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Social Trust in Property Ownership: A Study in The Kingdom of Saudi Arabia

by

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Abstract

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Ownership refers to the legal rights, obligations, and interests, all of which are formally recognised by a legal system. The regulation of property ownership dictates access to and control over land and other resources. In modern society, property ownership relies heavily on technology for identifying, record-keeping, and verifying property ownership to ensure compliance with the legal system. However, this reliance on technology introduces challenges such as fraud, incorrect information, and potential challenges like double sales as technology continues to advance. Further challenges can be encountered when it is regulated by several governmental entities to secure ownership. This research focuses specifically on the legal system in the Kingdom of Saudi Arabia, acknowledging the global nature of challenges but tailoring the investigation to the unique context of this region.

To address the challenges inherent in the land registration system, the research proposes a STF. Unlike existing approaches that primarily lean on technology, this framework delves into the underlying factors contributing to challenges and identifies key considerations for establishing a safe process for transferring ownership. The framework encompasses four categories of social needs for trusting systems: organisation, provenance, technical, and legal. Each category comprises a set of factors that should be considered during the development of the system. Importantly, this framework is designed in alignment with the interests of stakeholders who regularly engage with the systems and is validated by experts in governmental entities. The validation process is based on qualitative data and analyse using thematic analysis.

The STF supports the analysis of user requirement specifications to identify the necessary requirements. The user needs are analysed to identify the requirements needed using the scenario-based approach of transferring ownership, with the knowledge that this scenario avoids the challenges outlined. The identified requirements serve as essential inputs for constructing models using the Event-B formal methods, a mathematical approach that ensures the correctness and consistency of the requirements. The formal model is built using a correctness-by-construction methodology, that allows the

deduction of assurances for the trustworthy process of transferring ownership. The model undergoes evaluation by formal method specialists to guarantee the construction of an accurate model through the utilisation of discount expert review. Applying the formal method significantly affects system development. It aids in articulating implicit assumptions and clarifying system requirements. They highlight challenges with system requirements, and their rigour helps to understand the challenge better. Additionally, the formal method reduces implementation time and error by a large amount.

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List of Abbreviation

BCE Before the Common Era

KSA Kingdom of Saudi Arabia

MoJ Ministry of Justice

MOMRA Ministry of Municipal and Rural Affairs

NAFATH Saudi National Identity Provider with solid way of identifying people online with unique digital identity

PIS Paper Information Sheet

Provenance factors Related to records that provide a description of the individuals, organisations, entities, and actions associated with the creation, authority, or distribution of a certain piece of information or object.

REGA Real Estate General Authority

SRS System Requirements Specification

STF Social Trust Framework

UML Unified Modelling Language

Declaration of Authorship

I declare that this thesis and the work presented in it is my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signed:..... Date:.....

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Chapter 1

Introduction

Ownership refers to the legal rights, obligations, and interests recognised by a legal system [Honoré, 2013]. Property ownership, in its broadest sense, refers to the regulation that controls who has access to ownership of land and other resources [Waldron, 2023]. These regulations are disputed in regard to either boundary, land-use, or failure of proof ownership. These disputes cause challenges in property justification. The challenges vary according to the legal system. This chapter presents **a thorough overview** of property ownership through reforms according to the geographical locations. These reforms contribute to forming the concept of private ownership and develop the idea of the identity of the property ownership despite who are the owners. Then the research problem is presented. The research question is defined and the contributions of that research that are achieved.

1.1 Motivation

The concept of property ownership has dramatically changed over the centuries. It may vary depending on the region during the same period of time. Ownership and owner of a thing are defined according the legal system or public recognise. Owners of a land in one region would not be the same uses and benefit in another region although they own the land. The relationship between owners and ownership is defined according to the legal system.

Modern ownership relies heavily on technology to identify or record ownership and verify that properties are used in accordance with the legal system. However, as technology advances, managing property ownership faces new challenges. Understanding the problem's context is necessary before taking any action when technology is involved.

In the past, property, or more specifically, land, was scarce, and people could use it to meet their needs. Land provides essential needs for humans. It is the primary source of food supply in agricultural lands, with water and wealth extracted from beneath the land; it also gives people space to build their shelters and conduct trade. Using land is vital in human societies.

Land tenure has been reformed over the past centuries. The reforming of land tenure varied across regions, time, and disputes or conflicts that occurred because of conquering or seizing. While there were similarities in the use of land in different parts of the world at the same time, every region had its own approach to land tenure. Understanding the land reform lead to understand the concept of modern ownership and the disputes that cause the challenges in nowadays.

1.1.1 Land Tenure Reform in BCE

In early societies, some regions were dominated by customary tribes and others were under empire control. On the one hand, in Africa, south of the Sahara, for example, the lands were abundant and people tended to immigrate from one place to another as they grew, despite the fact that their lands were suitable for life [Powelson, 1988, p.260]. The lands were owned by a family or tribe whereby a general agreement was assigned to the tribal chief or elders. The agreement was based on custom, because the land was not considered as a precious commodity and there was not even a market for it. Therefore, the need for writing a law to control the land was not considered, because lands were abundant [Powelson, 1988, p.276].

On the other hand, in the Chinese Empire, the rules for holding the land were different. By law, all land belonged to the emperor, and said lands were assigned equally to people for producing crops or shelter, whereas emperors granted more land to relatives whose support they needed. Interestingly, the rules did not stand for a long time, because the rules of land tenure were plagued by bureaucracy, where the land was granted more to their proponents [Powelson, 1988, p.164].

The possession of the land, however, was different in the ancient Roman Empire. Rome was the first ancient society that registered land using the law. By law, the land was abstractly declared the right, obligation with land, and transferable with it. Although the land tenure was different in each province, private land ownership appeared in Italy. The private ownership was not for protecting the possession's rights, but it was easier to tax than communal land [Powelson, 1988, p.34].

1.1.2 Land Tenure Reform from Medieval Era to Present

During the medieval era, growth in population and heritage had influenced the land tenure system. Customary tribal and authoritarian empire land tenure continued in the same manner. In the African Sahara regions, the land was dominated by tribal custom. Because there was no declaring the right of a landholder, their land was easily subject to colonisation by a foreign country. For instance, Dutch East India came to South Africa in 1652 to set up its company in a freehold, and started to colonise the country, which prompted local tribes to resist its domination. Similarly, in the Chinese Empire, the land continued to be subjected to coercive feudalism for centuries, during which the Chinese dynasties were in a cycle; strong in the early stage and by the time the emperor aborted. Following this, a new emperor started because the land was prevailing, given to supporters by grace [Powelson, 1988].

In Northwest Europe, which was part of the Rome Empire province, the land had become scarce. Since people were mainly depending on the cultivation of land for living, and free wages labour was uncommon, people had started needing each other to survive [Powelson, 1988, p.309]. The needs were for those who produced crops, peasants, and for those who managed, organised and dispensed justice for the land, and protected the land from the exogenous force, lords. Thus, a feudalism contract was agreed between them [Powelson, 1988, p.310].

The feudalism contract between peasants and lords had a significant impact on the European economy. It had been transferring land from a means of subsistence into a means of realising a profit on commodity markets after enclosures occurred. These enclosures had distinguished land tenure as being common land or arable plots [Powelson, 1988, p.80] For example, in England, arable plots combine in a block, bond together and are surrounded by hedges or fences rather than being distrusted randomly on fields. However, while these enclosures caused the agricultural revolution, and pushed peasants to improve planting technology, they did not support smaller farmers because of the domination of large farms. This led to an increase in the number of opponents against the enclosures. The opponents then destroyed the hedges that surrounded the farms, which led to rebellions [Powelson, 1988].

After the rebellions, land tenure was reformed, thus giving rise to dramatic growth in the real estate economy. The growth has led to a flourishing of trade, industry, and agriculture. This growth would not be accrued unless there were freedom rights of the individual regarding holding land. These rights were a form of proof which the owner could use against the state. The defining of the right to declare to proof of ownership of a parcel and to whom it belongs, prevented further rebellions [Powelson, 1988, p.82].

1.1.3 Land Reform in Middle East

Land tenure in the Middle East was tribal custom until Islam's emergence in Makkah in AD 622. The emergence of Islam had redefined the concept of land. The land belonged to God, Allah, and was regulated by Caliph, who carried out Islamic obligations. Islamic law defined four categories [Sait and Peters, 2011]:

1. Private ownership, whether acquired by purchase or inheritance.
2. Stated-owned land (miri) where the state is the legal guardian under the trust of the community, which provides a range of access and usufruct rights for ownerships.
3. Endowed land (waqf). Waqf land devotes its benefit to certain people or general welfare.
4. Unused or dead land (mawat) which has no owner but which someone can take ownership of if they cultivate it.

This concept of land has not changed since the emergence of Islam. It has been practised in the Islamic world for centuries. The ideology of Islamic land law is religious and communism-based, where land ownership is structured through land reform with the principle of justice and equality. The practice of land reform was recognised when Prophet Mohammad suggested marking out land with stones beyond Makkah city and fencing of dead land (mawat) property to establish land rights as common practice [Sait and Lim, 2006]. This practice is called Iqta, which is the name of the land redistribution programme [Ridwan, 2019]

The practice of agrarian reform was developed as Islam expanded from the west and east. The expansion of the Ottoman Empire was based on notable land registration. The system was organised on the basis of Sharia Law and consideration of population diversity. The Ottomans divided the population into communities based on geographical, religious and social aspects, aware of the importance of recording land information and allocating land tenure [Cleveland and Bunton, 2009, Powelson, 1988, Hajrah, 1974].The archived information, such as the name of the villages or farms, the name of the landowner, the annual income, type of land, and boundaries, was important for managing the diversity of the regions of different cultures. This information was recorded in a book named Kanunname-I Kitaber-I Vilayet. The land registration system flourished during the Ottoman Empire in the sixteenth century and had a great influence on the economy at that time [Sait and Lim, 2006]

The history of land tenure illustrates the diversity of people's perceptions regarding the meaning of land as precious property. Regions, religions, and heritages shape the

diversity of perception, which in turn shapes the perception of their descendants. Although many nations, including Europeans and Middle Easterners, realised the importance of establishing a system and legislation for managing lands, these were not adequate or stable for a long time due to the massive growth in population [Powelson, 1988].

1.1.4 Land Reform in Arabian Peninsula

The Arabian Peninsula comprises many regions, such as Hijaz in the west and Najd in the middle. Hijaz is the cosmopolitan Muslim region, the cradle of Islam, and home to the two holy cities of Makkah and Medinah. The Ottoman Empire conquered the west coast of the Arabian Peninsula in 1517 and the whole of the west, while Najd and other regions were ignored by the Ottomans until a group of the tribe in Najd, Wahhabi, took control of the Holy cities Makkah and Medinah in 1808 [Vogel, 2000, Cleveland and Bunton, 2009]. This movement led to the Ottoman leader managing to seize Hijaz to restore Makkah from Wahhabi in the sixteenth century, and then to conquer Najd to stop its expansion power [Vogel, 2000]. However, the Ottomans' power was limited because of the domination of local tribal leaders [Eijk, 2010].The Ottomans' domination was enforced by tribal leaders so as to ally with a foreign power and other tribes to end their domination [Eijk, 2010].

After War World I and the dissolution of the control of the Ottoman Empire, the Arabian Peninsula region changed dramatically. By 1932 AD, eighty percent of the Arabian Peninsula had been united under the name of the Kingdom of Saudi Arabia by Abdulaziz, Ibn Saud. The unification started firstly with the conquering of Hijaz again in 1925, which freed it from Ottoman control [Vogel, 2000]; following this, Najd's tribes were combined together under his authority [Cleveland and Bunton, 2009].

The Kingdom of Saudi Arabia was running two legal systems after seizing Hijaz, namely the communal tribe in Najd and the Ottoman system in Hijaz. The legal system in Najd was simple and the cases overall were solved peacefully by a single judge in the main town, whereas the Ottoman code was derived from Sharia Law and influenced by western practice to be adaptable to its needs [Vogel, 2000, Nahedh, 1989]. The King put forth a decree to continue using Ottoman Law only in Hijaz. However, between 1957 and 1960, the law was implemented in the rest of the regions in Kingdom of Saudi Arabia [Eijk, 2010, Hajrah, 1974]. In 1927 the king issued several decrees regarding land and social reform that abolished traditional and tribal land and restored all the tribal land to state control through the Iqta method [Hajrah, 1974].

The early codification of land reform mainly contributed to transferring uncodified lands to urbanisation and increased farm production [Hajrah, 1974]. Therefore, the

distributed lands were insufficiently surveyed, poorly organised, and informally notarised during the distribution of the land, as stated by [Hajrah, 1974].

A revolution occurred in Kingdom of Saudi Arabia with the discovery of oil, with a consequent rapid increase in oil revenue, which the government of Kingdom of Saudi Arabia responded to. This led to a change in the organisation of government and policies, and these included administering and reforming land transactions.

The land registry has carried out several reforms since the creation of the country. The proof of ownership procedure is carried out according to the occupation of land (unregistered land) or deeds registration, where people agree between each other, and register the deeds officially at the land registry office. The government is a trusted party between the purchaser and seller. However, the government does not guarantee the proof of ownership in the case of conflicts or loss of deeds.

In 2002, a Royal Decree on the real estate registration system established a new system of organising property, including land title records [Ministry of Justice, 2018] . The decree made the Ministry of Municipal and Rural Affairs (MOMRA) responsible for the cadastral system, and the Ministry of Justice (MoJ) responsible for registering the land title and providing the proof of ownership rights [Ministry of Justice, 2018]. In 2018, a new government ministry was established, the Real Estate General Authority (REGA), as the only entity responsible for the real estate sector and the land registry system. However, it currently supports MOMRA and MoJ until it can take control of all collected data.

The land titles were initially handwritten. In 2008, an initiative was implemented for the MoJ to transfer all handwritten titles into an electronic format. The initiative included developing an electronic database, to make information retrieval (such as land ownership) faster, and to provide an identification number for the title. However, this system mandates the conversion of the handwritten titles into an electronic form before any new deal is processed [Scott et al., 2019].

1.2 Research Problem

The research problem focuses on addressing ownership conflicts resulting from fraudulent activities, lack of ownership, and double sales throughout the ownership transfer process in the Kingdom of Saudi Arabia. Ownership is the legal document that grants certain objects, such as a plot of land, to certain individuals for their own use and management [Waldron, 2023]. Legitimate technical systems facilitate the ownership process. The legitimate systems include justice and property management regulations. Technical systems use technology to facilitate managing properties and ensure compliance with regulations.

The land recording system in the Kingdom of Saudi Arabia is currently undergoing a transition between two systems. The first system is a traditional handwritten system that entails a manual process and relies on deed registration, wherein the presence of deeds is recorded rather than the ownership [Brennan, 2015]. The second system is an electronic system for managing titles. The establishment of this system took place in 2008, in accordance with the Royal Decree on the Registration of Real Estate Property. The Ministry of Justice is now implementing a programme to digitise all handwritten title deeds. The system relies on the registration of land ownership through database retrieval, enabling efficient recording and transfer. Since its recent implementation, the technology has exclusively been utilised for emerging regions [Alasmari, 2019, Alomar, 2011].

The joint administration by the Ministry of Justice and MOMRA, the conflict between the traditional/old system and the electronic title system, and the centralised database that is not based on solid data have led to the emergence of claims and disputes. These claims and disputes are caused by numerous factors, such as not properly stating the information boundaries, the absence of clear information in the traditional/old system (inaccurate information), issuing titles for land that is already owned (double sales), or unknown modification and loss because of centralisation of the database and the joint administration. Despite the support from Real Estate Authorities, the effort of the Ministry of Justice to move from the traditional system to the electronic system, and MOMRA using recent technology to identify accurate parcel information, the disputes have not yet been solved, according to [Alasmari, 2019, Alomar, 2011].

1.3 Research Aim and Questions

The aim of this study is to develop a safe procedure model for transferring ownership that aligns with both the socio-technical approach for addressing trust needs and the software engineering approach for addressing safety requirements in order to construct a social trust system. The socio-technical approach adheres to analysing the context of land registration in the Kingdom of Saudi Arabia by understanding how different stakeholders perceive the land registration system as trusted. The software engineering approach involves systematic analysis of the system specification of the ownership system to build formal modelling and verification of the procedure to address safety requirements.

The model is constructed according to STF that influence beneficiaries trust in addition to taking technical challenges into account. The beneficiaries could be citizens, businesses, or other governmental bodies. Citizens are the individual who has the right to own properties for personal use. Businesses are for the properties owned by the name

of a company or firm. The governmental bodies are other governmental bodies that own properties, called States.

In the Kingdom of Saudi Arabia, new initiatives have recently been proposed based on the 2030 Vision, and said initiatives contribute to increasing productivity and utilising lands. One of these initiatives is associated with the land registry. The initiative of developing a system where citizens are able to access and converyance their property ownership. Therefore, this research achieves its aim by pursuing the answers to the following question:

RQ: *How can technical safety encourage beneficiaries to trust a land registry system in the Kingdom of Saudi Arabia?*

The main research question is divided into three sub-questions. Each question has its own aim and objectives to pursue in answering the main research question.

- ***SRQ1:*** *What are the factors that influence beneficiaries' trust in a land registry system?*

  Aim: The question aims to identify the factors needed to perceive social trust.
  Objectives:

  1. To gain a comprehensive understanding of the context of the kingdom of Saudi Arabia.
  2. To analyse the process needed to transfer ownership in three relative countries.
  3. To analyse further challenges in the land registration system in the kingdom of Saudi Arabia.

- ***SRQ2:*** *What is an appropriate framework for investigating the registration of land in the Kingdom of Saudi Arabia?*

  Aim: The question aims to construct an abstract reference architecture and system requirements for transferring ownership through the sale of properties.

  Objectives:

  1. To confirm the requirements and the factor with experts.
  2. To identify the requirements needed for the sale of property.
  3. To analyse the system relationships that contribute to the system's construction.

- ***SRQ3:*** *To what extent is the constructed reference architecture and model applicable to the land registration systems in the Kingdom of Saudi Arabia?*

  Aim: The question aims to verify the reference architecture and model by employing the safety requirements of transfer ownership for land registry systems.

Objectives:

1. To construct a model for the ownership transfer process through sales.
2. To verify and validate the system requirements specification.
3. To evaluate the model with experts to ensure building the right model.

1.4 Contributions

Three new contributions are brought to the state of art by this research, which is based on a confirmed social trust framework on, requirements specification of transferring ownership through sales, and requirement validation. The contributions were consolidated via sequential triangulation, aligning the processes with Agile software development principles. These contributions are as follows;

C1 Social Trust Property Framework The framework underscores challenges encountered by land registration systems on a global context, prompting a comprehensive inquiry into the determinants essential for mitigate these challenges. A meticulous investigation was undertaken to elucidate the intricacies of property ownership registration processes within three distinct countries, thereby illuminating the factors inherent in these procedures. A subsequent, more further analysis was specifically directed towards comprehending the challenges embedded specifically in the land registration system of the Kingdom of Saudi Arabia. This investigative approach involved the categorisation of identified factors, followed by grouping and the synthesis of disparate factors cohesively. A further refinement undergoes goes a review process involving experts review who provided validation and confirmed the findings. The manifestation of these research findings holds significant relevance in directly addressing sub-research question SRQ1 and has been published at...

C2 The Requirement Specification of Property Ownership This research yields another significant contribution in the form of a property ownership requirements specification, emerging directly from the application of the social trust framework. This specification serves as a practical demonstration of the framework's applicability. The framework serves to support the analyse of the requirements of the ownership transfer process through a sale and ensure that the challenges in the process are mitigated. These research findings holds significant relevance in directly addressing sub-research question SRQ2.

C3 Formal Model for Transferring Ownership Finally, this research makes a notable contribution through the formal modelling of ownership transfer via sales. The

model shows the relationship between the land registration system and the stockholders, and ensures the critical safety requirements included within ownership transfer processes. Despite conscientious efforts to scrutinise user requirements, the formal model development exposes limitations and inadequacies in the initial specifications. Additionally, the verification process introduces essential requirements that effectively mitigate potential challenges, ultimately bolstering the overall ownership transfer process. These research findings holds significant relevance in directly addressing sub-research question SRQ3.

1.5 Publication

This section lists the peer-reviewed publications completed during my PhD candidature that are related to this thesis.

- Manar Altamimi, Nawfal Al Hashimy and Gary Wills,. 2022. Expert Review of the Land Registration Framework in the Kingdom of Saudi Arabia. Int. J. ICT Res. Afr. Middle East 11, 1 (Jul 2022), 1–18. https://doi.org/10.4018/IJICTRAME.304395
- Manar Altamimi, and Nawfal Al Hashimy, Asieh Salehi Fathabadi and Gary Wills, 2024. Property Ownership Formal Modelling Using Event-B and iUML-B. ABZ2024: 10th International Conference on Rigorous State Based Methods.

1.6 Report Structure

Chapter 2 provides a general background of land registration systems. This includes the title registry, the cadastre system, and land registry administration. It then presents the background of the land registration system in Saudi Arabia, as the main case in this report. The main challenges found in land registration is briefly discussed as well as the importance of trust in deals with properties. Promising new technology for the land registry is discussed.

Chapter 4 details the process of proposing a framework. The process consists of four stages, literature review, analysis of relevant examples, classification of the factors identified, and the proposed framework. **Chapter 3** presents the methodology used to answer the research question. The first section gives a general description of methodology, and the second gives the approach of applying the methodology to this research. Details related to ethical approval are addressed.

Chapter 5 explains the confirmation studies to confirm the the framework. The process starts with the factors needed through understanding the challenges **Section 5.1**. This

section outlines the research approaches implemented in investigating further challenges and requirement gathering in Saudi Arabia, while **Section 5.2** shows the detailed method applied to confirm the framework. At the end of each chapter, is a discussion related to the findings.

Chapter 6 applied the method employed to analysis the user requirement specefication. This chapter help to outline the user requirements to develop secure process of transferring ownership.

To confirm the validity of the user requirements specification, **Chapter 7** describes the details of construction and the process of transferring ownership using the formal method Even-b. This chapter includes the method of evaluating the mode and validating and verifying.

Chapter 2

Literature Review

This chapter presents the background and fundamental knowledge of the land registration systems. The land registration system globally in Section 2.1 will be described, including the law, cultural influence, the record systems, and the main factors behind the challenges. Section 2.3 will explain the process of land registration in the Kingdom of Saudi Arabia by investigating the law, culture, and record-keeping system. Section 2.4.4 explains the contribution of technology to address the challenges in the land registry. Lastly, Section2.4 gives a comprehensive discussion of the factors needed to mitigate the challenges.

2.1 Overview of Land Registration Systems

This section reviews the land registration system's components in a global context. Said components are the land registry, cadastre, and land administration.

2.1.1 Land Registry

Legally speaking, land registration is a process of recording [McLaughlin and Nichols, 1989] official records of titles or deeds so as to track the changes and document them in official land records [Zevenbergen, 2002]. According to the definition, land registration gives more information about "who" and "how". The land registry deals with recording legal documents related to land and how to maintain said documents.

These records are proof of ownership. They must be dealt with via a legal framework using formal title or deeds registration. The differences between these two systems have been defined by Deininger et al. [2003]. On the one hand, title registration, also known as the Torrens system, is "the entry into the registry that gives property rights legal validity, guaranteed by the state all entries the register are *prima facie* evidence

of the actual legal status of the land". On the other hand, the land deed registration system is recognised legally after the buyer and the purchase are agreed on to protect ownership of land. The reason for registering the land in deeds registration is to provide public notice that a specific land right has existed.

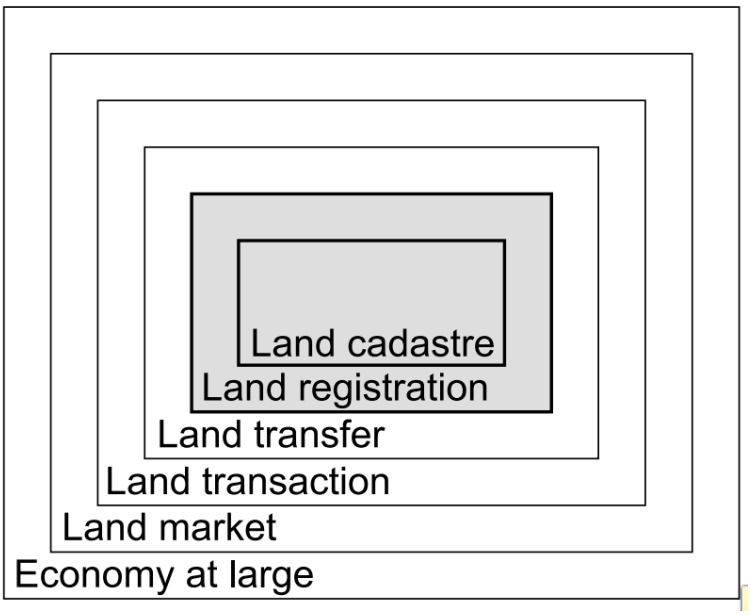

FIGURE 2.1: The representation of land registration as a nested subset systems [Zevenbergen, 2002]

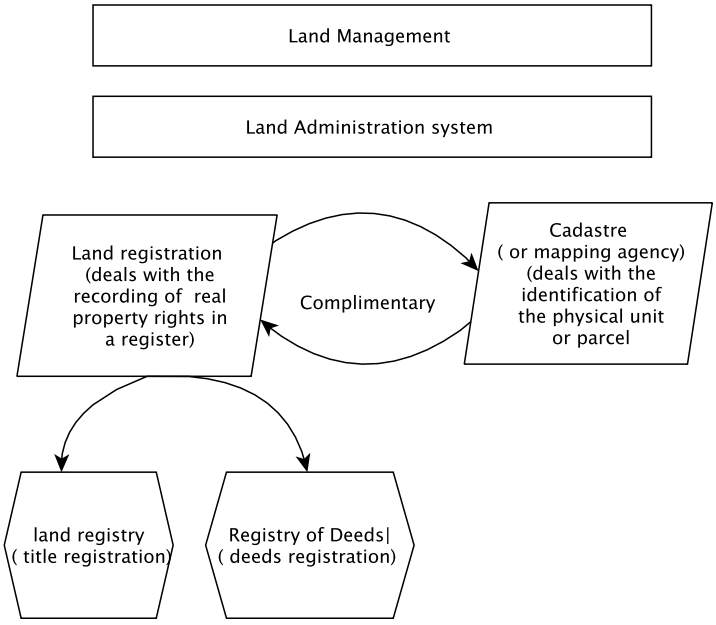

FIGURE 2.2: Land administration systems in Ireland [Brennan, 2015]

2.1.2 Cadastral System

Land registry cannot guarantee the ownership itself. It requires another system in order to clearly identify the boundary and location of a parcel. This system is called a cadastre. The cadastral system might be run by the same institution which runs the land registry, or supported by another organisation. The official definition of cadastre is concerned with where the land is and how much it costs [Zevenbergen, 2002]; this information is obtained by recording the data regarding the land boundaries and storing said data in a public inventory based on the survey method used [Henssen, 1995].

2.1.3 Land Administration System

While land registration records the legal documents of land and the cadastral system concerns the main information of land, such as the boundaries, the land administration system manages the interaction between land registry and the cadastral system. The definitions of the land administration system which have been found within the literature are defined based on the aspect and interest.

For instance, the United Nations Economic Commission for Europe (UNECE) defined land administration which focuses on the land market and systems maintenance aspect as a "process of determining, recording and disseminating information about ownership, value, and use of land when implementing land management policies" [UNECE, 1996], while Williamson et al. [2010] defined it in relation to interest in sustainable development for land management, as "the processes run by government using public- or private-sector agencies related to land tenure, land value, land use, and land development". These definitions are concerned about the "process" or dynamic nature of managing the information of land, which supports the investigation of the land information's accuracy when comparing today's two systems.

The relationship between the systems is represented as a nested relationship or a linking relationship. Figure 2.1 shows the relationship between the systems as a nested subsystem. The nested subsystem means that land registry and cadastre represent the core of the land administration system. This in turn means that a lack of functions in the inner box will affect the outer boxes. Another representation of an accurate relationship in the land registration system is shown in Figure 2.2 [Brennan, 2015]. Land registry and cadastre are linked through the land administration system.

2.2 Record-keeping Systems

Land registry deals with legal records that are based on record-keeping systems. The system records for a long time so that it is possible to keep authentic records, which

make up what is called an archival system. The archival system includes recording and securing information to ensure its source. These would make the records trustworthy.

2.2.1 Record-keeping in Land Registration systems

The record-keeping systems within the land registry are controlled by public organisations using the advantages of electronic government (e-government). E-government is a broad concept and has been defined from different perspectives. The World Bank [2002] defined e-government as "government-owned or operating systems of information and communications technologies (ICTs) that transform relations with beneficiaries, the private sector and/or other government agencies so as to promote citizen empowerment, improve service delivery, strengthen accountability, increase transparency, or improve government efficiency". This definition explains in detail that the relationship between the government and the beneficiaries is enhanced using information technology, while Abramson and Morin [2003] defined e-government as "the electronic interaction (transaction and information exchange) between the government, the public (individuals and businesses) and employees". This definition is abstract, and focuses only on the relationship between government and beneficiaries.

Because e-government deals with a massive number of beneficiaries and provides services 24/7, Information and Communication Technology (ICT) plays an important role in meeting administrative needs. Said needs include interconnectivity, efficiency and effectiveness, as well as accountability, delivering services, or decentralisation, transparency, and more [Yildiz, 2007].

In terms of land records, these are dealt with by systems: land registry and cadastre. Said systems, found within the literature, are administered by multiple public sectors [Zevenbergen, 2004, Thakur et al., 2019, Rizal Batubara et al., 2019, Vasquez et al., 2019, Brennan, 2015]. These systems are dissimilar. For example, the systems in India, Indonesia, and the Kingdom of Saudi Arabia are operated in an isolation manner [Thakur et al., 2019, Rizal Batubara et al., 2019, Alasmari, 2019], while those in the Netherlands are administered efficiently by a single organisation [Zevenbergen, 2002].

Because the recording land registry is based on archival science and interrelated with many disciplines such as law and computer science, proving the trustworthiness of records is essential. As law protects the ownership and gives a secure title, computation helps to keep and receive the information, and archive and organise the records; providing provenance information to the records makes them more valuable, reliable and trustworthy [Lemieux, 2016c].

2.2.2 Provenance

Since the land registry is concerned with the authenticity of the records, proving its provenance is important. The general perception of provenance among people is related to the art of history and museum artefacts, where it represents the history of ownership, while others encounter provenance as part of their work as auditors or archivers [Bachour et al., 2015]. However, the concept of provenance has recently become quite broad and has been defined according to the subject [Pérez et al., 2018]. In archival science, for example, provenance is defined as archival records which are linked to the organisation or individuals [International Council on Archives, 1994] and used as evidence or information to conduct legal or business activity [International Standards Organization, 2001]. The definition of the International Council on Archives [1994] presented the organisation's perspective, which creates, accumulates and/or maintains and uses the records before transferring them to archives, while the International Standards Organization [2001] referred to records which are used as evidence because the information about the creator or receiver of the records and reasons for recording are stated.

Similarly, provenance in Computer Science is related to the source of information. It has been defined according to either data or workflow context. In the data context, Buneman et al. [2001] defined data provenance as *lineage* or *pedigree*, stating that it shows "the description of the origins of a piece of data and the process by which it arrived in a database". In the same way Cheney et al. [2009] stated that data provenance involves data being returned by a database query and identifying why, how, and where data provenance is in the database. However, In the workflow context, World Wide Web Consortium [2013] codified the meaning of provenance as "a record that describes the people, institutions, entities, and activities involved in producing, influencing, or delivering a piece of data or a thing". Workflow provenance concerns the detail of information, from its creation to the final result of the workflow, whereas data provenance refers to sequences of steps of the SQL query from the database [Omitola et al., 2010].

2.2.3 Securing Provenance Information

Building trust in provenance information is not only an important factor of using, but also concerns the security of provenance information. Security of provenance information refers to the access control, non-repudiatity, integrity, and sensitivity [Moreau et al., 2010]. [Lemieux, 2016a] identified security as one of the challenges of capturing provenance information across distributed and heterogeneous systems. Moreover, a

systematic review of 25 provenance systems by Pérez et al. [2018] concluded that security needs further investigation, while other studies confirmed that security is an issue and needs to be addressed [Fadhel et al., 2015, Bachour et al., 2015]

2.2.4 Trust of Provenance Information

Provenance is metadata that records the source of the data, the semantic changes over time, ownership of the information, and who is responsible for changes. This data is recorded and valuable, as it is used for retrieving the information and conducting analysis [Wheat et al., 2016], as well as understanding the semantic changes, supporting decision making [Lemieux, 2016a], and adding quality [Missier, 2016]. Due to these valuable activities of using provenance data, it is important to build trust in said data. For instance, Venters et al. [2014] designed and built mechanisms as part of project trusted digital Spaces through Timely Reliable and Personalised Provenance, or STRAPP. These mechanisms combine a provenance model with a risk assessment model to improve trust.

2.3 Land Registration Systems in Kingdom of Saudi Arabia

After reviewing the land registration system in a global context, the land registry system in the Kingdom of Saudi Arabia is discussed. This includes describing the law, culture and the record-keeping system in the Kingdom of Saudi Arabia, as well as a general description of the challenges in current systems.

2.3.1 Law and Culture

Law as it has been discussed in [Galligan, 2006] serves the fundamental societal functions of safeguarding individuals from harm and establishing regulations for fundamental aspects of social existence such as contracts, property rights, and family relationships. The purpose of the law is to enhance and ensure the stability of social interactions that occur naturally and spontaneously. A culture, on the other hand, refers to the comprehensive set of socially acquired patterns of behaviour, beliefs, and customs that characterise a particular group of individuals [Birukou et al.]. Cultural patterns refer to the structured and recurring thought processes, emotions, and behaviours that are distinctive to the individuals within a specific society or subgroup of a society. The understanding of the law and cultural background of the Kingdom of Saudi Arabia leads to a better understanding of the forming of land tenure. The country is dominated mainly by Islamic values, where the citizens' religion is Islam. However, there

are also external influences on Saudi societies. Bechtold [2012] argued that the discovery of oil, demographic change because of a rapidly-growing population, modernisation, influence of western countries, and expatriate workforces, have caused a growth of consumerism. In consequence, a gradual change has influenced Saudi culture. Since the oil boom discovery in late 1939, social and cultural traditions have struggled with pressure brought on by the wave of western modernisation, on the one hand, and maintaining Islamic values on the other hand [Bechtold, 2012].

The formed government of the Kingdom of Saudi Arabia is an absolute monarchy, and is ruled by the house of AlSaudi. The Kingdom of Saudi Arabia is located on the Arabian Peninsula, which is the cradle of Islam and the home of two holy cities, Makkah Al-Mukarramah and Al-Madinah. The strategic location and existence of the holy cities have a significant impact on the forming of the judicial system. While Saudis' religion is Islam, the judicial system is characterised by the dominant role of Islam law, Sharia. Sharia is mainly sourced from the Quran, the Sunna of the prophet (sayings and deeds of the prophet, peace be upon him) [Eijk, 2010, Sait and Lim, 2006].

Land rights under the Islamic theory constitute a sacred trust and belong to the creator, Allah. However, these rights emphasise individual ownership with the redistributive concept [Sait and Lim, 2006]. In principle, the rights of land are related to using land, and if an individual fails to use the land within a certain time period, the state has the right to restore the land and give it to another person who can benefit from it [Sait and Lim, 2006]. The land tuner under Sharia Law consists of four types that identify the kind of ownership, as discussed in Section 1.1.3. However, dead land has been repealed because of water scarcity [Ministry of Justice, 2018].

Land administration under the Islamic theory is recognised in order to provide secured ownership to the Muslim community. As such, the state is the only body responsible for supervising land by applying the Islamic principle. The constitution and administration in Islamic theory are based on two main concepts, namely justice (Adel) and consultation (shura). These concepts provide all the necessary principles to administer the land sufficiently, fairly, and ultimately provide benefit to the community [Sait and Lim, 2006].

2.3.2 Record-keeping Systems In Saudi Arabia

The transferring of land ownership between parties is carried out through a customary and traditional process. At the beginning of the deal, the interested parties negotiate privately with the purchaser, including checking that the title is clear of any disputes or missing information. This process also includes visiting MOMRA and the Ministry of Justice to ensure that the information in the title is compatible and accurate, and investigating the land to ensure it is clear of any previous owners; the latter is achieved

by performing a site survey and questioning the neighbourhood. Later, the seller and buyer head to a notary to register and document the conveying title [Scott et al., 2019].

In terms of written documents, Arabic is the formal language which is used across the Kingdom of Saudi Arabia, while English is the second language and is widely used in the Saudi Arabian government. However, while the land titles are mostly written in Arabic, the titles that belong to the Economic Cities Authority are written in English to support international contracts [Scott et al., 2019].

Consequently, the conjunction administration is conducted by two sectors, namely the move from the traditional (old) system to the electronic title system, and the centralised database used for issuing electronic titles has contributed to existing land disputes and conflicts. Unsolved land disputes have a negative impact on economic and social aspects. Feder and Nishio [1998] claimed that the security land registry has a significant effect on the accessibility of the land title use, increasing the value of land, better investment, and greater income. In addition to this, Alasmari [2019] argued that the absence of a clear title which proves ownership has caused insecurity when it comes to investing in the property market, especially housing. Therefore, secure ownership is a critical factor that supports the production of land by using an effective ownership system.

These claims and disputes are caused by not properly stating the information boundaries, the absence of clear information on the traditional/old system (inaccurate information), or issuing titles for land that was already owned (double sale) [Alasmari, 2019]. Despite the effort of the Ministry of Justice to move from the traditional system to the electronic system and MOMRA using recent technology to identify accurate information of parcels, the disputes have not yet been solved [Alasmari, 2019].

The record-keeping centralised systems are undertaken by electronic government (e-government) services, with the advantages of ICT. The Kingdom of Saudi Arabia has recognised the importance of developing e-government to respond to growing needs. A supreme royal decree was issued in 2003 to formulate a plan to transfer government services and transactions to electronic form. This plan was run by the Ministry of Communication and Information Technology [Yesser, 2019].

E-government has been developing through a governmental programme called "Yesser". This programme was started in 2005 to provide a collaborative effort between government sectors to pursue the stated objectives of the programme [Yesser, 2019].

2.4 Analysis of Challenges the Property Systems : comparative example

By providing a global context for land registration in Chapter 2, the discussion can shift its focus to the social and technical factors that contribute to the challenges. The land registry systems vary in every nation. The systems do not depend only on the jurisdictions system, which provides secure land titles and the rights ownership, but also on disputes because of inherited land reforms, the organisations' involvement in maintaining the systems, and the technology used to keep the records. The these factors play an important impact in the emergence of the challenges in the land registry in the Kingdom of Saudi Arabia and in a global context. This Chapter contributes to give the main factors to construct social trust framework and contribute to answer SRQ1.

2.4.1 Cultural Disputes in Land

Culture is an important factor which influences land registry. Since people link to the land which belongs to them, culture is related to the communication between people, how the communication is formed in verbal language, and the people are understood, and their sense of common fundamentals, rules, or principles [Hodge et al., 1988]. Additional , culture is a collective programming of mind that distinguishes the members of one group or category of people from others [Hoftede et al., 2010].These definitions of culture illustrate why the land registry is different from one country to another.

In terms of land and its related challenges, understanding said challenges, proposing suitable solutions, and raise the social trust have to be accomplished in order to understand the high level in the organisation and how the people think, feel and act; indeed, this would help to perceive the challenges and propose a suitable solution [Hoftede et al., 2010].

The disputes in land tenure are not an instantly-solvable problem. This problem is rooted in the history of reforms. The several reforms in India, for example, have led all states to have their own procedure of managing their lands [Thakur et al., 2019], whereas the disputes in Lithuania, which are related to restitution after it gained its independence, are still unsolved [Sabaliauskas and Petrošius, 2015]. Also, the dispute in land is related to whom has the political power in the land; for example; in Cyprus [Yapicioglu and Leshinsky, 2020]

Unsolved disputes would be an obstacle when it comes to sufficiently benefiting from the lands. It might take endless time to settle the dispute or the land becomes unuseful. For instance, the lands where challenges remained unsolved because of restitution

in Lithuania for a long time became smaller parcels after the land inheritance [Sabaliauskas and Petrošius, 2015] or a long time of dispute between two political groups although they have treaty [Yapicioglu and Leshinsky, 2020]. Therefore, the lands become economically useless.

