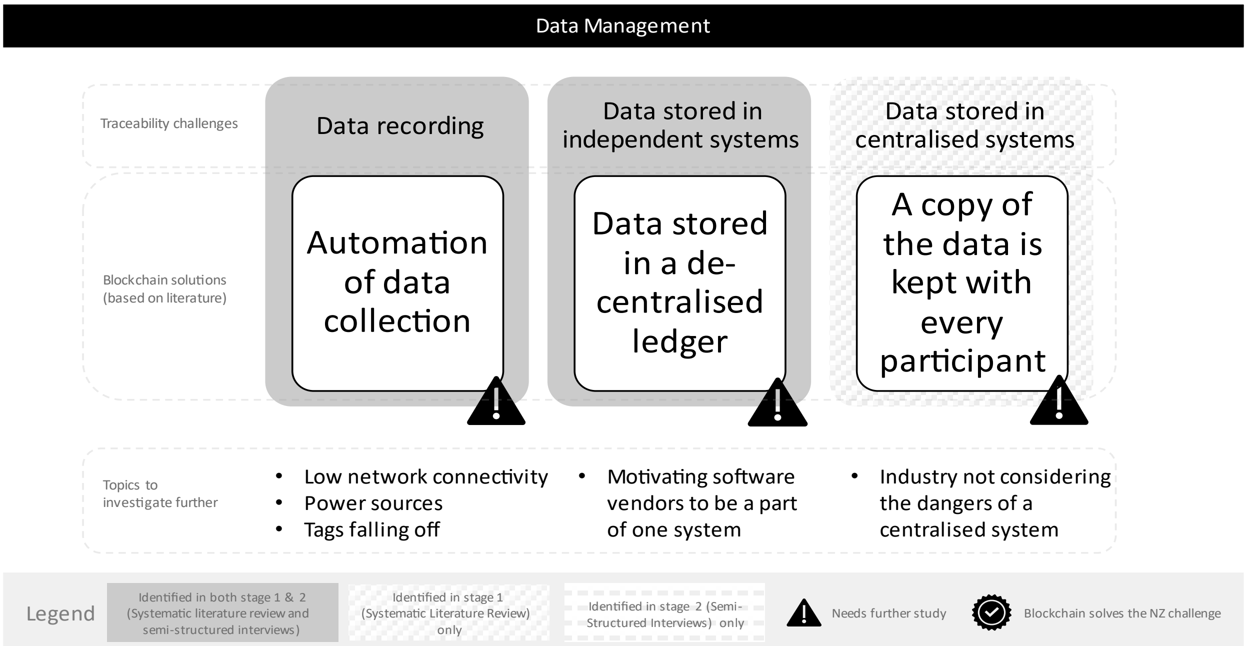

Figure 13: Data management summary

5.2 RELATIONSHIPS

5.2.1 Participants' varying attitudes

Although the literature suggests that there are varying attitudes to traceability, the reasons behind those attitudes were only revealed through the interviews. Unless there is a sensible regulatory or a commercial reason, farmers consider that procedures relating to traceability are a burden. However, the challenge is that when traceability data is needed, not having them readily available leads to disastrous outcomes such as the MBovis outbreak where authorities found it difficult to trace and isolate animals/farms who were affected. Currently, the value of traceability data that farmers record is not apparent to them unless there is an emergency such as MBovis. As suggested in the literature review, blockchain systems can help the industry realise the importance of recording traceability data (Creydt & Fischer, 2019). This concept has already been trialled (Cao et al., 2021). Before ordering an agri-product, buyers can check the quality of the goods based on what is recorded in the blockchain. When the buying decision is based on the data recorded in the blockchain, sellers are motivated to record accurate data because they understand its worth. Thus, a blockchain-based traceability system can help educate all users involved in the livestock supply chain about the value of traceability data. Therefore, a blockchain system could be the answer for varying attitudes on traceability.

5.2.2 Verifications by third parties

The literature identified that verification by third parties hinders the efficiency of livestock supply chains, but the interview participants did not. They accepted verifications by other parties as the norm. The reason could be the non-awareness of participants about how easily verifications can be carried out by integrating IoT devices with a newer technology like blockchain. Many farmers think that technology-based verification systems does not work. For them, manual verifications are an easy and fool-proof method. However, the New Zealand government is investing in research to automate meat quality measurements (AgResearch, 2016). When combined with a tamperproof recording system such as blockchain, these automated quality measurements can reduce the need for third party verifications. Government involvement is promising and validates the view in the literature that verifications can be carried out without human intervention. However, more research is recommended to understand if verification by third parties is a problem that needs a technical solution.

5.2.3 Privacy concerns

Many interviewees reported that they do not have access to the data they need because, for privacy reasons, the data owner does not wish to share the data. On closer inspection, the resistance to data sharing appears to be based on commercial reasons. For instance, stock agents prefer not to reveal the farm where the animals are raised nor their previous health records to prevent buyers from affecting their business. Scenarios like these can easily be solved with blockchain based systems that employ smart contracts. For instance, if buyers know what type of animals they are looking for, a smart contract could be set up to pre-purchase animals that meet the defined criteria. That way, only the required data is accessed. By using smart contracts and privacy controlled blockchains, both parties can ensure that only the necessary data is revealed to the other party (Khan et al., 2021; Nazarov et al., 2019). For instance, a buyer's smart contract could be programmed to buy animals that have not resided at more than two farms. The smart contract will select animals that match the criteria but could be programmed to not reveal the identity of the farms. Thus, a blockchain implementation could be a win-win solution for those who need data for decision making and those who have second thoughts about sharing that data. Therefore, blockchain can possibly address the privacy concerns in the existing livestock traceability system.

A summary of the relationships discussion is shown in Figure 14.