2.4.2 Traditional Procedure

The challenges in land registry systems are not only due to shortcomings in the legal system but mostly caused by inefficiency in the record-keeping system in land registration systems. Thakur et al. [2019] discussed that the challenges in land recording in India are due to the procedures in land records, where each state is working inconsistently, and many state departments or agencies are involved in the land registry process. According to Thakur et al. [2019], this caused a lack of transparency between the departments and an inconsistency in land records. Therefore, it can be said that these challenges affect the land registry's accountability and provide high-integrity records to the beneficiaries.

Similarly, Rizal Batubara et al. [2019] explained that the system of land registry in Indonesia has long and complex processes and activities to transfer ownership, and a number of organisations are involved in these processes. Moreover, because these processes and activities are closed and kept far away from public engagement, land registration is not accountable and transparent.

The land registration processes in India and Indonesia are not different from those in the Kingdom of Saudi Arabia and Honduras. The land registry in the Kingdom of Saudi Arabia is linked to two government sectors. One system records the information about the parcel, while the other registers and organises the land title [Alasmari, 2019] as discussed in Section 2.3.2, whereas the number of departments involved in HonduraS' land registry has led to an inefficient system in terms of providing accurate land boundaries information, invalid land titles, and incomprehensive land registry [Benbunan-Fich and Castellanos, 2018].

2.4.3 Electronic Procedure

Despite the effort of moving from the manual procedure to digitising records using a centralised database, the challenges in the land registry still exist. More challenges have emerged because the organisations involved in maintaining the land registry system are not integrated, although the centralised database facilitates data entry, retrieves the information, reduces falsified entries, and makes the land information more accessible. Any update of records in one system makes them incompatible with other systems. This situation has arisen in India, the Kingdom of Saudi Arabia, Indonesia, Honduras,

and more [Rizal Batubara et al., 2019, Alasmari, 2019, Benbunan-Fich and Castellanos, 2018, Thakur et al., 2019]. Indeed, these challenges are in the form of double sale, inconsistent records, or land boundaries conflicts.

Many examples have shown that the centralised database provides a secure and reliable system because said system is controlled by one organisation and strict policies are followed to maintain the system. The republic of Georgia was controlled by two government agencies, both of which had overlapping services [Shang and Price, 2019].To overcome the problem, the two agencies were replaced with a single agency [Shang and Price, 2019]. Therefore, Goderdzishvili et al. [2018] claimed that the property registration system in Georgia is one of the best systems, as it provides fast service, transparency, reliability, and citizen-friendly engagement. However, despite the effort made by Georgia to improve its system, the country still faces challenges when it comes to providing data integrity data and protecting the system from manipulation and cyber-attacks from outside because of the vulnerable centralised database system [Shang and Price, 2019].

2.4.4 The Technology Used in Land Registration

From the challenges discussed in Section 2.6, it is clear that recording land information in the land registry is interrelated with many disciplines such as law, database, and archival science. As such, the technology used is not able to provide all the necessary factors to address these challenges. Said challenges push the idea of proposing a theoretical secured and distributed title database to overcome problems such as loss of data, forgery, or being subject to attack [Szabo, 1998]. Szabo [1998] claimed that this system would overcome the challenges and provide a secure, distributed database, while also preventing external attacks. However, this proposed system does not technically work [Hayes, 2019].

Another technology which is promoted to tackle security challenges in electronic records is using a digital signature. This technology would allow owners to transfer their land without a physical presence at the closing stage of transferring. However, Brennan [2015] claimed that this may affect the liability of the system.

Furthermore, blockchain is another technology promoted to tackle these challenges. Blockchain technology comprises distributed ledgers, where all new transactions combine into a block and are linked to the end of the previous block [Peck, 2017]. These blocks are distributed across a peer-to-peer network after they have been verified by the majority of the nodes using a consensus mechanism [Carter and Ubacht, 2018]. The technology eventually replaces the intermediary's services companies [Peck, 2017]. Blockchain provides security and immutability to data recorded in nodes across the network.

TABLE 2.1: Countries are in progress for adopting recent technology or they have already applied it

Countries	Description of the system	Type	Status	Source
Georgia	A piloted land tile registration	Using blockchain technology for record-keeping	Adopting in progress	[CNN, 2017]
Swedish	Testing Record-keeping transaction for property	Using blockchain technology for record-keeping	Adoption in progress	[Testbed, 2017]
Brazil	A piloted land transfer registration	Using blockchain technology for record-keeping	Adopting in progress	[CoinDesk, 2019]
Estonia	Securing medical record-keeping, and hosting government records	Recording of land transaction and medical records	Has adopted	[GovInsider, 2019]
The UK	Examining the technology in digital preservation	Archives	Adopting in progress	[National Archives and Records Administration, 2019]
Honduras	Land registry system	Using blockchain technology for record-keeping	Proposed implementation	[Lemieux, 2016c]
Dubia	Land registry system	Using blockchain technology for record-keeping	Adopting in progress	[Smart Dubai, 2020]
Republic of Cyprus	Land registry system	Using blockchain technology for record-keeping	Adopting in progress	[Themistocleous, 2018]
Ukraine	Land registry system	Using blockchain technology for record-keeping	Adopting in progress	[Themistocleous et al., 2019]
Illinois	Land registry system	Using blockchain technology for record-keeping	Adopting in progress	[Themistocleous et al., 2019]
Ghana	Land registry system	Using blockchain technology	Adopting in progress	[Vos et al., 2017]
Chicago's Cook County,	Land registry system	Using blockchain technology	Adopting in progress	[Vos et al., 2017]
Tanzania	Land administration system	Using blockchain technology	Adopting in progress	[Kombe et al., 2017]

TABLE 2.2: A summary of using technology in land registration system

Source	Type of contribution	Comments
[Szabo, 1998]	applying distributed title database in land registry	theoretical secured and distributed title database to overcome problems such as loss of data, forgery, or being subject to attack.
[Brennan, 2015]	Electronic records using a digital signature in land registry	The core use of this technology is to allow the user to transfer the title electronically with no need to present at the closing stage of transferring.
[S. Kejriwal and S. Mahajan, 2017]	Analysing the fraud issue in land registry	The core challenges in property-related information are due to the variety of the system used. This has led to a lack of transparency and efficiency, as well as the high occurrence of inaccuracies which have great potential to give rise to fraudulent activities. The author proposes that using blockchain would create great opportunities to overcome these challenges.
[Kombe et al., 2017]	Proposed blockchain model	A proposed model for using blockchain in Tanzania to create a secure and robust land administration system and title registration systems.
[Anand et al., 2016]	Blockchain application	Presents some of the applications which could be used in land administration systems, such as coloured coins and title registration.
[Torun, 2017]	Proposed blockchain solution	A study to propose a solution to reduce the challenges in boundary surveying by capitalising on the advantages of blockchain.
[Thakur et al., 2019]	Proposed blockchain solution	An exploration of using blockchain technology for land record management in India. The paper claims that ownership and land estimation value will be clearer and fraudulent activities will be minimised. Moreover, the system will be more accountable because the transactions will be non-reputable and open to the public.
[Rizal Batubara et al., 2019]	Examination of transparency and accountability	An examination of the possibility of blockchain enhancing transparency and accountability in governmental institutions.
[Shang and Price, 2019]	Propose blockchain project	Discusses a pilot project in Georgia to adopt blockchain in land registry to address the challenges in its systems.
[Notheisen et al., 2017]	Smart contracts	Discusses that the bureaucratic and organisational efforts for the administration of the database and registry would be minimised.

Blockchain was originally proposed by Satoshi Nakamoto to address the challenges in an electronic cash system called Bitcoin. Bitcoin allows two persons to send money with no need for a financial institution [Nakamoto, 2008]. However, a review study conducted by Risius; and Spohrer [2017] to investigate the option of using blockchain in disciplines other than solely cryptocurrency.

There are many proposed solutions that address the challenges related to the land registration system. Shang and Price [2019] discussed a pilot project in Georgia to adopt blockchain in the land registry to address the challenges in its system. As yet, none of the proposed solutions have been adopted. However, Estonia and the United Arab Emirates are the leading countries when it comes to using the technology [GovInsider, 2019, Smart Dubai, 2020]. Table 2.2 summarises all of the proposed solutions, while Table 2.1 illustrates that countries around the world are developing a system using blockchain technology. Most of these countries are proposing a blockchain system in their environment.

In addition to the previously-mentioned technologies, a smart contract is another promoted technology in the context of solving the challenges in the land registry. It was first proposed by Nick Szabo in 1994. Nick Szabo [1996] defined the smart contract as "a set of promises, specified in digital form, including protocols within which the parties perform on these promises". However, the technology at the time of proposing the smart contract was insufficient to support these protocols [Omohundro, 2014].

The idea behind proposing a smart contract in the context of the land registry is to eliminate notaries or the registers who are checking the process to establish whether preconditions have been obtained before transferring the ownership [Vos et al., 2017]. Notheisen et al. [2017] claimed that the bureaucratic and organisational efforts for the administration of the database and registry would be minimised. However, the complexity of smart contracts would add vulnerabilities to the system if it was poorly designed [Vos et al., 2017].

Following the emergence of blockchain, which eliminates the need for a trusted third party, a smart contract underlying blockchain has been constructed, because the smart contract will be enforced by the consensus mechanism that the specific blockchain is using [Stefanović et al., 2018].

The combination of blockchain and a smart contract could make it possible to automate the transferring of ownership of land. Vos et al. [2017] claimed that the automated process of transferring the ownership will possibly be accomplished by using a smart contract with blockchain, while Stefanović et al. [2018] claimed that a possible solution would be using blockchain and a smart contract to address the problem of double sale.

2.5 Social Trust in Using Land Registration

Trust is a key-value when it comes to the land because of its impact on the social relationship. Social Trust is related to the social network of people who share "social virtues" [Welch et al., 2005]. Social virtues can be as communication, integrity, reliability, obligation, honesty and more. These social virtues are what are people are looking for when it comes to the land market.

Within the scope of this research, land is a monetary asset that requires a specific set of factors necessary to transfer ownership. These factors contribute to enhancing social trust. Social trust stems from the trustee's ability and behavioural integrity to accomplish a task [Tomlinson et al., 2020], as well as the positive and negative social aspects of past experiences [Schwerter and Zimmermann, 2020]. Developing trust between trustor and trustee plays an important role in mediating the process of exchange interest [Welch et al., 2005]. Because transferring lands between people has to go through a government institution, the joint interaction of social trust and the institution is important to consider when investigating the challenge in the land registration systems.

Social trust in the land registration system is in compliance with enhancing the safety of the system when developing a system for land registry. Land registration systems are a form of social communication between many stockholders: owners, purchases, organisational entities, lawyers, agencies, and others. The more stakeholders involved, the more complexity appears in the systems and emerging challenges. Baxter and Sommerville [2011] described the system when humans, machines, and the environmental aspects interact with each other as socio-technical systems. They emphasise the need to look at people, machines, and context factors when developing a system using socio-technical systems design (STSD). Social trust is necessary to consider when developing systems. These systems should be safe by design to raise trust.

2.6 Discussion

According to the analysis in Section 2.4, three main challenges found in land registration systems globally that should be consider when developing social trust technical system. They were fraudulent activities, lack of ownership, and double sale, as shown in Table 2.3

Fraud is the use of one's occupation for self-benefit through intentional misuse or potential misuse of the resources or assets of the employing organisation [ACFE, 2002]. According to Association of Certified Fraud Examiners [ACFE], the main forms of fraud are: internal/employment fraud, and external fraud. When an

TABLE 2.3: Problems and challenges found in land registration systems

Problem	Problem Description	Papers
Fraud	It generally denotes the corruption or forgery in land registration systems.	[Thakur et al., 2019, Kombe et al., 2017, Benbunan-Fich and Castellanos, 2018, Themistocleous, 2018, Eder, 2019, Rizal Batubara et al., 2019]
Lack of clear ownership	Lack of of defining the ownership where properties are subject to claim.	[Thakur et al., 2019, Themistocleous, 2018, Eder, 2019, Alasmari, 2019]
Double sales	It denotes a property that was sold to two sellers at the same time at different times.	[Thakur et al., 2019, Kombe et al., 2017, Benbunan-Fich and Castellanos, 2018, Alasmari, 2019]

individual commits fraud against their company, internal frauds occur, while external frauds occur when a third party involved. Thakur et al. [2019] states that the organisational structure that maintains land records in India led to fraudulent transactions such as double sale, non-owner sale, unauthorised buyers, backdated transactions, etc. Moreover, the technology used to record land title is vulnerable to tampering and fraud by non-trustworthy entities in the network [Benbunan-Fich and Castellanos, 2018].

Lack of clear ownership is related to the inefficiency exhibited by cadastral inadequacy, incomplete land records, land title validity, and lack of a detailed land register. Failure to provide sufficient information had led to land disputes where the ownerships are not secured [Thakur et al., 2019, Themistocleous, 2018, Eder, 2019, Alasmari, 2019].

Double sales encompasses consecutive sales by the same seller to different buyers of the same particular product [Scholtens, 1953]. This issue is not only fraudulent activity, but also occurs because of a lack of definition of ownership at the time of granting the land title and the involvement of multiple governmental bodies [Alasmari, 2019].

Fraud, lack of defined ownership, and double sales challenges represent insecurity property ownerships in land registration systems.

2.7 Summary

This chapter provided an introduction to the main components of the land registration system in a global context, namely record-keeping systems, and discussed the subjects related to land record-keeping, such as provenance. Following this, a particular description of the system used in the case of Kingdom of Saudi Arabia was provided.

After describing the system, a deep description of the challenges were given. The literature shows that cadastre and land registry systems are maintained in the same department or multiple departments. For each case, there are challenges which appear in their system. Those countries whose cadastre and land registry are administered by a department are more efficient than countries whose systems are administered by multiple departments.

Similarly, the land registration system in the Kingdom of Saudi Arabia is not different in the global context. It consists of a cadastre and land registry which are managed by different departments. However, what makes the Kingdom of Saudi Arabia different from other countries in a global context is its law and culture, although the challenges are similar in the other countries mentioned. Since the land registration systems are based on record-keeping, the investigation of the provenance of record-keeping is important. Provenance is a method used to define the authenticity of the records, and which generates or modifies the records. This approach could be achieved by using the semantic web W3C provenance-data model.

The literature, after describing the systems in a global context and in the Kingdom of Saudi Arabia, highlights three major challenges with the system that contribute to insecure property ownership in land registration systems. It is necessary to consider many factors, such as culture and how people deal with each other, in addition to their connection to the local history of the area, to propose a suitable solution. Also, the involvement of government organisations as intermediaries, either in the form of proving ownership or the use of technology to manage properties, inevitably contributes to more challenges. The land registration system uses a variety of technologies, including digital signatures, blockchain, and smart contracts. However, every technology has its own pros and cons when it comes to tackling the challenges related to land records. Challenges pertaining to investigation ought to be guided by a framework that focuses on a specific region. The procedure for developing the framework is detailed in Chapter 4.

Chapter 3

Research Methodology

Research methodology refers to the choices that are made in research design for studying a phenomenon [Silverman, 2017] . This includes an appropriate model or framework, research design, methods of data gathering, validation, data analysis strategies, interpretation of the findings, and so on [Silverman, 2017]. It also refers to the process of conducting the research [Creswell, 2007]. The research design is chosen based on the nature of the research problem [Creswell, 2012].

This chapter provides detailed information about the methods used to address the main and sub-research questions of the study. It starts with Section 3.1 that shows a road map of the research methodology. Section 3.2 and Section 3.3 present the research designs that address the research questions, while Section 3.4 reviews the research questions.

3.1 Research Approach

Figure 3.1 presents the approach that leads to answering the research questions. The approach unfolds in two parts. The first part concentrates on social discipline methodology, whereas the second part is about technical discipline methodology. The approach incorporates activities that align with the agile software development process [Salo and Abrahamsson, 2007]. The agile software development process is a method of iterative development that provides an opportunity to build the model effectively.

The social discipline consists of identifying the user's needs. The user's needs analysis is conducted using a four-stage general technique proposed by Maguire and Bevan [2002] to write system specifications. The four-stage process consists of four stages to analyse the user requirements. The first stage is to gain a broad understanding of the context. The second stage involves gathering specific information that aligns with the

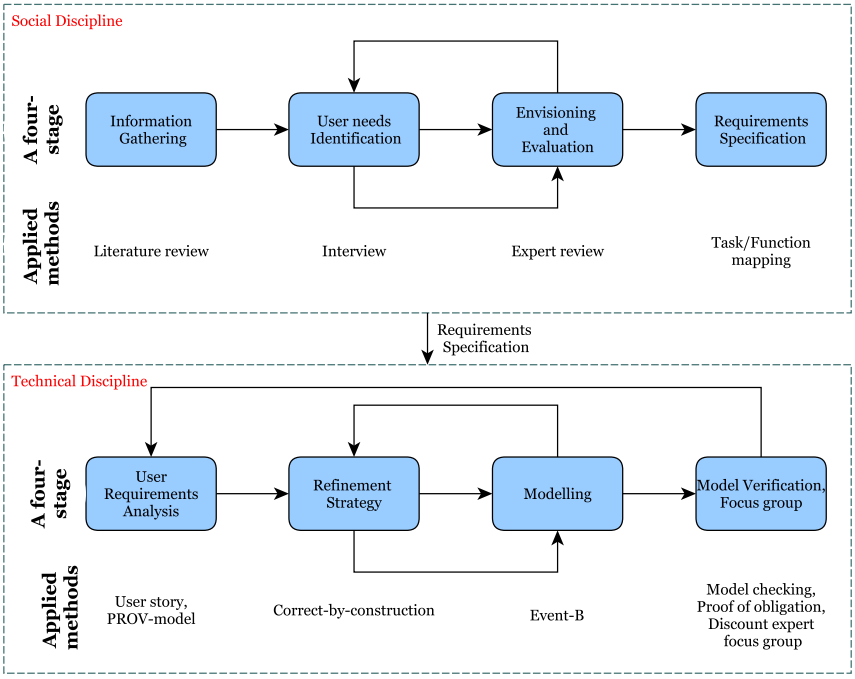

FIGURE 3.1: Research approach

user's needs, then refining this information to validate the requirements. Lastly, write the requirement specification.

This study involves a literature review to gain an understanding of the context, followed by conducting interviews to identify the user's needs and validate the findings with experts. Finally, we utilised function mapping to form the specification. These stages align with the development of a Social Trust Framework (STF). The framework offers abstract elements of the situation that contribute to simplifying a problem in a methodical way [Pidd, 2003].

The STF's construction unfolds in three phases. The initial phase is to determine the initial factors needed to mitigate the challenges by reviewing the literature and examining the ownership transfer process in three countries. This step encompasses gathering the information to establish a contextual understanding, thereby laying the groundwork for the subsequent phase. The second phase involves the actual development of the framework. This includes identifying categories, assembling groups of components, or combining various factors. Once the framework is constructed, the expertise of professionals is sought in the final phase to validate the results, offering a critical perspective for refinement. The three phases of constructing the STF align with identifying the user's needs. Figure 3.2 visually depicts the framework development process.

The technical discipline comprises developing the formal model of transferring ownership. Four stages contribute to the formal model's construction. The first stage is understanding the user's needs that align with the findings from the framework. Then, develop the strategies to construct the model, model the process, and finally verify the model.

3.2 Research Methods Applied to the Social Discipline

Sociological research methodologies play a pivotal role in acquiring a comprehensive understanding of user demands. The designs encompass qualitative, quantitative, or multi-method research designs. The selection of the research methodology is according to the nature and objectives of the study. The methodological approach involved in this research endeavours to comprehensively grasp societal requirements within a carefully structured framework.

The subsequent sections explain the chosen method design and articulate the practical implementation of the research design. These explanations are crucial for demonstrating the adoption of the intended research, thereby ensuring a sociological perspective that is responsive to user demands.

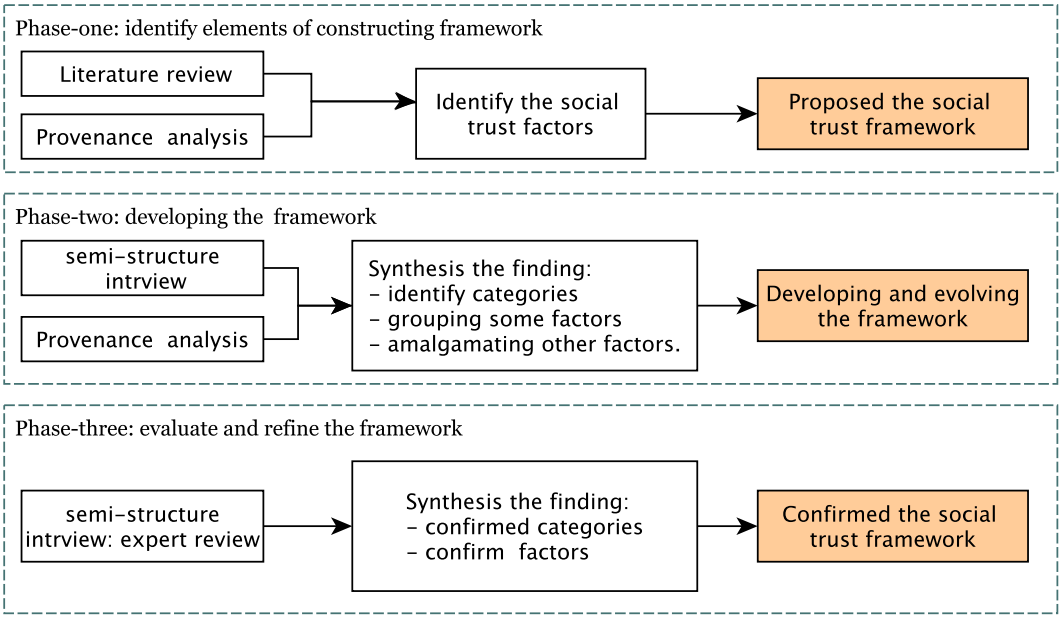

FIGURE 3.2: The framework development process

3.2.1 User Requirements Analysis

Requirements are an essential step for understanding users' needs and specifying the characteristics of a system prior to making attempts to develop it [Grady, 2010]. They lead to designing successful information and interactive systems [Maguire and Bevan, 2002]. They describe what the system will do or what the user will do with the system. They can be functional or non-functional requirements. Functional requirements are statements that describe what the system actually does. Non-function requirements are statements that describe system constraints. System requirements give functional details about what the user needs.

A general process for user requirements proposed by [Maguire and Bevan, 2002] is followed to develop system requirement specifications (SRS). The process starts with gathering information. Gathering information is about comprehending the context and stakeholders. User identification is followed to understand the user's needs. There are different ways of understanding the user's needs, such as through interviews, focus groups, scenarios, and user cases. Then, it is important to create a prototype to demonstrate the user's needs once the first set has been developed. This can be described using affinity diagramming or a story board. Last is writing the system requirements specification (SRS). The specification can categorise, prioritise, or set criteria for achieving the requirements.

The presented Figure 3.1 previously shows the applied method in social discipline for every stage. This process guides the answers to the sub-research questions.

3.2.2 Qualitative Research Design

Qualitative research is mostly suited for exploratory research when the variables or theories are unknown [Creswell and Creswell, 2017]. It is useful for exploring a problem and developing a deep understanding of the main phenomenon [Creswell, 2007]. This could be accomplished by engaging with individuals, sharing their story, hearing their voice, and understanding the content and setting from an individual's perception of what can help overcome the problem [Creswell, 2007]. Qualitative research is characterised by openness and flexibility, where the researcher can modify the research design and focus during the research in order to adapt new findings and relationships [Maxwell, 1996]. This method differs from others in terms of collecting data, a sample approach, and how it is analysed. However, the data described with this method may be subjective and influenced by the perspective of the researcher [Ramona, 2011].

Many techniques are used to gather data in qualitative research. These include case studies, personal experiences, introspections, life stories, interviews, documents, and

productions, along with observational, historical, interactional, and visual texts. [Denzin and Lincoln, 2017]. The type of technique chosen is based on the nature of the research.

3.2.3 Interview Design

Interviews are widely used in qualitative research as an instrument for data collection [Ryan et al., 2009]. They seek to gather data about people's experiences for a particular purpose [Oishi, 2003]. Interviews are useful tools for examining and comprehending the challenges that individuals confront in a particular situation. Interviews can be conducted individually or in a group. Individual interview is a process of data collection in which the researcher asks questions and collects responses from only one participant [Creswell, 2012]. A group interview, or focus group, is used to gain shared understanding from multiple individuals, as well as eliciting opinions from specific individuals [Creswell, 2012]. It is useful when the time is limited, and the interaction of participants yields good information [Creswell, 2007] . The data gathered from an individual represents that participant's view, while the focus group tends to be influenced by other people's thoughts.

After the questions have been developed, they have to be piloted before conducting the interview. The pilot interview is a trial procedure in which questions may be subsequently changed based on feedback from a small number of individuals who complete and evaluate the questions [Creswell, 2012]. A pilot is intended to test the validity of the questions before they are used in the study. It also enables questions to be refined where necessary.

Question design The questions in the research project were designed according to the objectives that meet each research question. Considering the first research question (see section 1.3), an exploratory descriptive research design was chosen because it would help to investigate further challenges. In addition, the design also helps to understand the context of the land registration system and identifies other important factors linked to the framework.

The methodology used to develop the questions was based on a Goals Question Metric (GQM) approach. This approach was originally used as a tool to define a set of goals and evaluate them in specific organisations [Caldiera and Rombach, 1994]. This approach helps researchers collect the data that meets the objective of the study and helps them reduce the burden of data collection [Koziolek, 2008]. The questions are designed using a top-down approach by first defining the goal of the question and then defining the question to research that goal according to the set of metrics.

Both the study questions were asked in a semi-structured individual interview, conducted either face-to-face, via Zoom or Microsoft Teams, or by phone, because the interviews were held during the COVID-19 pandemic. The interviewees were selected based on their interests, job background, previous experience, and expertise. The data gathering stopped at the point of data saturation.

Interview protocol The participants received a polite phone call at their place of employment asking if they would be interested in taking part in the study. If willing, Paper Information Sheet (PIS) was sent to them by email. The PIS gave general information about the interview objective and the time needed to conduct the interview. Because the interviews were conducted during the COVID-19 pandemic, most of the interviews were conducted online using Zoom. For this reason, the consent form was sent to them by email, to which they replied with an agreed consent. Upon their agreement, an email was sent to agree on a suitable time to meet them. However, some interviews were conducted face-to-face after the lockdown was eased. In that case, the PIS and consent form were provided before starting the interview.

During the interview, the introduction and the questions were shared to give them time to think before they answered. Face-to-face interviews were recorded by voice memo and notebook, while the interviews that were carried out using Teams video conferencing or Zoom were recorded using QuickTime. Fortunately, all the participants were familiar with Zoom, and they felt comfortable using it. Interviews were recorded after they acknowledged and agreed to the process. Participants took 30-45 minutes to answer the questions, on average.

After the interview, they were warmly thanked for their time and involvement. They were asked if they needed more information about the study. After that, they were asked if they could recommend people who would be interested in participating.

3.2.4 Interview Piloting Design

The interview questions were piloted before the interviews were conducted. The pilot interview gave an opportunity to determine the flaws, language, and clarity of questions and to check the weaknesses and limitations within the interview design [Turner, 2010, Booth et al., 1991]. The pilot test for this study was guided by Gani et al. [2020] .

Gani et al. [2020] described in detail the design and procedure for conducting a pilot test to validate the instruments before the interview. For designing, Gani et al. [2020] demonstrated the method, the participants, the setting, and the instruments. They also give a concise description of conducting the pilot in three stages: before, during, and after the pilot interview.

Pilot procedure The exploratory interview and expert review instrument were tested and validated before conducting the interview. The design and procedure of the pilot test were described in Section 3.2.3. Below is the procedure for undertaking the pilot test.

The Pilot Test Methods: the procedures were taken into consideration, stating the participant, setting, research instrument, and process of carrying out the pilot.

The Participants: The participants chosen for the pilot study were recruited via purposive sampling, which was based on the research objectives.

The Setting: The pilot interviews were carried out during the COVID-19 pandemic. Therefore, the one-on-one individual interview modes were online or by phone.

The Research Instrument: The research instrument used in the pilot test and both studies was a semi-structured interview. During the posing of questions, a note was kept of the language, fluency, flaws, and question clarity. Checks were made if there were pauses during the interview, indicating whether the questions were written incoherently and concisely.

The Procedures The pilot interviews were undertaken in three stages: pre-interview stage, interviewing stage, and post-interview stage.

Pre-interview Stage: In this stage, the participants were identified based on the needs of the study. The questions were prepared as above; this included the date, time, and the technology needed to conduct the interview.

Interviewing Stage: The interview started by greeting the participant, providing brief information about the research, and emphasising how the given information would contribute to its success. The questions were posed sequentially, followed by probing questions to gain clarification. To obtain rich information, recording and taking notes were used during the interview, with the interviewee's permission. It took no more than 30 minutes to complete an interview. After the interview, the interviewee was thanked and asked whether they needed more information about the study.

Post-Interview Stage: After each interview, the interview was transcribed verbatim. This allowed the amendment of questions with regard to the objective of the study.

3.2.5 Sampling Design

Sampling in qualitative research is the totality of participants involved in the study [Robinson, 2014]. The sample should meet the purpose of the study, which is to gain a

deep understanding of the problem. The strategy of selecting the population, its size, and recruiting participants should be carefully identified.

The population should be purposefully selected to meet the purpose of the study [Creswell, 2012] by identifying particular categories or groups; this is called Stratified Sampling [Robinson, 2014]. The selected group could be homogeneous or heterogeneous [Robinson, 2014, Creswell, 2012]. Homogeneous means that the selected group shares the same characteristics, such as demographics, geography, etc. Conversely, heterogeneous means that the selected group exhibits a range of different characteristics.

The size of the population is typically small to maintain their individuality during analysis [Maxwell, 1996] and to prevent the researcher from biassing the data [Robinson, 2014]. Also, the time needed to provide an in-depth understanding of the problem depends on the population size [Creswell, 2012]. The size of the sample depends on reaching data saturation, i.e., when no new data emerges [Saunders et al., 2007, Creswell, 2012].

After identifying the population and its size, the recruitment of participants should be carefully undertaken. Many methods are available, but when the participants are unlikely to respond, snowball sampling is chosen [Robinson, 2014]. A snowball sample is when the interviewer asks the participants for recommendations of acquaintances who might be interested in participating, which leads to ”referral chains” [Robinson, 2014].

Purposeful sample The purposeful approach in a qualitative study is to determine the sample that would provide useful information to understand the central phenomena. Geographical homogeneous sampling was chosen for the exploring issue interview, i.e., uniform characteristics of individuals to be interviewed before the data collection begins. In contrast, heterogeneous sampling was chosen for the expert review. This strategy helped to gain a comprehensive view from different groups.

Determination of the sample size: The saturation data occurred in the exploratory interviews when 15 participants had been interviewed, whereas in the expert review, the saturation data occurred when 8 experts had been interviewed.

Recruitment of participants: The recruitment of each participant had to match the criteria that were set in the study.

For the exploratory interview, the participants should have experience investing in land. This sample was obtained by first contacting the government's Etmam in Housing Programme to provide the researcher with a list of investors who have issues with land titles. The interviewees were also asked at the end of the interview to recommend more participants who shared their interest and met the recruitment requirements.

For the expert review, the human resources department of the Real Estate General Authority was contacted to provide a list of experts. The interviewees were also asked at the end of their interview to recommend more participants who shared their interest and met the recruitment requirements.

3.2.6 Research Analysis Design

Choosing methods for analysing the data depends on the applied methodology. Thematic analysis is broadly used in the qualitative analytical approach [Roulston, 2001, Boyatzis, 1998]. It is used for "identifying, analysing, and reporting patterns (themes) within data" [Braun and Clarke, 2006, p.79]. It forms the key component of qualitative data by combining similar codes to cluster major ideas about the data [Creswell, 2012].

Analysis of content is another method used for the identification of patterns across qualitative data. It is sometimes handled as a thematic method [Braun and Clarke, 2006]. However, content analysis mainly provides counts (frequency) and allows initially qualitative data to be analysed quantitatively [Braun and Clarke, 2006]. Typically, the thematic analysis method is not treated as quantity measurement compared to content analysis but rather depicts valuable data related to the research question and counts the prevalence of data patterns across the data [Braun and Clarke, 2006].

Data analysis approach To analyse the data obtained from the interviews, thematic analysis was adopted. The theme was developed using an abductive approach to meet the purpose of the analysis. The themes were predetermined based on the initial framework. The themes that emerged were combined or dissected by the researcher while analysing the data.

The interviews were guided by Braun and Clarke [2006], Creswell [2012] . They were first transcribed, then analysed using MAXQDA tools, which support the Arabic language. The interviews were carried out in the Kingdom of Saudi Arabia, and the interviewees were all Arabic native speakers.

Analysis started with detailed data by converting the audio transcription to general codes and themes with a coding process [Creswell, 2012]. This step involved simultaneous analysis and data collection, as well as iterative analysis and data collection. The narrative approach helped in understanding the connection between categorisations and making the data interpretation more coherent and concise [Maxwell, 1996]. The process of analysis followed the advice of a pioneer in qualitative research [Braun and Clarke, 2006, Creswell, 2012]. The process can be summarised in six steps.

Step 1) Interview Transcription: Interviews were transcribed and organised ready for analysis.

Step 2) Initial read: An initial active reading through the interviews was important to gain a sense of categorisations that can ”fracture” or chunk the data by giving them a label that describes each chunk. These chunks were predetermined according to the initial framework.

Step 3) Code Text for Description: Many chunks or segments of data were identified since these steps proceeded simultaneously with data collection. The output was many segments of text.

Step 4) Code Text for Themes: The coding went through an iterative process to reduce the segments to 4 to 5, until the themes that represented the data were reached by grouping segments, removing redundant segments, and identifying connections between the segments.

Step 5) Representing The Description and themes: The segments identified enabled comparison between data in the same category and contributed to the development of a connection with narrative analysis.

Step 6) Producing the Report: Finalise the findings by translating all the text to English, then interpreting the findings using narrative analysis.

Thematic analysis process The thematic analysis process can be carried out in two ways: the deductive approach and the inductive approach [Braun and Clarke, 2006]. An inductive or ”bottom-up” way is a process of coding the data without attempting to integrate it into a previously existing coding framework or the analytical preconceptions of the researcher [Braun and Clarke, 2006]. In contrast, the deductive or ”top-down” way is the process of coding the data that is characterised by the conceptual or analytical interests of research in the area [Braun and Clarke, 2006]. Combining both methods leads to the abductive approach [Silver and Lewins, 2014].

3.2.7 Multi-method Research Design

Multi-method research design generally refers to using two or more methods in a research project. However, Stange and Crabtree [2006] used multi-method terminology to refer to the integration of qualitative methods and quantitative methods. They described their approach using the terms multi-method and mixed-method interchangeably. Indeed, multi-method denotes a research design that uses two different research styles in a research project. Anguera et al. [2018] attempted to draw a dividing line between the two terminologies. They claimed that multi-method is comprehensive, meaning the combination of two methods, whether the research design is using two approaches of qualitative methods, quantitative methods, or both methods, because it provided a potential solution to the difficult questions in social science [Greene,

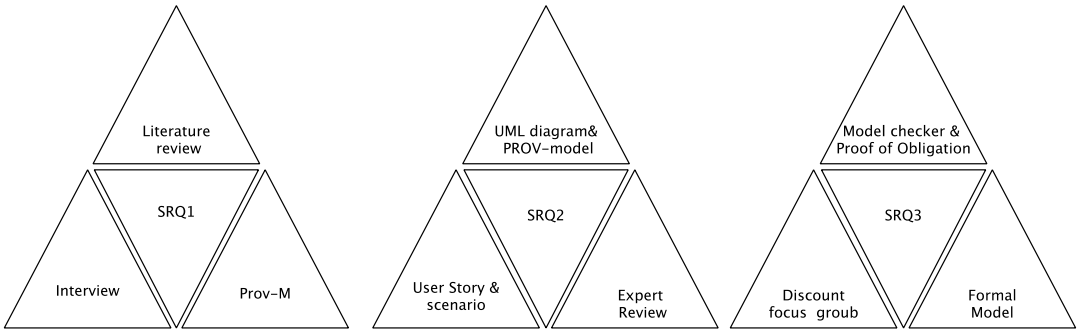

FIGURE 3.3: Triangle technique to the research questions

2015].Therefore, multi-methods are not limited solely to the integration of qualitative and quantitative methodologies but rather encompass a broader meaning. It refers to the integration of two styles for gathering data within a single study. It might combine qualitative interviews with qualitative observation or quantitative survey research with a quantitative experimental study.

3.2.8 Triangulation Approach

Every research method has some limitations. Combine several research methods so that information from other sources can be used to overcome the limits of one method. Therefore, validate its accuracy [Creswell, 2007].

Triangulation is the process of using various data sources or multiple data analysis techniques to increase the validity of a research project[Salkind, 2010]. It is a useful strategy for qualitative, quantitative, or multi-method research [Golafshani, 2003], which evaluates the findings through cross-verification of two or more sources [Bogdan and Biklen, 1997], to strengthen the result by improving the validity and verification. Using multiple sources, such as observation, theories, interviews, evidence from the literature, and recordings, can lead to a comprehensive understanding of the phenomena being studied [Bogdan and Biklen, 1997]. Therefore, triangulation helps to identify the weakness or bias that could be found using only one resource.

Methodological triangulation can be either simultaneous or sequential [Saunders et al., 2007]. Simultaneous design means collecting the data from both studies, analysing them separately, comparing the results, and thus developing the interpretation. In a sequential design, the research collects one study and then analyses the data. The interpretation from the study applies to the subsequent study.

Sequential triangulation Sequential triangulation is a technique used to combine the findings from two studies to answer a research question. They were answered in three stages to validate the finding as presented in Figure 3.3. This method was essential to

compare the data resulting from the previous step with the other findings in order to confirm the findings. Employing sequential triangulation enabled an understanding of the gap between different perspectives and lent support to the research findings; the results were confirmed through the use of triangulation.

3.3 Research Methods Applied to Software Engineering Discipline

The goal of social methodology is to offer the research resources needed to identify system requirements. However, this section provides an introduction to the engineering discipline used in designing a system as well as the tools needed to construct a formal model.

3.3.1 Software engineering

Software engineering refers to a set of contemporary software development methodologies [Shaw, 1990]. The process involves designing, coding, testing, and implementing a system. Software engineering research areas address problems using research methods in specialism [Holz et al., 2006]. These problems produce results and evaluate the results' validity. At every stage of the process of development, the system utilises specialised research methods. This approach is utilised to address parts of SRQ2 and SRQ3. Following data collection, SRQ2 mainly focuses on describing the system specifications using a user story. SRQ3 is primarily devoted to the design stage of the system. In the design, the requirements are modelled using UML, then a formal model is developed to ensure the validity of the system specifications.

3.3.2 User Story and Scenario

A scenario describes the system from the user's point of view. It provides the narrative tasks of user behaviour. The scenario is written in natural language and follows user story mapping. User story mapping is a useful tool that can be used for describing user behaviour [Patton and Economy, 2014]. It gives a pattern for telling a story, organising thoughts, and breaking down the big picture [Patton and Economy, 2014]. The method of presenting user story mapping is by writing the story in notes. Every note tells one task or one story. The notes together show the whole picture of the story. The pattern of writing a story using the following pattern

As.., I want to.., so that..

This method is used in the third stage of user requirement analysis and before writing the requirements specification, 3.1.

3.3.3 Modelling

Modelling, as outlined by Fowler (2004) in his work on UML, is a visual approach to constructing a control system. Its benefits include enhancing understanding, extending and repurposing system components, and mitigating risks prior to the actual development of the system. This method proves valuable in communication with stakeholders, articulating requirements, testing, and illustrating the interaction among various systems. Additionally, modelling facilitates the capture of multiple system viewpoints. For example, a database analyst might contemplate data entity relationships as a mechanism for data management.

This thesis employs three distinct models to represent the transfer of ownership. The proof-model analysis is applied to identify challenges and assess weaknesses in the process. Formal models play a crucial role in enhancing comprehension of the specification, eliminating ambiguity, and refining the documentation of the specification. Before delving into the formal modelling of the process, UML models are employed. These UML models serve as a preliminary step, aiding in the construction of both the static and behavioural components of the system.