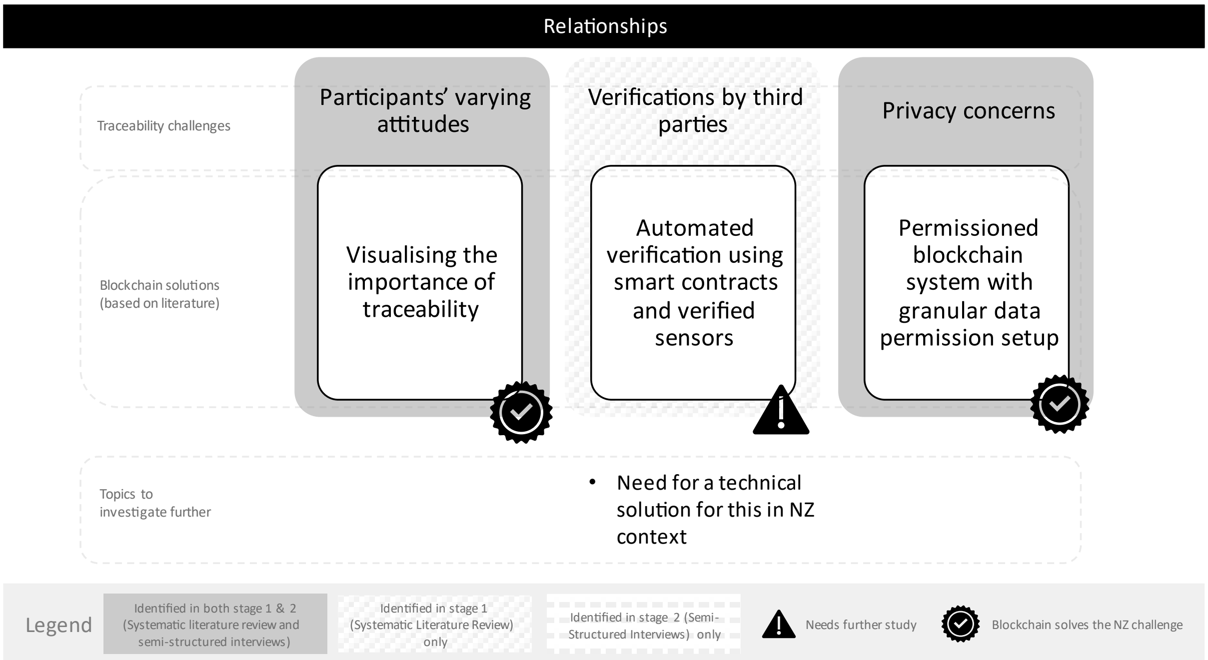

Figure 14: Relationships summary

5.3 Transparency and compliance

5.3.1 Transparency of participants' actions

Interview participants did not discuss the transparency of participants' actions along the livestock supply chain. That may be due to the trusting nature of New Zealanders. Some companies have made detailed traceability data available to overseas consumers to gain their confidence (Fonterra, 2017). This shows that outside New Zealand, transparency of participant actions is considered important. With a blockchain system, the same level of detail can be made available to both local and international consumers. Given that livestock-based products constitute a high percentage of New Zealand exports (The International Trade Administration, 2019), it is important to ensure that transparency of actions is built into New Zealand's traceability system. A blockchain system could ensure such transparency however, more research is recommended in this area to understand how this theme relates to New Zealand context – does it occur in other forms or why is this not a challenge in New Zealand?

5.3.2 Validation of recorded data

Both the literature review and the interviews suggest that the validity of recorded transactions is questionable. Many still rely on labels, signed contracts and mutual trust. A blockchain system would help validate the recorded traceability information but it is important to plan how the system would handle the need to correct mistakenly added data, as blockchain systems are known for immutability (Hofmann et al., 2017). Research on editing a blockchain record is promising (Gricenko, 2020; Workie & Jain, 2017). Therefore, a blockchain-based livestock traceability system can ensure that recorded data is valid and accurate.

5.3.3 Tracking law abidance

The interview participants did not talk about adhering to laws and regulations. The reason might be that many of them are not in the exporting business. However, a blockchain-based trading platform as suggested by the literature has the potential to assist international trade. It is promising to see that the industry is already moving in that direction with international data standards whereby all participants record the traceability information in the same format (Cooke, 2020). Consequently, any participant can query data to check if the livestock product adheres to their local laws, or better yet, use a smart contract to control which livestock products can be imported to a country. However, upgrading the traceability system to that level means significant investment in process changes as every action at every stage of the supply chain must be recorded. Therefore, more research is needed to understand mandatory data that should be recorded in New Zealand and the cheapest way to record them accurately.

A summary of the transparency and compliance discussion is shown in Figure 15.

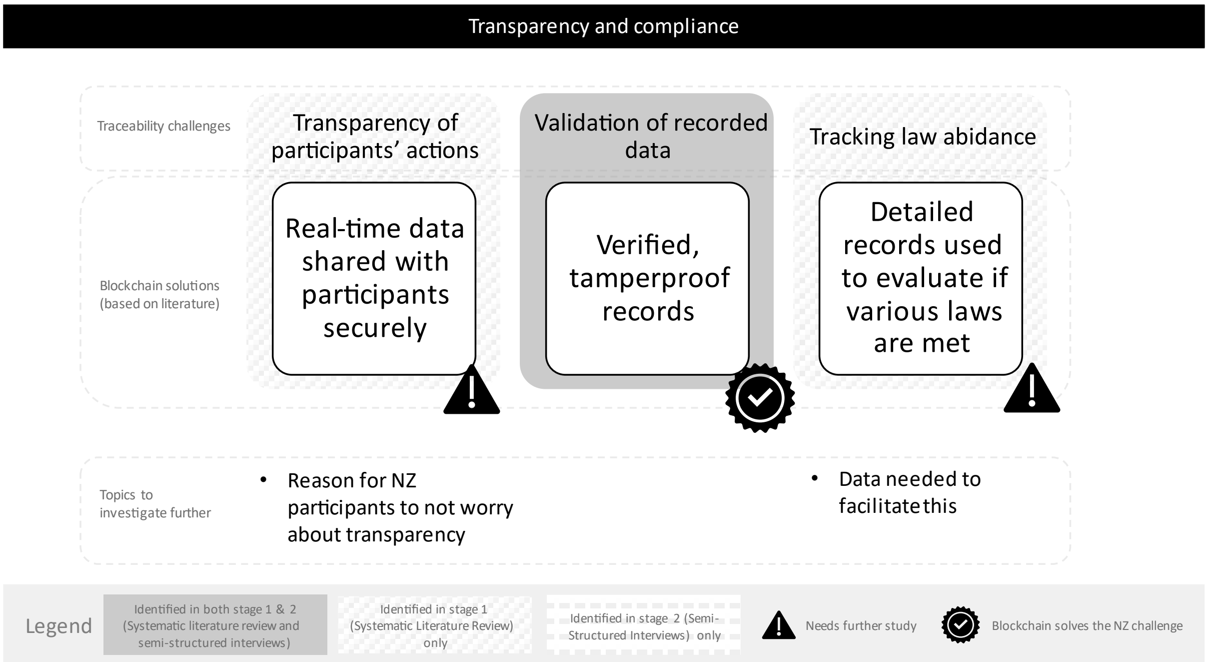

Figure 15: Transparency and compliance summary

5.4 VISIBILITY

5.4.1 Food safety and quality

Although the challenges discovered during the literature review, such as the inability to trace products rapidly in the event of a recall and discovering inadvertent contamination, were reiterated during the interviews, many participants felt that tracking a pack of meat to its original farm and detecting contamination is almost impossible under the current regime. However, a blockchain implementation along with smart contracts and IoT devices can enable fast tracking of goods back to their source and identification of contamination (Azzi et al., 2019; Fortuna & Risso, 2019). This highlights the importance of consumer as well as industry awareness of latest updates in livestock traceability. When consumers and the industry are aware of the technical possibilities, instead of rejecting ideas as impossible, they may start trying to overcome problems with technical solutions.

5.4.2 Origin of food products

Both the literature review and the interviews confirm that tracing livestock products back to their originating farms is challenging. Although the literature suggests possible ways of overcoming the challenge via blockchain such as keeping tamperproof records generated via verified sensors, it involves significant process changes and hence a big cost. As farmers already find the existing system too cumbersome to use, they may not be willing to invest in a more advanced system. On the other hand, when businesses are motivated by profit, they do not hesitate to invest in better traceability as explained during the interview with a representative from a meat exporting business. Therefore, solving the origin tracking problem via a blockchain-based system is possible. Eventually, that will lead to better traceability and low-cost origin tracking.

A summary of the visibility discussion is shown in Figure 16.

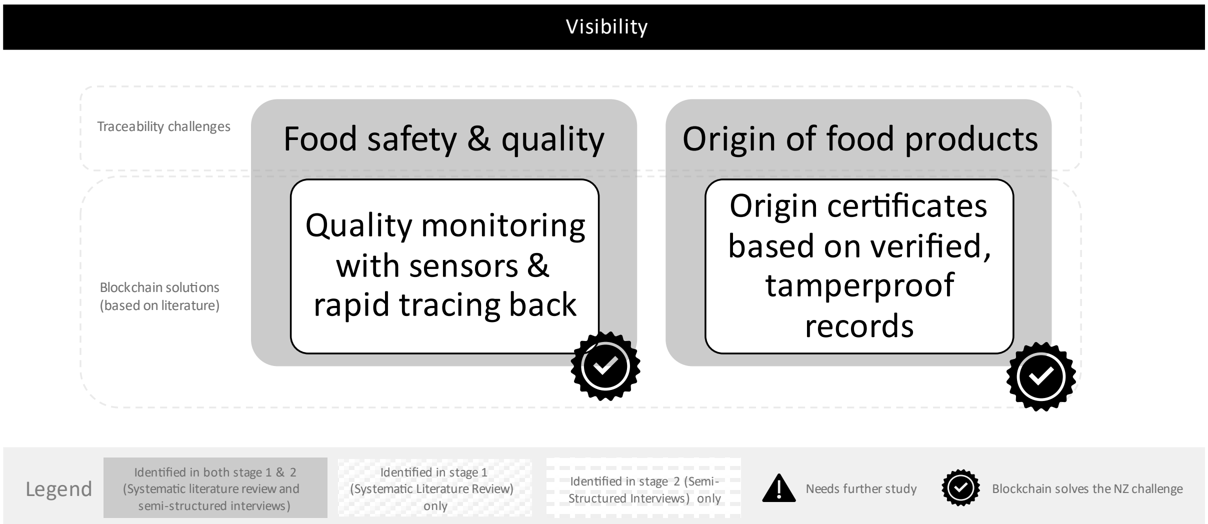

Figure 16: Visibility summary

6 LIMITATIONS AND FUTURE RESEARCH

This section discusses the limitations of this study and outlines suggestions for future research.