3.3.3.1 PROV-Model

At core concept of representation provenance lies the PROV data model, comprising three distinctive notations. The first is represented by an oval-shaped entity, symbolising a physical or digital record, whether it be on a web page or within a chart. The second notation takes the form of a rectangular activity, signifying either the source entity's existence or the attribute of its alteration. Lastly, the pentagon shape is attributed to the agent, which could be an individual, a software entity, or a person assigned with responsibility.

An alternative approach to represent the provenance data model for detecting threats in IoT systems involves utilising an attack model, as proposed by [Fadhel et al., 2019]. This model builds upon the PROV-N semantic model notation [Missier et al., 2013], incorporating rules within the model. Primarily focused on threat detection during the enumeration of systems, the attack model enhances the representation of the data model. This representation within the attack model employs three distinct notations:

Entities which are shaped as circles. An entity represents physical or digital records, such as a web page or chart.

Processes which are shaped as squares. They represent the process that takes an entity as input and produces another entity as output.

Stakeholders which are shaped as diamonds. These represent stakeholders. The agent can be a person, a piece of software, or can ascribe responsibility.

The latter representation has been utilised to identify challenges and analyse user requirements, aiming to assess potential hazards that the process may encounter.

3.3.3.2 UML models

The Unified Modelling Language (UML) serves as a graphical language and a standardised approach for visually designing, constructing, and documenting software specifications, as highlighted [Fowler, 2004]. UML facilitates the system analyst in visualising system specifications, promoting shared understanding among stakeholders [Fowler, 2004]. In this process, class diagrams and activity diagrams are employed to model the static and behavioural components of the system, respectively. The class diagram identifies the necessary set and relationships for initiating formal model construction, while the activity diagram illustrates the sequence of states or actions within the process. In the thesis, UML models play a crucial initial role in the construction of the formal model.

3.3.3.3 Formal methods

Formal methods have long been employed as an effective approach to address the intricacies of software systems. These methods offer a mathematically based language, a rigorous methodology, and a set of tools dedicated to the specification, design, and verification of both software and hardware components [NASA, 2023]. While formal methods do not guarantee the absolute correctness of a system, they play a crucial role in constructing systems that enhance understanding and expose inconsistencies, ambiguities, and defects in the specification [Clarke and Wing, 1996]. In the development of systems, formal methods can be utilised to specify system behaviour, ensure compliance with the system specification, define the system boundary, and ascertain that system properties are established through rigorous verification processes.

Model verification can be accomplished through either model checking or theorem proving [Clarke and Wing, 1996]. Model checking, as an automatic technique, is capable of constructing a finite model of a system while maintaining assumed properties on the model. Theorem proving involves employing mathematical expressions to prove specific properties of a system.

Event-B is a modelling language that uses a mathematically grounded approach, incorporating elements such as functions and theory sets to construct models developed by Abrial Abrial [2010]. Event-B utilises the Roding toolset for model construction. This language is rooted in the state method for system development [Butler et al., 2004]. Employing set theory and a refinement strategy, Event-B systematically constructs models, addressing system complexity. The inclusion of proof obligations ensures consistency between different levels of abstraction in the model.

In the realm of software engineering, formal methods find application in supporting the development of systems at various stages [Roggenbach et al., 2022]. In this study, a formal method is employed to systematically build the process of transferring ownership, validate specification requirements, and address the SRQ3.

3.3.4 Discount Expert Focus Group

A focus group, as described by Fink [2003a], is an in-person qualitative interview involving several participants simultaneously. Typically, the number of participants is kept small. This method proves valuable for eliciting and gathering participant opinions on a specific case.

An expert focus group involves participants who are all experts in a specific field, typically ranging between 5 to 10 participants [Fink, 2003b]. The analysis becomes more costly and time-consuming as the number of participants in the interview increases. However, a discounted expert focus group proves to be a cost-effective and efficient method for obtaining valuable feedback within a reasonable timeframe.

A discount expert focus group, classified as a discount usability method [Nielsen, 1989], involves three to five subject specialists. This method offers a quick and cost-effective way to obtain feedback while focusing on specific aspects. Nielsen [1989] argues that, despite revisions made to the design to accommodate feedback from numerous specialists, discount usability consistently yields optimal results.

In the context of evaluating the construction of the model, a discount expert review is employed. This tool facilitates interactive interaction with participants to ensure building the right mode that fulfils the requirements required and offers valuable feedback. Model evaluation relies on input from domain experts who participate in expert evaluations, a distinctive technique for reviewing system design during development to gain insightful domain feedback [Nielsen, 1989]. Evaluators' feedback, who must be subject-matter specialists not involved in the design process [Harley, 2018] contributes to the following:

- assesses the strengths of developing the model.

TABLE 3.1: Summary of research questions, selected research methods, result, and result validation

	Part of Question	**Research Method or Activity**	**Result**
How can technical safety encourage beneficiaries to trust a land registry system in the Kingdom of Saudi Arabia? This question was divided into three sub-questions			
SRQ1	Identified factors	Literature review	List of factors
	Ownership procedure analysis	PROV-model	Proposed social trust framework
	Investigate the challenges	Interview	Further factors for mitigation the challenges
SRQ2	Confirmed factors	Expert Review	A list of confirmed social trust factors
	Identifying user requirement	User Story and scenario	List of requirements
	System modelling and Hazard analysis	UML diagram PROV-model	Requirement representation
SRQ3	Modelling the requirements	Formal model	Safety process of transferring ownership
	Model evaluation	Discount focus group	Set of recommendations of constructing the model
	Model validation and verification	Model checker and animation	A consistent model

- identifies issues in designing the model.
- provides recommendations for better model construction.
- highlights the best practices or strategy of designing a model.

3.4 Research Questions

When researchers acquire knowledge using a one-sided approach to address the research questions, it can lead to irrational conjectures presented in the study. The conjecture from this research is that, through technical safety , it is possible to enhance users' trust in transferring ownership in the land registration system. Applying methods suitable to the sub-research questions would contribute to answering the main research question. The methodology begins with an investigation of the user's needs to understand the social side using social study methodology. This investigation leads to answering SRQ1 and part of SRQ2. Then, discipline methods are applied to construct a safety model using formal methods to address also SRQ2 as well as SRQ3.

Based on the research questions listed in Section 1.3, and the methodology in Table 3.1, here is a description of how to employ the methodology.

The details justification of using the method as follows:

1. SRQ1 was answered in three parts. The first part is examining the literature and proposing factors that contribute to mitigating the challenges 2.6. Then, analyse the procedure of registering ownership in three different counties using Prov-Modelling. This method contributed to comprehending the context and investigating further factors. Lastly, conduct an interview to investigate other challenges that people face when they are selling and purchasing property in Saudi Arabia. The findings from the study should confirm the challenges, contribute to identifying requirements, and provide a better understanding of the system, which might lead to a refinement of the framework before confirming it with experts.

2. SRQ2 was answered in three parts. The first part is conducting an interview with experts to confirm the framework. Then, analyse the system requirements for transferring ownership. The requirements are analysed and envisioned using scenario-based requirements analysis. Identify the hazards during the process that caused the challenges using the PROV model. Lastly, the requirements are modelled using UML diagrams.

3. Despite the fact that the interval between SRQ2 and SRQ3 to model the requirement, SRQ3 is answered in three parts. Firstly, model the requirement using a formal model, then evaluate model construction with experts in the method. Lastly, during the construction, the model is verified using tools attached to Event-B, a model checker, and proof of obligation.

Every research question has been answered using three methods to vary the answers using sequential triangulation 3.3.

3.5 Ethical Approval

Before conducting any study involving people, it is compulsory to obtain approval from the research ethics committee.

Interview Study: The ethics approval reference number is 59904. The ethics committee at the University of Southampton approved this on 04/07/2020.

Expert Review Study: The ethics approval reference number is 62057. The ethics committee at the University of Southampton approved this on 24/11/2020.

Expert Review Focus Group: The ethics approval reference number is 75443. The ethics committee at the University of Southampton approved this on 19/07/2022

All participants were informed about the study in advance. The consent of all participants was obtained in writing once they had agreed to participate. Their participation

was optional, and they could withdraw at any time if they no longer wished to participate in the study. Participants were also assured that the data was anonymous and confidential. At the end of the study, all the data gathered was deleted.

3.6 Chapter Summary

The research approach is presented in this chapter. This made it possible for the researcher to choose the best strategy for addressing the research questions. The discipline-specific research methods were briefly described. This is followed by how it applies to this research and the rationale for the chosen approach.

The employed method uses a qualitative multi-method to address the research question. The research question was triangulated to validate the findings and sequentially confirm the STF and validate the social needs. The factors represent the social needs to construct land registration systems. Social needs were collected using interviews and expert reviews. Finally, the social need validated by constructing a model using a formal method. Software engineering approach was employed according to construct the model.

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Chapter 4

Framework Development

The previous chapter 2.4 has discussed the background of land registration systems, the challenges of land registry, and reviewed a comparative example in a global context in terms of challenges. Existing approaches frequently fail to address the challenges in the land registration systems due to a failure to consider social factors and focus solely on technology. Therefore, it is imperative to understand the social needs and use technology to respond to their perspective since the land registration systems heavily serve social requirements. This chapter proposes a STF. This framework provides an instrument before conducting a qualitative study with beneficiaries from the system. The proposed framework can be utilised to investigate system development and requirements in the context of the land registry in the Kingdom of Saudi Arabia.

The process of developing the framework to meet the aim of the present research. The framework development consists of three stages. This chapter describes in detail phase 1. The process of constructing the proposed framework in phase one consists of four steps, namely **Review**, **Analyse**, **Classify**, and **Build**. The first step presents a comprehensive understanding of the problem. Following this, the challenges are specified by analysing three use cases and identifying the factors that could overcome the challenges in the land registry. Moreover, this step points to exactly where the double sale occurs during the process of registering a land title. Furthermore, these factors are categorised into five groups, as they can address the social-technical challenges. The proposed framework contributes to answering SRQ1.

4.1 Framework Development Process

The investigation of the land registration systems should be undertaken according to a framework that helps to understand the context and take appropriate action to reach

the conjecture of the research. The conjecture from this research is that through providing technical safety, it is possible to enhance beneficiaries' trust in the land registry system. Despite the lack of a specified methodology for constructing a framework [McMeekin et al., 2020], the framework-constructing methodology used in this study is in line with other works [Squires et al., 2016, Kallio et al., 2016]. In Chapter 3 Section 3.1, we briefly describe the construction process of the framework.

The **initial phase** 4.2 is to determine the factors by reviewing the literature and examining the ownership transfer process in three countries. It involved reviewing the literature review to understand the land registration context. This includes identifying the factors that led to the challenges, analysing the factors using relative examples, and examining the process of purchasing properties in three countries. **Phase two** Chapter 5, Section 5.1 involves investigating further challenges in the local context because of their absence in the literature review, then interviewing land registration experts to confirm the framework. **Phase three** Chapter 5, Section 5.2 confirms framework is discussed in .

4.2 Social Trust Factors for Land Registration Systems

The process of identifying the factors is construed in four steps in order to identify the factors in the context of the land registration system in terms of mitigating the challenges. The process began with a review of the context of land registration systems, which provided a broad insight into the land reform process. This step uses a comparative analysis of three countries with similar challenges in their systems. Then, the identified factors are analysed and grouped under the same categorisation. Finally, based on the findings, a Social Trust Framework (STF) is proposed. This process is describe briefly in Figure 4.1.

Review: reviewing the context of land registration Reviewing is the first step in acquiring comprehensive understanding about land reforms. The review includes an examination of land registration systems both globally and locally, with a focus on identifying and analysing the main challenges 2.6. This analysis is further supported by a comparative example, which is discussed in Chapter 2 and Section 2.4. Subsequently, a comprehensive analysis was conducted to compare the land registration system in the Kingdom of Saudi Arabia and identify the related challenges. In conclusion, the review provides a the the context and challenges 4.1 in the land registry.

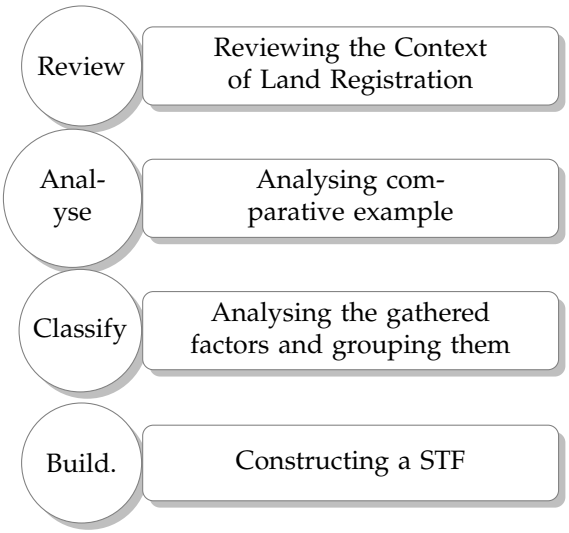

FIGURE 4.1: Steps of developing the framework

TABLE 4.1: Analysing the problems based on the country

Common Problem in Global / Country	Double Sale	Lack of clear rights ownership	Fraud*	Source
India	✓	✓	✓	[Thakur et al., 2019]
Indonesia	X	X	✓	[Rizal Batubara et al., 2019]
Kingdom of Saudi Arabia	✓	✓	✓	[Alasmari, 2019]
Ghana	X	✓	✓	[Eder, 2019]
Greece	X	X	✓	[Themistocleous, 2018]
Honduras	✓	X	✓	[Benbunan-Fich and Castellanos, 2018]
Georgia	X	X	✓	[Benbunan-Fich and Castellanos, 2018]
Tanzania	✓	✓	✓	[Kombe et al., 2017]

* The literature has not specified exactly what type of fraud. The fraud could be referred to as double sale, lack of the clear rights of ownership, forgery or corruption.
✓: the problem EXISTS according to the source.
X: the problem does NOT exist according to the source.

Analysis: analysing use cases In this step, we analysed numerous cases from various countries around the world to understand the challenges in the land registry system. We examined these use cases in the literature through discussions, comparisons, reports, and interviews. Moreover, the challenges that have been identified from the literature in Section 2.6 are fraud, lack of clear rights of ownership, and double sale. Table 4.1 summarises the challenges in many countries. However, most of the resources mention fraud as a major challenge in the land registry without specifying exactly what type of fraud they are referring to, whereas other resources specify the types of challenges.

To investigate the problem more precisely and identify exactly where the double sale challenge occurs in the process of registering a land title in the land registry, three use cases were chosen. These use cases exhibit similarities in the land title

registration process, such as the involvement of numerous organisations in the land title recording, the inconsistency of their records, or the absence of technical linkages between them. Moreover, the land registration process is complex because many departments are involved. Identifying the exact departments that are responsible for the challenges could help to investigate said challenges deeply during the step of confirming the framework.

The analysis of the three use cases is based on the relative examples discussed in Section 2.4, using Prov-Model to assess the process of registering properties , and to identify the vulnerabilities such as a double sale. The process of registering a record in the land registration system in the chosen use cases goes through multiple departments, inconsistent systems, and taking a long time. The records verification requirements from each department are different in order to confirm a transaction.

To discuss the model briefly, Figures A and Figure B in 4.2 and Figure B in 4.3 show the process of registering land ownership in India, Indonesia, and the Kingdom of Saudi Arabia, respectively. Based on the problem mentioned for each case, it is clear that they share quite a similar process of registration. Therefore, after completing the analysis of the three uses cases in the three countries, the land registration **Processes** are grouped by similar activities, as well as similar reports for **Entities** and **Stakeholders**. The main processes have been revised regarding the challenge on the system and extracted from the processes that are out of the scope of the research. It is clear that there is a similarity between the three cases: **Title Clearance**, **Check and Validation**, **Site Survey**, and, finally, **Register the title**. The double sale challenge could be occurring between the processes **Check and Validation**, as shown in Figure 4.3, because the information presented by the site survey could point incorrectly to the land record.

Looking at the Kingdom of Saudi Arabia context, the site survey is processed at MOMRA in the survey department, whereas Notary is processed at MoJ in the notary department.

Therefore, several factors need to be addressed. Fraudulent activities are acts of manipulation of property information for personal gain. This activity results in a lack of accountability, reputation, authenticity, integrity, security, or editability. Double sales are a form of fraudulent activity. However, it facilitates the practice of selling a property to multiple owners. They have an impact on the accountability, security, reliability, authenticity, reputation, and integrity of the system. The absence of non-editable, transparent, and digital signatures may also be a contributing factor. Vulnerable systems, susceptible to fraudulent acts and double sales, result in a diminished capacity to establish ownership, leading to a lack of clear ownership.

TABLE 4.2: A: analyses of land registration process in India, B: analysis of land registration process in Indonesia

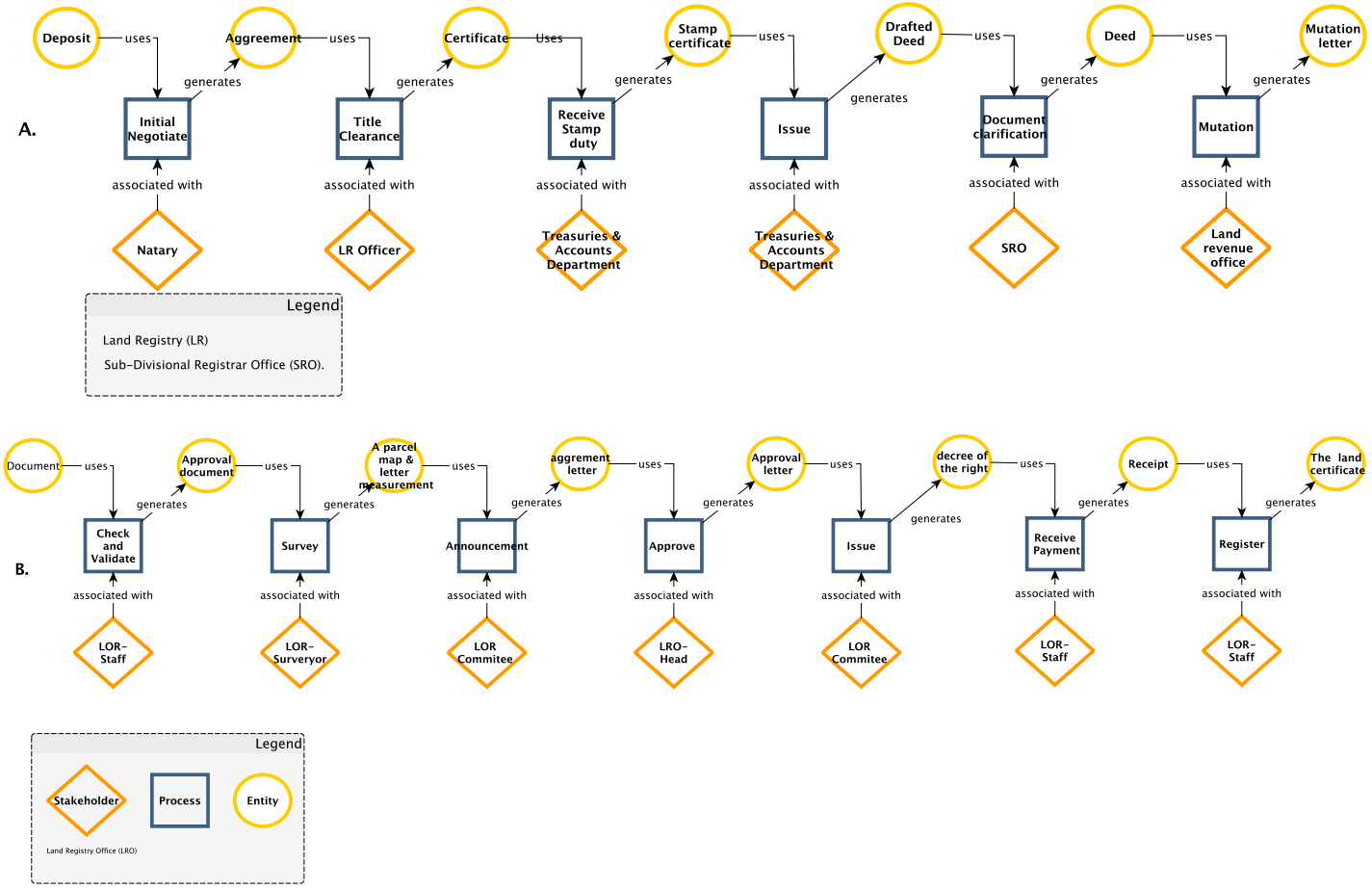

TABLE 4.3: A:the combined processes in land registration B: analysis of land registration process in the Kingdom of Saudi Arabia

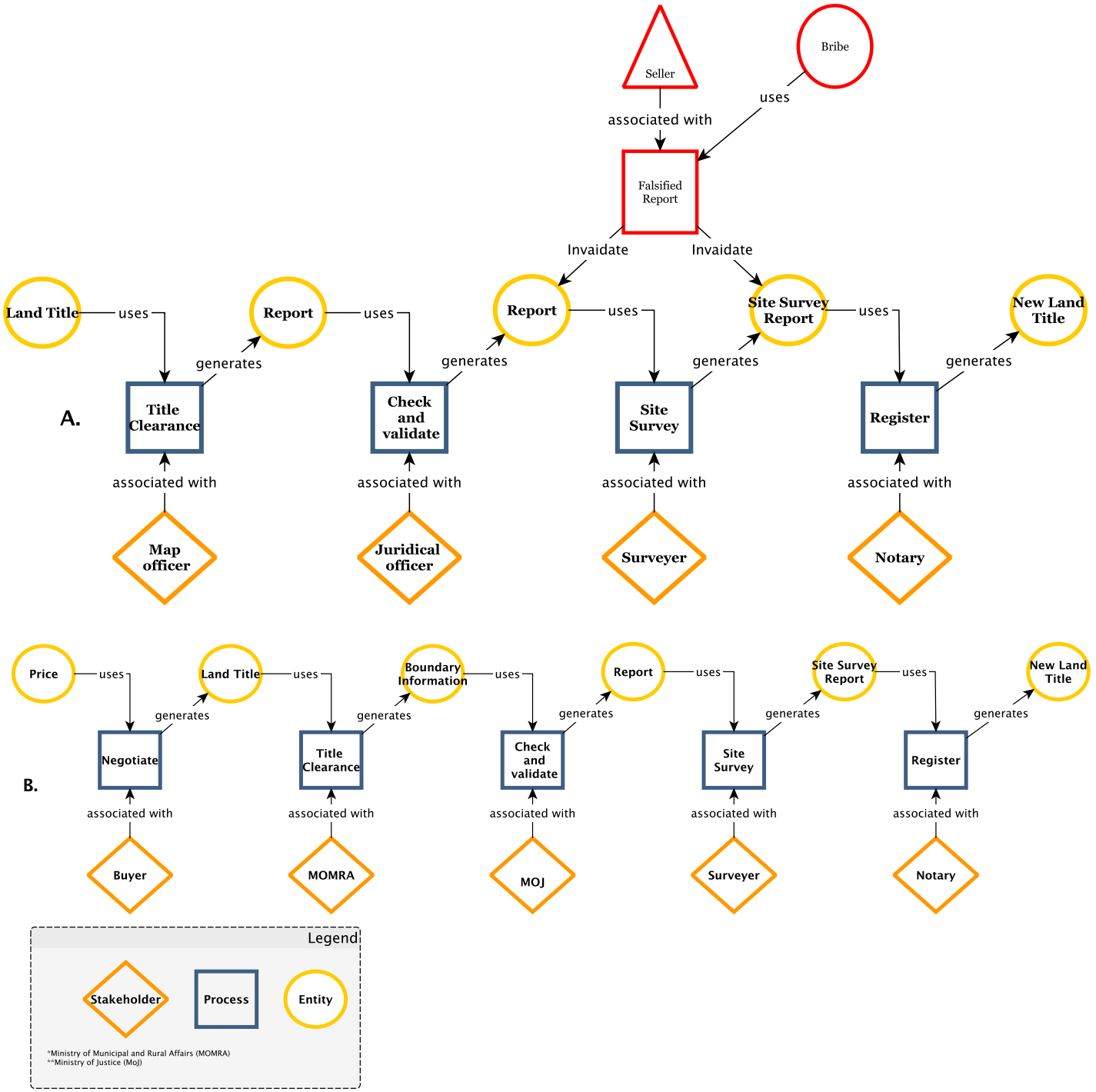

TABLE 4.4: Analysis of the problems according to the land registry context

challenges / Factor	Fraud	Double Sales	Lack of ownership
Non-editable	✓	✓	
Rights of ownership			✓
Accountability	✓	✓	
Secure land title			✓
Transparency		✓	
Security	✓	✓	
Auditability	✓	✓	
Authenticity	✓	✓	
Reliability	✓	✓	
Integrity		✓	
digital signatures		✓	
Non-reputable	✓	✓	
Source	[Thakur et al., 2019, Kombe et al., 2017, Benbunan-Fich and Castellanos, 2018, Themistocleous, 2018, Eder, 2019, Rizal Batubara et al., 2019]	[Thakur et al., 2019, Kombe et al., 2017, Benbunan-Fich and Castellanos, 2018, Alasmari, 2019]	[Thakur et al., 2019, Themistocleous, 2018, Eder, 2019, Alasmari, 2019]

Classify: grouping the gathered factors In this **step**, the identified factors are classified into groups that could help to enhance beneficiaries' trust after the investigation of the technology in Section 2.4.4 , which contributes to solving the challenge. From Section 2.2 , it is clear that the problems in the land registry system are not only because of shortcomings in the legal system, but are mostly caused by inefficiency in the record-keeping system and technology. The core of the land registry is the legal records that are recorded by using a legal framework to provide a secure land title and rights ownership. These records have to keep their **provenance** to prove their originality alongside secure provenance information. However, the provenance and security of information constitute a challenge as the information might be subject to change. Therefore, the immutability factor should be considered so that the information is not altered or modified.

Table 4.4 shows the factors that could overcome the challenges in the land registration system, while Table 4.5 classifies the factors based on the culture and law, as well as the technologies that address said factors.

Build: construct the social trust framework The last **Step** is to construct the final representation of the framework. This includes showing all the relationships between the land registration system and how the influential factors support said system.

TABLE 4.5: Analysis of the factors and grouping them to meet the aim of the research

Factor \ Categorisation	non-editable	Right of ownership	Accountability	Secure land title	Transparency	Security	Auditability	Authenticity	Reliability	Integrity	non-repudiation	source
Provenance			✓		✓		✓			✓		[Moreau et al., 2010]
			✓		✓					✓		[Lemieux, 2016a]
			✓							✓		[Herschel et al., 2017]
									✓			[Missier, 2016]
Law and Culture		✓		✓					✓			[Abdulai, 2006]
Security								✓		✓	✓	[Burrows et al., 1989]
								✓		✓		[Cullen et al., 2000]
								✓		✓	✓	[Zhou and Gollmann, 1997]
Immutability	✓		✓		✓	✓						[Ølnes and Jansen, 2018]

The framework in Figure 4.2 shows the participation of the system in the land registry. As discussed in 2.1.3, there are two public sectors involved in the land registry process in the Kingdom of Saudi Arabia: the cadastral system and the land registry. The cadastral system is controlled by MOMRA, whereas the land registry is maintained by MoJ. To accomplish the aim of the research, the identified factors are grouped into five categories based on the investigation of the **Classifying** step: provenance, culture and law, security, and immutability. It is believed that these factors could have a significant influence on enhancing beneficiaries' trust. Therefore, these groups have been placed in the category **Social Trust**.

4.3 STF: Social Trust Framework

The process of the construction of the framework was discussed in the previous sections. This section concerns the detailed discussion of the main components of the framework.

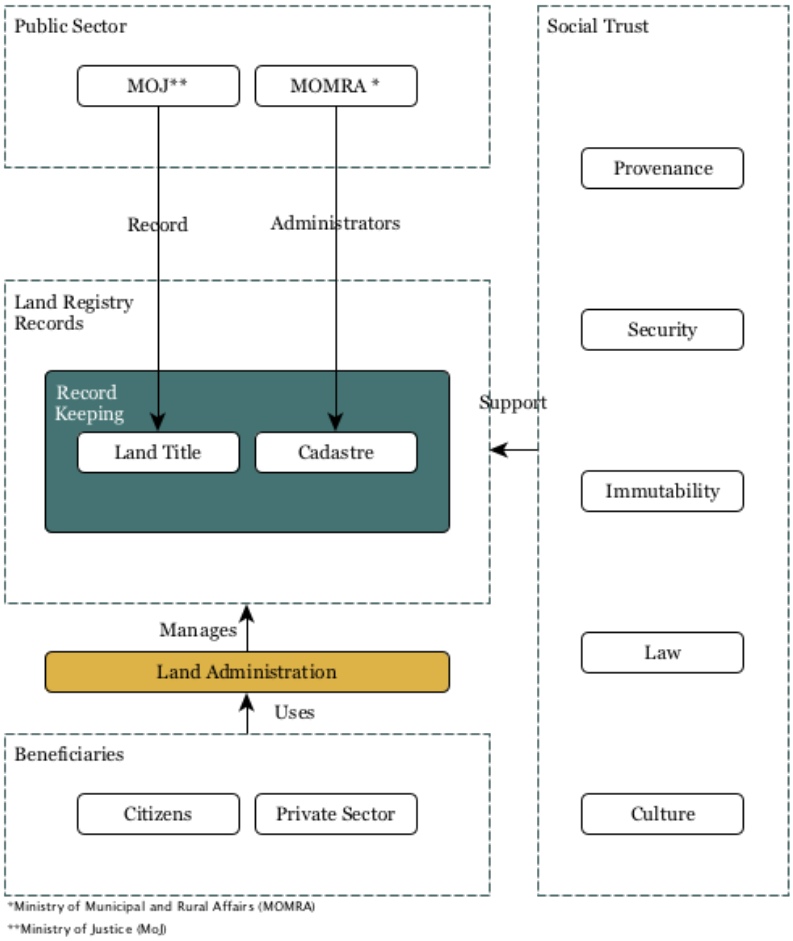

FIGURE 4.2: Social trust framework for land registry in the Kingdom of Saudi Arabia

To deliver **Social Trust** to the land registration system, five main factors are considered: culture and law, provenance, security, and immutability, as shown in Figure 4.2. These factors support the land registration systems. The land registration systems are Title Registry that is recorded by MOJ and Cadastre that is administered by MOMRA. MOJ and MOMRA are organisational bodies called public sectors. The users of these systems could be citizens or private sectors. Citizens are the individual who has the right to own properties for personal use. Private sectors are for the properties owned by the name of a company or firm. Both of them are called beneficiaries.

Culture and law the proof of ownership or transferring of land from one person to another must be carried out through formal titles or deeds registration. The conveyance is conducted through transferring action of sales, purchases, grants, inheritance, exchange, auction, or cancelation of rights for the public interest. These actions are related to the law or cultural aspects.

To control the conveyance, a formal document is required to define and administer the rights according to the legal framework. This provides a trusted framework through which beneficiaries can claim their rights in case of disputes [Lemieux, 2016b]. Every country has its own laws and culture which are used to provide secured ownership to its beneficiaries.

Provenance land registry records are developed for public interest and it is important to share them with the public. Therefore, providing the records' provenance is critical, as this presents the source of the data, the semantic changes over time, ownership of the information, and who is responsible for said changes.

Considering the provenance of records adds value to the systems. It allows the system to be more transparent since the records are accessible to the public and, as a result, makes the system auditable [Moreau et al., 2010].

Security securing data provenance adds another layer to protect the records. Securing data provenance is associated with access control, data integrity, liability, and accountability of the records [Moreau et al., 2010]. Access control defines the policy and process to access the data provenance, whereas data integrity is about ensuring that the data remains unchanged and not tampered with during the transferring [Moreau et al., 2010]. Liable and accountable records are designed to guarantee the accuracy or objectivity of the records [Moreau et al., 2010].

Immutability is a crucial factor for cases of land registry. It places restrictions on records so that they cannot be altered or modified.

4.4 Summary

This chapter gives a brief explanation of the initial phase of developing a framework. The framework was built based on the knowledge gained from reviewing the literature and analysing challenges in similar contexts. The framework consists of five factors needed to develop a system. Developing land registry systems should align with the law and the culture of the intended country. Also, the land registry is a record system that should provide the record's provenance and be secured, and these records should be unchanged. The identified factors provide a preliminary framework before conducting a qualitative study. The following chapter 5 presents two qualitative studies aimed at investigating additional factors to mitigate the challenges and subsequently validating the framework with experts. This chapter includes the findings and discussion.

Chapter 5

Findings of the Confirmatory Study

The chapter 4 was about the first phase of the framework development process. The framework consists of the factors needed to overcome the challenges. Then the proposed framework is further investigated by conducting a semi-structured interview to understand the user's needs to overcome the challenges. The findings of the study were reviewed by experts. The findings from this chapter assist in the completion of the first contribution and respond to SRQ1, which concerns the qualitative validation of the STF.

5.1 Challenges in the Land Registry

Chapter 2 and Section 2.4 investigated the land registry to understand the challenges in a global context. This enabled the development of a framework that helps overcome the challenges in the land registration system in Saudi Arabia. Chapter 4 proposed a framework and described the framework's development process, detailing factors, and components in Chapter 3.2.

Before presenting the confirmation of the proposed framework, it was necessary to investigate the challenges in Kingdom of Saudi Arabia by interviewing the land registry beneficiaries. These findings were used to refine the proposed framework before it being confirmed by experts. The development of interview questions for exploring the challenges, the methodology applied, and the procedure for data gathering, are explained in Section 5.1.1. Section 5.1.2presents the findings from exploring the challenges, leading to the refinement of the framework in section 5.1.3.

TABLE 5.1: The objective of exploratory questions

Sub-Research Question 1	Type of Question	Question Number	Objective of the Questions
Investigation further challenges through analysing the process of transferring ownership.	Open-ended questions (qualitative research)	(Q1-Q3) background information	Explore the participant's background (Experience, interest land type, and location).
		(Q4 -Q8) Troubleshoot problems during the process of purchasing property	Explore the challenges that investors faced in process of purchasing the land.
			Identify how to overcome the challenges.
			Investigate more challenges based on their previous cases occurred.
			Identify what are the causes of the challenges.
			Recognise the type of challenges.
		(Q9- Q13) Identifying challenges by exploring missing information	Understand the reasons of perform the due diligence
			Understand what the due diligence are to clear the title in MOJ.
			Understand what the process to clear the land information in MOMRA.
			Investigate other organisational parties involved in the process of purchasing land
			Investigate important information are available and easy to access.
			Investigate contradictor information between organisational parties.
			Investigate the technology contribution to overcome the mentioned challenges.
			Explore the information needed to add value to the land title.
			Explore the influence of transparent information on land title can add value to the land title.
		(Q13-Q14) Identifying challenges in the court.	Explore challenges in court
			Identify the time needs to settle cases.
		(Q15) Participant's voice	Explore participant's needs to enhance technical, organisation, and transparency.
			Explore participants opinion of proposed procedure for land registry process.

5.1.1 Developing The Questions

The nature of the interview questions for this study is exploratory. The questions were designed to explore more challenges to answer the first research question, using a top-down approach. They were written at a conceptual level and an operational level corresponding to specific metrics using GQM (see Appendix A).

The interviews were semi-structured and presented in five sections. The First section were open-ended and closed questions that explored the interviewees' backgrounds. This included their experience, type of land, and in which regions the interviewees were experienced. The Second section posed direct questions about the challenges and how they dealt with them, specifying precisely whether the challenges were technical or organisational, and presenting previous cases. In the Third section, the questions asked about the information in the land title record. These questions were trying to find out if there were more challenges, and gave the participants the chance to think deeply about the reasons behind the challenges. The fourth section was about cases before the courts that they have encountered, and discussed the challenges and time taken to complete them. The Fifth section discussed participants' ideas for enhancing the system by improving transparency, improving the process of purchasing lands, and the potential technology to overcome the challenges. Table 5.1 summarises the objectives of each question, and the list of questions is listed in Table 5.2.

5.1.1.1 Pilot Interview

The participants involved in the pilot phase were five people known to the interviewer and who were familiar with buying and selling lands: three real estate agents, and two investors. The demographic characteristics of these participants are summarised in Table 5.3. The interview instruments were quickly analysed, and then enhanced after each interview. The changes included checking the structure of the question, fluency, and understandability. However, after the third interview, it was recognised that the population sample chosen did not meet the objectives of the study as the interviewees only cared about selling the land and getting their commission, ignoring challenges with the lands and the process. Therefore, the population sample was shifted to the investors.

In the following interviews, one interviewee was an international investor and worked in a consulting company in real estate. He was knowledgeable about the challenges, but he was conservative in criticising the system. The questions were restructured to make the interviewee more comfortable. In the last interview, the questions went smoothly and the participant gave answers that met the objectives.

TABLE 5.2: Interview questions

Section	Question	Factors in the framework
Background of the interviewee	Q1) How many years of experience do you have in real estate?	General
	Q2) What type of property classification do you specialise in?	
	Q3) Which area in the kingdom you are working on?	
Troubleshoot problems during the process of purchasing property	Q4) From your experience in last three years which is the most complex element of Land registration system process:	F1) Security F2) Immutable F3) Culture
	Q5) With regards to the confidence in land registration system can someone else claim ownership of a parcel of land?	
	Q6a) What is the most challenge you faced when purchasing a property?	
	Q6b) How do you solve it?	
	Q7) Can you mention some of the previous cases that you had before buying land that could cause you severe consequences after the purchase?	
Correctness and completeness of the information	Q8) How would you describe the process of accessing the information in the Ministry of Justice (MOJ) to confirm the ownership?	F4) Provenance
	Q9) How would you describe the process of accessing the information in the Ministry of Municipal and Rural Affairs (MOMRA) to confirm the information in the land title?	
	Q10) Have you been experiencing contradictory information between MOJ and MOMRA?	
	Q11) What is the information missing in the land title that needs to make the property purchase more convince?	
	Q12) How do you know the number of deals occur on a specific property?	
Cases in Court	Q13) From your experience in the past three years what are the main reasons for legal disputes related to lands and titles that you have faced?	F5) Law
	Q14) How long it takes to settle legal disputes?	
System Enhancement	Q15) If you were in the position of decision-maker in the land association what would you do to improve the below: The transparency within the system The transaction journey of the buyer and seller of a land The adoption of new technology.	Improvement

TABLE 5.3: Demographics of participants

No.	Pseudonym	Experience	Occupation	Interview Mode
1	Abdu	6 years	Interested in land	Phone
2	Alth	10 years	Real estate agent	Phone
3	Almeg	35 years	Real estate agent	Phone
4	Alshahi	22 years	Real estate agent	Phone
5	Daw	10 years	Investor	Online
6	Are	10 years	Investor	Online

5.1.1.2 Interview Procedures

The interview approach was designed as semi-structured, and one-on-one, with both open-ended and closed questions. This type of interview does not allow the individual interviewee the opportunity to share their experience but enables the researcher to gain a comprehensive understanding of unexpected challenges raised by the interviewees. The objectives of the interviews were as follows:

1. Identify participant's experience in the process of purchasing land.
2. Determine the participant's need of information for the purchase of land.
3. Determine the challenges encountered with land title.
4. Determine to what extent the technology helps to overcome these challenges.
5. Find out how to improve and clarify land registration.

By achieving these goals, the challenges with regard to the land will be explored in-depth.

The interviews were conducted with 15 investors, one of whom withdrew. All the participants experienced challenges in selling and buying land. Participants were only considered if they had worked in the field of selling and buying land for at least three years, and had either worked for a real estate investment company or had contributed to this field. This study was set in the Kingdom of Saudi Arabia and focused on the Riyadh Region, Western Regions including Jeddah and Makkah, and Eastern Regions. These are clearly shown in the following Table 5.4.

5.1.2 Findings

The aim of this section is to present the result from the interview by analysis interview data using thematic and content analysis and MAXQDA tools. The results from the interview was organised into two sections, which were the demographics of the interviewees and the interview analyses.

TABLE 5.4: Interview setting

ID	Date	Length in mins	Experience	Speciality	Experience in
1A	22/07/2020	28:48	12	Residential, Commercial, Undeveloped	Riyadh, Dammam, Jeddah
1B	22/07/2020	20:17	25	Residential, Commercial, Undeveloped	Riyadh, Dammam, Jeddah
1C	24/07/2020	50:26	25	Undeveloped	Taif, Makkah, Jeddah
1D	27/07/2020	42:15	12	Residential, Commercial, Undeveloped	Riyadh
1E	29/07/2020	52:00	10	Residential, Commercial, Undeveloped	Riyadh, Dammam, Jeddah
1F	20/08/2020	31:49	15	Residential, Commercial, Undeveloped	Jeddah,Makkah
1G	25/08/2020	15:38	20	Residential, Commercial, Undeveloped	Riyadh, Dammam, Norths
1H	25/08/2020	20.01	3	Residential, Commercial, Undeveloped	Riyadh, Jeddah, Makkah
1I	01/09/2020	59:00	15	Residential, Commercial, Undeveloped	Riyadh
2A	20/07/2020	21:00	14	Residential, Commercial	Riyadh, Dammam
2B	21/07/2020	15:30	36	Residential, Commercial	Riyadh
2C	10/08/2020	21:29	7	Residential, Commercial	Riyadh, Dammam, Jeddah
2D	25/08/2020	31:16	7	Residential, Commercial	Riyadh, Dammam
2E	05/10/2020	20:00	6	Residential, Commercial	Riyadh

TABLE 5.5: List of themes

No	Themes	Description
1.	challenges	List all the challenges in the land registration systems.
2.	Organisational factor	This theme discusses the challenges in land registration systems related to organizational factors.
3.	Provenance factor	This theme is looking at the land title and border information, and whereby the completeness and correctness of the information is valuable.
4.	Technical factor	This theme discovers any challenges related to this factor and listens to the participants how they are pleased with the systems.
5.	Legal factor	This theme seeks to understand the challenges related to this factor and discusses how the legal response to the challenges and how long takes to settle the cases, as well as give the participants a chance to pose more challenges.

5.1.2.1 Demographics

The 14 remaining respondents were divided into groups relevant to their knowledge. Table 5.4 summarises their backgrounds and shows the interview settings. The respondents divided into two groups by experience:

1. 9 participants were knowledgeable in all types of property and more specifically, in undeveloped areas.
2. 5 participants were knowledgeable in more developed areas.

5.1.2.2 Interview Analysis

The thematic analysis from the interview data resulted in five themes. The themes were mapped and developed, based on the interview question listed in Table 5.2. The themes are summarised in Table 5.5. These five themes emerged from the findings and are described in detail below.

1. Present the challenges (Theme 1).
2. Analyse the emerging phenomena: Organisational, Provenance, Technological, Legal (Themes 2, 3, 4 and 5).
3. Infer the conclusions inductively along with the participants' views to address the challenges.

Theme-1: challenges Based on the collected dated, the major challenges are classified into three challenges:

fraud: Cadastral challenges means the dimensions of the actual land do not match with the dimensions in official records. 9 out of 14 of respondents of the first group reported an overlap between neighbouring land parcels, which contradict the land title. This issue could be found in both undeveloped and developed areas. However, it seems that the issue is found more in undeveloped lands, and the contradiction does not appear until investment in the land begins.

All the investors from the first group had experienced an overlap between land parcels when asked about variation between actual and official records. *"Yes, it occurred previously in confirming the area of land, or there is overlaps"*,**1A**. *"Yes, it happened. But it is not necessary only the identity of the plot. It is possible that the area of the land on nature differs from the title. From experience, it is permanently happening. It may be in the wrong information entered by mistake, but the customary governs more than the system. If the deed of your land five hundred meters in Nature 400 square meter. The 400 is the actual land area"*,**1B**. *"Yes, now I have a problem in a land that has an organisational master plan and it was bought from the owner according to an electronic title. After the conveyance, it became clear that there is overlap with the neighbouring land and this claim was made by the municipality itself that the land has an area of about 17 thousand meters. The case is still on the court of more than five years"*,**1C**. He added more information *"Unfortunately, land had previously been purchased, have a master plan from the Municipality, then it became clear later that there is overlaps with the neighbouring land"*. However, the **1D** confirm the issue but it rarely occurred *"Little we faced it because it has been verified by the MOMRA and the Ministry of Justice. The MOMRA approves the information on the title, and in the event of a disagreement, the MOMRA updates its information and then informing the Ministry of Justice of the new dimensions. The most important is the title it self"*.

In contrast, the two investors from the second group had mentioned this regard. The investor **2C** claims that the overlap challenges appear at the time of raising a project, *"The land was acquired to build a project, and of course, the owner of the neighbouring land had a claim that the boundaries are smaller than the boundaries on the title, and therefore we took part of his land. Therefore of course the court began to issue a ruling on the matter. We also did not know about it at the time of the acquisition, except when indications were raised that there was a commercial project"*. This was followed by a statement from **2A** when she asked about the major challenges found in the court, she responded that the overlap between neighbouring lands could be existed more in farms than in commercial or residential lands.

Double sales challenges occur when multiple owners have a legal document proving their ownership to the same land. This seemed to occur only on undeveloped areas, according to the information. None of the second group

experienced double sales challenges, whereas 5 out of 9 respondents of the first group had. This issue is found in lands that were granted by Government, and at the same time the lands were *mawat* or granted more than one time. More critical is absence of the technology used to manage them. Some comments by the participants about the problems of claiming ownership are listed below. *"Claiming the land does not own it cannot unless it has a double land title on the same land. Why? Because there is no technology in the past. So it would happen that a deed is issued from a notary that I purchased from MOMRA , and at the same time, someone applied to it and demanded (mawat) and had a deed"*, **1A**.

"The second reason is the double deeds. Meaning that a land deed is for two people, there are many in the Hijaz, and you can find in Riyadh, both have a deed. One has a deed that owns five hundred million or any area. Surprisingly, another one obtained a second deed on the same land. This has become a duplication of deeds. It means that it has become a unit of land with two deeds. It occurred because there were no systems in the past, no cadaster system", **1C**.

"Land on which more than one owner has been purchased (duplication of the deeds). These lands were granted (a grant deeds) as the land was granted twice at different times. We bought the land from the first owner. The first owner updated the deed from manual to electronic, but the second owner did not update the deed. If the two deeds are updated, it may be known that there is duplication in the deed. But this problem happened 9 years ago, and now the current system requires all beneficiaries to update the deed so that the problem of duplication of the deed is detected and the problem is avoided", **1D**.

"Sometimes there are double titles. There is a person who has a deed on a particular land, and at the same time, there is another person who has a deed on the same land who brought it up with another procedure and caused many problems"..."There are also several methods of issuing deeds in the Kingdom, namely the compensation deeds. So that it has been searching for the land is believed to have no owner. After registering the land, the owners of the land become clearer. For example, there is a plan in the eastern region located on the sea, which has three deeds, one for his tribe, one for compensation, and one for the inheritors", **1E**.

falsified information: Lack of clear ownership is related to the failure to provide efficiency cadastral information, incomplete land records, land title validity, and lack of a detailed land register. However, in this study, it has been recognised that the lack of clear ownership is not only related to the latter, but it could be subject to suspend. The suspension, according to the data, is linked to **basis land acquisition**. The land acquisition in Saudi Arabia, was described briefly in Section 2.3, could be granted, *mawat*, or purchasing from the government. This acquisition called the **basis of ownership** when the land conveyance moves to private ownership. The statement provided from the participants organised as follow:

1. **The land is undeveloped because either it has a lawsuit**. This confirm by investor **1A** *"We bought land and it was checked in the MOMRA with an electronic deed on it, everything is perfect. we started to obtain a building permit and start the project. they, MOMRA, asked to wait because they want to check and make sure of the validity of the title of this land. This decision is available on all lands to more than ten thousand and it takes two months in the past, and now it takes two days for the result to be extracted. After checking it, it became clear that it had a lawsuit as the land was of agricultural origin, so how did the notary give the grant or the deed to cultivation? I am wondering, I am the fourth buyer of this land, so this land has a cadastre from MOMRA and a deed, but upon extracting services and starting to study them, then it became clear that it has this legal problem. If this problem occurs, its only solution is to go back to all those who have already bought it. This problem led to negotiations for two years, in the end, we took our right. However, the situation led to a delay and waiting until the end of the legal order for the land. There is no clear legal way that if you take the land it will be clear and there are no problems with it. If he had taken the land and sold it without developing it, this problem would not have occurred. But if he wanted to develop the land, problems would arise with the committee. Sometimes the land is sold with its problem"*.
2. **The basis of ownership**concerns problems related to amendment to the regulations which weaken the land title, a lack of authenticity, or is subject to competing claims of ownership, or to hidden challenges in the past. However, others see this problem as related to inadequate workflow between organisations. These comments were given by the investors.**1A** stated because of different in legislations *"Different legislations. There is no strength in the title. For example, I have a title, and it is a approved title, and it could be electronic. After a while, there is a problem with the title, because the notary who approved it must review all the titles that were issued from him"*. **1B** stated three reasons which are absent of authenticity, the titles are claimable by anyone, and historical challenges on the land. *"Firstly, the biggest challenge is always authentic of the title in which the basis of the title has a problem. We have friends and I know them well and they have big problems. Many people have lands that have been canceled and lands that have been ruled by an appeal in the court and withdrawn by another decision, which is a state property because the basis of the title was wrong forty or fifty years ago"*, then *"The property of land is authentic ownership. The fact that this property where has a final authenticity can have problems. Suspensions are possible. Possible as it is now in the lands north of Riyadh has been suspended. Like what happened in Neom in Yanbu, lands were stopped. This expresses fears in the event that anyone wants to buy land. Suddenly the*

owner does not have control over it". Lastly, he stated *"The security of the title is the biggest problem facing us. You go to buy an approved title, which is canceled, and it has an old problem before forty years old and the buyer does not know about it"*. However, **1C** stated the challenges is lack of organisational aspect *"The reasons for the cancellation belong to the people and things are organisational aspects. For example, titles have a claim because they were issued without legitimate justification"*,

3. **Governmental development projects for the community** investors wait for completion of the project or at least the announcement of the type of project being developed. In this case the time matters and can cause a loss of their investment. *"Land is suspended for several months in order to study a specific project"*, **1C**, and **IE** *"The Public Investment Fund directed to buy lands in the Qiran area, but it was later found, before emptying, to freeze the sale and purchase in the area because the Public Investment Fund wants to invest in the region" .... "The eastern region, for example, is an oil-rich region. After the development of the lands, it becomes clear that there are oil pipelines running from under the ground. Since Aramco is considered one of the largest companies in the Kingdom, it has the power to stop real estate units that conflict with its interests. Much of the lands in the eastern region are satisfied because of project being developed, or because of the presence of oil pipelines"*
4. **Unspecified** where problems could occur for unknown and unclear reasons. *"This story happened two weeks ago, we owned land four years ago, this land conveys to one of our partners to be developed. Meaning the owner is one, but the ownership has been transferred to one of the companies affiliated with the same owner. As a result of this matter, the land must be entered into the Title Examination Committee, knowing that the owner is himself. The land was entered into the committee, it was accepted by the committee, and it was released to the new owner, who is one of the owners of the company. Like father and son. During the past two weeks, the bank was notified that the title was invalid by "decommissioning the credit," knowing that the title was validated by the committee and approved. Meaning that the land information has been removed from the system. The land area is 307 thousand meters, AlNargis neighbourhood. I also heard that there are some villas owned by owners decommissioning them, meaning that they no longer own them (decommissioning the credit). I mean, I own land for a long time, and without notifying us of decommissioning it, the owner no longer owns the real estate unit"*, **1D**.

Theme-2: Organisational Factors According to the investors, the problems are related to **history, multiple organisations, claim ownership, and regulation**. The first group experienced more problems than the second. However, respondents from the second group seemed concerned more about the regulations changing often without being told or warned. The participants provided these statements.

Historical considerations: On one hand, considerations when purchasing 10,000 square metres or more of undeveloped land, an application is passed to a committee called the Title Inspection Board. Although the land title may be issued and authorised by the Board, the title is subject to cancellation and even suspension by the government at any time. **1E** stated that the clearance should be pass through the committee"*Any land of more than 10000 square meters must pass through a committee and it is a bureaucracy. It's role is to clarify the ownership and investigate the basis of ownership. If the ownership was not declared or had been falsified, the title is suspended until addressing the challenges*". The committee's tasks are to clarify the clarity of the title, while investor **1D**, stated in term of validity of the land title "*The land was entered into the committee, it was accepted by the committee, and it was released to the new owner, who is one of the owners of the company. Like, father and son. During the past two weeks, the bank was notified that the title was invalid 'decommissioning the credit' knowing that the title had been validated by the committee and approved. Meaning that the land information has been removed from the system*". **He** added more information to explain this matter when he asked the challenges in purchasing land "*I am an agent of a company that takes areas of more than seventy thousand residential units to one million square meters. systematically, the title is up-to-date, valid, and there are no problems with it. However, problems appear later due to the basis of the old title. How was the title extracted? How was the procedure for extracting the title? Does he have previous problems? We are concerns about the event of buying lands with very large areas. We must be careful. We must check the deed information in the notary public for free of problems*".

Sometimes problems have not arisen until the land is being developed, which could end up in court for long time.**1A** stated "*We bought land and it was checked by MOMRA and it is an electronic title on it, everything is perfect. We started to obtain a building permit and started the project. they, MOMRA, asked to wait because they want to check and make sure of the validity of the title of this land. This decision is mandatory on all lands to more than ten thousand and it takes two months in the past, and now it takes two days for the result to be extracted*". **1A** emphasised "*the problems that occurred in the eighties and seventies, we are suffering from now, and there are no regulations that halt them*". For example, **1E** stated with this regard,"*We have an investment (distressed shareholding over 20 years) more than 10 million meters and a presence of 8,000 investors. From my personal analysis, the problem is mainly historical (core historical problem)*". Therefore **1B** insisted that "*There must be a cleaning of the past so that there is a certain date After that all the exciting titles become authentic titles, as well as in the physical registration to solve many problems and historical challenges*".

On the other hand, only one investor from the second group was concern about the land is free from previous challenges, "*I imagine, it had no past problems, unsolved claims, or possible future deduction challenges. Especially when buying land and*

of course it is important that knowing about a project that is under study, under implementation, or proposed or an idea in order to include a deduction from the land", **2C**

Multiple organisations: Respondents did not refer to challenges of multiple organisation involvement because the services are already provided for developed land. However, for undeveloped land, the matter is different. A number of respondents reported challenges because of the number of organisations involved when they invest in real estate, "*When we talk about white lands development lands, sometimes thousands of units, the lands take a longer regulatory time to approve them. It is a matter of MOMRA, and it is a matter of MoJ and several agencies such as electricity, water, services, and other agencies. Organisational is the challenge*", **1B**. Regards to this matter, **1C** stated that "*Here we return today to. whom, and who is responsible for the property in the Kingdom. Today the responsibility is lost. It is lost between the Ministry of Justice in the first place, between the courts (Sharia courts), and the Ministry of Municipalities and the Real Estate Authority has been part recently*", and **he** added " *Today, it is assumed that the Real Estate Authority is responsible for everything. Meaning that the titles are not issued by notarial offices, MOMRA, or nothing. The authorisation is from the Real Estate Authority. Today, we are dealing with the Real Estate Authority, and the Real Estate Authority is bound by joining controls, tied to the Ministry of Municipalities. It is tied to strong procedures. Therefore, the issuance of the title means whoever bought the title, it is impossible for it to interfere with others, or to have a possible action that the title is defective, halted, or cancelled*". Therefore, **1A** recommended "*it would be better if the building system merged with a specific department for taking data from notaries and MOMRA, and the cadastre information is accessible even if the buyer has to pay for these services*". Additionally, **1E** stated " *All the land information is combined, building permits, and land ownership (area according to the title, area according to nature, area according to the surveyor). Often there is a lack of information due to the multiple agencies responsible for that*".

Claim ownership: Respondents reported the problems of claiming ownership to undeveloped land. This could take two possible forms. On the one hand, there could of multiple titles to the same land. On the other, there could be an unregistered purchase agreement."*Claiming the land that does not own it cannot happen unless it has a double land title on the same land*", **1A**. **1D** added regards to this matter, "*Land on which more than one owner has been purchased (duplication of the deeds). These lands were granted (grant deeds) as the land was granted twice at different times*". Also, **1E** stated, "*Sometimes there are double titles. There is a person who has a title on a particular land, and at the same time, there is another person who has a title on the same land who brought it up with another procedure and caused many problems*". However, when **1F** asked the same question he replied immediately, "impossible", but after posing the same question in different words, **he** stated "*It could happen, but I have not faced before. It is a few cases. It does not worth mentioning. As such, it could be two titles on the same with old dates. With a new system is no because the new (electronic)*

title is void what came before, he can no longer claim the lands unless he has a strong argument".

On the other hand, it could be there an unregistered purchase agreement. **1B** stated "*Probably yes. It could be an old, undocumented purchase agreement between the seller and the buyer in which he can raise a lawsuit in court. Also, it is possible that it was a previous contractor with a previous owner or on a basis in which there were two titles on the same land. based on the current system, it still allows this thing*". Also, **1G** clarified "*having someone claim ownership is a problem that a person may involve in. I am already the owner of the land, or I am already in the process of buying it even if the title is not conveyed yet. For example, I was the purchaser of the land before someone, but he came after me and bought the land. I claimed in court that it was true that he transferred the title in his name, but I was a buyer before him, and I had a partnership contract that I paid a deposit. This problem is a property dispute*". However, **he** added that "*Yes, of course, it's ownership. But the proof of ownership or not is back to the judicial authorities. But anyone who claims the land to own it is up to the judicial authorities. Mostly, electronic title that were turned into solid arguments, the old title that were handwritten into the mostly electronic titles in which these problems were reduced and became fixed in the public system. But claim ownership of land is possible for anyone to own the land owned by him, but judges often rule it quickly*".

Respondents state from **the second group** that the impossibility of claiming ownership to developed land when they were questioned about claiming ownership, here are some of the statements:

"*Never, possible in villages but not in cities*", **2A**.

"*Impossible*", **2B**.

"*No one can I believe. It is digital at the Ministry of Justice. Even the title became digital, and it became difficult for anyone to claim ownership of the land. I did not encounter any problem. I believe today has become more organised*". **2C**.

However, **2D** reported that two projects related to government sectors could not be completed because there were people living on it by customary law, "*A certain ministry gives us the project on the basis that I want to develop it with the ministry. We entered the site or the land on the basis that I would work, and we discovered that the people around us would enter the region and claim that this land is theirs. Sometimes we actually meet them living in it. The problems of encroachment we face with government land*", **2D**. **He** added more clarification, "*I mean, people live in it by customary. We directed it in southern Saudi Arabia, and we directed it in Hail. We used to work for a specific ministry, but there were multiple beneficiaries on their land and lived there for long periods. They did not take her by convention, and no one prevented them from that period. But honestly, all of the two projects could not be completed*".

Regulation: Respondents reported concerns about changing regulations after purchasing land, which reflected on the price and type of investment. **1A** stated

that " *system change: you might take a residential unit and the commercial unit in front of you that has limited heights. After a while, changes in heights on all the buildings of the street that is in front of you and become ten floors*", and he added " *We are neglected by the real estate system and quite often the building regulations change*". Also, **1D** added concerns to the uncertainty to change regulations along the number of system they are dealing with " *Previously in the physical system, then the electronic system, the title is clear, whether physical or electronic, but the person does not have knowledge of what new regulations will be imposed on this land after conveyance*". Also, **1E** had the same thoughts of concerns about using two systems, "*Previously, deeds and now converted to electronic, there are two types of electronic titles: electronic title registered in kind and an electronic title that are not identical to reality. There are many physical deeds and they need converting to electronic ones. In this case, it takes a long time to convert. Sometimes there are double titles*".

Additionally, respondents from the **second group** stated the same matter. **2C** stated, " *The most common problem I encountered was the challenges of the old hand-written deeds on the front and back, based on any modification, purchase or sale, all written on the same paper*".However, **2A** concerned about the changing regulations to lands around her " *I was scared of those around it. Sometimes it was a learning canter, after which the changing of the types of schemes around it would turn out. Likewise, the streets themselves. if you take a commercial building and a small building next to me, then I was surprised, but it is a tower or something else that was not taken into account, so my activity is not the same place that I expected*". Also, she added " *Of course, I have a problem recently, the new decision is that commercial land, but part of it has been changed to residential land. For example, the project should be seen in the commercial, so the back is residential. My project has been cancelled because residential land is part of it, so this means my work makes a permit for only commercial construction*". she continued explaining the issue after she asked when she knew about the changes. She stated that "*No. After purchasing the land. The problem is because this is a new decision when the new regulation has released. The permit was issued on the commercial land area only. I mean, if the area of the land, for example, is six thousand, then the commercial space is three thousand, and the rest is subject to a residential permit*".

Theme-3: Provenance Factors This concerns the authenticity of records. Respondents reported access to incomplete information, a variation in information between that recorded and the reality, and sometimes a hidden basis of ownership (previous ownership). These appear in title information, land information, and varies between government bodies. However, it seems that the first group experienced more of this incompleteness and variation. **Title information:** The respondents were asked about the information they needed, how they verified it, and where they should go to confirm the title information. Some respondents indicated this process of confirmation was based on their expertise in this field, while others reported missing data. Here are some of their statements.

"*Of course, the basic information is the land number and the masterplan, the area of the land, its lengths, a clear boundary of from the East and the West, as well as of course there are geographic coordinates. Indeed, if there is a precise registry, it is going to be very excellent*", **1B**.

"*All the land information is combined, building permit, and land ownership (area according to the title, area according to nature, area according to the surveyor). Often there is a lack of information due to the multiple agencies responsible for that*", **1E**.

"*The most important thing is the title number and date. The most important information that must be available is area name*" **1D**.

"*I hope that it has a barcode on the same document that gives me the location of the land and its dimensions in Google, as the shape of the land as if I visited it*", **1F**.

"*The basis of the title that based on had been issued. For example, it is usually written title number, its area, the owner, and the boundaries. However, it could be added the title has been issued based on a deed of fortification, on the basis of a deed of ownership, or on the basis of a revival deed issued by a city general court. Meaning adding only one line*", **1G**

Some respondents from the **second group** were satisfied with the information provided, while others reported some information should be, but wasn't, available with the title as shown in their statements:

"*After the new system, we were not confronted with residential land in Al Sharqiyah and in Riyadh*". **2A**.

"*No, praise to Allah, if there are official papers, I will never doubt*", **2B**.

"*No, we haven't faced that*", **2D**.

"*Its place, which is surrounded by mosques, services, neighbours*", **2B**.

" *Of course, if there are images of the land that identify the images from Google Maps, or it is possible to provide a link or numbers to confirm the validity of the land... there are some observations but for other reasons. It is possible that something is not updated, the title is not updated, or the system is out of date. Perhaps, for example, a land that was divided into two lands was done by two titles, but by the system, it is still on its old number*", **2C**.

Land information: The respondents were asked specifically about the information of the land. They indicated that the information was scattered across many departments and employed a customary process to check the information. Here are some of their answers:

1B said that after confirming the title, the land information should be confirmed as well, but confirming the land information is a customary process, "*The second thing is we go to the lands and properties in the municipality of the region and try to make sure that there are no problems. Then thirdly, the people of the commercial market in the*

region as they are experience and knowledge of the problem and that it has occurred. and experience and expertise that does not have the owners of the main market until now".

There is no official process that can performed to check the land information, although other participants stated that this process can be done by a third party. "*the surveyor takes the points of the lengths in the title, if it is correct*", **2D**

"*Contracts are made with engineering offices through them, the MOMRA and the concerned authorities are reviewed to verify the extent of the compatibility of the land with the dimensions, in addition to knowing the requirements for the area because on the basis of them the costs required to build the infrastructure are known*", **1E**

"*The engineering office goes to confirm the dimension according to actual, Google maps, or a system in the municipality, which is the surveying department to define the borders, and the municipality rarely goes to confirm the borders. The area confirmation through the engineering office where they upload them through the municipality's site, and the engineering office has an access to it. The concerned authorities rely on the area uploaded by the engineering office that has pre approval. The municipality has a complete plan, but I have one piece of the plan. The engineering office must determine exactly what the boundaries of the land are within the plan. The engineering office submits a request to the municipality that the plot of land is such that the one who owns it is such a boundary to the north, south, east, and west, then the municipality is approving the plan from the engineering office. Yes, we do this method for every land we buy*". **1F**

Some participants reported that even when the land information was confirmed by different procedures, it there was still a risk. "*This question regards the master plan. This is issued by the MOMRA. Unfortunately, land had previously been purchased, have a master plan from the Municipality, then it became clear later that there is overlaps with the neighbouring land*", **1C**.

One participant stated that there a service is provided by the government to help check the land information. "*The Municipality has an investigation service of land information on the actual land, according to what I heard from my colleagues in the company, by entering the land coordinates in the housing program 'White Land Fees' and the location of the land shows to me. Often the coordinates of the lands are given by an engineering office that confirmed to actual land*", **1D**.

Checking the land information is a critical step in deciding whether to invest in a particular property, and every participant's experience showed that the process to do this is inconsistent.

Previous ownership: About provenance, the respondents were asked if they knew the previous owners of specific land. This information was previously recorded in the deed system, where all the owners were listed in the same deeds. However, after moving to the new title system, this information is not shared with the buyers. The respondents were asked if they knew of such deals that

have happened. Some respondents stated this information is not available, others stated that it could be found from the MoJ, or by using the MoJ website. Here are some of their statements. However, they all said that this information is not available at the time of purchasing the land.

"*Ministry of Justice is the one in which the number of deals and trades is found. It takes time and connections because no specific agency has this information*", **1A**

"*it is not there. We require this matter to have*", **1B**

"*It is not there. Information available at the Ministry of Justice*", **1C**

"*Difficulty obtaining it. there is no service like this. Now from my experience, I know people who have problems with their title. If you see his name in the documents, I know that this land has problems, because this person is suspicions*",**1D**. When **he** was asked how easy to get this information, **he** replayed "*No it is not impossible. This information is available with the Ministry of Justice at the Title Verification Committee. When they are reviewing the title, the sequence of title, the title are reviewed from the basis of ownership to the current buyer, but this information is not visible to the buyer. If they appear, I can make decision to buy from and sell to those who help me make the purchase decision. Information is available with the Title Review Committee. When the title are revoked, they are revoked according to a hierarchy of ownership basis. This information is not visible to the buyer*", **1D**

"*By entering the website of the Ministry of Justice, but you need to track the checks until they reach the basis of the title. The information is there, but it takes time to extract the information*", **1E**

"*Unfortunately, this information does not know any owners on this land and how many people bought it and it is not available to the buyer*", **1F**

"*Of course, you get it through records in the notaries. I don't think there is an ease of getting it*",**1G**.

"*Systemically, in a possible way through the court because there is a problem of the title requires the sequence of the title. Name moved to another name. There is no systematic way to define the title sequence*", **1G**.

"*The easiest way is for the old deeds, such as a deal made with the same deed, but the new title differ*",**2C**

"*I usually remember you were writing it in the back you were writing by hand. Now what I see is that the last owner is present*",**2D**

Theme-4: Technical Factors

Technical factor Respondents had positive reactions to the current technology used, although many of them demanded more development on the technical side, especially on GIS technology. The technology used is digital title and adding authenticators, who are attorneys. These have a permission to access the electronic

justice systems using their national identification number system (ABSHER). However, respondents indicated that even when the land records are digitised, they do not reflect the land records reliably. Below are the statements of respondents when they were asked about the technical challenges and about the authenticity of electronic titles. "*We don't have a clear GIS for the kingdom. There is always a difference between ours master plan with the one who is in the MOMRA and the borders of the neighbors with you. It was difficult, but now, it began to dissolve, though the technical solution was not completely complete. Also, the transfer of title , some are old and some are new electronic*", **1A**

"*Technically we aspire to the best. Of course, now the certified notaries have given law firms the possibility of conveyance, but within limits not exceeding ten thousand meters and not exceeding one million riyals. These borders must be opened and developed like the rest of the neighboring countries. Meaning that anywhere in the municipality or law firm we can empty and transfer ownership and facilitate many things of course and others until now the writings of justice are still in control but in the right way*", **1B**

"*Technical there has been a great development in the last years or the last two years*", **1B**

"*Technically in the Ministry of Justice in the field of conveyance lands, very great steps have been taken and the conveyance process has been made easier for individuals, as the conveyance process takes place at home, as well as documentation through Absher between seller and buyer. But, the problems are in the partnerships and the form of agencies that come from the board of directors in being a company compared to individuals, as he is able to convey from the house through Najiz*",**1D**

"*I was scared of those around her. Sometimes it was a learning centre, after which the changing of the types of schemes around it would turn out. Likewise, the streets themselves. if you take a commercial building and a small building next to me, then I was surprised, but it is a tower or something else that was not taken into account, so my activity is not the same place that I expected*", **2A**

"*The technical aspects, on the contrary, have evolved in the last two years because it added other than the notaries public service which is authenticators. But it is for certain areas. Certain areas of less than two thousand and five hundred may convey through authenticators more than 2,500 at the notary. after that they raised them to ten thousand. The authenticators was necessary in your region after that the authenticators in all regions of the Kingdom*", **1G**

When **1B** and **1E** were asked whether the electronic land records should be confirmed before purchasing, they stated:

"*Yes, always for many reasons. we fear that many electronic titles have stopped*", **1B**

"*Yes, the electronic title does not mean that the title is verified*", **1E**

The respondents showed the importance of using technology to link all the government bodies responsible for the real estate and facilitating the title conveyancing. **2D** stated that the conveyance should not be restricted to a certain sized area, "*I believe that conveyance is by notary public when its area is more than ten thousand square meters. If something is on a larger and wider scale, it is more comfortable for us*", also **1C** and **1E** agreed with this regard respectively, "*A suggestion that one party be responsible for the property, which is the one that enforces the laws, with a platform. The real estate reference is the sole reference, and the Ministry of Justice is linked with MOMRA and Agriculture and the rest of the other bodies*", "*The solution is for there to be one party responsible for the association of all parties*".

interestingly, **1A** suggest using blockchain, "*I hope they settle the real estate registry company, but it is a private company, using blockchain and how to benefit from it*" , and **2C** suggest as well the blockchain would be benefit to the real estate, " *Today I think that it is one of the most technological matters that we benefit from, especially since real estate is in a time series, ownership opportunities and other services are the blockchain, and I expect it to serve the real estate sector in particular*".

Theme-5: Legal Factor 8 out of 14 respondents had encountered lawsuits that ended in court after they had purchased land, which often took a long time to settle. However, it seems that investors from the first group had more lawsuits than the second group. Only one respondent in the second group had a lawsuit, the others not having faced cases. Here are their statements when asked what main law cases they faced, and the time taken to settle those cases.

First Group. Overlap of the boundaries of a property was faced by the majority of participants, caused by the suspension of the title for a certain time. However, the time is important since any delay puts investors in financial difficulties when stopping projects. Below are some of their statements.

"*overlaps and land basis where is a land revived or granted ... the situation is taking too long*", **1A**. "*Overlapping and canceling and stopping the title...Years may extend to ten years*", **1C**.

"*Proprietary overlap ... Ownership overlap takes from two to three years*", **1E**.

Participants stated that there are titles that are not authentic and undocumented sales, which are major obstacles to investing.

"*The first need is the biggest reason always is the authentic and authoritative title that the title is basically was issued, and the second problematic is that there are undocumented sales. Sharia is acceptable and may cause a problem .....Three generations have gone through the last projects*", **1B**.

"*We won a case because title was canceled and the title was decommissioned. The land area is more than 100 thousand square meters. How was this title canceled? The Ministry of Justice notified the Court of Appeal to cancel the title and ordered the buyer to return to*

the seller. We are the buyer, and a case was filed with the existence of the pledge deed and contracts, and then a case was filed with the General Court to recover the amounts that were paid and justify that the deed had problems and was ineffective and that the owner concealed this information .... It took us 8 months, the judgment was issued up to one year in which the execution judgment is issued without delay", **1D**

There is incomplete information, or even absence, of natural resources information, such as height of water table under land, of land was previously a valley and has been filled in, or was a dumping ground for factory waste. A current case concerns a project failing because of the absence of information about the nature of the land, in which the investor does not know what is underneath the land until he has invested in it. This issue is related to the basis of the title as there is no history of tracking the use of this land.

"*The nature of the land. I do not know what is under it. Once I bought a land and it was a dump. When inquiring about the condition of the land previously, it was a waste incinerator. I do not know that it is a dump. The municipalities were contacted about the reason. It was not mentioned that the land was not mentioned as a landfill. In addition to the water problem .... This case lasted for a year and a half at a time. This company collapsed because the investor could not pay salaries and there was no work or production. At that time a letter was raised to the High Commissioner and we explained our situation*", **1F**.

"*As the basis of the property on which the title was issued ....many years at a time*",**1G**.

Second Group. Only two participants encountered cases that ended up in court as result of changes in regulation without them being informed. "*ownership of course. Land boundaries and problems with neighbours or with surrounding lands. Of course, when I am in a residential complex project or something else, there are some differences between the owners and neighbour properties .....There is something in it for two or three months for the same disagreement that has occurred over the transgression of borders*",**2C**.

"*I have not encountered anything from two to seven years*", **2D**.

5.1.3 Discussion: Land Registry challenges

The primary goal of interviewing investors was to investigate challenges in the land registration systems. However, from the analysis using the thematic and content approach, an understanding of the challenges, and the reasons behind them, were identified. The challenges and the causes of the challenges were therefore the main findings of this study. These findings had a significant impact on the proposed framework.

TABLE 5.6: Analysing the challenges according to the factors based on collected data

Main Factor	Sub-factors / challenges	Fraud	Double sales	Falsified information
Organisational factors	Governance	1A, 1B, 1C, 1D,1F,2C, 2E	1B,1A	1E, 1I, 1H, 2B, 2E
	Regulation	1F,1G,2C, 2E	1E,1D,1C	1A,1D, 1I, 1H, 2A
	Ownership claim			1E,1A,1B,1C,2D, 1D,1I, 1H, 2E
	Historical consideration			1G,1E,1D,1B, 1I, 1H
legal factor	legal	2C,1E	1A,1D,2A,2E	1E,1G,1F,1D, 1C,1B,1I, 1H, 2D

The study unveiled three primary challenges mentioned by the participants, which align with the conclusions drawn from the literature review. However, the term falsified information has replaced the original lack of ownership challenge. This name reflects the factors that contribute to the difficulties of manipulating property information **First**, more than half were facing challenges in the overlapping of borders, where the actual dimensions do not match the dimensions in the official records. **Secondly**, double sales challenges were found only on undeveloped land. This occurs as a consequence of using the old system (physical system). The old system granted the same land to different people on different dates because of the absence of technology to manage information on the lands granted. Thus, double sales is not a technical issue. The **third** challenge identified was the lack of clear ownership . It is related to the failure to provide efficient cadastral information, incomplete land records, land title validity, and the lack of a detailed land register. Apparently, anyone could claim ownership, which is an obstacle to investors having secure investments.

The framework in Chapter 4 is composed of five factors: Provenance, Security, Immutability, Culture, and Law. Analysis of the challenges led to these factors being reworked for the next step. This process is now described.

According to the participants' statements, a number of reasons lay behind the challenges. Misleading governance and regulation were the source of the challenges. Also, ownership claims and historical matters led to a lack of clear ownership. These reasons are characteristic of organisations involved in the land registration system, the process of maintaining the records, and those employees responsible for land registry. Therefore, these influences were grouped into organisational factors. The association between the factors and the challenges is linked by participants' statements, which are summarised in Table 5.6.

Additionally, the law factor has been renamed to the legal aspect. The legal aspect is composed of the framework of law that the organisation must follow to manage the land registration system. The statements from the participants show that some of the

challenges were caused by people are not using the systems to record their agreement, their customary practice of dealing with land, their inheritance, or their unregistered conveying. This is why the law factor was renamed.

Provenance, Security, Immutability, and Culture also have been reworked. Provenance has been divided into four factors: Accountability, Transparency, Auditability, and Reliability, following the literature. Security and Immutability are concerned with keeping the record technically secure and maintaining its immutability. These two were grouped together as they belong to the technological aspect. Because Culture refers to people and to employee behaviour, it was moved into the Organisational factor.

Factors were added when five or more participants stated that as an issue. Thus, Governance, Regulation, Ownership claims, Historical considerations, and Culture became part of the Organisational factor. Provenance includes Accountability, Transparency, Auditability, and Reliability. Security and Imputability were joined into technological factors. Finally, Legal factors were used instead of law. These new factors were included in the framework prior to the expert review. Also, some blanks were added to the framework to make it open for modification by the experts. Figure 5.1 shows the amendment of the framework to be examined by the expert in the next step.These factor are describes according to the thematic analysis below.

Organisational factors represent the causes of challenges in managing the system.

Governance refers to the number of government entities involved in the land registration system.

Regulation refers to the regulation and policy to manage the properties.

Ownership claim refers to the process of registering the title either after purchase or claiming ownership.

Historical consideration detonates the difficulty of inspecting the historical information of property.

legal factors denotes the number of claims that ended in a lawsuit.

5.2 Framework and Requirements Confirmation

The first phase of the methodology was an exploratory issue interview, where the data was collected from the real estate investors. The second phase was an expert review where the data was collected from experts to confirm the framework. The development of the interview questions, the applied methodology, and the procedure for data gathering, are explained in section 5.2.1. Section 5.2.2 presents the findings from the expert review, leading to the framework confirmation in section 5.3.

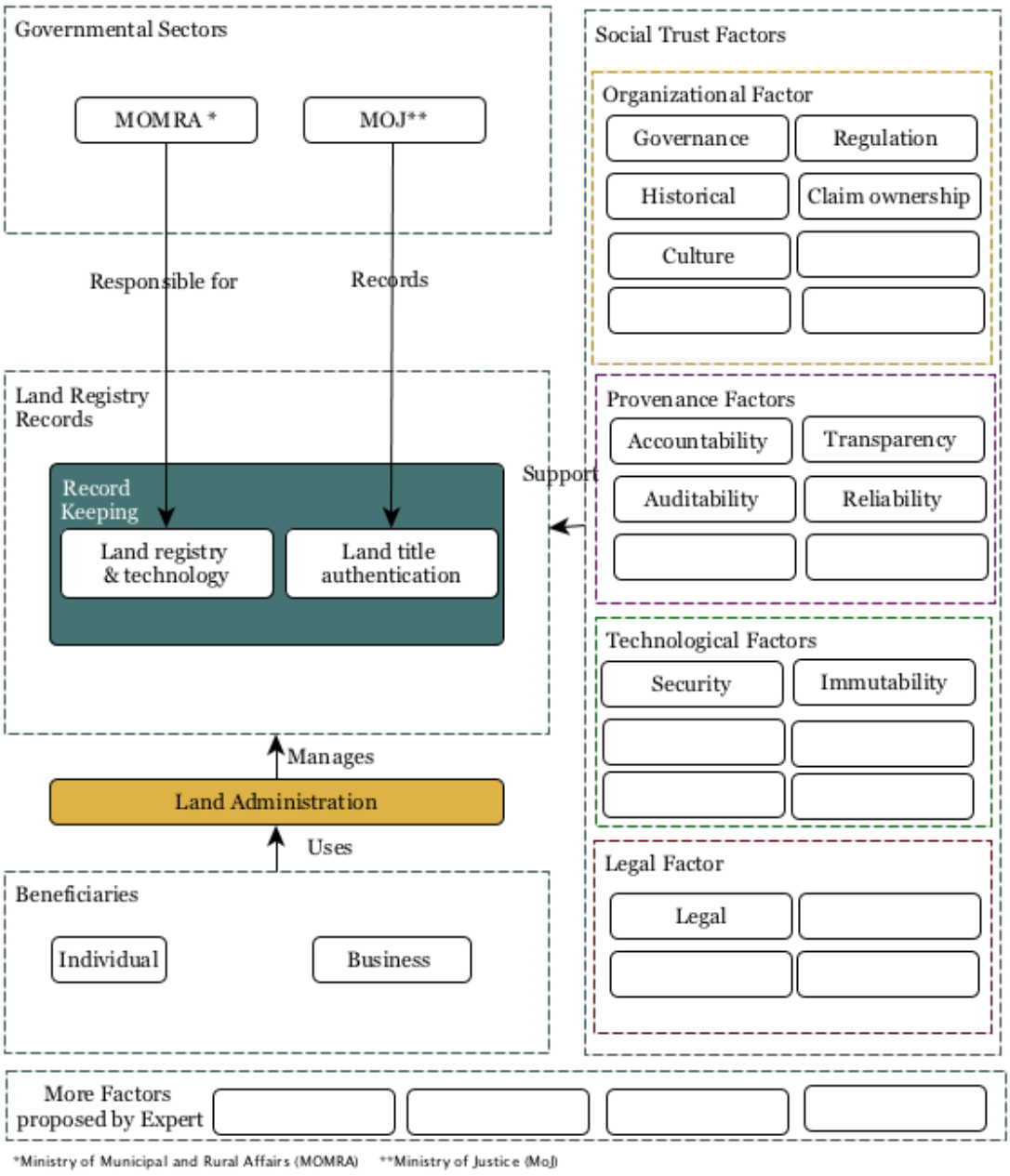

FIGURE 5.1: Framework amendment

5.2.1 Developing The Questions

The purpose of the expert review was to confirm the proposed framework was identified in Chapter 4. The interviews were designed as semi-structured, consisting of eight questions, using GQM to ensure that the factors are important to the land registration system. They explored more factors, relying on the comprehensive understanding of the experts working professionally in this field. Table 5.7 summarises the objective of the questions, while Appendix B gives details of the questions using GQM.