6.1 FOCUS ON SPECIFIC SEGMENTS OF THE SUPPLY CHAIN

This research is focused on the traceability challenges faced by suppliers, processors, policymakers and software developers involved in the livestock supply chain. The end-consumer and retail perspectives are not considered. This might also be the reason why some challenges had to be categorised as needing further study in the Discussion section. Therefore, more research is needed to study how blockchain technology can be adapted to meet their needs. Further, this study identified that implementing blockchain technology will incur a considerable cost. At least a part of that cost will have to be borne by the end-consumers. Research to investigate if end-consumers are willing to share the cost of an improved traceability system would be an interesting future investigation.

6.2 FOCUS ON NEW ZEALAND CONTEXT

As this study has a New Zealand context, the results may not be fully applicable to other countries. However, some topics covered in the research are of interest beyond New Zealand. To achieve a sense of generality and understand common traceability challenges in other parts of the world, similar research in other contexts is needed.

6.3 QUALITATIVE DATA

As qualitative research, this study offers rich insights to the topic. However, the findings cannot be supported by statistics. If similar studies are conducted in other contexts, the qualitative nature of this study makes it difficult to compare results. A similar study conducted by employing quantitative methods will help quantify the results and facilitate the comparison of results in different contexts.

6.4 FOCUS ON BLOCKCHAIN

This study only evaluates blockchain technology as a potential solution for traceability challenges in New Zealand. It does not investigate if there are other technologies that could potentially solve traceability challenges and does not compare blockchain with any other technology. Therefore, to complement this study, research exploring other technical solutions for New Zealand traceability challenges is recommended.

7 CONTRIBUTION

The purpose of this section is to illustrate the contributions of the research to the knowledge and the industry.

7.1 CONTRIBUTION TO KNOWLEDGE

This study makes three contributions to knowledge. Firstly, it identifies and categorises New Zealand's livestock traceability challenges – an area that has received very little scholarly attention. This research addresses that gap by gathering insights directly from the major parties involved in the traceability aspect of the livestock supply chain.

Secondly, the study adds to the growing body of blockchain research, which often claims, theoretically, that blockchain technology is an ideal method to improve livestock traceability (Lin et al., 2018; Picchi et al., 2019; Shew et al., 2021; Tian, 2016; Yang et al., 2020). Earlier research is often conceptual and promotes blockchain as a solution to all traceability problems. This investigation takes a real-world approach and, therefore, a more nuanced view of how blockchain technology can or cannot address traceability problems is presented. Further, based on the interviews, additional considerations when implementing a blockchain-based solution for New Zealand are identified.

Thirdly, the study considers three perspectives to emphasise that a blockchain implementation can potentially address challenges faced by many parties. This helps to identify potential implementation challenges for each participant group.

7.2 CONTRIBUTION TO INDUSTRY

The study contributes to the livestock trade in New Zealand and beyond. Firstly, for policymakers, the study supplies insights into challenges faced by various parties involved in the industry. It also shows what farmers think of current regulations and can prompt useful discussions. These insights can help shape future policies.

Secondly, for those who develop and design traceability software and hardware systems, the study supplies insights on how their systems perform in the field. It provides an opportunity to research ways to improve the usability of existing systems.

Thirdly, this study increases awareness of the priorities and constraints of various stakeholders in the livestock industry. In doing so, it highlights the importance of a taking a holistic approach by considering viewpoints of all the stakeholders when developing a new traceability system to overcome existing challenges.