5.2.1.1 Pilot Interview

The expert review instrument was tested and validated before conducting real interviews as with the previous interview. The design and procedure of pilot test was described in Chapter 3, Section 3.2.3. The participants involved in the pilot phase were two PhD students and two academic staff from the University of Southampton. The interview instruments were quickly analysed and enhanced after each interview. The enhancement included checking that the questions were well structured, fluent, understandable, and met the objective of the study. The improvements from the pilot test were not major and was mainly the editing of some complex sentences.

5.2.1.2 Interview Procedures

The approach was designed as a semi-structured, open-ended, and one-on-one interview. The interview's participants were identified using the snowball approach, because the sample is scarce and difficult to get a response from.

The interviews were conducted with 8 experts, all of whom were experts in the field of land registration systems. They were working for the Real Estate General Authority (REGA) of Kingdom of Saudi Arabia and for the World Bank. The process of conducting the interview was as described in Chapter 3, Section 3.2.3.

5.2.2 Discussion of Findings

The aim of this section is to present the results of the expert review using thematic and content analysis and MAXQDA tools. The results are organised into two sections, which were the demographics of the interviewees, and the interview analyses.

TABLE 5.7: The objective of expert review questions

Sub-Research Question 1	Type of question	Questions	Objective of the Questions
confirming the factors with experts.	Open-ended questions (qualitative research)	(Q1 - Q2) Would you, please, describe your job role? How long have you been working in this role?	Introductory questions for knowing the expert's background.
		Q3) What factors that are important to consider in the framework? Why?	Explore the important of considering the factor according to their background.
		(Q4) Are there any additional factors you think should be included and which category should they go into? Why?	Explore if their other important factors were not considered.
		(Q5) From your knowledge and experience, do you think some of the identified factors need to be regrouped in within the proposed framework?	Confirm if the factor had been ground properly.
		(Q6) Is there any (organisational/provenance /technological/legal) factor you believe should be renamed?	Confirm if the factor's name had been named properly.
		(Q7) From your knowledge and experience, do you think of any other category(s) needs to be added to the proposed framework?	Investigate if there are missing main factor.

TABLE 5.8: Interview setting

ID	Date	Length in minutes	Job role	Experience
EX1	03/12/2020	37:33	Technical consulting in title registration programs and responsible in title registrations in the technical part.	1.5 years
EX2	09/12/2020	51:23	Program and supervision of enabling projects and planning land registration projects located in the Authority.	1.3 years
EX3	13/12/2020	50:26	Urban planning space engineering and worked in MOMRA, "MOMRA policy".	29 years
EX 4	17/12/2020	38:14	World Bank retired officially and doing consulting work. He was the global lead specialist on land administration at the World Bank. More specifically, he was responsible for all matters relating to cadastral land registration in the World Bank's program worldwide.	44 years
EX 5	23/12/2020	28:01	A project manager in the IT section. More precisely for delivering portals and systems that need to be developed for real east general authority.	3 years
EX 6	31/12/2020	50:26	Providing legal advice on land registration, running court cases on land registration, drafting laws on land registration, educating people on registration.	35 years
EX 7	06/01/2021	56:36	A chief information officer (CIO)/General Manager's REGA for IT department. Mainly force on the technology base.	17 years
EX 8	03/02/2021	36:53	a real estate consultant in the real estate industry and also a real estate development and establishment of real estate PMOS and strategies and initiatives and helping organisations in the real estate development industry to achieve their strategic goals and develop their internal capabilities and achieve the initiatives that related to the strategy, either by monitoring and controlling strategic initiatives that will enable the company to achieve its goals. also, a national transformation project in KSA and in Jordan related to specific industry challenges in the real estate, work for the housing program and KSA supporting achieving the goals of the Kingdom's vision in the housing initiatives.	14 years

TABLE 5.9: List of themes

No	Themes	Description
1.	Framework review	Demonstration the relationship of governmental bodies
2.	Organizational factor	Demonstrates the characteristics of the organisation
3.	Provenance factor	Demonstrates the important of the provenance
4.	Technical factor	Demonstrate the technology used in the land registration
5.	Legal factor	Demonstrates the important of the considering the legal factor.

5.2.2.1 Demographics

The land registration systems in Kingdom of Saudi Arabia are a joint administration by MOMRA and MoJ. In 2018, a royal decree was issued making Real Estate General Authority (REGA) the main regulator for real estate. Currently, REGA facilitates the workflow between MoJ and MOMRA, until it gradually becomes the sole responsibility for land registration. The expert participants were therefore chosen from REGA. It is the official regulator and has a comprehensive overview of the workflow between the parties. Also, the experts from REGA met the objectives of this study. Table 5.8 describes the demographic information of the participants.

5.2.2.2 Expert Review Analysis

The thematic analysis from the interview data was described in detail earlier. The coding produced five themes that help to confirm the proposed framework. The themes were mapped based on the interview questions listed in Table 5.7. The list of themes are summarised in Table 5.9. These five themes derived from the proposed framework.

1. **Framework Review:** After asking the participants about their backgrounds, an overview of the relationship between government bodies and their beneficiaries was given. The proposed framework showed there was a link between REGA and government bodies. However, all of them have been clarified and their relationships specified, and the beneficiaries confirmed, as well as each sector's role. Here some of what participants stated:

   "*In the current system MOMRA is responsible for the technical side of the registration and the cadastre, MOJ is responsible for documenting the registration of land ownership*", **EX1**. **EX2** stated clearly the workflow for each sector, "*The physical registration process requires the presence of the first registry where the judge is needed to authenticate the first registry. At every first registry that MOMRA takes place. It must be checked and approved by a judge assigned by the Minister of Justice to supervise a specific region and appointed for him technical and legal assistants. Their primary function is to approve works, dealing with objections, announce the release, complete them, and ultimately issue the title.*" Also, **EX5** stated "*There may be a difference in it. MOMRA is in charge of the*

surveying, verifying the spatial dimensions of the plots, and making sure the information corresponds with reality. OMJ is Responsible for authentication. Ensure that the information is in the instrument and that the owner mentioned in the instrument is the real owner. Also, The responsibility is finally through the appointed judge and agrees with the data that was delivered from MOMRA."

Other experts not only clarified MOMRA and MOJ's positions, but described REGA's position. **EX2** "*The transfer of jurisdiction stipulates that the General Real Estate Authority is supporting both sides until the new regulation is issued by the General Real Estate Authority in addition to the new real estate registration system. The responsibility of the MOJ is the legal process (authentication plus gates for each stage*". Also, **EX3 and EX7** stated respectively "*Now we are in the transition period, support for MOMRA and MOJ*", " *The REGA is facilitating the functions because there are some function within MOMRA , and other from MOJ. These functions are not owned by REGA but they just facilitate based on royal decree*". however, EX6 stated immediately when he saw the link between MOMRA and MOJ "*This is in the future*".

Only **EX1** noticed that the state is also one of the beneficiaries of the system,"*Amendment to the beneficiaries of the real estate systems is business, individual, and* ***state***".

2. **Organisational Factors**: The participants were asked to give their thoughts on the factors related to the organisational factor. All experts agreed that the organisational factors are very important. However, some experts disagreed about some of the factors' names. Among the most interesting statements from the respondents related to the sub-factors:

   (a) **Governance**.

   All the experts stated that Governance is vital when it comes to land registration. No matter their background, they all felt that the problem of responsibility between MOJ and MOMRA is unclear, or has multiple responsibilities for managing land. Unclear responsibilities led to misleading information, system reliability, accountability, and transparency. Unclear responsibilities also led to confusion among the beneficiaries. Below are some of the most interesting quotations:

   EX1 said that clarity of the responsibilities between the government sectors is needed "*MOMRA is responsible for lands within the urban boundary and the ministry of agriculture is responsible for lands outside the urban zone. In the current situation, it cannot be considered, but in the future, the land registry will have one legislator responsible for the lands. This means that all agricultural or non-agricultural lands are within the urban boundary or outside the urban boundary, and the data is provided by one. To date, physical registration has not been completed. In the event that the authority is the only one to legislate, and it puts the policy and the private processor, data registry,*

and then the implementation would be a subsidiary of a consulting firm affiliated with the Public Investment Fund. Therefore, there will be only one legitimate authority. The aim of the data registry is to have an ID for the parcel on all lands. In this case, all lands are linked and there is one data provider and it has reliability." This is followed by **EX3** "*Very important, at the level of the world, the concerned authorities differ in real estate systems. Some countries put one body responsible for them. Some countries have two sides, and others have more than a specific side. In the past, there were two main bodies, Momra and OMJ, in addition to the Supreme Council, which was responsible for appointing a judge. Currently, two other bodies have entered the body. The financial arm of the two parties is the PIF in terms of establishing a company for real estate registration. It is now in the jurisdiction confused and needs fair governance between the parties to determine the jurisdiction and responsibility. There is no unified supervisory authority. Attempts to land registrations in all regions of the Kingdom have failed because each side aims at the other side in the absence of any support, a failure. Governance in the jurisdiction is very important. I fully agree that there will be one complete side in terms of the existence of structure to implement the system and that the work of the authority will not be intrusive on the work of other parties.*"

When comes to defining responsibility, **EX2** highlighted the importance of giving assurance that landowners are able to differentiate the responsibility for each sector to avoid beneficiaries wandering between them. "*Very important. For me, the basis of the framework. In the past, there was not clear governance to deal with real registration in the Kingdom between the relevant authorities. It was not properly defined, which led to the overlapping of responsibilities and the suspension of physical registration and refraining from the application because of this issue. There is no single party responsible for it. In addition, the regulation explains the work adequately and transparently. It also resulted in a lack of clarity if the system was implemented. In the event of an objection (dispute), it is not known from the relevant authority to the judiciary. The goverence is the starting point.*"

EX4 and **EX6** thought that good Governance is way of making people trust the system, "*So that type of registry is supposed to be a guarantee then to the owners of their ownership and the basis for linking to the other organisations*" , "*Yeah, of course, it's important because it's the basis of trust. If you don't have good governance, the public won't trust you, and if they don't trust you, they won't use the system*".

EX5 stated that governance is important to help manage the workflow and define the organisational structure between the sectors. "*certainly, it is important, because in the event that the titles are registered at the level of the Kingdom. Governance needs to follow the matter. For example, who has the*

authority, the organisational structure, and the level of approval, and the governance for the existing data, and what is the standard used. Currently, there is no clear governance between the two responsible for registration. There is gap between them. the Authority is currently working on arranging the positions between them and facilitating the registration process" whereas, a technical expert **EX7** thought " *we cannot build without considering the governance. If there is no system we will not be able to build anything. To start as IT teams, we need to gather all the requirements, business models that we need to build then we have to look at the regulations and laws. These drive to start building the system. as they have procedures, we can translate them into automation workflows*".

(b) **Regulation**. Some respondents confirmed that regulation plays an important role in encouraging people to register their lands officially and preventing unregistered sales, by making the systems simpler and inexpensive. Other experts stated that problems occurred because of multiple regulations. One technical expert stated that regulations are the way to impose a clear workflow, but having so many regulations confuses the beneficiaries to that they do not follow the law.

"*The regulations normally focus on making it easier and simpler for people to to register because you want to encourage them to do so, you don't want people to avoid it because the whole process is too complicated and it needs people need to trust the system. So the regulations make it simpler, cheaper and just more user friendly to use the system. And that in itself then becomes something that makes the economy move better because people are using the system and they know they'll happily go to the bank and get and get a mortgage or so on. happily buy and sell, rent and so on, but it's the regulation that makes it make it easier to do that.*",**EX4**.

Regulation should defined in a way that encourages people to register their land and avoid unregistered sales. " *It's to encourage people to do what you want and in this case, it's in to encourage people to register their land and documents*",**EX6**.

As for the link between regulation and technology, it should be simple for people to use. "*Very important because it is the tool that directs the work. Very important and must be present in order to contribute to encouraging people to register land*",**EX5**.

However, the number of regulations makes it harder to follow the system. "*The current regulations has difficulty (the judiciary) due to the presence of more than one legislator for the system.*",**EX1**.

"*The old or current real registration system. I agree with the importance of this point, and I see that the 2002 AD system was a very detailed system. But it is preferable to match it with detailed information about the method of alerting*

based on the current variables. Legislation should be linear and flexible. And take into account any change that may occur in the future",**EX2**.

"*It is important to consider. without regulation and laws that imposing how we can move forward in the workflow, we cannot build anything. we can not made any change without knowing how it going to be done*",**EX7**.

(c) **Historical Consideration**: All the experts have a consensus about the important of historical information. Every one has presents his view in different angel. Here are some quotes:

It is important to provide an absolute title to land: "*The idea of the land registry is to prove the ABSOLUTE ownership. That is the reason all the history has to be there. We cannot undertake land registry for land in dispute*", **EX7**.

It should be done only once: "*Well, it's if you doing the first time digitalisation of the deeds you're creating the profile for the first time in historical consideration is very, very important because you have to be confident that the person that you're recording is the owner, is really the owner, and there's no problems. Once you've done that, you don't need to do it again*"**EX4**.

It is evidence of ownership: "*Yes, well, that's true. That's always a consideration. But it's it's the procedures, process and information and information you might want to say documents what you really documents and surveys you can put in brackets. It's information relates to the legal information like the deed or the occupation, evidence of occupation. And it also relates to the boundaries where the boundaries both are important. Equally important*"**EX6**.

It the base of ownership: "*t is the basis of registration. In the event that the information is incorrect, how is it recorded? "***EX5**.

It is part for each process of issuing the first registry according to the royal decree: "*This is settled. Any instrument in the ministry and the owner of the instrument wants planning*"**EX3**.

It is important for international investors to trust the system: "*It is true that this is important to us, especially the history of certain land. We note that it is a cause for fear in investment, especially foreign investors. Many companies have passed by us in the past. They entered the Kingdom's market and exited in a short period of time due to the lack of absolute ownership of the property, and at the same time, the historical land was not true*"**EX2**.

It is the first step in processing the physical land registration, and then making the transaction: "*The current system of real-estate registration includes two parts: The first part: extracting the real estate document or deeds, and the second part, the transaction begins with the transfer of ownership, ownership segments, or the merging real estate units*"**EX1**.

However, as the information is being important and valuable to the system, all the experts argued that the name of the factor should be rename. Four experts prefer to call the factor "*first registry*" because historical information is a process of issuing the first registry. **EX3** and **EX6** suggested to rename it to "*Property Records data*" and "*land title investigation*", respectively. **E4** said this factor is done only for the first time. It does not need to do the historical matter every transaction occurred. However, he did not suggest a name for the factor

(d) **Ownership Claim** All the experts explained that this factor is important to the framework in different ways. Here is what some experts said:

EX3 and **EX5** stated that ownership claim is an issue in land registration systems rather than a factor. "*Multiple title deeds. This is one of the problems found now. These problems were created by the old system. We have instruments on more than one land. It means land on it more than one instrument. We have problems applying a grant order more than once on the same land. Multiple title deeds on the same land*". "*It is important to consider, but the importance of physical registration is to overcome this point. Almost it is the primary goal of recording rather than being a factor*", while **EX1 and EX6** explain the what ownership claim is as the way of owning the land "*In land registration, data deeds are matched with data registration. Sometimes they do not match. There are lands that have registered information, and sometimes lands that do not have verified information. Also, , there lands were owned by 'mawat' and have identity papers. The solution to these problems is physical registration. Duties of the Authentication Committee*", and "*They are all true. That's correct, but there's also what about divorce or inheritance, Unregistered land agreements, living on the long time by custom, and Overlapping land*".

However, **E2, EX4, EX7,** explain that the ownership claim is one step of process of deliver first registry, respectively "*This is an entry into the first registry*"." *the claim of ownership comes at the first time of registration but other deeds system, you can do it at any time. You can make a claim because the deeds do not guarantee title. They they are just best evidence, whereas the title register under that 2002 law and the new law that they're just preparing 2002 law, which which is a brand new law that's going through a process at the moment, the title is actually guaranteed, but it's after first registry after the claim is made*". "*This is important. There is something called owners index. In the platform, there is a function where allows users to browse the name of the owners and the land information. From this, users will able to raise claim ownership if they owned the land*".

(e) **Culture**: Five of the experts interviewed explained the importance of the culture to the framework, the rest remaining silent.

The five experts stated that cultural matters are important to understand people's needs to develop a system that met their needs. Here some quotations from the interview.

"*The systems differ from each other due to the culture matter*", **EX1**.

"*In the case of adding culture to the system, physical registration consider the culture in the 2002 law, and I did not find any system can do that. An incompetent person, for example, has been cursed by God with illness, insanity, forgetfulness, or loss of consciousness. There is no system that has dealt with this problem, to my knowledge, except for the physical registration system of the Kingdom of Saudi Arabia. Treat problems of the community itself. I see that it is new and there is no problem with it*", **EX3**

"*I think this is very important in in Saudi Arabia, more so than it would be, for example, here in the U.K., because you have a history, you have a history of ownership by occupation just through through customary it's been there for for a very, very long time. People know what they own, but maybe not the whole extent of it. And maybe they've never had a date or registered so that they still have rights. It's just that they're not recorded anywhere. So looking at the culture, it has to be taken into account because as I say, even though they haven't got recorded rights, they still have rights. And hopefully when the when you cannot to register all of the land, you will include all of these people who who would make a claim on their historic basis. I think you also have a different procedures in Saudi Arabia, because you have more much more family oriented, family oriented ownership, you know, very often, you know, they all live on the same plot as the parents. They had basically effectively as much more sort of collective ownership, if you like, under one major head of family, which you don't see so much in many other cultures. So, yeah, this is important. And and I would say especially for Saudi Arabia.*", **EX4**

"*Very important and one of the things that must be considered. For example, many people are sensitive in terms of displaying information about owned lands, while in other countries, publicising information. This is the basis of the system for publishing land ownership in the public*", **EX5**

"*From a technical perspective, it is important to be there because at the end people are going to use the system and we need to know what they need. Therefore we need to consider it to facilitate the IT system to encourage people to use it. For example, how to increase transparency*", **EX7**

3. **Provenance Factors**: There was clear agreement on the importance of this factor when it comes the land record. The provenance factors were defined clearly and explicitly in Law 2002. Below is a collection of some of the statements made in this regard:

   (a) **Accountability**:

in regards the information comes from many source "*Among the things in the 2002 system is a comprehensive multi-purpose system. So that the information belonging to owner is updated with the authorities responsible for it. Meaning, for example, the redemption of building lands, how the registry is supplied. It comes from the main source, which are the secretariats, the municipalities, and the property registry responsible for them are the authentication bodies, which are the Ministry of Justice and the courts in the mortgage. I think it is a good important*",**EX3**.

With regards knowing who are responsible for making mistake"*That's very important. Yes. Yep. And they should be liable also to pay compensation if they make the same mistake. Yeah. Which is which organisations make mistakes. So they should include some sort of compensation* ",**EX4**.

In term of the the modifying the data "*Yes, in the event that the document is issued, it is not subject to appeal. Some documents are issued and the objection period is 60 days. The objections are studied and a decision is decided on them, or they are referred to the court. The system took it for this point*", **EX1**.

(b) **Transparency** The experts stated the transparency is one of the goals of the land registration system to prevents challenges such as corruption or bribery. here what the expert stated:

"*All right, transparency is very important, you don't have such a too much of a problem with you don't have a problem with corruption or bribery and things like that, at least not that I know of in Saudi Arabia. Some countries have that is a big problem in their registries, but I don't think Kingdom of Saudi Arabia does*", **EX4**.

"*Excellent because it is taken from the publicity in the Law 2002* ", **EX2**.

"*One of the most important goals of the land registration systems in the world is transparency, and on this basis, this system was found. One of the goals of the Kingdom of Saudi Arabia is absolute transparency in accordance with the state's regulations*", **EX3**.

(c) **Auditability and Reliability** All agreed on these factors are not only provide a solid information base for the land record, and could be valuable to enrich the system, but they are the base of the process of conveyance ownership .Here is what the experts stated:

"*with data registration we can invest in data in any way. It is possible by using the ID, the historical information will be shown. Yes, it is important to be considered as an official document*", **EX1**.

"*Very important because the registration process means confirming a person's ownership of a certain property based on the arguments, proofs and documents he owns. It should be a basis in provanance factors*", **EX3**.

However, EX4 and EX7 this factor is done in the first registry process as it part of recording history "*if you're if you've gone through a good process of registering a property and the legal rights to a property, the history is not so important. But there are always big cases of disputes and always be cases of problems that might occur. And so you need to be able to go back and trace the previous land records in those cases*", **EX4**.

"*The auditability is going to be there if the first registry is there. After the first registry is issued, the people will be able to trace back the information and to know the route of the name of the owners. This gives a solid record especially if the investors want to invest*", **EX7**.

Six experts agreed on the name of the factors, while **EX6** had significant opinions on Accountability, Transparency, and Auditability. He suggested investigating a deep definition of Accountability from a land registry perspective. He recommended a good reference for that. He also mentioned making a balance between Transparency and Privacy, especially in the Saudi Arabian context, and suggested renaming the factor to **Transparency and Privacy**. Lastly, in the Auditability factor, the system should not only traced backwards to the information, but it should be able to trace back and forward.

4. **Technological Factor**: All experts agreed the importance of technology, as it links the all the government bodies together. Therefore, security and maintaining immutability is quite important. Only technical experts and those with long experience gave justifications for how the technological factors are important. Among the most interesting statements from the respondents were:

   (a) **Security**: In terms of the protection of the system from internal and external attacks, the experts showed the procedures needs the protect the system.

   "*Yeah, that's very good. And I mean, you've got all sorts of things, especially with hackers and all sorts of people. So the so the control of the security of the system is very is is absolutely essential. And the other thing that you do with the security is you track and track who makes changes. That's quite important, because if you want if you want if you have a system in place and someone makes a change to the to the system, it's very important to find out who did it because they may have had some ulterior motive for making changes that have a generally in the statement you made*"**EX4**.

   "*In the portal that we are currently working on, we use IAM authentication for the National Centre. There is a double authentication using the OTP code that is delivered to the mobile*"**EX5**.

   "*We are using the Nafadth Alwatany to access the system for authentication when the employee using the system. This system is secure as it is located on the "national information centre". it is built according to the NCA standard and*

cybersecurity recommendations. Sharing data, record keeping, the connection between governmental bodies are subject to a high-level secure network to ensure security. there are many elements that have been considered to increase the security level"**EX7**.

(b) **Immutability**: The experts' thoughts about this factor are part of security and preventing the information to be manipulated. However, when an explicit definition was given, The experts seem to agree on the importance of the factor. The system will be more reliable, and able to forward back to track the changes.

"*Part of Security policy. You Can we add the classification data*"**EX1**.

"*Very important because having the ability to modify the data will affect reliability*"**EX5**.

"*It is very agreed upon, and if there is a mistake, it will be compensated according to the error in the used system*"**EX2**.

5. **Legal Factors**: All experts agreed on the importance of the legal factor, and they just added more data to what they were told. However, one suggested adding more sub-factors. It is important in terms of the basis of the title and describing the conveying framework. Below is a collection of some of the most noteworthy statements made in this regard:

"*Yes, very important. It is the basis of all Land Registry based on legal factor*",**EX1**.

"*It is only important to add otherwise, for example pre-emption, easement (or otherwise)*", **EX3**.

"*Well, you know, the legal factor is is very, very important because, I mean, it is basically a legal action that is occurring, if you're will. So this is the legal factor is much more important, for example, than the survey sector, because, you know, you always have to pass*", **EX4**.

"*there are more legal factors than that. I mean, there's the law to establish the system. So what you're talking about here is The legal framework for. You have two legal frameworks, one is for the title registration system for deed registration system and the other, and the other one is the legal framework for conveyancing*", **EX6**.

5.3 Discussion STF: A Social Trust Framework

The framework was confirmed using the sequential triangulation process. First, the framework was built to overcome the problems in the land registration system by reviewing the factor behind the challenges from the literature, comparative example, and

attack model. This framework was then revised by interviewing investors. The findings from these interviews added new factors to the framework. The revised framework was then discussed with experts. This resulted in agreement, renaming, exclusion, addition, and regrouping of factors.

The interviews with experts working in managing land registration systems, as well as experts knowledgeable in the system in Kingdom of Saudi Arabia and around the world, has led to significant advantages gained from a deep understanding of land registration systems. This has provided good expectation for research opportunities, along with knowing what the beneficiaries need from the system. It has changed the way of looking at the system. The idea of land registry is not just that of protecting the land rights, overcoming the problem with the system, or linking the organisations together. It is a system where all government bodies, individual, business (beneficiaries) can access an integrated system, such as utilities, transportation, communication, and others, as well as linking to social networking.

The land registration system in Kingdom of Saudi Arabia went through many reforms until the Real Estate Authority was established as part of these reforms, and sole government body responsible for the system. Currently, it is working to facilitate and support MOJ and MOMRA workflow by using the law issued in 2002. This law stated that the workflow between them gives the land its own identity, no matter who is/are the owner/s, protecting the owner's rights, and more. This law is thus multi-purpose, as it was described by the experts.

The 2002 law applied first in the region of Huraymila, where the experts' said all land had been properly registered. This had taken a long time to accomplish and, in the end, it failed because there was no organisation primarily responsible for reforms and other aspects, such as internal and external awareness, training, funding, and an unclear business model. These aspects were mentioned when the experts talked about the organisational factors.

Some experts mentioned that having only one organisation responsible and meeting the other factors, will not guarantee the success of the land registration system. There must also be political support from high up. Other experts agreed that the factor interoperability, between all the organisations and REGA, was needed to create a harmonious system.

All the experts agreed that the provenance of records and its sub-factors should be in the framework. Indeed, they mentioned that this factor was handled in the 2002 law, and it is one of the basic requirements of the land registration system, especially when the first registry is issued. This means no one would later be able to claim the land title document. Therefore, all the provenance factors are important, whether in first registry or during the conveyance process.

TABLE 5.10: Amendment on the factors based on the expert review

	Renamed (R) /Excluded (E)/agreed(✓)							
Factors/ expert	**ex1**	**ex2**	**ex3**	**ex4**	**ex5**	**ex6**	**ex7**	**ex8**
Organisational Factor								
Governance	✓	✓	✓	✓	✓	✓	✓	✓
Regulation	✓	✓	✓	✓	✓	✓	✓	✓
Historical consideration	R	R	R	R	R	R	R	✓
Ownership Claim	E	E	E	E	E	R	E	E
Culture	✓	✓	✓	✓	✓	✓	✓	R
Provenance Factor								
Accountability	✓	✓	✓	✓	✓	✓	✓	✓
Transparency	✓	✓	✓	✓	✓	R	✓	✓
Auditability	✓	✓	✓	✓	✓	✓	✓	✓
Reliability	✓	✓	✓	✓	✓	✓	✓	✓
Technological Factor								
Security	✓	✓	✓	✓	✓	✓	✓	✓
Immutability	✓	✓	✓	✓	✓	✓	✓	✓
Legal Factor								
Legal	✓	✓	✓	✓	✓	✓	✓	✓

Legal perspective is also important to consider, whether the land title was first issued (first registry) or by conveyance. During the cycle of the workflow of issuing the first registry, there are three times when it is possible to claim ownership, whether it is because of a land border problem, a double sale, or others. Also by law, for 60 days from registration, anyone can claim to own the land, but after the land title document has been issued, no one can claim it. Also, the legal part can specify when that transaction occurs, according to the Shari'ah. A legal expert suggests that the legal factor should be divided into two: the legal framework for the system, and a legal framework for buying and selling.

The experts found that there were other components and elements in the factors that should be added and excluded. However, all the experts were satisfied with the grouping of factors. Therefore, the proposed STF was revised, based on the following arguments.

1. **Added Factors**. Every expert proposed factors from their experience. A lawyer added more factors to the legal, whereas a technical expert added more factors to technological, and so on. There was some of sharing of thoughts when it came to organisational factors. Every category will be discussed separately and is summarised in Table 5.10.

   The importance of the factors was the first question posed. It gave them a chance to open the discussion on a certain area of the framework. They were then asked

TABLE 5.11: Factors suggested by experts

Category	New Factor	ex1	ex2	ex3	ex4	ex5	ex6	ex7	ex8
Organisational Factor	Awareness	✓				✓	✓		
	Interoperability or integration with system				✓			✓	
	funding						✓	✓	
	political support						✓		
	training						✓		
	business model						✓		
Provenance Factor	Real estate authenticity	✓							
	Source of title deeds			✓					
	key identifier							✓	
Technological Factor	the survey	✓	✓		✓				
	innovation / adaptability / embrace technology		✓					✓	
Legal Factor	Objections	✓							
	Legal framework for the system						✓		
	Legal framework for the buying and selling						✓		✓

to recommend more factors. Some of the suggestions were relevant to the objective of the research, while others were not. Table 5.11 lists all the factors by experts.

(a) Organisational Factor: This was considered the only factor that would help avoid the problems in the land registration system and help to build a reference architecture and model. The experts identified two new factors: **awareness and training and political support and funding**.

Awareness and training were proposed by three experts, citing this as the reason for the failure of the previous attempt of applying the 2002 law. Although these factors were given separately, they are related to each other. One way of making people aware of the new system is by promoting it to them and also by showing them how to use it. Thus, awareness and training are linked to each other.

Political support and funding are also considered in the framework. Political support means all high-level positions in the government support the system by promoting or providing for its needs. This includes funding the system. Funding means all the resources that the system needs, whether financial, human, buildings, or other. Therefore, political support and funding go hand-in-hand.

(b) Technological Factor: The initial idea of considering security and immutability was to provide security measures to keep the records safe, and preventing the records being altered externally or internally. However, the experts had contradicting thoughts. The technology used in surveying for mapping must come together with the system's adaptability to embrace new technology. **Surveying** was recommended by three experts, whereas **innovation** was suggested by two.

(c) Legal Factor: this factor was composed of only one factor. All experts agreed on the importance of this factor, except for the lawyer in real estate and one other who consulted in real estate. The lawyer insisted that the factor should be split into two. One concerns the legal procedure needed to issue the registration for the first time, and the other concerns the due diligence needed for selling or purchasing land. The other expert also suggested elaborating the factor. Therefore, the factor was divided into **legal framework for the system** and **legal framework for buying and selling**. Their points were convincing, and they were considered in the framework.

At this point, it should be noted that several other factors were referred to, but since they were not relevant for the proposed framework, they were ignored. These are

(a) All the factors suggested for Provenance were ignored as it is part of the provenance factor.

(b) Organisational factor: Interoperability or integration with the system and business model are part of the governance factor.

(c) Legal factor: Objections are part of the process of developing the regulations.

2. Excluded Factors. Six of the experts showed their hesitation about the ownership claim factor. Four of them stated that the claim factor was part of the process of executing the first registry which avoids the claims. The others stated that the factor is the goal of the system, where no one could claim on the title once it has been issued. One suggested that this factor should be part of historical consideration, while others thought it should not be part of the framework. Upon this evidence, this factor was removed.

It was possible to amend the framework after assessing the findings of the interviews with the experts; the framework was examined and confirmed by the experts. One factor was given a different name, one factor was excluded, while a total of six new factors were added to the STF, as seen in Figure 5.2. The STF describe the system relation on the left whereas the confirmed factors on the right. The summary of the factors are

Organisational factors represents the causes of the system management challenges.

Governance refers to the number of government entities involved in the land registration system.

Regulation refers to the property management regulations and policies.

First registry The first legal registration process requires a judge to authenticate the ownership of property.

Political support and Funding refers to all high-level positions in the government that support the system by promoting or providing for its needs.

Culture refers to the comprehensive set of socially acquired patterns of behaviour, beliefs, and customs that characterise a particular group of individuals.

Awareness and Training refers to promoting new systems to people and also showing them how to use them.

Provenance factors A provenance factor is a record that details the individuals, institutions, entities, and activities involved in the production, influence, or delivery of a particular piece of data or item. This improves the system for the following reasons:

Accountability refers to how the system is able to show the source of the information, who is responsible for making mistakes, and who is modifying the data.

Transparency refers to how the system is able to prevent corruption or bribery.

Auditability and Reliability refers to the system that provides a solid information base for the land record, and could be valuable to enriching the system.

Technological factors refers to using the technology to link all the governmental entities together and, importantly, considering the following factors

Security refers to the access control, data integrity, liability, and accountability of the records.

Immutability refers to placing restrictions on records so that they cannot be altered or modified.

surveying refers to using the technology to collect the data from surveying systems.

Innovation refers to using the latest technology to ensure precision when collecting data from surveying systems.

Legal factors refers to legal procedure according to country

System legal framework refers to the procedure to register the property.

Conveyance legal framework refers to due diligence needed to transfer ownership, such as selling or granting

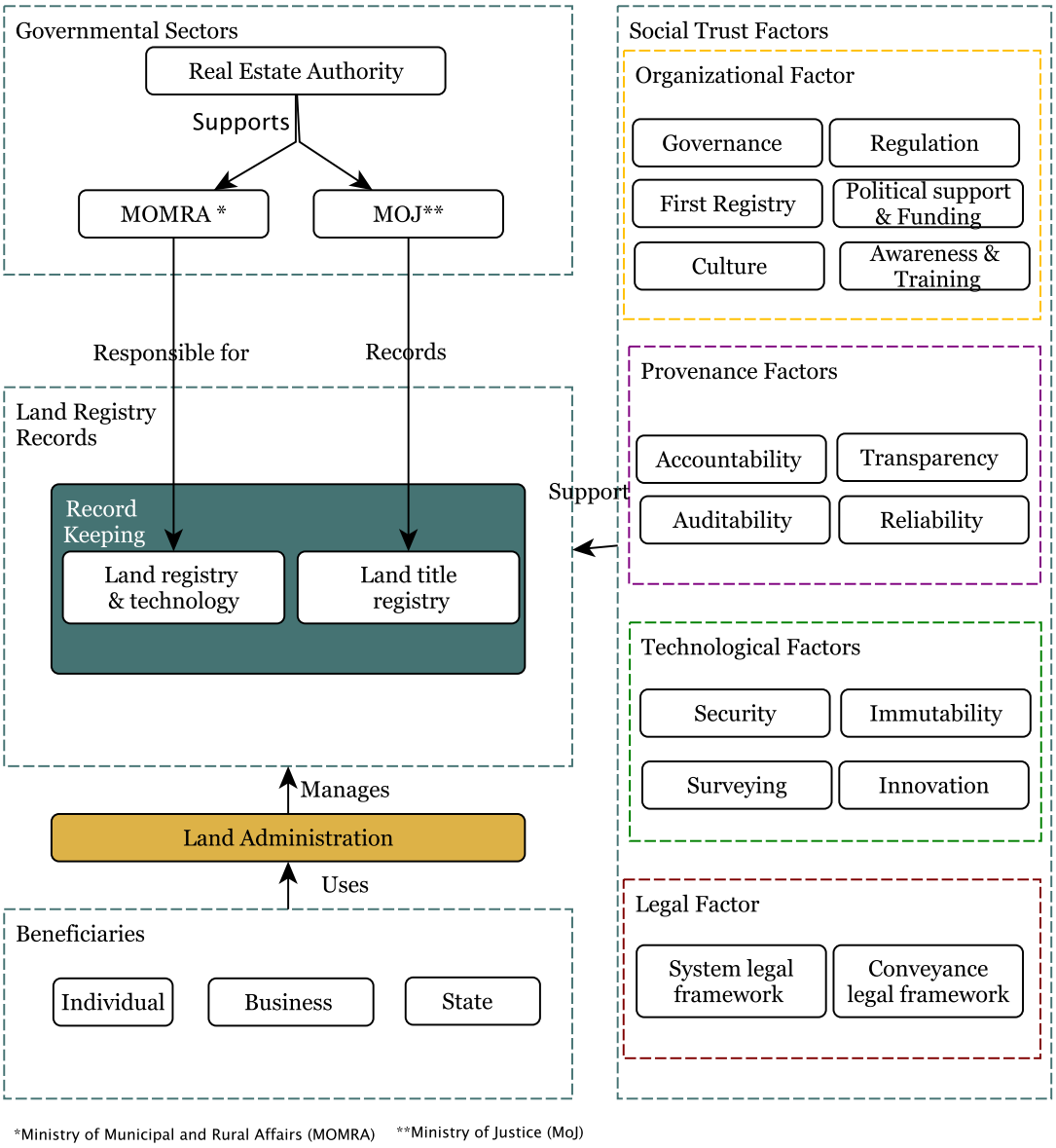

FIGURE 5.2: Confirmed framework

5.4 Chapter Summary

The chapter first discussed the approach applied to the research study. Two styles of qualitative study were chosen, and sequential triangulation procedures were adopted for the multi-method approach. To answer the third research question 1.3, an expert review was adopted to confirm the proposed STF. Eight experts from the Real Estate Authority and experts from the World Bank were interviewed. The collected data was analysed thematically and in content using MAXQDA tools.

The findings were discussed in detail based on the themes used in the analysis. The findings showed general agreement on the structure of the proposed factors and introduced further factors to the framework, as well as renaming some and excluding others.

The findings were triangulated with the relevant literature, and the challenges for the development of the framework were explored. Thus, the framework was finally organised into four main factors: organisational factors, provenance factors, technological factors, and legal factors.

The subsequent chapter deliberates on the applicability of the framework within the domain of land registration systems. The established framework substantiates the establishment of an ownership transfer process, facilitating the examination of user requirements and system relationships.

Chapter 6

Analysis of Ownership Requirement Specifications

The social trust framework, elucidated in Chapter 5, has developed through a synthesis of literature review findings and insights gleaned from two qualitative studies—an exploratory interview and an expert review. This framework delineates a comprehensive set of factors needed to design land registration systems, such that mitigation of the identified challenges identified in Section 2.6 . These set of factors delineate the requirements needed for constructing models using a software engineering methodology. This methodology guides the formulation of system requirement specifications, delineating the fundamental needs for system development. This chapter, in addressing SRQ2, contributes significantly through the second contribution, C2.

6.1 System Requirements Engineering

The requirement analysis is conducted by applying a four-stage general methodology to analyse the user requirement specification for transferring ownership [Maguire and Bevan, 2002] as discussed briefly in Chapter 3. The requirement analysis methodology includes gathering the information to understand the context, understanding the user needs identifying the challenges, envisioning and evaluating the information, and then writing the requirement specification.

The first and second stages were conducted to gather the information needed to understand the context and user needs and develop a framework accordingly. The finding from these studies is to identify the challenges, define the potential users, and stakeholders, and provide information about processes that intervene in transferring ownership. The finding from these studies was used to develop a land registry framework 4.

Following the understanding of the context and challenges, the next stage is to design and envision the system, and write requirement specifications. However, defining the pre-system condition is essential to define clearly the purpose of modelling.

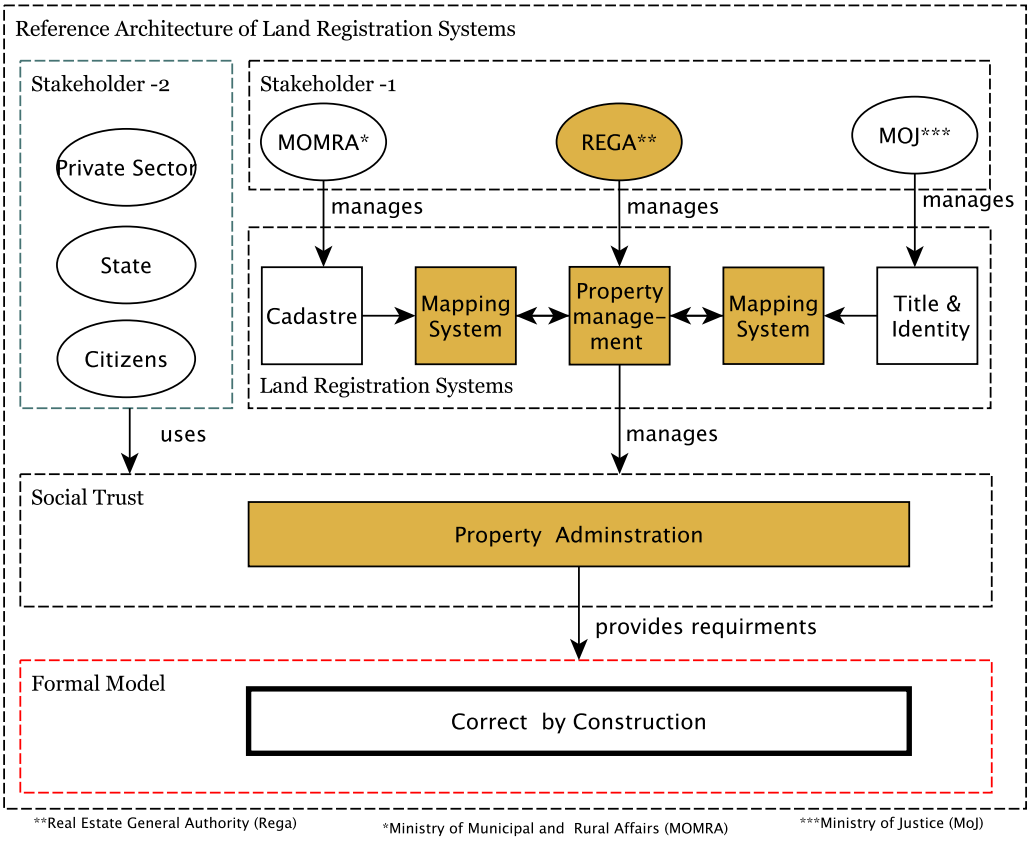

FIGURE 6.1: System architecture of land registry systems

6.1.1 Pre-System Condition and System Architecture

As part of system design and requirements in software engineering, system boundaries and system architecture should be clearly presented to give a complete scenario design of future systems.

6.1.1.1 Pre-System Condition

Transferring property ownership should be fed with registered property information and linked to the corresponding title. The registered property information has its own identity apart from the owner and has been confirmed by MOMORA, called "*First Registry*". The "*First Registry*" is indisputable according to the organisational factor. Every

property information belongs to one "*title*". The "*title*" system is managed and operated by Moj. The "*title*" information includes references to the property information and a list of property owners. The owner's identity is declared and defined by an external system managed by the Interior Ministry, Nanfath. The integration of the owner identity system and the property information to operate the "*title*" is provided by Rega. In the interest of the study, the property information, user identity, and integration between these two systems are given. This information is essential to guaranteeing the functionality of the process. Transferring ownership is a process that starts when an interested party intends to own a property and ends when the owner transfers the property ownership, or conveyance. The intention of owning a property depends on the legal framework.

Transferring ownership is carried out through many legal actions. It could be conducted through the transfer of sales, grants, inheritance, exchange, auction, or cancellation of rights for the public interest. Despite the legal action, challenges can be encountered in the process of transferring ownership. Modelling the purchasing property process is proposed to demonstrate mitigation of the challenges and provide a trustworthiness process to enhance social trust.

6.1.1.2 System Architecture

System architecture visualises relationships between systems and shows different views of the system. Figure 6.1 shows the system architecture of land registration systems in the Kingdom of Saudi Arabia. It shows the information flows between system components. **Stakeholder-2** shows beneficiaries' who are using the system. They were interviewed to understand the context of the system. **Stakeholder-1** is the group of governmental entities that are in charge of managing the system. Every governmental entity is responsible for a system. These entities were interviewed to confirm the STF, **social trust**. The last part of the architecture is where the **model** is built based on the framework.

6.1.2 Design Visioning and Evaluation

The third stage uses affinity diagram techniques to depict the process for demonstrate how to mitigating the challenges. This includes scenario-based and threat-based requirements analysis followed by system design using activity and class diagrams.

6.1.2.1 Scenario-based Requirements Analysis Method

The use of the scenarios is one of the methods used in requirement analysis in software engineering. It captures the user interaction with system design. The scenario was constructed and derived based on the understanding of the system from the previous studies undertaken during the development of the land registry framework. The scenario method that is adopted in this study is user story, see Section 3.3.2 Chapter 3. User story gives detailed realistic user behaviour on how to carry out the task in the future system. Part of the user story is a caricature Persona that represents the main future user of the system.

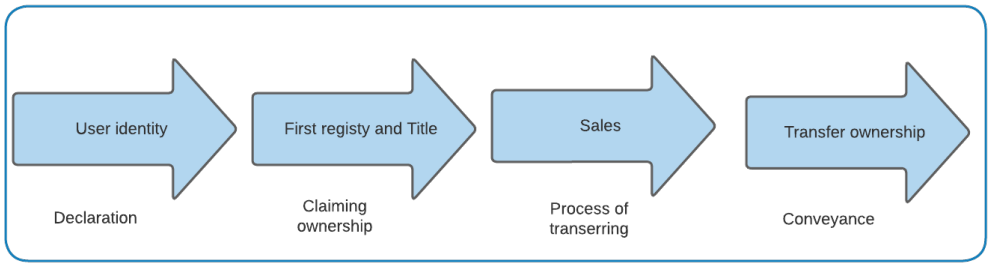

FIGURE 6.2: Abstract property ownership process

The process scenario is break down into four steps as shown in Figure 6.2. These steps are showing the storytelling regarding the legal framework of transfer ownership; property conveyance through selling.

Declaration is when the users are able to access the system.

Claiming ownership is when the owner is able to claim their ownership.

process of transferring ownership is when purchaser is able to purchase the property.

Conveyance is when the ownership transfer to the purchaser.

Each step is telling the activities as a list of a user story with corresponded to a requirement and factor reference from the framework. The user stories are summarised in Table 6.1, Table 6.2, and Table 6.3. This approach provides insight into user behaviour thought to create a meaningful procedure and interactive presentation to express the consequences of activities. As the scenario needs caricature to play the role despite the type of user, there are three main roles; purchaser, seller, and owner. These are detailed descriptions of caricatures in the property ownership process.

Alice is a purchaser who would like to have convenient access to the property information and to be able to verify the property information before owning a property, US01, US03.

Bob is an owner who would like to have an access to his properties and be able to sell his proeperty, US01,US03.

Ted is an official seller representative who has permission to sell a property, US01,US03.

Alice can be an owner of other properties.

Bob owns properties and can purchase other properties.

Ted can be the owner of property, as he can sell his own property or act as an agent and sell property on behalf for other people.

In this scenario **Bob** permits **Ted** to sell the property on his behalf, US05. likewise. Alice can only purchase a property owned by Bob, US02.

The process of property ownership starts when users are able to declare their identity US01-US03.Also, the property information has its own identity regardless of who is/are the owner/s. The property information attached to the property title shows the list of all owner/s, US04.

Once users declare their identity, **Bod** has to have claimed *title* to claim his shared in property ownership,US04 and **Alice** and **Bob** are capable to declare their *identity* during the process,US05. Once this step is accomplished, the *property ownership* is assigned to **Bob** and the *title* can be transferred to **Alice** through a legal framework, US6, US07.

Once the property has a clear list of owner, the property can now be bought and sold. if **Bob** sells the property by himself, he should change his role from an owner to a seller, US08.Otherwise, he can permit **Ted** to sell the property on behave of him US09. Then, **Ted** can sign the property to open to sell at this step, US10. The property can be requested from many interested purchasers, US14. **Ted** can either accept only one request, US11 or step back from not selling the property, US12. Meanwhile, **Alice** can request to buy many properties at the same time, US14. The accepted request allows **Alice** to review the property information after showing her interest to purchase the property, for example, paying a deposit, US15, US16.

Showing interest to purchase prevents undesired requests and proof that the requestor is highly interested to own the property. Furthermore, the property information is shared as part of the process. This gives **Alice** time to negotiate with **Ted**, visit the property, and decide to purchase, US16. Henceforth, **Alice** can either accept to proceed with her interest to purchase or withdraw the transaction. In the case of withdrawal, the proof of showing interest can come off a list according to the legal framework. Subsequently, **Ted** can assign the property on for sale again, US13.

Once the proof of purchase is verified,US18, US20, the ownership can be transferred to **Alice**, US19. **Alice** has many attempts to make payment in case of any failure, US21. This step is quite critical and should be done carefully according to the legal framework. The identity of **Alice** and **Bob** should be declared. **Ted** should confirm he has permission to sell the property. The archive property information should be original to the source, and accessible by the owner, US22. Lastly, all the information is kept and archived for any further needs. These requirements are in compliance with STF. Table 6.4 ensures coverage of key factors like governance, security, transparency, accountability, regulation, audibility, and reliability, integrating them into the system requirements. It emphasises unique user identities to prevent fraud (REQ01), the ability to register and demonstrate property compliance (REQ02), and role declarations for accountability (REQ03). It also highlights mechanisms for property reclamation and ownership preservation (REQ04), and user identity utilisation for system interaction (REQ05 and REQ06). Detailed role definitions and their implications are covered under requirements REQ07 to REQ15. Additionally, the system facilitates information exchange under regulatory and governance standards, enhancing accountability and reliability (REQ16 and REQ17). Finally, it ensures adherence to conveyance legal frameworks, maintaining provenance factors according to organisational criteria (REQ18 to REQ22).

6.1.2.2 Threat-based Requirements Analysis Method

Although the scenario captures the main activities to accomplish the buying and selling process, safety requirements were not assessed. Threat analysis was applied to identify these safety requirements. This process starts with the main activities captured from the previous method. Threat analysis uses three symbols to represent a task in the process as discussed briefly in Chapter 3.

The process commences with accessing the system using an activity **Access account**. This activity needs an input of user identity from the Nafath system and this activity could be accessed by any user of the system. The output of the activity is the input to the next activity.

Figure 6.3 Section A shows all the activities required to accomplish the transfer of ownership. The process does not only show the sequence of the activity, it also shows the user's activity. For example, when the purchaser needs to make an offer on a property, the activity "**Offers a property**" needs the property information that was the output of "**Adding a property to sale**" and producing an output, property information.

Threat model uses to investigate safety requirements to save the system from challenges:

TABLE 6.1: Requirements analysis using user story

A. process of Establishment				
Code	User Story	Requirements	Req Code	Factor Reference
US01	As Bob and Alice, I want to be able to access Nafath gate so that I declare my identity.	The user must be able to register to the system.	REQ1	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US02	As Bob, I want to be able own many properties, so that I can manage them.	The user must be able to own many properties.	REQ2	☑ Organisation Factors ☐ Provenance Factors. ☐ Technological Factors. ☑ Legal Factors.
US03	As Bob, Ted, and Alice, we want to be able to manage the account so that it reflects our current account info	The user must have different roles in the system based on the intended action.	REQ3	☑ Organisation Factors ☐ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
B. Well-defined properties				
US04	As Bob, I want to be able to claim back all properties I owned, so that I can add a property on sale.	The owner must allow to claim back properties they own.	REQ4	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US05	As Bob, Ted, and Alice, we want to be allowed to declare our identity so that we can access properties.	The user must declare their identity to access the property information.	REQ5	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US06	As Bob, I want to be allowed to l view all the properties I owned, so that can sell them.	The owner must be able to view any property they own.	REQ6	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US07	As Alice, I want to be able to request to access property info that I want to buy, so that I am able to make deposit.	The buyer should be able to request to buy a property that is on sale.	REQ7	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.

TABLE 6.2: Requirements analysis using user story

Exchange property information				
Code	User Story	Requirements	Req Code	Factor Reference
US08	As Bob, I want to be able to permit Ted or me to sell properties I owned, so that I can add a property on sale.	The owner should change their role to a seller to be able to add their properties on sale	REQ8	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☑ Legal Factors.
US09	As Bob, I want to be able to permit Ted or me to sell properties I owned, so that I can add a property on sale.	The owner must be able to permit a seller to sell the property to be able to sell the property on their behalf.	REQ9	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☑ Legal Factors.
US10	As Ted, I want to add the property that I have a permit on to sale, so can receive requests to buy.	The owner could be able to add the property who owns on sale.	REQ10	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☑ Legal Factors.
US11	As Ted, I want to accept an offer from Alice to buy a property, so that I can share the property information.	The owner(seller) should be able to accept a request from the buyer for property they got permission.	REQ11	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US12	As Ted, I can refuse all the offers from buyers, so that I no longer need to sell the property.	The owner (seller) should be able to refuse requests from the buyer for property he owned.	REQ12	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US13	As Ted, I can add the property on the sale after I refused all the offers from request, so that I can receive request from buyers.	The owner could be able to add the property on sale after he refused a request from a buyer.	REQ13	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US14	As Alice, I want to be able to request properties to buy, so that I can access the property info.	The buyer should be able to request to buy properties that are on sale.	REQ14	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US15	As Alice, I want to pay the deposit so that the property is on hold until ends of the offer.	The buyer could be able to make deposit after requesting to buy a property.	REQ15	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.

TABLE 6.3: Requirements analysis using user story

Code	User Story	Requirements	Req Code	Factor Reference
Exchange property information [continue]				
US16	As Alice, I want to be able to access property information, so that I want to buy the property.	The buyers must be allowed to share property information if it was made a deposit.	REQ16	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US17	As Alice, I want to be able to withdraw my offer to buy the property, so that I no longer want to buy the property.	The buyer could be able to withdraw from buying a property after sharing property information.	REQ17	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
Conveyance				
US18	As Ted, I want to receive a confirmation of the amount of the property, so that I send the ownership to Alice.	The owner must able to receive a confirmation of payment.	REQ18	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US19	As Ted, I want to be able to confirm to send the ownership to Alice	The owner must be able to accept to transfer the property ownership to the requested buyer.	REQ19	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US20	As Alice, I want to make payment to buy the property, so that I own the property.	The buyer could be able to make a payment after sharing property information.	REQ20	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US21	As Alice, I want to make another payment to buy the property if there is insufficient amount, so that I own the property.	The buyer must be able to repay the amount after the failure of making the payment	REQ21	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.
US22	As Bob, I want to be able to access the archive property information, so that I can access previous information.	The owner should be able to access the archive property information	REQ22	☑ Organisation Factors ☑ Provenance Factors. ☐ Technological Factors. ☐ Legal Factors.

TABLE 6.4: Requirements according to STF

Factors	Description	Requirements
governance Accountability transparency Security	Unique user identities across subsystems help prevent fraud.	REQ01
Regulation first registry	Allowing users to show their property that meets regulations and first registry.	REQ02
Regulation Accountability and transparency	Declaring the role of the user according to the regulation and providing accountability for the system.	REQ03
-Audibility and reliability -First registry	Allowing users to claim back their properties and be able to track them and ensure the preservation of their ownership.	REQ04
- Security - Governance - Accountability - Transparency	Allowing users to use their identity to use the system and provide content to use the system.	REQ05 and REQ06
- Security -Governance - Accountability - Transparency - Regulation - Audibility and reliability	Defining an explicit type of role to access the system, specifying the actions and consequences.	REQ07 - REQ15
- Governance - Accountability - Transparency - Regulation - Audibility and reliability	Allowing users to exchange information according to regulations and governance and adding system accountability, transparency, audibility, and reliability.	REQ16 - REQ17
- Governance - First registry - Accountability - Transparency - Regulation - Audibility and reliability - Conveyance legal framework	According to the conveyance legal system, users could maintain the provenance factors according to organisational factors.	REQ18- REQ22

Fraud fraud concerns the user's identity in the activity in the process. In every action, the user's identity should be verified. The check should be done with a reliable system such as the Nafath identity system. For example, the main activity that needs checking the user's identity is when the user registers **Register a user**, the purchaser makes an offers on a property, **Offer a property**, and the owner accepts or refuses an offer,**Accept/Refuse offer** as shown in Figure 6.3, Section B.

Double sale it necessary to ensure that the process includes requirements that prevent the owner from selling the property to many purchasers. Referring to Figure 6.4 Section A, double sales could occur at the end of the process of transferring ownership. In this case, the property has been disabled from receiving further requests from other purchasers, and at the same time, the property has to be exclusively sold to the interested purchaser. Once the ownership is transferred, the previous owner should not be able to see the property under their name and the only new owner could view the property information. Therefore, the current owner and the purchaser should sign a digital signature to transfer the ownership to the purchaser. Also, another safety requirement needs to allow the purchaser to become the new owner of the property. The property information should be encrypted using the purchaser's (new owner) information.

Falsfied information: falsified information concerns the property information. It could occur in a number of processes when the property information is accessed. The property information subject to threat in property registration, **Register a property**, selling the property, **add a property on sale**, sharing property information, **Share property** and agreement on the sale, **Withdraw/agree in sale** according to Figure 6.4 Section B. Therefore, before registering a property, the owner should claim their property ownership to prove their ownership. Also, when property information is shared, the property information should be verified.

According to the threat analysis, a number of requirements should be considered to overcome the challenges. These requirements are listed in Table 6.5 corresponding to the challenges. Considering the control requirements, the process of transferring ownership is extended including the control requirements in Figure 6.5.

6.1.3 Requirements Modelling

In the third stage, affinity diagram techniques are developed to identify the relationships in the system before starting formal modelling. Activity and class diagrams are used to represent the system's relationships. The activity diagram captures a different aspect of the system as well as modelling the states of the system. According to the scenario and the assumption, there are three user roles and information provided by external entities. Every user is represented in isolation using swimlane representation.

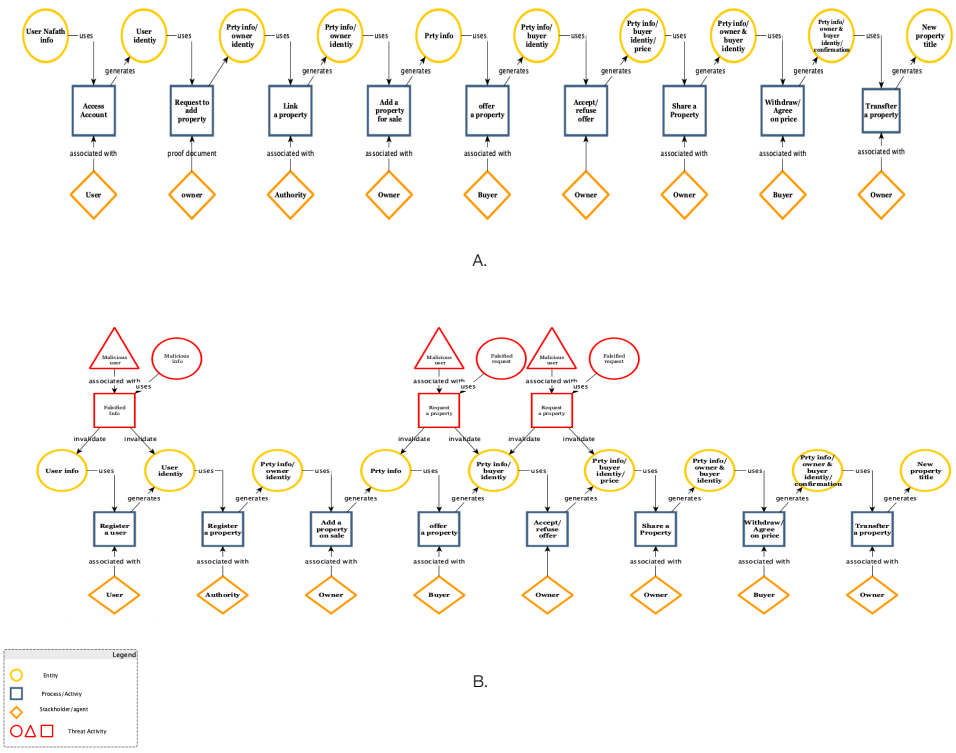

FIGURE 6.3: Threat analysis- A is process of transferring ownership threat analysis and B is fraud threat analysis

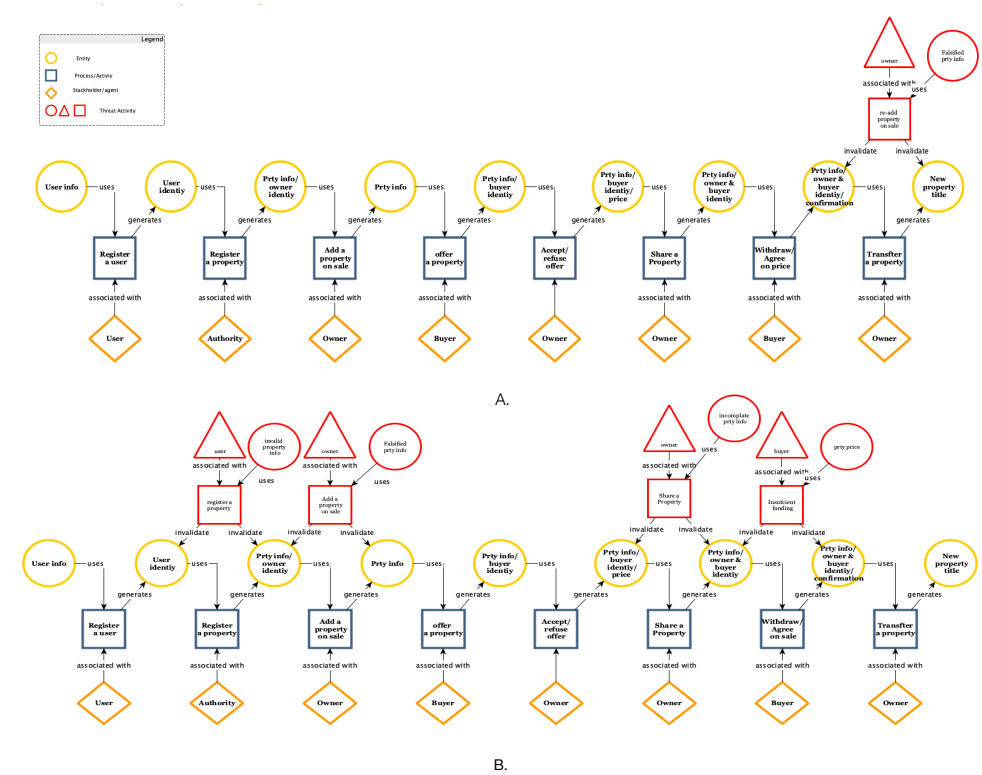

FIGURE 6.4: Threat analysis- A is double sale threat analysis and B is falsified information threat analysis

TABLE 6.5: Control requirements analysis using threat modelling

Double Sale			
Code	Process	Requirements	Req Code
P1	Transfer a property	The user(owner and buyer) must be able to sign a digital signature upon an agreement on to transfer the ownership	REQ1
P2	Transfer a property	The buyer must be able to encrypt the property information using their keys in completion of sale.	REQ2
Falsified Information			
P3	Register a property	The owner must be able to confirm the property details are correct.	REQ3
P4	Add property on sale	The owner must be able to receive a token from the system that allows authorised to add the property to market.	REQ4
P5	Share property	The owner must be able to receive a token from the system that authorised to share the property.	REQ5
P6	Withdraw / agree on sale	The buyer must be able to receive a token from the system that authorised to requesting to buy a property.	REQ6
Fraud			
P7	Register a user	The user must be able to receive a token from the system that authorised registration.	REQ7
P8	Offer property	The buyer must be able to receive a token from the system that authorised to requesting to buy a property.	REQ8
P9	Accept/ refuse	The owner must be able to receive a token from the system to accept or refuse.	REQ9

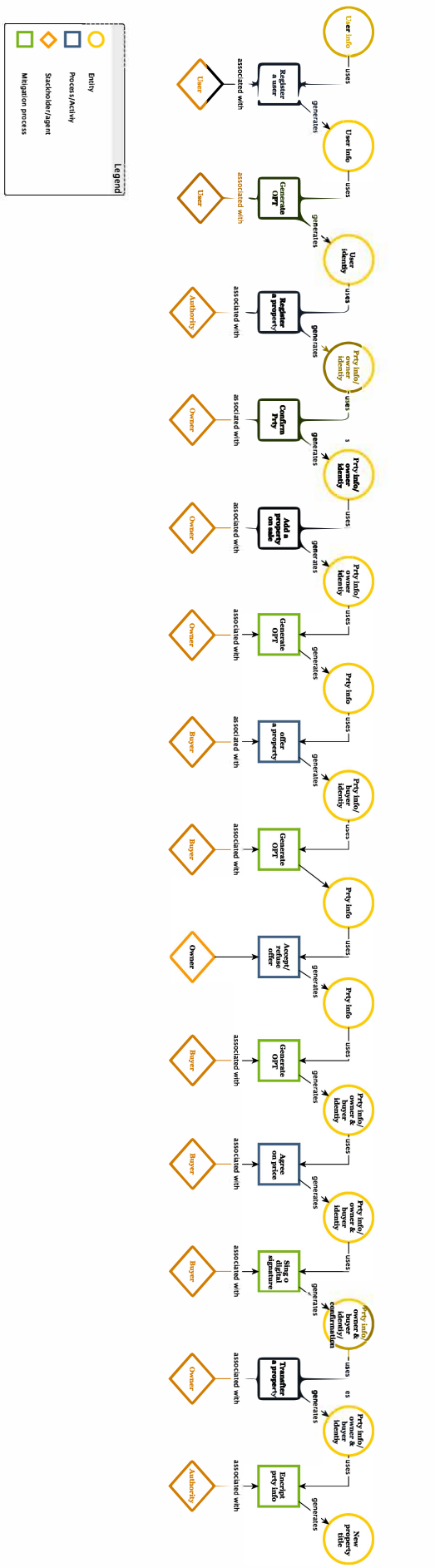

FIGURE 6.5: Threat modelling: process of transferring including the control requirements

The activity starts when the user registers on the system; the property manager knows who owns what properties, and the owner can put the property up for sale. Once up for sale, other registered users can request information about the property. A purchaser (who is registered on the system) could request to buy and make the payment. Once the purchase is complete, ownership is transferred, and the transfer of ownership is recorded by the property manager. As it is shown in the diagram 6.6.

The activity diagram failed to show all the system relationships. Hence, a class diagram was used to fill in the gap. The class diagram declares the relationship between users and the main objects of the system. The main objects in the systems are property information, **PROPERTY** and association with the title, **TITLE**. Also, there is a claimed title, **CLAIMED TITLE** associated with the **PROPERTY** but it is held by a user and equivalent to the **TITLE**. This **CLAIMED TITLE** is used to claim back the user ownership of the property. Also, as it mentioned earlier, there are three different roles of the **USER**, **OWNER**, **PURCHASER**, and **SELLER** are derived from the user object, **USER**. The **USER** should hold a valid token , **TOKEN** that is issued by the authority, **AUTHORITY**. This **TOKEN** is associated with the **TITLE** title that the **USER** owns. The **OWNER** owns the **TITLE** and the **SELLER** can sell **TITLE**, and the **PURCHASER** can purchase a **TITLE** that on a sale. The objects and the relationship is shown in Figure 6.7.

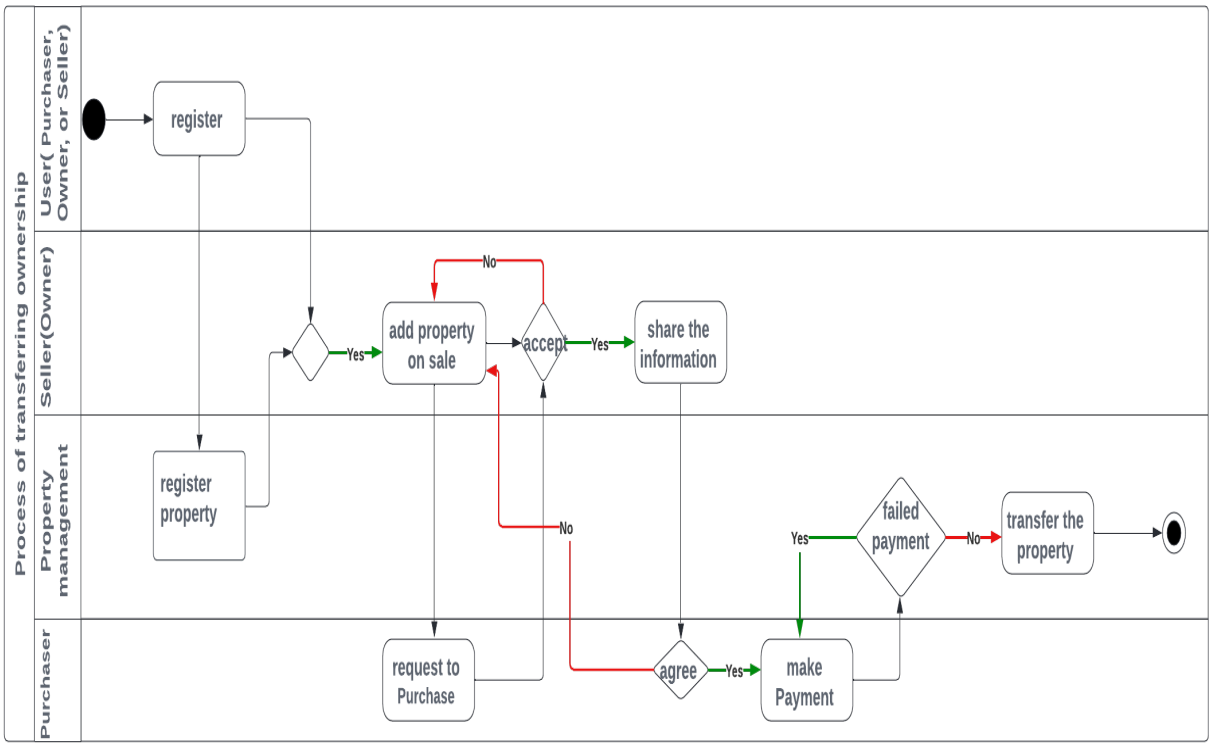

FIGURE 6.6: Activity diagram

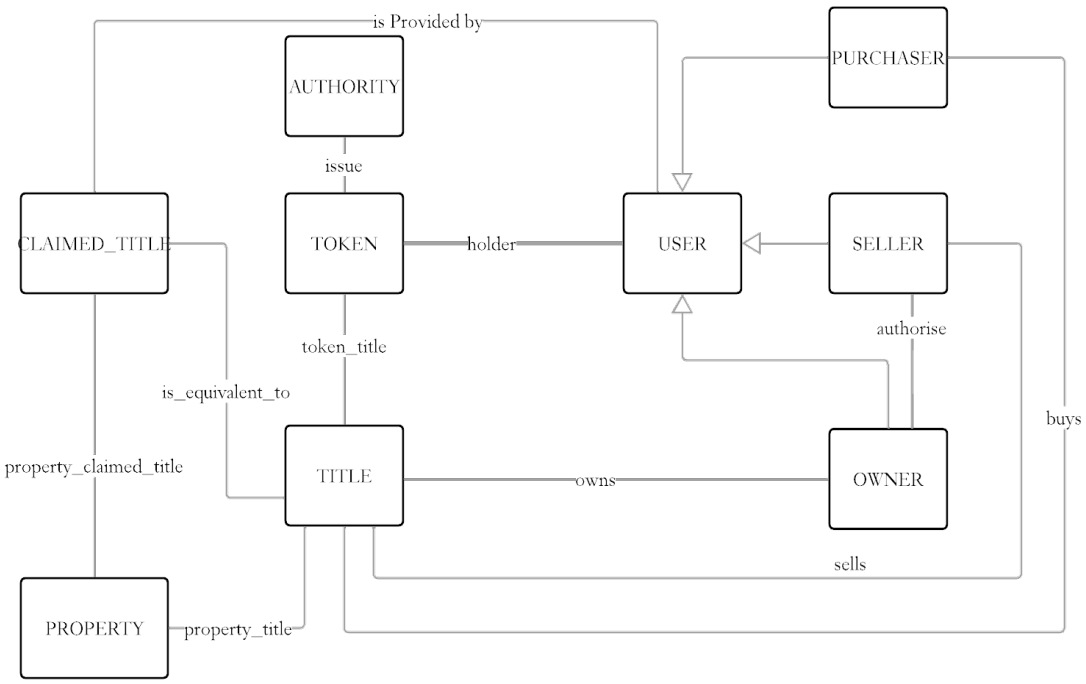

FIGURE 6.7: Class diagram

6.2 Requirements Specifications

As a result of the requirements analysis, requirements specifications are listed. The list of requirements is the result of information gathering by understanding the context of the system, understanding the user needs using user story and persona and envisioning and elevation of the system using threat modelling, activity diagram, and class diagram. The requirements from **REQ 1** to **REQ 22** are control requirements analysis using user story, and requirements from **REQ 23** to **REQ 31** are control requirements analysis using threat modelling.

REQ 1 The **User** must be able to register to the system.

REQ 2 The **User** must be able to own many properties.

REQ 3 The **User** must have different roles in the system based on the intended action.

REQ 4 The **Owner** must allow to claim back properties they own.

REQ 5 The **User** must declare their identity to access the property information.

REQ 6 The **Owner** must be able to view any property they own.

REQ 7 The **Purchaser** should be able to request to buy a property that is on sale.

REQ 8 The **Owner** should change their role to a **Seller** to be able to add their properties on sale.

REQ 9 The **Owner** must be able to permit a **Seller** to sell the property to be able to sell the property on their behalf.

REQ 10 The **Owner** could be able to add the property who owns on sale.

REQ 11 The **Seller** should be able to accept a request from the purchaser for a property they got permission.

REQ 12 The **Seller** should be able to refuse requests from the **Purchaser** for property they owned.

REQ 13 The **Owner** could be able to add the property on sale after he refused a request from a **Purchaser**.

REQ 14 The **Purchaser** should be able to request to buy properties that are on sale.

REQ 15 The **Purchaser** could be able to make a deposit after requesting to buy a property.

REQ 16 The **Purchasers** must be allowed to share property information if they made a deposit.

REQ 17 The **Purchaser** could be able to withdraw from buying a property after sharing property information.

REQ 18 The **Owner** must able to receive a confirmation of payment.

REQ 19 The **Owner** must be able to accept to transfer the property ownership to the requested **Purchaser**.

REQ 20 The purchaser could be able to make a payment after sharing property information.

REQ 21 The **Purchaser** must be able to repay the amount after the failure of making the payment.

REQ 22 The **Owner** should be able to access the archive property information.

REQ 23 The **User** must be able to sign a digital signature upon an agreement to transfer the ownership.

REQ 24 The **Purchaser** must be able to encrypt the property information using their keys in the completion of the sale.

REQ 25 The **Owner** must be able to confirm the property details are correct.

REQ 26 The **Owner** must be able to receive a token from the system that allows authorised to add the property to market.

REQ 27 The **Owner** must be able to receive a token from the system that authorised to share the property.

REQ 28 The **Purchaser** must be able to receive a token from the system that authorised to request to buy a property.

REQ 29 The **User** must be able to receive a token from the system that authorised registration.

REQ 30 The **Purchaser** must be able to receive a token from the system that authorised to request to buy a property.

REQ 31 The **Owner** must be able to receive a token from the system to accept or refuse.

6.3 Summary

This chapter addresses SRQ2. The research question consists of applying the framework to elucidate the user's needs in the ownership transfer process. The findings result in a system relationship and a list of system specifications. The reference architecture determines the assumptions needed to build the model. The reference architecture consists of three essential systems: user identity, property information, and the relationship between user identity and property information, namely the title system. Every system is managed by an external entity.

The system specification followed a four-stage general methodology by Maguire and Bevan [2002]. The first two stages were conducted by answering research question SRQ1. The answers were about collecting the information and determining the user's needs. In the third stage, a user story and persona were applied first to define the requirement specification, followed by threat modelling to determine the control gap that needed to be filled.

The user story and persona are used to define the main activities to complete the process of transferring ownership. The transferring ownership applied is the sale legal framework to transfer ownership. To transfer ownership through sale, if the seller is an agent, then they need permission to sell the property from the owner. The seller should promote their property, receive requests from purchasers, accept or refuse the offers, receive the deposit from the purchaser, share the property information with the purchaser, and then transfer ownership to the purchaser (new owner).

Although the user story captures the main activities, a control requirement remains undefined. Therefore, a threat model has been applied to specify these requirements. The treated model defines the activity as a process that needs input and output. The findings of this analysis are a list of requirements that mitigate safety requirements. Further, part of the requirements analysis involves representing the requirements in a graphical way through an activity diagram and a class diagram. The activity diagram shows the state of the system, whereas the class diagram shows the system relationship.

The findings of this chapter are employed to build a model of the system using formal modelling.

Chapter 7

Requirements Validation and Ownership Modelling Design

The system specification that has been carried out in Chapter 6 requires validation to ensure their accuracy and consistency. The formal method is one of the approaches to constructing a formal model to ensure the validity of the requirements. According to estimates, fixing errors during system testing costs 10 times more than errors committed during the construction phase and could cost more than 25 times more after the system has been released [Leffingwell, 1997]. The model is reviewed with formal method experts and varied using model checking and proof of obligations.

This chapter provides an overview of the model language and the diagramming software applied in this chapter. Additionally, we provide a brief description of the model construction approach and then provide a brief explanation of the model evaluation. This chapter, in addressing SRQ3, contributes significantly through the third contribution, C3.

7.1 Overview of the Event-B and iUML-B Formal Method

Event-B [Abrial, 2010, Hoang, 2013] is a formal method supporting refinement strategy for system development. The structure of Event-B consists of two components: **context** and **machine**.

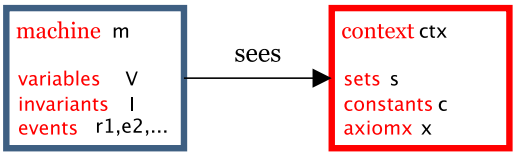

FIGURE 7.1: Modelling components.

Context represents the static data that contains following elements:

sets defines an abstract type of entities.

constants list of constants used by a model.

axioms contains list of predicates that defines the rules for context part.

Machine represent the dynamic part of the model that contains the following elements:

Variables v, list of the state variables of the model.

Invariants I(v) contain a list of predicates that defines the properties of the variable. These properties must remain true in the whole model.

Initialisation is a special type of event where all the valuables should initialised.

Events e, defines the transition events of the model. Each event contains a set of conditions, guards, and actions that variables can change when the guards are satisfied.

A **machine** may see a **context** that allows the machine to access the information in the context. The form of an event e define as follows:

any t **where** G(t,v) **then** v := E(t,v) **end**,

where t is an event parameter, G(t,v) is an event guard, and v := E(t,v) is an event action.

A machine may be refined by another, and a context may be extended by another one. In every refinement, the proof of obligation should be discharged to maintain the consistency of the modelling. Figure A 7.1 shows general structure of Event-B model, and Figure B 7.2 shows the construction representation of modelling.

Event-B is associated with a tool-set, Rodin [Abrial et al., 2010]. Rodin is a facilitated toolkit for modelling that offers verification and validation tools. Model verification maintains the consistency of the model during the refinement process using proof of

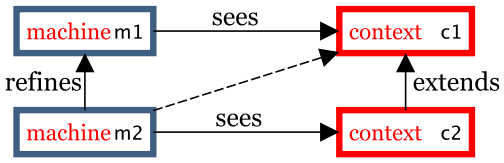

FIGURE 7.2: Modelling refinement.

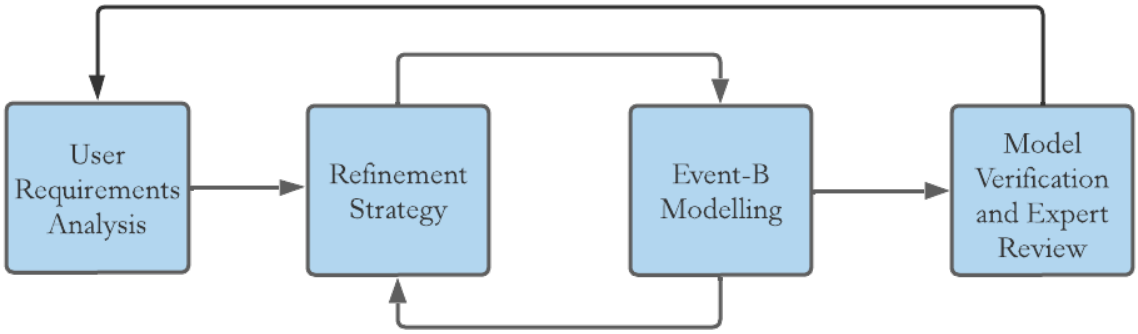

FIGURE 7.3: Model development methodology.

obligations, whereas validation ensures building the right model using the simulation-based method.