In general, the research illustrates that the actions of every participant have an impact on the overall traceability of the system. Every supply chain participant needs to understand that each participant may have their challenges and that their actions could be the root cause of another participant's difficulties. Thus, the study motivates all parties involved to work towards finding solutions to existing challenges and hints that an adoption rate of a new system could be low if existing issues are not addressed. The study also highlights the importance of context by emphasizing that the New Zealand domestic livestock industry runs on trust, whereas in other countries that may not be the case.

8 CONCLUSION

This study contends that the New Zealand livestock traceability system is due for an upgrade. The current practices and the system hinder the traceability of animal-based food products in New Zealand. The dissertation illustrates the traceability challenges experienced by various parties (such as farmers, software developers and other stakeholders) in the livestock supply chain. Difficulties related to data and relationship management, transparency, and visibility are identified and methods for addressing them using a blockchain-based traceability system are discussed. Almost every New Zealand issue was found to be able to be dealt with by a blockchain-based system, provided that workarounds are planned for problems such as low network connectivity and lack of power sources at rural locations.

Industry requires a set of easy-to-use applications that are well integrated, or one application that can handle various types of animal data such as health and movements. The goal is to ensure that the right data is available to the right person at the right time. Automation of most tasks is preferred to reduce both labour costs and human error. Improved management of food recalls, disease outbreaks, food quality/safety, and origin claims are other expectations of a traceability system. Further, assurance that the collected data is accurate, tamperproof, and verified is highly valued.

As discussed, a blockchain-based traceability system can help address most of those challenges. However, costs involved in business process changes and hardware upgrades can be substantial. Nevertheless, improvements in the availability of accurate data can increase business profits by reducing costs associated with food recalls, disease outbreaks and quality monitoring. Therefore, increasing industry awareness of a blockchain-based traceability system is important. A blockchain system integrated with smart contracts can also motivate supply chain participants to contribute to the accurate recording of traceability data. The collected data can then be used efficiently to manage disruptive situations such as food recalls and animal diseases.

So far, livestock traceability has been about how disciplined humans are in recording the life story of animals. In the future, it is going to about how accurate machines are in recording data. Although challenging, switching to a blockchain-based system today will help futureproof New Zealand's livestock traceability system.

9 Appendix

9.1 Selected articles for the systematic literature review

Title of the paper	**Supply chain context**	**Reference**	**Journal**
1. The power of a blockchain-based supply chain	Fish	(Azzi et al., 2019)	*Computers & Industrial Engineering*
2. A blockchain use case in food distribution: Do you know where your food has been?	Egg	(Bumblauskas et al., 2020)	*International Journal of Information Management*
3.Blockchain and more - Algorithm driven food traceability	Food in general	(Creydt & Fischer, 2019)	*Food Control*
4. Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges	Food in general and poultry	(Feng et al., 2020)	*Journal of Cleaner Production*
5. Application of Blockchain and Internet of Things to Ensure Tamper-Proof Data Availability for Food Safety	Plant and animal-based food	(Iftekhar et al., 2020)	*Journal of Food Quality6.*

6. Potential blockchain applications in animal production and health sector.	Animal based food	(Makkar & Costa, 2020)	*CAB Reviews*
7. Technological Decentralization and Livestock Data Management in Kenya: The Moderating Effect of Blockchain Technology	Livestock data management	(Muganda et al., 2020)	*International Journal of Advanced Research in Computer and Communication Engineering*
8. A business model analysis of blockchain technology-based start-up	Livestock data management	(Park & Sung, 2020)	*Entrepreneurship And Sustainability Issues*
9. Blockchain-Based Traceability and Visibility for Agricultural Products: A Decentralized Way of Ensuring Food Safety in India	Plant and animal-based food	(Prashar et al., 2020)	*Sustainability*
10. Blockchain Potential in Tilapia Supply Chain in Ghana	Fish	(Rejeb, 2018)	*Acta Technica Jaurinensis*
11. The acceptance of blockchain technology in meat traceability and transparency	Meat	(Sander et al., 2018)	*British Food Journal*
12. Blockchain-Based Agri-Food Supply Chain: A Complete Solution	Food in general	(Shahid et al., 2020)	*IEEE Access*

13. Blockchain Technology in the Food Industry	Food in general	(Fortuna & Risso, 2019)	*Emerging Issues in Management*
14. Thai Agriculture Products Traceability System using Blockchain and Internet of Things	Livestock data management	(Surasak et al., 2019)	*International Journal of Advanced Computer Science and Applications*
15. A Permissioned Distributed Ledger for the US Beef Cattle Supply Chain	Beef	(Ferdousi et al., 2020)	*IEEE Access*

9.2 Quotes from interview participants

Theme	Sub theme	Code name of the interview participant and the quote
Data Management	Data Recording	• F1 – “lack of mobile coverage and internet in areas too makes things challenging”
	Data stored in independent systems	• F2 – “it'd be nice to think that we could integrate them so that you're only recording at one place, we use Cloud farmer for recording the medical data, or the any animal health data. And we use the scales themselves to record weights. Scales come with a weighing program”
Relationships	Participants’ varying attitudes	• F1 – “if you could record, record that in the cloud to the NAIT number - That would be quite good. But yeah, I don't think NAIT's got that capability at the moment. And I don't think farmers have got the willingness to, to do that to be fair” • U1 – “the older generation of farms, they understood the core foundations and principles, traceability was important because they'd gone through movement control areas and not been able to get their product to export market. But the current generation does not know that”
	Verifications by third parties	• U2 – “farmers will sign a essentially a legal contract to say that that's the process they use for the way they're going to train those animals. And we will use somebody like a show quality to audit a certain number of farms each year, to make sure that they comply with those requirements, but yeah, aside from that, unless you audit every single farm every single time they supply some livestock to this doesn't necessarily guarantee”

		• U3 – "if you're supplying a program that has a requirement for a mark for a label claim, they may they will randomly choose a farmer. And they'll ask you to show you the Rick the declarations. If it's a whole of life claim, they will go back to that farmer and ask the farmer to see his records" • U4 – "it's more of a declaration than any way and we can't be on the farm to watch what cows have been eaten"
	Privacy concerns	• SD 1 – "we should be able to ensure that data is not accessible by other parties" • F 1 – "some farmers do not like their data to be accessed by other parties. So they'd like to keep the data in their hands" • F 1 – "I don't think farmers have got the willingness to, to do that [Make their data available to other parties] • F 2 – "we have a stock agent in the middle and that's an his or her interest to make sure that we don't develop a relationship with the purchase – because you know, that's their livelihood" • U 4 – "dairy industry is a data intense industry now, they have worked out that through, getting the genetics, right. And if you look at a cow, sounds very inhuman but look at a cows conversion unit of grass to protein. And that's what the genetic analysis and breeding they've managed to get it so they know what breeds and what genetic variations will generate the best conversion. But that information is not shared very freely. And it's held with proprietary systems and DIGAD national database" • U 4 – "we've seen out of MBOVIS more farmers wanting to know the history of an animal from the biosecurity perspective. Before they bring it on farm. They often don't get experts in the information until the animals on the property and they've created receivables. And the records have been transferred. It's too late animals already there"

Transparency and compliance	Validation of recorded data	• U1 – “one of the things that's coming out around in this logic mapping sessions around data quality is the need to do point in time verification of animal location. We should be unlocking that info and attaching to an animal record”
Visibility	Food safety and quality	• U3 - “if we made an antibiotic free claim, and let's say somebody bought a steak in the US, and they had the technology to check residual, and they found residual antibiotic in that one steak, then I honestly don't see how we'd ever find the cattle beast that it come from because that one steak would go back to the you know, to the primal cut, the primal cut's then gonna be linked back to the animal, before you could even begin to actually work out where the farm was”
	Origin of food products	• F1 – “when someone's in a restaurant eating your steak, you want them to see that this come from this place and a picture of your hill, but I could be wrong, but I don't think you can trace a bit of steak back to its property” • U2 – “we would love to be able to go back to, you know, beyond the processing plant back to the farm that it came from, and ultimately back to the animal”

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