The construction of model in this Chapter is demonstrated using iUML-B. iUML-B [Said et al., 2015, Snook, 2014, Snook and Butler, 2006] is a diagrammatic modelling notation utilising state machine and class diagram. iUML-B represents the front-end for Event-B language where the repository is shared to generate the Event-B elements automatically. A class diagram visualises the context component including sets, constants, and properties. A state machine represents the transition of the model through events that are associated with the context.

7.2 Model Development Methodology

Event-B modelling requires informal requirement specifications. The informal requirement specification has been conducted in detail in the previous Chapter 6. The specifications describe the functional and non-functional requirements of software at a high level. Furthermore, building a formal model has to follow a refinement strategy to ensure the validity of construction. Once the model is constructed, it is reviewed by experts in a formal model to ensure it meets the specifications. The experts' review is not reflected only on the model but on the entire model development methodology. The methodology is an iterative-based method, as shown in Figure 7.3. It starts with user requirements analysis, then outlines the refinement model strategy, followed by modelling. Refinement strategy and modelling are iterative until an appropriate strategy is identified. Once the model is constructed, it is evaluated by formal model experts. Their reviews have reflected back on the entire process of developing the model. The expert review, along with the provided tools that are associated with Rodin, contributes to validating and verifying the requirements.

1. **User Requirements Analysis** is conducted by applying a four-stage general methodology [Maguire and Bevan, 2002] to analyse the user requirement specification

for transferring ownership. This methodology includes gathering the information to understand the context, understanding the user needs and identifying the challenges, envisioning and evaluating the information, and then writing the requirement specification. The first and second stages were conducted Chapter 5. The third stage involved identifying and indexing challenges using the affinity diagram technique. This includes using scenario-based and threat analysis to indicate the hazard activities followed by system design using activity and class diagrams. The diagram-based analysis led to the development of the iUML-B modelling. Lastly, a task/function mapping technique was utilised to establish the essential minimum user requirement specification. The system analysis methodology identifies the main component of the system and the information transition between them. The methodology is based on iteration analysis. This provides a comprehensive understanding that reflects on building the model. The details of the step was presented in the Chapter 6

2. **Refinement Strategy** Before starting to model a system, it is necessary to achieve an appropriate strategy. It provides a plan for constructing a model, identifying abstractions, adding details to the model, and introducing safety properties. The strategy can be either [Dghaym et al., 2018, 2021];

   (a) building a safe model in the abstraction, then adding properties in the refinements.

   (b) building an unsafe model in the arbitration and adding safe requirements in refinements.

   (c) building a correct-by-construction system and adding softy requirements as needed.

   The strategy being adopted is correct-by-construction. This strategy can be achieved using Event-B modelling [Punnoose et al., 2014]. It helps a modeller build the system gradually, clarify any ambiguity or missing requirements in the system specification, and add safety requirements as needed to mitigate the challenges.

3. **Event-B Modelling** is created through analysing the needs of the user and employing iUML-B [Snook, 2014, Snook and Butler, 2006, Said et al., 2015] and infinite diagrams. The diagram is automatically translated into Event-B language by the iUML-B. Other derails are added according to the requirements specification.

4. **Model Verification and Expert Review** The model is verified through the utilisation of model checking and proof of obligation [Snook, 2014, Snook and Butler, 2006, Said et al., 2015]. The utilisation of these tools can effectively address system behaviour and the failure to develop a consistent model. Additionally, the modelling involves a rigorous evaluation process with domain experts who critically analyse the model with a specific focus. A focus group is used to conduct the

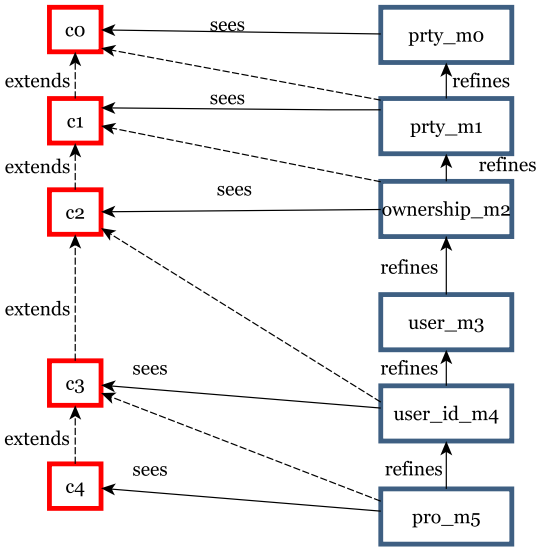

FIGURE 7.4: Refine strategy.

evaluation, which is followed by a review to confirm that the model's construction was conducted correctly. Hence the experts examined if the model complies with both the requirement specification and the model's intended purpose.

7.3 Refinement Strategy and Modelling

System analysis and iterative modelling have helped to shape the refining strategy that eventually emerges. The strategy takes into account other potential legal procedures that might be introduced later rather than solely focusing on one legal process. However, we will only address the challenges associated with selling property to transfer ownership, and we will discuss later how this strategy can be extended to other legal processes.

Modelling using Event-B refinement allows for the abstraction of the system from specifics and focuses on specific challenges at different levels of refinement in addition to gradually building the model. This preliminary modelling seeks to comprehend the system under development, clarify any ambiguities in the system specification, and identify any system attributes that are needed in order to improve the requirements.

The result of the iterative system development is the following strategy, 7.4

Abstract Model: Define Property

In spite of the legal framework used to transfer ownership and the types of users, the abstract model shows the components required to begin the process. This includes the specifics of the property, the title, and ownership claims.

First Refinement: Property Control

Property control needs to be identified with clarity at this level to describe the event's activity. Authority has control over it.

Second refinement: Ownership

At this level, ownership is outlined and solely belongs to the owner/s.

Third refinement: User Type

At this level, the type of user is explicitly introduced.

Fourth refinement: User Identity

Detailed information is added at this level. This involves declaring user access control to prevent fraud activity.

Fifth refinement: Ownership Process

Detailed information is added at this level. This involves explicitly defining the ownership transfer process.

We provide an extended list of requirements, labelling each one so that we can later refer to it. In each of the following requirements, "the system" refers to the process of transferring ownership. We built on and added new requirements as a result of the iterative process, despite the requirements having been rigorously analysed. Each refinement begins with a list of requirements needed and a context explanation, followed by a machine explanation. Then, we ensure that each refinement is automatically verified using proof of obligation. If the proof of obligation reveals a contradiction in the refinement, We should manually verify the model.

7.3.1 Abstract Model: Define Property

Property is a fundamental element of the ownership model. Each property is associated with a title that lists all the owners, but a title can have one or more owners. The quantity of owners is indeterminate. However, for the purpose of clarification, the maximum number of owners is restricted to four. The title has two states that indicate the status of claim ownership. Once owners claim ownership, the status of ownership is either confirmed or claimed. Alternatively, the property remained unconfirmed or unclaimed. The analysis previously did not provide a detailed account of this property's narrative. It was achieved through the iterative development of the model and rigorous evaluation by experts. Thus, the requirements are further refined in the following manner:

REQ 32 A property must be related to one title.

REQ 33 The title must be able to be claimed by the owner.

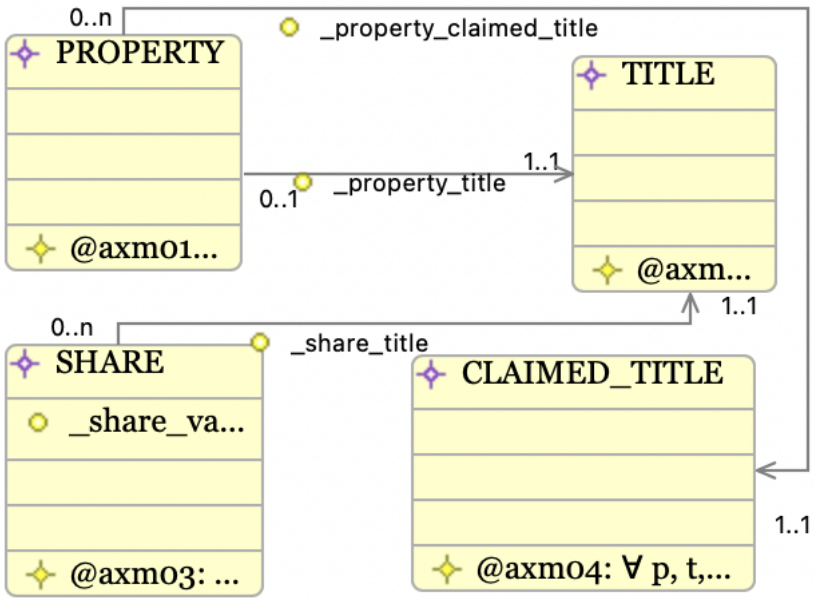

FIGURE 7.5: Class diagram representing the main sets in the abstract model.

REQ 34 The title must have either an unconfirmed title or a confirmed title.

REQ 35 The title must have one state on the system.

REQ 36 The title must have an initial state: unconfirmed title.

REQ 37 The title should change the state once all the owners claim ownership.

REQ 38 The title could have a value that represents its cost.

REQ 39 The title must stay in a confirmed state after the owners claim ownership.

REQ 40 The confirmed title must have the maximum shares.

REQ 41 The maximum shares per title is four shares.

context, c0: is divided into four sets based on the REQ 32, REQ 33 and REQ 40 PROPERTY, TITLE, CLAIMED_TITLE, and SHARE. These sets and the relationship are represented using iUML-B in Figure 7.5. The PROPERTY represents all the information about the property, and every property is associated with one TITLE. The TITLE is an official record that includes the list of owners. The CLAIMED_TITLE is a record that the owners hold to claim their ownership. Every title holds four shares, SHARE, where every share is associated with one owner according to REQ 41. The specification of the relationship between sets is describe using axioms:
@axm01: _equivalent_to = _property_claimed_title∼; _property_title , this ensures that the title and claimed title are associated with the same property.

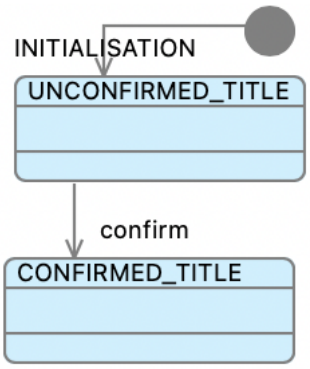

FIGURE 7.6: The state machine that shows the state of the model.

@axm02: $\forall t \cdot t \in TITLE \land finite(\_share\_title \rhd \{t\})$
$\Rightarrow card(\_share\_title \rhd \{t\}) = MAX\_SHARE$, this ensures that the claimed title matches to the actual title. @axm03: $MAX\_SHARE = 4$
@axm04: $\forall p, t, ct \cdot p \mapsto t \in \_property\_title \land \_property\_claimed\_title(p) = ct$
$\Rightarrow \_equivalent\_to(ct) = t$, this ensures that the the claimed title is equivalent to the title.

REQ 38 indicates that every share is associated with natural number that represents its value.
@title_value: $\_title\_value \in TITLE \rightarrow \mathbb{N}_1$

machine, m0: from REQ 34 REQ 35 and REQ 36, we model the state of the TITLE rather than the property. The PROPERTY information is unchangeable according to requirements. The TITLE is modified when owners claimed for their ownership. However, we do not model the owner yet in this level. There are two states of the TITLE:

- UNCONFIRMED_TITLE: a state where the title is not claimed or incomplete claims by the owners.
- CONFIRMED_TITLE: a state where all the owner claimed back their ownership of a property.

REQ 40 ensures that the confirmed title is associated with the number of shares:
@inv01: $share\_title \in SHARE \nrightarrow TITLE$.
The state of the title changed from an unconfirmed to a confirmed title when a confirmed title is associated with maximum shares, then the title could be transferred, REQ 37. The state of title is not moved back to the previous state, REQ 39. This representation is modelled using iUML-B state machines as shown in Figure 7.6. We model in this level the state of the title and when the title can be changed using confirm event and restricted by the invariant:
@distinct_states: partition(TITLE, UNCONFIRMED_TITLE, CONFIRMED_TITLE).

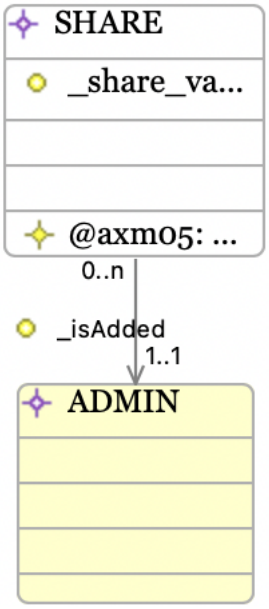

FIGURE 7.7: First refinement: class diagram.

```
1  EVENT confirm:
2  ANY
3    title
4    prty
5  WHERE
6    @grd01: title ∈ UNCONFIRMED_TITLE
7    @grd02: finite(share_title ▷ {title})
8    @grd03:card(share_title ▷ {title}) = MAX_SHARE
9    @grd04:ctitle ∈ dom(_equivalent_to)
10   @grd05:_equivalent_to(ctitle) = title
11 THEN
12   @act01: UNCONFIRMED_TITLE := UNCONFIRMED_TITLE \ {title}
13   @act02: CONFIRMED_TITLE := CONFIRMED_TITLE ∪ {title}
14 END
15
```

In the abstract, it was our intention to model just the property with no regard for the owners. We will add additional details in accordance with the refinement strategy. While consistency is automatically checked using proof of obligation and verified using model checking, the model can be further refined.

7.3.2 First Refinement: Control the Property

In this refinement, we model the entity that controls the property. This can be modelled by extending the **context** and introducing new sets, ADMIN, as shown in Figure 7.7 The requirements are needed in this level are:

REQ 42 The authority must be added to the system. req10

REQ 43 The authority must confirmed the title after the owners claimed their ownership. req11

The admin user confirmes the title when owners claimed their property using
@inv01: isConfirmedby $\in$ CONFIRMED_TITLE $\rightarrow$ ADMIN
@inv02: isConfirmedby$\sim$ $\subseteq$ _isConfirmed.
At this level, the state of this property has to satisfy the invariants and guards.

Based on the requirements, we extend the **context** and introduce new sets, ADMIN and PASSWORD as shown in Figure 7.7. Admin users regulates the property and confirms the ownership when the user claims their properties. This is represented in the machine model as invariants.
@inv01: regulates $\in$ admin $\leftrightarrow$ PROPERTY
@inv02: confirms $\in$ admin $\leftrightarrow$ TITLE
@inv03: $\forall$ a, p $\cdot$ a $\in$ admin $\wedge$ p $\in$ regulates[{a}] $\Rightarrow$ _property_title(p) $\in$ confirms[{a}]

The **machine** m0_property is refined to m1_control_property. In this refinement we add a default admin user who is regulated the property and confirms the title.

```
1  EVENT confirm:
2  REFINES confirm
3  ANY
4   adm
5  WHERE
6   @grd7: adm ↦ title ∈ _isConfirmed
7  THEN
8   @act1: isConfirmedby := isConfirmedby ∪ {title ↦ adm}
9  END
10
```

The admin users who are regulate the property are the same users who are confirmed the title when the owners claimed for their property using inv03. Int this level, the state of this refinements are satisfying the invariants.

7.3.3 Second Refinement: Modelling. Ownership and owner

This refinement entails the modelling of ownership of the title and the association with owners. The ownership represents the proportion of ownership that each owner possesses. In order to establish ownership, it is necessary to prove ownership of the four shares. An owner could claim ownership of their property by providing proof of their

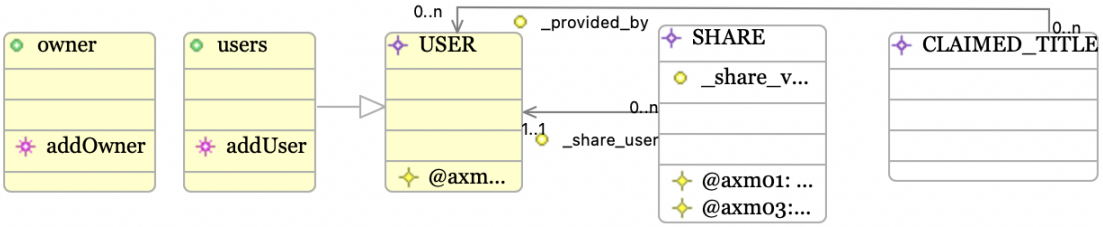

FIGURE 7.8: Second refinement: class diagram.

claimed title. After confirming ownership, the title becomes attainable for sale. This refinement satisfied these requirements, REQ 1, REQ 2, REQ 3, REQ 4, REQ 5, and REQ 25 These requirements assert ownership, as previously mentioned in the analysis, prior to carrying out any conveyance transaction. This refinement extends the **context** Figure 7.8 and refines the **machine** Figure 7.9

Accordingly, the context extends to build static part to model ownership. We introduce a USER, REQ 1, set to define owners, REQ 3, and associate it with CLAIMED TITLE, REQ 2, REQ 4, number of shares, REQ 40, and the date of the ownership, REQ 5. The associate is restricted to satisfied the ASM REQ 41. The associate is restricted to satisfying the assumption using an axiom.

$$
\begin{aligned}
&\text{@axm01: } \_\text{unconfirmed\_ownership} = \_\text{share\_title}^{\sim}; \_\text{share\_user} \\
&\text{@axm02: } \forall u \cdot u \in \text{ran}(\_\text{share\_user}) \land \text{finite}(\_\text{share\_user} \rhd \{u\}) \\
&\Rightarrow \text{card}(\_\text{share\_user} \rhd \{u\}) \leq \text{MAX\_SHARE} \\
&\text{@axm03:} \forall t, ct, p \cdot p \in \text{PROPERTY} \land t \in \text{ran}(\_\text{share\_title}) \land ct \in \text{CLAIMED\_TITLE} \\
&\land p \mapsto t \in \_\text{property\_title} \land ct \in \text{dom}(\_\text{equivalent\_to}) \land \_\text{equivalent\_to}(ct) = t \\
&\Rightarrow \_\text{provided\_by}[\{ct\}] = \text{ran}(\text{ran}(\_\text{share\_title} \rhd \{t\}) \lhd \_\text{unconfirmed\_ownership})
\end{aligned}
$$

@axm01 is the association title with users. @axm02 ensures only a maximum of four owners for each. @axm03 ensures that only owners can claim ownership if and only if they have a copy of the claim title that is equivalent to the title.

The **machine** is refined to support the specification in the context, REQ 6 and REQ 25. The ownership structure, which consists of the three components of share_title, share_user, and ownership. We define users according to USER type to represent system users. share_title is number of shares. share_user is an association of users with shares. ownership is an association title with users. One kind of user role, the owner, is introduced at this level. The range of ownership ran(ownership) are the owners. A safety invariant is added to keep four owners per title:

$$
\begin{aligned}
&\forall t,s \cdot t \in \text{CONFIRMED\_TITLE} \land s \mapsto t \in \text{share\_title} \land \text{finite}(\{s\} \lhd \text{share\_user}) \\
&\Rightarrow \text{card}(\{s\} \lhd \text{share\_user}) \leq \text{MAX\_SHARE}
\end{aligned}
$$

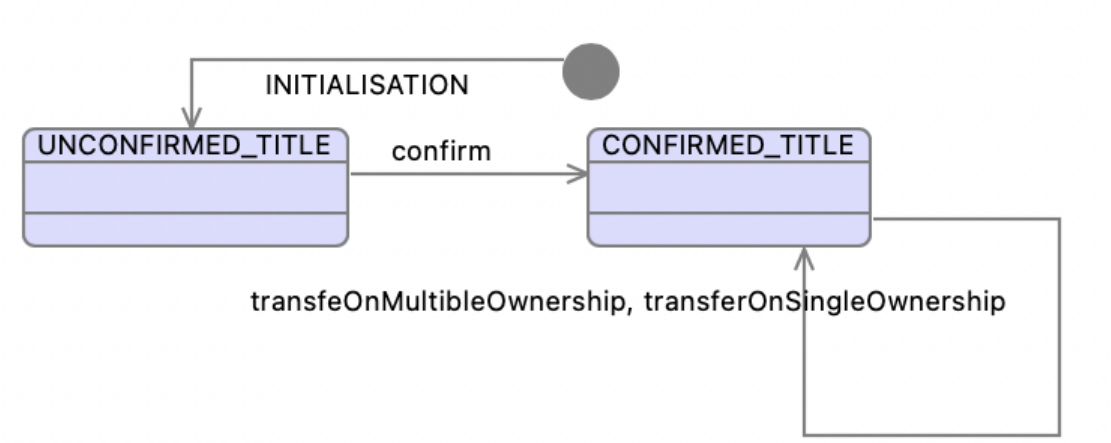

FIGURE 7.9: Second refinement: state machine.

An archive of ownership should be kept as part of the requirements. Archive information is a timestamp of transfer ownership. We model this by first assigning all of the shares to the model's user and then to the transfer date:

$$\text{@inv05: } archiveOwnership \in share\_title \leftrightarrow users$$
$$\text{@inv06: } archiveDate \in archiveOwnership \rightarrow DATE$$

@inv05 and @inv06 keep track of changes of ownership when ownership is transferred. This invariant shows the origin and source of the information and is able to be traced back.

We added the title and authority user in the previous refinement to finalise the transaction. In this improvement, archive information is included along with user and share titles, REQ 16.

```
1  EVENT confirm:
2  REFINES confirm
3  ANY
4   usr
5  WHERE
6   @grd6: usrs = dom(share_title ▷ {title}) ◁ _share_user
7   @grd7: ran(usrs) ⊆ ownership[{title}]
8   @grd8: finite(dom(share_title ▷ {title}) ◁ share_user)
9   @grd9: card(dom(share_title ▷ {title}) ◁ share_user) = MAX_SHARE
10 THEN
11  @act01: owner := owner ∪ usr
12 END
13
```

The action needed to make the transferring ownership are updating ownership with new owner, add the user to the owner set, and update the archive information. however, the guards are required to complete the transaction are essential:

- The title has to be a confirmed title, @grd1.
- Authority user who finalised the transaction, @grd7.
- Ownership and owner information, @grd2 & @grd3.
- Despite The fact that we have not yet introduced the purchaser, we define the purchaser user as local parameter. But since they need to be included to the owner set, we must include the purchaser here. Also, The share cannot be purchased by the owner, @grd4 and @grd6.
- Share should be archived along with the new owner. But they should not all be archived with the same date, @grd5.

```
1  EVENT transferOwnership:
2  ANY
3  title adm shr onr prch dt psw usrown
4  WHERE
5   @grd1: title ∈ CONFIRMED_TITLE
6   @grd2:shr ↦ title ∈ share_title
7   @grd3: shr ↦ onr ∈ share_user
8   @grd4: prch ∈ users
9   @grd5: dt ∈ DATE
10  @grd6: prch ≠ onr
11  @grd7:isConfirmedby(title) = adm
12 THEN
13  @act01:share_user := (share_user \{shr ↦ onr})∪ {shr ↦ prch}
14  @act02:ownership := (ownership \ {title ↦ onr}) ∪ {title ↦ prch}
15  @act03:owner := (owner \{onr}) ∪ {prch}
16  @act04:archiveOwnership := archiveOwnership ∪ {shr ↦ prch}
17  @act05: archiveDate := archiveDate ∪ {shr ↦ prch ↦ dt}
18 END
19
```

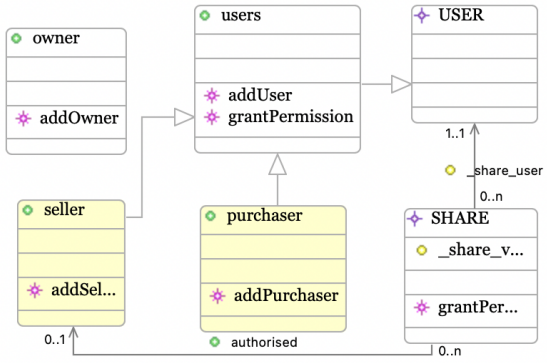

FIGURE 7.10: Third refinement: class diagram.

7.3.4 Third refinement: User Type

The user can play different roles at different states in the model. The roles of the user are subsets of the user: owner, seller, or purchaser. The user can play all the roles, but they cannot play the same role in the same transaction. When an owner intends to sell the property, the owner should permit themselves or someone else to do so. This refinement satisfied requirements REQ 19, REQ 20, and REQ 21 and modelled using iUML-B class diagram in Figure 7.10:

In this refinement, we introduce new sets or add restrictions. The context remains unchanged. However, the **machine** is refined and adds new variables. We define the type of user and grant authorisation. The ownership should be sold by the seller, who is granted permission by the owner using the event grantPermission.

```
1  EVENT grantPermission:
2  ANY
3   this_SHARE
4   onr
5   slr
6   title
7  WHERE
8   @grd1: this_SHARE ∈ SHARE
9   @grd2: title ∈ CONFIRMED_TITLE
10  @grd3: this_SHARE ↦ title ∈ share_title
11  @grd4: this_SHARE ↦ onr ∈ share_user
12  @grd5: slr ∈ seller
13  @grd6: this_SHARE ∉ dom(authorised)
14 THEN
15  @act01: authorised(this_ownership) := slr
16 END
17
```

purchaser and seller are types of users who intend to purchase or sell a property. They can be added by using event addPurchaser and addSeller, respectively. However, we need to explicitly define the purchaser and seller as a type of user to maintain the consistency of the model, @grd2.

```
EVENT addPurchaser:
ANY
 prch
WHERE
 @grd1: prch ∉ purchaser
 @grd2: prch ∈ users
THEN
 @act01: purchaser := purchaser ∪ {prch}
END
```

```
EVENT addSeller:
ANY
 slr
WHERE
 @grd1: slr ∉ seller
 @grd2: slr ∈ users
THEN
 @act01: seller := seller ∪ {slr}
END
```

Adding @inv3: authorised ∈ SHARE ⇸ seller in this refinement cause inconsistent in the event transferownership when grant the seller to sell property. To solve it, the guards are added to ensure the seller is a granted to sell the property and an action to remove the permission from the seller.

```
EVENT transferOwnership:
REFINE transferOwnership
ANY
slr
WHERE
 @grd1:shr ∈ dom(authorised)
 @grd2:prch ∈ purchaser
 @grd3:slr = authorised(shr)
THEN
 @act01:authorised := {usrOwn} ⩤ authorised
END
```

However, other events remain unchanged because they do not cause inconsistency to model.

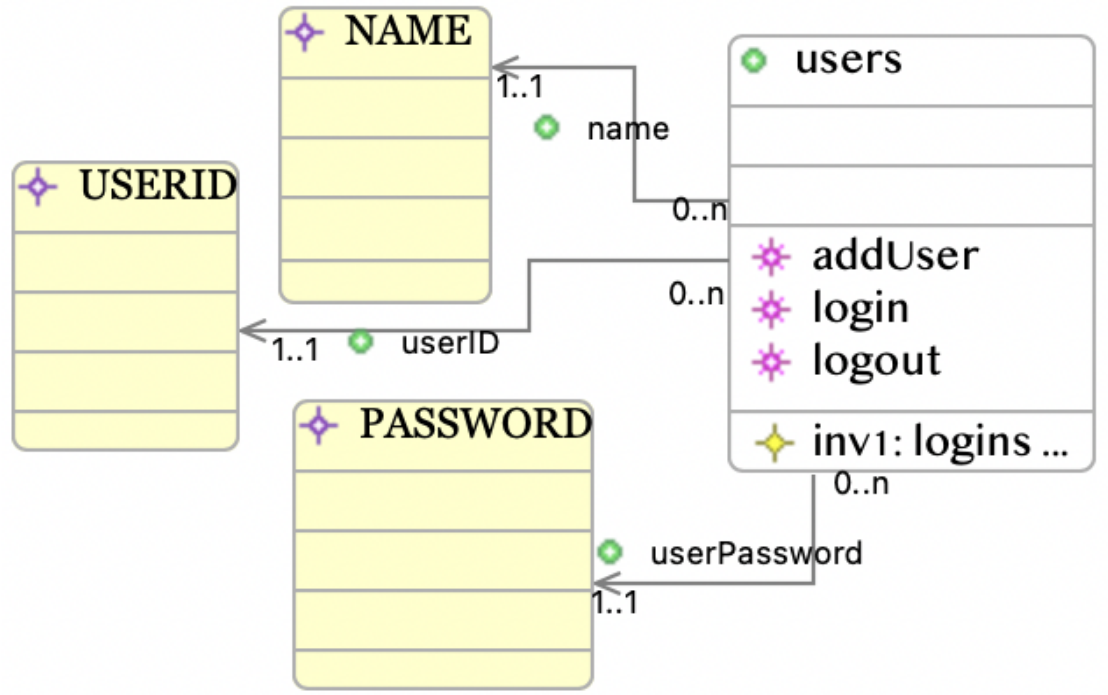

FIGURE 7.11: Forth refinement: class diagram.

7.3.5 Fourth Refinement: Modelling User Identity

This refinement focuses on preventing fraudulent activity by enforcing a security policy. The requirements REQ 29 - REQ 30 in analysis are implementation requirements. These requirement are replaced by new ones to establish user's identity. To meet the requirements, each user is given a name, user ID, and password. New sets are added at the context levels of NAME and USERID, see Figure 7.11.

Further action needs to be added to ensure the safety of the model and prove the user's identity. The user must log in to perform any action. This can be modelled using the variable logins and adding two events: login and logout. logins variable is a subset of user. When the user logs in, they should declare their userid and password. logout is basically removing the user from logins set.

```
1  EVENT login
2  ANY this_user
3  WHERE
4   @grd1: this_user ∉ logins
5  THEN
6   @act1: logins := logins ∪ {this_user}
7  END
8
```

```
EVENT logout
ANY this_user
WHERE
 @grd1: this_user ∈ logins
THEN
 @act1: logins := logins \ {this_user}
END
```

Introducing new invariants makes the model inconsistent at addUser and login events. To solve this, the proof of obligation has to be proved by either adding action or guards to the events.

```
EVENT addUser:
REFINE
 addUser
ANY
 pw no nm
WHERE
 @grd1: pw ∈ PASSWORD \ {init_root_password}
 @grd2: no ∉ ran(userID)
 @grd3: nm ∈ NAME
THEN
 @act01: userPassword(this_users) := pw
 @act02: userID(this_users) := no
 @act03: name(this_users) := nm
END
```

```
EVENT login
ANY psw
WHERE
 @grd1: this_user ∈ dom(userPassword)
 @grd2: this_user ∉ logins
 @grd3: psw = userPassword(this_user)
THEN
 @act1: logins := logins ∪ {this_user}
END
```

7.3.6 Fifth Refinement: Modelling The Process

This refinement involves the modelling of the property acquisition process according to the specified requirements, REQ 10 - REQ 21. The process commences when the

TABLE 7.1: List of the roles based on the transition.

Transition\State\Role	NOT_FOR_SALE	ON_SALE	ON_HOLD	SOLD
confirm	Authority			
sell		Seller		
refuseAllOffer	Seller			
requestToBuy		Purchaser		
acceptOffer			Seller	
withdrawOffer		Purchaser		
depositPayment			Purchaser	
makePayment				Purchaser
rePayment				Purchaser
insufficientFund			Authority	
faildPayment		Authority		
paymentAccepted				Authority
transferOwnership	Authority			

state of title is CONFIRMED_TITLE. The CONFIRMED_TITLE state is extended to include additional states, as depicted in Figure 7.12. It is important to mention that once the title is confirmed, it can only exist in four states. The state of the CONFIRMED_TITLE may change depending on the transition. The initial state is NOT_FOR_SALE once the title is confirmed. This transition is executed by the confirm event, which is performed by the authority. Each transition in Figure 7.12 is carried out by multiple users, each fulfilling their assigned roles. For example, a seller engages in the activities of sell and acceptedOffers.

Given that a confirmed title cannot be associated with several states throughout the purchasing process, it is crucial to specifically specify the user's role and their connection to ownership. This will ensure that distinct users are identified for different states. For instance, multiple purchaser can make requests to acquire a property, but only one request is ultimately accepted. The associations are guaranteed by the invariant presented in the Class Diagram. Other relations in the diagram meet the process. Safety invariants are included to assure the safety of the model, such as; @inv1:dom(isRequested) $\subseteq$ dom(isSold) .
This invariant ensures that any title that is requested should be on sale. Similarly, additional invariants are encompassed in other states. These invariants have the possibility to safeguard a share of the property that is being sold to other buyers and prevent double sales. More specifics on the state, transition, and role of the transition are listed in Table 7.1.

Since the confirmed title cannot be in more than one state per process of purchasing, role of user and association with ownership should be explicitly defined to indicate different users at different state. For example, more than one purchaser can request to buy property, and there is only one purchaser who is accepted their offer. These association are ensured using invariant below and shown in Class Diagram 7.13.

```
1   @inv_1: isSold ∈ ownership ⇸ seller
2   @inv_2: isRequested ∈ ownership ↔ purchaser
3   @inv_3: approvedOffer ∈ ownership ⇸ purchaser
4   @inv_4: approvedOffer ⊆ isRequested
5   @inv_5: paidDeposit ∈ ownership ⇸ purchaser
6   @inv_6*: paidDeposit ⊆ approvedOffer
7   @inv_7: payment ∈ ownership ⇸ purchaser
8   @inv_8*: payment ⊆ paidDeposit
9   @inv_9: partition (payment, failed, succeeded)
10  @inv_10: purchasing ∈ purchaser ↔ ownership
11  @inv_11: purchasing ∼ ⊆ isRequested
12  @inv_12: paymentAttemps ∈ payment → ATTEMPT
13
```

Invariant inv_1 holds an ownership for a specific seller. The seller can sell many ownerships at the same time but the ownership can be sold only by one seller. This invariant holds a seller of each ownership. Invariant inv_2 and inv_10 hold an ownership to a purchasers or purchasing to ownership, respectively. An ownership can be requested by many purchasers and a purchaser can request many ownerships at the same time. inv_2 invariant indicates all the requestors for specific ownership, whereas inv_10 who is the purchaser despite the state of the process. The reverse of purchasing is a subset of the requesters inv_11. One of the requestor is approved by the seller inv_3. The approved offer is associated the ownership to a purchaser. Also, The approved offer is a subset of requesters inv_4. One of the approved offers for particular ownership should pay a deposit to hold the property for them inv_5. This is also a subset of those who paid the approved offer inv_6. If the seller and purchaser have a deal, the purchaser should make payment inv_7 and it is a subset of paid deposit set inv_8. Payment has two states to indicate if the payment failed or succeed inv_9. There are limited attempt for the purchaser to make payment. if the payment failed for three times, the state of the title is back to ON_SALE state again inv_12.

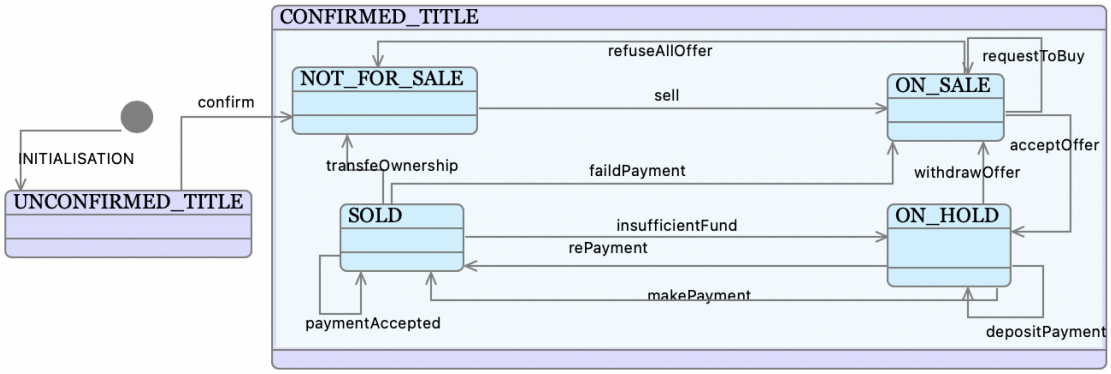

FIGURE 7.12: Fifth refinement: state machine diagram.

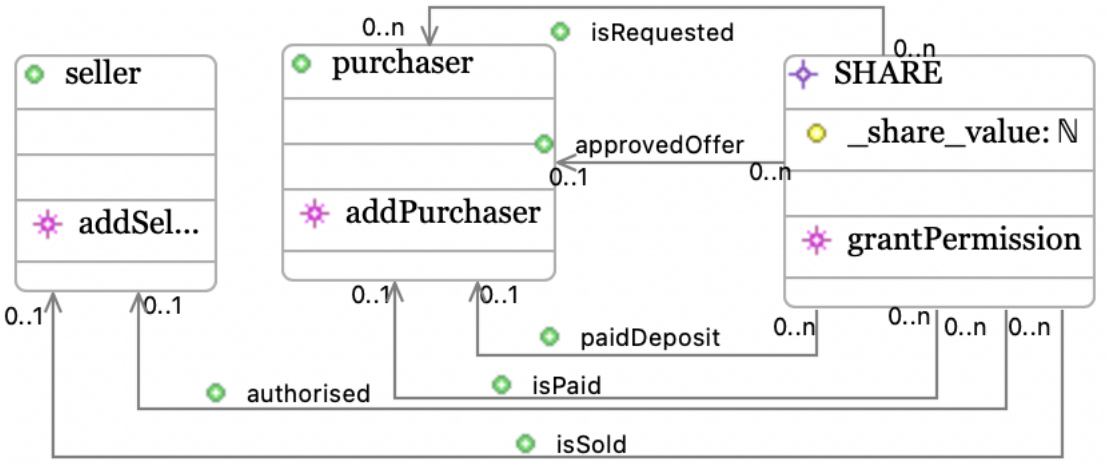

FIGURE 7.13: Fifth refinement: class diagram.

This refinement has to go through a manual inspection because it failed the proof of obligation test. The transferOwnership event is one of the events that has to be modified to move the model to the consistent mode. We can achieve consistency through modifying the guard, invariant, action, or any combination of these. Based on the manual inspection, we need to strengthen the guard to cope with the recently added invariants and add a few new actions to reflect the modifications. We need to ensue that the payment is succeeded before transferring ownership:

- the payment has been paid successfully @grd1.

However, to return to its previous status of NOT_FOR_SALE, the ownership must also be clear of any relationships. The save state demanded that every relationship between ownership and others be eliminated as shown in @act1 – @act11.

```
EVENT transferOwnership
REFINES transferOwnership
WHERE
 @grd1: usrOwn ↦ prch ∈ succeeded
THEN
 @act1: SOLD := SOLD \ {title}
 @act2: NOT_FOR_SALE := NOT_FOR_SALE ∪ {title}
 @act3: isSold := {usrOwn} ⩤ isSold
 @act4: payment := {usrOwn} ⩤ payment
 @act5: amountPaid := {usrOwn ↦ prch} ⩤ amountPaid
 @act6: paymentAttemps := {usrOwn ↦ prch} ⩤ paymentAttemps
 @act7: isRequested := {usrOwn} ⩤ isRequested
 @act8: approvedOffer := {usrOwn} ⩤ approvedOffer
 @act9: paidDeposit := {usrOwn} ⩤ paidDeposit
 @act10: succeeded := succeeded \ {usrOwn ↦ prch}
 @act11: purchasing := purchasing ⩥ {usrOwn}
END

```

7.4 Model Evaluation

Model construction is followed by model evaluation as it was described in Chapter 3 Section 3.3.4. In essence, it is a review of the model by experts to ensure that it is valid and complies with the system's specification requirements. The expert assessed the model and used the feedback to improve the model-development process.

The experts participated in the focus group review are experts at constructing formal models. The focus group was conducted in accordance with the [Nielsen, 1989] and the participants received the materials they need to evaluate the model.

Participant Four team member participated in the focus group in formal method.

Material The material given in the focus group was as follows:

1. A presentation of strategy and model including diagram
2. A number of questions regarding
3. A discussion of the strategy
4. A discussion of the model
5. A set of open-ended questions
6. A discussion of the recommendations to improve the

Procedure At the middle of July 2022, a focus group meeting was organised at the organisation's workplace. The scheduled meeting time was between 90 and 120

minutes. Each participant received the requirements specifications after being informed that the meeting had been recorded. First, the presentation about the subject and discussion the challenges were given. Participants were urged to talk about these challenges and pose queries. Notes were collected during the discussion, and the team members received feedback.

Experts feedback Here is a list of their feedback. The feedback is categorised into general feedback, feedback on the strategy of building the model, feedback on requirements, and some recommendations for better modelling. The feedback is summarised bellow and full meeting is attached in the Appendix C

General :

1. The process of transfer ownership has been reviewed and agreed by the experts in the beginning of the meeting as it has been followed in this research.

Modeling

1. The experts emphasise adding a guard in the event rather than an invariant of transferring ownership to avoid the owner selling property to himself.
2. In the case of shared ownership, there should be two separate events different from solo ownership.
3. The share should be explicitly defined in the model that shows the percentage of ownership.
4. The abstraction level should be defined as a compliant system with no security requirements. However, this option would make the abstraction level complex and not easy to represent.
5. To remove some of the complexity of the system, the experts recommend having only one owner for each property. However, this opinion will not represent a realistic system.
6. In model development, security requirements have to be represented to ensure the safety of the model.

Requirements

1. They emphasise using function requirements rather than a description of the requirements.
2. A better way to write requirements is by using the MOSCOW tool.
3. The requirements have to incorporate security requirements.

Recommendation

1. The purpose of the system has to be clearly defined before writing the system specification by giving a high-level description of the system.

7.5 Discussion

The land registration systems consist of multiple systems that ensure secure ownership. When reviewing the land registration systems in the Kingdom of Saudi Arabia, three important challenges arise in relation to proof-of-ownership 2.6. These challenges are about a customary process to obtain property ownership to ensure ownership remains undisputed. The literature suggests that addressing these challenges requires the use of the right technology. However, our analysis reveals that not taking certain factors into account is the cause of the problems, despite the use of technology. In conjunction, these factors are used to build an appropriate model that might provide a safe environment for improving the recipients' perception of secure ownership conveyance.

The argument made here aims to demonstrate how the approach used to depict the construction property ownership model constitutes it. Building a property ownership model using formal modelling is used to address the challenges. The argument began with a defence of utilising the formal model to develop the model, followed by a discussion of the strategy, model construction, and model evaluation.

7.5.1 Formal Model

Ensuring the validity of the requirements can be achieved using requirements inspections, requirements prototyping, requirements testing and viewpoint-oriented requirements validation [Raja, 2009]. However, formal models could bridge the gap between informal and formal requirements and decrease testing phase errors. The model is created and developed using an Event-B-based discrete transition system.

Event-B is a formal specification language used for system-level modelling and analysis. The formal model is built in two stages: developing a refinement strategy and modelling.

The refinement strategy should be applied concurrently with modelling until a satisfactory model that satisfies the specification is obtained. The refinement strategy explains the processes used to develop the model and defines the framework of its construction.

Modelling is a representation of needs and a strategy for addressing challenges. It contributes to articulating implicit assumptions, clarifying system requirements, and gaining a better understanding of the challenge by revealing defects in the system requirements. The outcome was determined by the formal specifications for the model, which were created, validated by expert review and animation, and verified with proof of obligation.

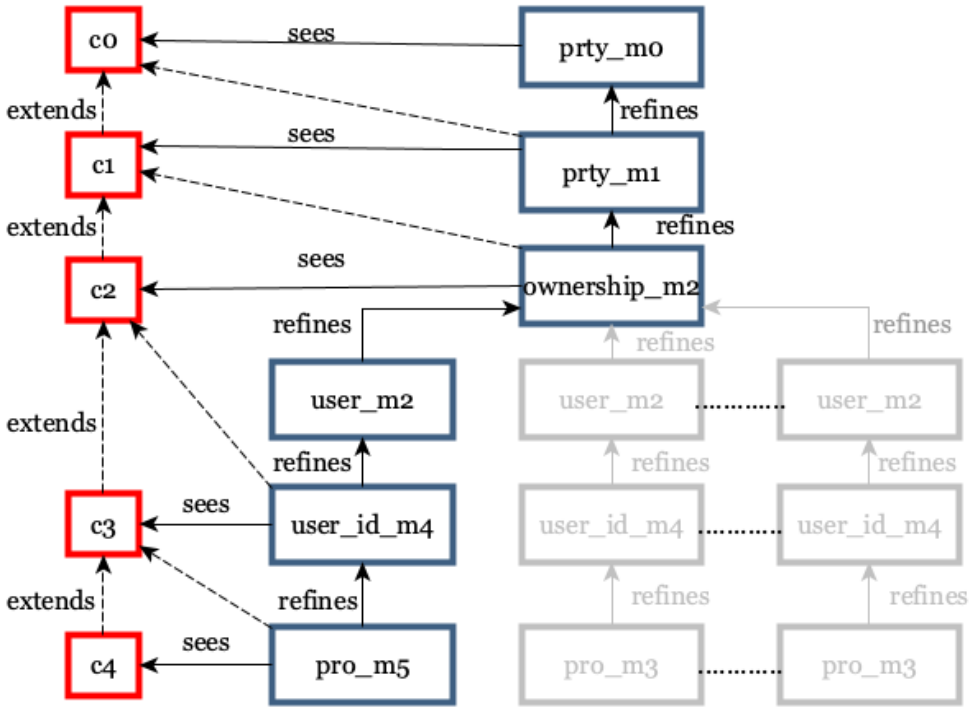

FIGURE 7.14: The extended refinement strategy.

7.5.2 Model Construction

The model-building process is described in the following sections. Each of these processes has a purpose even though they are being built concurrently.

The refinement strategy was quite a challenge to develop. It requires a thorough comprehension of the challenges and precise requirements specifications. In spite of being thoroughly developed in Section 6.2, evaluate the model with the expert, and adequate attempts have exposed several crucial requirements that are either missing or poorly expressed.

On one hand, the experts have recommended building a clean system at an abstract level regardless of safety requirements and considering an owner to remove the complexity of the system. However, considering this approach led to an unrealistic scenario of property ownership and added more complexity to the later refinements.

On the other hand, the attempts, including the experts' recommendations, concentrate on two perspectives—user type and challenges—while the analysis disregarded or missed an essential perspective. This perspective should be the core of the system, property. According to the framework, the property is taken from a system known as the first register. This leads to additional assumptions about the environment in which the system is used.

Taking property perspectives into account is essential while developing a refining strategy. The strategy is appropriate for all types of ownership and user types. The property controller is defined in the first refinement after the property information is described at the abstraction level. The second refinement deals with declaring who owns the property, including the owners. Any sort of ownership transfer could benefit from these three refinements. The refinements that follow are specific to one type of transferring ownership. The user types should be specified in order to transfer ownership through sales. Purchasers and sellers are the two types of users in this instance. However, beneficiaries are the people whom the user enters to transfer ownership of inherited property. The final refinement described the conveyance regarding the legal requirements. Figure 7.2 shows the possibility of extending the model to meet more types of transferring ownership.

Modelling The requirements specification is reflected in the strategy. The reflection reveals that the following property-related requirements are missing that shown in the abstraction and first refinement REQ 32 - REQ 43.

The refining strategy has not only just clarified the specification; it has also removed some specifications or kept others in place. The tables 8.2 and 8.3. display the model's representation of the specification. The tables shows requirements specification enhancement.

- REQ 1 has been modified from a user register to the system to the user introduce to the system. The model is not verified the user identity but using the user's identity form other system.
- REQ 10 has been modified the user role from owner to seller to meet the specefication.
- REQ 25 has modified the user type from owner to Authority to meet the system specification.
- REQ 26 to REQ 31 has been removed because these requirements are implementation requirements.
- REQ 32 - REQ 43 haven been introduced during model construction.

Additionally, the experts advise writing the requirements in a standardised manner to increase their accuracy and readability. The MoSCoW technique is one of the technique was advised. Utilising the MoSCoW technique, requirements can be categorised and prioritised according to the needs. MoSCoW is four-step approach to describe the requirements and indicate their propriety. It compromises from **M**ust have, **S**hould have, **C**ould have, and **W**ill not have requirements. Must requirements that are included int he abstraction. Should requirements indicate safety requirements to keep the system safe from the challenges. Could requirements are need to define the process of transferring ownership. Lastly, Will not requirements are excluded from the requirements.

TABLE 7.2: Summary of requirements after modeling.

Req code	Status*	Requirement Description
REQ 1	M	The User must be able to introduce to the system.
REQ 2	U	The User could be able to own many properties.
REQ 3	U	The User must could different roles in the system based on the intended action.
REQ 4	U	The Owner could be allowed to claim back properties they own.
REQ 5	U	The User should declare their identity to access the property information.
REQ 6	U	The Owner could be able to view any property they own.
REQ 7	U	The Purchaser could be able to request to buy a property that is on sale.
REQ 8	U	The Owner could change their role to a Seller to be able to add their properties on sale.
REQ 9	U	The Owner could be able to permit a Seller to sell the property to be able to sell the property on their behalf.
REQ 10	M	The Seller could be able to add the property who owns on sale.
REQ 11	U	The Seller could be able to accept a request from the purchaser for a property they got permission.
REQ 12	U	The Seller could be able to refuse requests from the Purchaser for property they owned.
REQ 13	U	The Owner could be able to add the property on sale after they refused a request from a Purchaser.
REQ 14	U	The Purchaser could be able to request to buy properties that are on sale.
REQ 15	U	The Purchaser could be able to make a deposit after requesting to buy a property.
REQ 16	U	The Purchasers could be allowed to share property information if they made a deposit.
REQ 17	U	The Purchaser could be able to withdraw from buying a property after sharing property information.
REQ 18	U	The Owner could able to receive a confirmation of payment.
REQ 19	U	The Owner could be able to accept to transfer the property ownership to the requested Purchaser.
REQ 20	U	The purchaser could be able to make a payment after sharing property information.
REQ 21	U	The Purchaser could be able to repay the amount after the failure of making the payment.
REQ 22	U	The Owner should be able to browse the archive property information.
REQ 23	R	The User will not be able to sign a digital signature upon an agreement to transfer the ownership.
REQ 24	R	The Purchaser will not be able to encrypt the property information using their keys in the completion of the sale.
REQ 25	M	The Authority could be able to confirm the property details are correct.

M: requirement has modified N: a new requirement is added U: requirement remains unchanged R: requirement has removed.

TABLE 7.3: Summary of requirements after modeling.

Req code	Status*	Requirement Description
REQ 26	R	The Owner will not able to receive a token from the system that allows authorised to add the property to market.
REQ 27	R	The Owner will not able to receive a token from the system that authorised to share the property.
REQ 28	R	The Purchaser will not able to receive a token from the system that authorised to request to buy a property.
REQ 29	R	The User will not able to receive a token from the system that authorised registration.
REQ 30	R	The Purchaser will not able to receive a token from the system that authorised to request to buy a property.
REQ 31	R	The Owner will not able to receive a token from the system to accept or refuse.
REQ 32	N	The Property must be related to one title.
REQ 33	N	The Title must be able to claimed by owner.
REQ 34	N	The Title must have either state: unconfirmed title or confirmed title.
REQ 35	N	The Title must have one state on the system.
REQ 36	N	The Title must have initial state: unconfirmed title.
REQ 37	N	The Title should change the state once all the Owners claimed their ownership.
REQ 38	N	The Title could have a value that represent its cost.
REQ 39	N	The Title must stay confirmed state after the Owners claimed their ownership.
REQ 40	N	The confirmed Title must have the maximum shares.
REQ 41	N	The maximum number of shares per Title is four.
REQ 42	N	The Authority must be added to the system.
REQ 43	N	The Authority must confirmed the title after the owners claimed their ownership.

* M: requirement has modified N: a new requirement is added U: requirement remains unchanged R: requirement has removed.

7.5.3 Model Verification

Model verification entail thorough investigation to ensure that the formal model accurately captures the requirements and upholds consistency through different levels of abstraction. The ownership model is validated by experts in formal models, theorem proving, and prob model checking.

Theorem Proving The guard strengthening (e/g/GRD) and invariant preservation (e/v/INV) Proof Obligations (POs) are two of the POs in Event-B theorem proving technique. The e/g/GRD PO (where e is the concrete event name, and g is the abstract guard name), ensures that the concrete gaurds are stronger than the

TABLE 7.4: Proof of obligations summary

Element Name	Total	Auto	Manual	Undischarged
Ownership model [a]	288	184	104	0
m0_property	12	4	8	0
m1_control_property	4	3	1	0
m2_ownership	38	20	18	0
m3_UserType	13	8	5	0
m4_user_identity	11	6	5	0
m5_model_process	203	138	65	0

[a] The POs in context level is not included here.

abstract ones. The e/v/INV PO, (where e is the event name, and v is the invariant name), ensures that the property specified in the invariant inv is preserved by event e. Together, these formations offer a methodical and rigorous methodology for validating theorems in Event-B, hence enhancing the creation of reliable and verifiable formal specifications. Event-B enables the development of systems that conform to defined attributes by enforcing event guards and invariants. This enhances the overall dependability of software and system architectures.

Table 7.4 shows the statistical proof of obligation associated with the ownership model. The model comprises a total of six machines. The model yielded a total of 288 POs. A total of 64% of the cases were successfully proven using the default setting of the Rodin prover. In spite of this, a large portion of the POs that did not go through automatic discharge were linked to problems with invariant preservation. The invariant preservation ensures that the safety requirements that we specified are held before and after execution of all events on the machine.

The majority of the proof of obligation takes place in the last refinement, with a total of 203 POs; 65 POs are manually proved. An example of invariant preservation manually proved is
@inv1: paidDeposit $\subseteq$ approvedOffer.
This inv1 is discharged when the depositPayment event is executed. This invariant ensures that the title has not been approvedOffer for particulate buyer. This unproven invariant is discharged by adding an guard to the event and ensure the share belongs to the buyer set after transferring ownership.

Prob Model Checking Model checking using ProB in Event-B Leuschel and Butler [2008] is an effective tool for probabilistic behaviours in system models. By integrating Prob model checking into the model construction phase, we gain the ability to capture and assess these uncertainties within the model. This tool allows for exploration of potential system states and behaviours, addressing scenarios

where outcomes are influenced by probabilistic events. It provides a comprehensive understanding of scenarios, has the capability of capturing both deterministic and stochastic aspects, and fosters a more realistic representation of complex systems during the construction phase.

Model checking contributes of ensuring the prevention of double sales in the transfer of ownership, bolstering the safety of the system by incorporating various properties into the model. It facilities model performs as expected, acting as a robust safeguard against occurrences of double sales. It reveals a sequence of events that trigger based on specified conditions and adhere to the machine's invariants. For example, the sell event, which is designed not to be active unless the seller is explicitly permitted by the owner. Furthermore, the model-checking process enforces that when the share status is set to ON_SALE, other shares with the same title cannot be sold to different sellers concurrently. In essence, model checking empowers the modeller to employ their human judgment, especially in scenarios where the actual outcome deviates from the initially anticipated result. This validation mechanism becomes instrumental in ensuring the integrity and reliability of the model under diverse circumstances, reinforcing the prevention of undesired incidents such as double sales in the transfer of ownership

7.6 Summary

This chapter discussed the method undertaken to validate the requirement specification for transferring ownership through modelling using formal methods. The chapter started with an explanation of the language used for modelling and the tools used to perform the modelling. The model development methodology guides the modeller to model the system, while the strategy of modelling ensures the model is constructed correctly.

The method consists of four steps: user requirement analysis to understand the system specification; identification of the refinement strategy and modelling; and expert review to evaluate the model construction. The system specification was conducted in the previous chapter 6. The refinement strategy and modelling were conducted side by side to construct the model correctly. The strategy showed a map of how to build the model, starting from an abstract view and adding details as needed. Modelling uses a mathematical equation to ensure the specification is correct and to clear up any ambiguities. The modelling was reviewed with experts at an early stage of development to ensure the model was constructed correctly and met the system specifications.

The model is verified using model checking and theorem proving. Also, the discussion includes limitations during the modelling of the process. In conclusion, applying

the formal method significantly affects system development. It aids in articulating implicit assumptions and clarifying system requirements. They highlight challenges with system requirements, and their rigour helps to understand the challenge better. Additionally, the formal method reduces implementation time and error by a large amount.

Chapter 8

Conclusion and Research Opportunities

The land registration systems in the Kingdom of Saudi Arabia are made up of subsystems. The reference architecture in Figure 6.1 shows the abstraction relationship of these subsystems. Every subsystem is managed by a separate governmental entity. Involving subsystems and multiple entities in the land registration system contributes to encountering challenges in managing ownership. The property ownership is a system where linked between a survey system and user identity system to manage the process of transferring ownership. The ownership could be transferred to many owners which caused a problem called double sales. Another challenge is when the process failed to identify the identity of the owner and they were able to steal the property ownership. The challenge includes the potential owner is not able to access accurate or missing information about the property.

A summary of the conducted work is presented at the beginning of the chapter, then research directions are investigated.

8.1 The Property Ownership Model: a summary

The conjecture from this research is that involving technical safety in transferring ownership would enhance beneficiaries' trust in the land registry systems. The thesis is divided into three sections that address the sub-research questions: the development of the STF, system specifications for transferring ownership, and the development of the ownership model 8.1. Chapter 2 presents a review of relevant literature on land registration systems. Chapter 2.4 revealed the challenges in registering land and the factors. These challenges and factors were discussed with experts in Chapter 5, which led to confirming the framework and answering SRQ 1.

TABLE 8.1: An overview of the work conducted to complete this research

Sub Research Question	Methodology	Result
RQ: How can technical safety encourage beneficiaries to trust a land registry system in the Kingdom of Saudi Arabia? This question was divided into three sub-questions		
SRQ1:What are the factors that influence beneficiaries' trust in a land registry system?	Semi-structured interviews with real estate investors, triangulated with analysis the process of registering property and literature review	confirm the factors proposed in the previous study, and suggest new factors
SRQ2: What is an appropriate framework for investigating the registration of land in the Kingdom of Saudi Arabia?	Semi-structured interviews with real estate investors, triangulated with Semi-structured interviews with experts and with analysis the process of registering property	System specification of transferring ownership.
SRQ3:To what extent is the constructed reference architecture and model applicable to the land registration systems in the Kingdom of Saudi Arabia?	system requirements specification, triangulated with formal model and expert review focus group	validate and verified requirements

The framework was applied to address the SRQ2 in Chapter 6 concerning the system specification for transferring ownership through sales. The results of the investigation contribute to the development of the model in Chapter 7 and addressing the SRQ3. The research conducted to accomplish this study is summarised in Table 8.1.

8.1.1 The Development of The STF

Chapter 4 discussed the confirmed social framework in detail. The first method used to confirm the framework was to construct a conceptual framework. The conceptual framework was grounded by reviewing and analysing the literature and conducting an analysis accordingly. The literature review appraised the land registration system components and challenges in a global context and then specifically in the Kingdom of Saudi Arabia. This involves reviewing the technology used and how it contributed to overcoming the challenges. Nevertheless, analysis of the process for registering ownership was conducted in India, Indonesia, and Saudi Arabia to identify the obstacles in the process and indicate the factors needed to overcome them.

A set of elements and components were extracted and contributed to the development of the framework. After that, the framework formulation was validated through a process of triangulation involving a semi-structured interview with 14 investors and another semi-structured interview with 8 experts. The findings of this triangulation study indicated that all of the components within the framework were perceived as significant. Nevertheless, some alterations were implemented, including:

1. Introduce categorisation and organise the factors accordingly.
2. Adding factors that support the framework such as Awareness and training, Political support and funding, and Political support and legal framework.
3. Exclude some factors as they are part of other factors.

4. Identify the benefits of the system and the relationship between the systems.

For that, the final factors in the framework consisted of organisational factors, provenance factors, technological factors, and legal factors. Each of these factors consists of a sub-factor, as shown in Figure 5.2. Additionally, the framework describes the relationship between the systems and how each governmental entity contributes to the system as a whole. The findings of the confirmed framework are presented in Chapter 5.

The social trust framework was developed to provide a structured reference point for modelling the process of transferring ownership according to the legal framework. In the research, the framework can be used to understand the research context, including the problem. Further, the potential use of the framework to explore and guide other processes of transfer ownership.

8.1.2 The System Specifications of Transferring Ownership

The framework was further investigated to explore how it might help mitigate the challenges in the land registration system and answer the second research question. More precisely, the framework supports the analysis of requirements specifications for transferring ownership before the construction of an ownership model. With that in mind, a four-stage general methodology by Maguire [Maguire and Bevan, 2002] was applied to analyse the user requirement specification for transferring ownership. This methodology includes gathering the information to understand the context, understanding the user needs, identifying the challenges, envisioning and evaluating the information, and then writing the requirement specification. The first and second stages were conducted in Chapter 5.

Following the findings from two previous stages, the third stage involved identifying and indexing challenges using the affinity diagram technique. This includes using scenario-based and hazard analysis, followed by system design using activity and class diagrams. Lastly, a task/function mapping technique was utilised to establish the essential minimum user requirement specification [Maguire and Bevan, 2002]. This system analysis strategy identifies the main components of the system and the information transition between them. The strategy is based on iteration analysis. This provides a comprehensive understanding that ultimately reflects on the construction of the model.

8.1.3 The Development of The Ownership Model

Considering the confirmed ownership framework and the user requirements specifications, the ownership model was constructed to confirm the requirement specifications by applying formal methods. The formal modelling significantly affects the system's

development. It aids in articulating implicit assumptions and clarifying system requirements. It highlights defects in system requirements that contribute to understanding the requirement better. Additionally, the formal method reduces implementation time and error by a large amount.

Four steps were taken in building the model. The initial step was to analyse the user needs, followed by strategy development using the outcome and system modelling. A model evaluation with formal modelling experts was then conducted. The model was primarily built in such a way that it could overcome challenges and be expanded to use other ownership transfer processes. The model is verified using the tools that are included with Rodin. Additionally, it aids in the evaluation of the model by human judgement.

The end result of the modelling produces a safe process for transferring ownership that can be used as a template to improve the beneficiary's view as well as clear instructions for carrying out the process. The model can also be used to share information among developers in order to create a system and implement change at the organisational level, either to gain supporters with persuasive arguments or to increase stakeholders' understanding and awareness.

8.2 Research Limitation

Despite conducting the research thorough comprehensive study , like any other research, this study has its limitations. The limitations are enumerated as follows:

1. Incomplete or inaccurate information in the first registry may reflect negatively on the ownership system as a whole. The investigation of property information requires knowledge about the procedure for registering a property for the first time, the critical data present in the systems, the different kinds of properties, the sectors in charge of the property information, the stakeholders, and the technology employed.

   Also, the land registration system depends on another system to declare and identify user information. The study refers to this system as Nafath. The system has to conduct further research and develop guidelines for connecting to the ownership system so as to prevent fraudulent attempts at stealing user identities.

   Although these two aspects and combining them together could add value to the STF and improve the trustworthiness of land registration systems, they constitute a significant investment in time and resources that could span several years.

2. The model-building strategy has solely focused on one aspect: transferring ownership through sale. However, including other aspects requires understanding

the process, the stakeholder, and the legal aspect of undertaking the transfer. This can be done by adding details of refinements, as was shown in the discussion 7.5. Considering adding these aspects to the property information and how these details reflect on the process of transferring ownership, this could require further intensive investigation.

8.3 Research Opportunities

The work that could be undertaken in the future is presented here so that the current research can be extended on applying the framework and the model on other aspects of land registration systems.

1. Integrating Blockchain technology into the ownership transfer process opens up numerous possibilities for additional exploration, ultimately improving and promoting social trust within the system . Blockchain serves as an extra level of trust by guaranteeing that all participants in the blockchain network possess identical and unalterable property information[Griggs et al., 2017, Kundu, 2019]. The immutability of the property information stems from the fact that it cannot be changed until every copy of the information in the decentralised network are adjusted at the same time [Lapointe and Fishbane, 2019]. Additional inquiry is required to effectively incorporate the technology and examine its possible advantages and difficulties. The integration with process encompasses diverse methods, such as investigating procedures to adopt it, implementing standardised protocols for data interchange, or constructed a framework of integration. These exhaustive analysis will facilitate the identification of the optimal and safest methods to integrate blockchain technology into the process of transferring ownership, thereby establishing a more transparent, secure, and trust-enhancing system. Another notable feature of blockchain technology is its ability for tracking and retrieve changes made over a period of time [Lapointe and Fishbane, 2019, Lemieux, 2017]. This specification, in conjunction with the First Registry Factor, offer an interesting research opportunity to delve into further.

2. Adopting the framework and model in other countries. While originally the framework and model were tailored to the specific legal and cultural nuances of the Kingdom of Saudi Arabia, the framework developed in this research exhibits a globe potential. The framework can be used in other countries with their own legal systems and cultural contexts. By incorporating the current framework and model, other countries can further exploit factors for adoption.

3. Adopting the ownership model The ownership model is based on socio-technical systems that require interconnected relationships between people, culture, goals,

infrastructure, and technology. Adopting modifications to processes could make organisations reluctant to make drastic changes. A socio-technical systems framework called [Baxter and Sommerville, 2011] might be used to implement socio-technical systems in a cost-efficient manner. The ownership model provides a tools that can easily engage the stakeholders and ensure their needs are included. This requires conducting intensive qualitative data to ensure meeting their needs.

4. The model is more than a property ownership. The model is built so that it can be used for more than just property ownership. The model might be used for any jointly owned assets, such as luxurious jewellery, harvesters, and more . In order to create a generic model and explore its application, more research is needed. This can be achieved by studying multiple cases that contribute to the development of model guideline revisions that safely transfer ownership.

Appendix A

Appendix A : Land Registry challenges

Exploratory Interview for Land Registry Issues

Developing the question based on the Goal Question Metrix (GQM)

Goal	Purpose Issue Object Viewpoint Context	Identify Basic information about an interviewee Specifying the background the interviewee Investors in real Estate Land registration system in Saudi Arabia
Question Metric	Q1 M1	**How many years of experience do you have in real estate?** Number of years
Question Metric	Q2 M2	**What type of property classification do you specialise ?** Identifying which type of property that interviewees are specialised in
Question Metric	Q3 M3	**Which area in the kingdom you are working on?** Identifying where the interviewees specialize in

Goal	Purpose Issue Object Viewpoint Context	Investigation Culture / process Exploring more issues by investigation the previous cases, trust, and challenges. Investors in real Estate Land registration system in Saudi Arabia
Question Metric	Q4 M4	**From your experience which is the most complex element of Land registration system process:** Technical or Organizational aspects Kindly answer why Allow the interviewee to talk about the issues in technical or organizational aspects and how this issue occur.
Question Metric	Q5 M5	With regards to the confidence in land registration system can someone else claim ownership of a parcel of land? Likely, Unlikely, or Impossible, kindly answer why? Investigate more issue with regard of trust
Question Metric	Q6 M6	What is the most challenge you faced when purchasing a property? Investigate more issue with regards of challenges
Question Metric 	Q7 M7	how do you solve it? Overcoming the issue with regards of challenges
Question Metric	Q8 M8	Can you mention some of the previous cases that you had before buying a land that could cause you severe consequences after the purchase? Investigate more issue with regards of their previous experience.

Goal	Purpose Issue Object Viewpoint Context	Revealing more issues in terms of information. Missing information Exploring more issues in process of purchasing lands Investors in real Estate Land registration system in Saudi Arabia
Question	Q9	How would you describe the process of accessing the information in the Ministry of Justice (MOJ) to confirm the land ownership?
Metric	M9 M10 M11 M12	Transparency Complete Availability Auditability
Question	Q10	How would you describe the process of accessing the information in the Ministry of Municipal and Rural Affairs (MOMRA) to confirm the information in the land title? Prob: in term of the simplicity of accessing information and availability at the time you need
Metric	M9 M10 M11 M12	Transparency Complete Availability Auditability
Question	Q11	Have you been experiencing contradictory information between MOJ and MOMRA? kindly tell me a case
Metric	M13	Integrity
Question	Q12	What is the information missing in land title that needs to make the property purchase more convince Tell me more.
Metric	M9 M10 M11	Transparency Complete Availability
Question	Q13	How do you know the number of deals on a specific property?
Metric	M9 M11	Transparency Availability

Goal	Purpose Issue Object Viewpoint Context	Revealing more issues in terms of law. previous court cases Exploring more issues in with regards of issues end up to the court Investors in real Estate Land registration system in Saudi Arabia
Question Metric	Q14 M14 M15 M16	From your experience what are the main reasons for legal dispute related to lands and titles in KSA? Right of ownership Reliability Secure land title
Question Metric	Q15 M17	how long it takes to settle legal disputes Time taken to solve the issue

Goal	Purpose Issue Object Viewpoint Context	Suggesting solution to their issues Lack in the current system Exploring more idea in with regards of issues that has been faced Investors in real Estate Land registration system in Saudi Arabia
Question Metric	Q16 M18	If you were in the position of decision-maker in land association what would you do to improve the below (a) The transparency within the system. (b) The transaction journey of the buyer and seller of a land. (c) The adoption of new technology. Further information to understand their needs.

Appendix B

Appendix B: Framework Confirmation

Expert review for Land Registry for Confirming the Framework

Developing the question based on the Goal Question Metrix (GQM)

Goal	Purpose Issue Object Viewpoint Context	Identify Get more information of the context Framework confirmation Expert review Land registration system in Saudi Arabia
Question	Q1	Would you, please, describe your job role?
Metric	M1	Specifying the type of role
Question	Q2	How long have you been working in this role?
Metric	M2	Number of years in the field
Question	Q3	What factors that are important to consider in the framework? Why?
Metric	M3	Yes/No with reason
Question	Q4	Are there any additional factors you think should be included and which category should they go into? Why?
Metric	M4	Yes, give a factor with reason No, satisfied with factors
Question	Q5	From your knowledge and experience, do you think some of the identified factors need to be regrouped in within the proposed framework?
Metric	M5	Yes, suggest new regroup with reason No, satisfied with grouping
Question	Q6	Is there any (organisational/provenance /technological/legal) factor you believe should be renamed?
Metric	M6	Yes, suggest new name with reason No, satisfied with names
Question	Q7	From your knowledge and experience, do you think of any other category(s) needs to be added to the proposed framework?
Metric	M7	Yes, suggest new factor with reason No, satisfied with factors

Appendix C

Appendix C :Discount Focus Group

Here are how the feedbacks are categorise in four group.

1- **General**
2- **Modelling**
3- **Requirements**
4- **recommendation**

Here RA confirm the process of purchasing property and the restriction.

RA: you have two different entities, properties and Users. And in relation to these two properties, you define a number of functional requirements. So for example, assuming ownership.
I'm a user who can register and then I after registration I can assume ownership. So, I will be linked with a property. Then I can put forward my property for selling. Now all properties will be bought, only properties that they put forward for sale.

And then if a property is put for sale, then I can buy it. So the process of buying maybe change exchange of ownership. So you have an event that another registered user that it is not the current by the current owner can assume ownership of a registered property and then the exchange can take place. And you can you can imagine any other similar high level events, right? What else? So registration of user, registration of property, assuming the ownership, linking the property with user, putting forward the property for sale, sell, agreed, change of ownership, Anything else I don't know. You might you might ask you other events like

Commented [MA1]: Comments-1

AS: this might be in one single purchase, the same buyer and seller should be different. This can process as invariant and then in the relevant event since can be guard,

RA: well, I would say guard in the 1st place rather than invariant.

AS: why should be a guard not invariant?

RA: Invariant might be stronger than guard.

RA: So the only event apparently at the moment we need to check is there when that the change of ownership take place, right? So in other events, all of it's irrelevant. This is why I say guard rather than invariant.

SH: yeah. I mean you model the, you know, that's the, the main invariant is basically ownership, you know, relationship between the user and properties. Then generally you know the only event that your critical is. You know the event that changed ownership. Yes,

Commented [MA2]: 2

RA: the ownership is in the way that he defined is their relationship. Because one person can have many properties, a property can be owned by more than 1%. So this relationship. So in that sense (many to many) , you might need more structure to define whether the ownership is solo or shared.

SH: While many of you get the cardinality, you know, just look at relation between user and ownership and it doesn't matter if it, you know, a single some ownership.

MM: Well, it might be changes this time maybe a solo ownership but maybe the other buyer is many shares.

SH: you know it had to be consistent with the the ownership like there was solo ownership, ownership in was exactly one, you know one owner and you know one thing. So

Commented [MA3]: 2

Here why I should have different event in shared ownership.

RA: the transfer of ownership for single owner and multiple owner is different. Yeah. This is why you might need different events.

SH: So I'm trying to be in your really not a year because I just thought of right. If you happen to go ownership, right and one person tried to buy the the property, one owner tried to buy the the other. Like you mean that you know he bought the owner of the current owner of that particular property and he also tried to buy the other one,

SH: So, you know, he's actually the owner and the buyer of the same properties. Yeah,

Commented [MA4]: 2

RA: Yeah, it is possible. It is possible, yeah, it is possible. I included this but maybe in different, Yeah, so

MM: right. Yeah, because there is 3 conditions that may be have been maybe a joint ownership that when a buyer can, when owner can buy other shares, owner shares.

RA: So the other thing is when you when you introduce joint ownership, so you have to

MM: introduced the percentage, Yeah, I, yeah, the last requirement I defined precisely the percentage of ownership. It has to be clear from the beginning, so that we can apply later on smart contract. That's one to one relationship.

RA: what is the best way to represent **(asking about the representation of joint ownership)**

SH: the property with another? It had to be higher order of functions because you have the you know the basically the access to the user and the percentage. So that three entity.

MM: This is called tokenization. Like tokenize the property,

SH: we want to see that you know for this particular property, user one owns 40%, user2 owns 65% all the function or record

RA: other functions too. Yeah, there's two ways to do it. You know, either

SH: the record is kind of you already tokenize.

Here NF interval the conversation:

NF: Yeah, yeah. We're also forgetting that when you buy a house, you could be you and your wife. So you have two different users and two different shapes.

Here we back to the main subject
NF: So I'm a bit not being a former method person, so I'm a bit confused. So in the abstract we define a clean system. But does that clean system also need to have the layer of complexity to add the chain
or is it a second refinement?

RA Yeah, this is this is well,

AS: there are alternations

Here a discussion about the abstract level by RA

RA: some aspect of it. It should be in the abstract, but this is the complexity. So what we try to
to pose. So the problem has a lot of complexity, even the clean system. One solution might be to say, OK, I will go for a simplified system that each property has one owner and it can be sold to 1 by. So this is the simplification you know and then the refinement and no change. Well, in the refinement probably not. So
some aspect of this can be just simply added in the refinement. So, so, so the refinement is not solution to everything.

The formal definition of refinement is that it will be very
strange in sence, and so all the behaviour that allowed by the refined machine should be included in the behaviour of the abstract machine. OK, yeah,

Commented [MA5]: 2

AS: so you can do data refinement, then we can replace anything.

RA: Well, the terrifying doesn't means that you can change the behaviour. Yeah,

AS: unless you do which has abstract, the simple as abstract and then you

RA: you can make your abstract general.
But here
so when you clearly say, OK, it has one owner how you make it general,

AS: you can add the new relationship to your record and you feel to your record for example
to specify that percentage,

SH: yes, but in this. But then you basically you they can't fight with you change the notion yeah basically you kind of you. let's say you have exactly 1 primary owner and then you the requirement again that's secondary owner anything like that. Yeah. But there is not the the way that you probably
sees actually the specification it clearly says that there is only one on the kind of misleading. Yes, yeah that yeah we actually you can have your multiple owner.

Here is about the recommendation
NF: So that is your advice to manar to create a clean abstract naive solution and then reiterate on the same abstract keep adding things to it. So she has a complete complex picture of a clean system. Yeah. So I would say that clearly this one here we list attract system you're for me it is the ownership relationship. So it had to be

SH: and you know, to talk about ownership relationship, which means that you need to have both near the user and outside you know. Otherwise, you know the system would be.
I mean you can start out with, you just use a little. But it does nothing. It doesn't give you the, the, the, the, let's say the specification of you know the system and generally talking about ownership you know link between the user and the ownership that that we might recommendation here to talk about the ownership and focus on you know the property of that you know what would be the the things that you can go wrong with that particular ownership. You know the kind of thing. I'm not sure that you need **to have the exact percentage including** that at that level or the percentage can be introduced at the, you know, let's say in the refients of that.
But you're trying to think about your what is the properties that you you want to the system to to to conform to what is **the the safety of the system**? You know what? What do you consider to be wrong or incorrect when when you're talking about the ownership,
you know as well, which I must say then you at the moment, given that it can can have multiple ownerships and things like that, you know I cannot see any nothing much wrong with that new because you can you know,

Commented [MA6]: 2

RA: ownership only makes her model a bit complex. This is why I said maybe she can go with a simple functional specification with one ownership and you know all the functional requirement with single ownership and then try to play with these in term of security requirements. And then if she has time later, maybe she can come up with a more realistic system with multiple ownership. But that in my view that could be a separate string, so means that we'll talk more realistic system. You have your own chain of abstract and refinements rather than combining with this.

Her is asking about security requirments

MM: So what do you mean by security requirements? Can you give me an example of that?

RA: So security. So here requirement that prevent fraud. Hmm, OK. The user must have a token so the user can sell a property that doesn't belong to them. This is the man. The quality. Yeah, yeah, this is this is from my viewpoint is the

security requirement OK? It's like a bank account. If I don't have money in my bank account, how I should be able to transfer it to another or by a I

NF: I think every good she doesn't have it here. But yeah you did this in the persona analysis when you created your model, yeah, you did personas and then he created some requirements. So those are the functional requirements that result referring to extracted from persona. So apply this to the abstract. But again, what this is saying is for each of the contribution you can come up with a clean system, maybe not too complex and then start to test the security requirements.

RA: Yeah, did incorporate. Yeah. Incorporate the control as a so identify sound like normal, identify wonderful. That is why people are able, for example, to claim ownership of property, or why they are able to sell a property that doesn't belong to them. These are one liabilities. And then what do you do? You incorporate some controls that prevent this, and you're even here.

Good Question about abstract
NF: So how do you know your abstract is is good enough?

RA: Well, discussion, discussion that you did it. You need to validate it in your with your domain. Except, yeah.

NF: So this is what you were expecting to see Like, yeah, so that had the a clean system.

RA: Yes. So this is, this is what we had basically two days because she had a model, we said, OK, this model, for example, has ownership but no property. Ownership without property doesn't mean anything. We have multiple owners. She couldn't see it or she didn't at least include it in this model. So partition between ownership buyers and sellers is not necessarily valid. In some cases you can buy more share of the same property, so you are owner as you increase your share can happen, you can sell your share, have changed some. These are these are informal validation after the main single you know,

Another answer from AS
good abstraction. So different people's is based on human judgement, satisfying the dominant expertise.

NF: It's like in like in from a software requirement point of view, you list your functional requirement and then you start to test these requirements. If the tests are passed, I'm fine. That means you have a complete picture. So I'm not a formal methods person. So I thought the modelling should should test for these and say oh this property satisfied, satisfied. This is how I know that my system is complete. But here we're talking about do I have the right element to begin with, Do I have the right requirements? So should she come to you with the list of requirements. 1st and say these are my requirements, I'm going to model them. Yep. Or say no. This is how my users, my processes, my everything. This is my abstract model, because if the abstract model itself using the formal verification can run these tests, then you only need the requirements.

RA: So it depends what do you mean by testing. So do you mean unit testing, Integration testing? Do you mean acceptance testing? So acceptance testing in a sense is a validation, is not a verification other kind of test our verification code. So, but in normal software engineering we do it late maybe or maybe by focus group and other things we discussed the requirement to see whether we captured the essence of the system. So so always we tell our students. So verification and validation. Validation. Am I building the right system? Yeah OK ohh I am I building I find fantasy system that doesn't have any link with the reality and and this has both aspects. So, So the proof basically proved that we have an event-b we mostly is helping with the verification, not validation. Verification validation happening by, you know, describing your system in term of some functionality and whether this functionality makes sense or not.

SH: so I just realised that you. So do you see the ownership? You want to have treatment, just sign on. Yeah, yeah, yeah. Because, you know, talk about the fraud that you need to have your owner and the seller to be separate because you can say that you're the seller must be the owner of the property or something like that, or part of the properties. so you need to do all this again,

Here is showing them list of requirements

RA: Does she need to think very carefully about the requirements.

SH: And I think I saw that you actually have a list of requirements that actually you put your starting point and then we can look at it and yeah, we can look at the requirement.

Here Reza Asking if modelling requirement is essential using formal modelling

RA: But The thing is whether these requirements are modelled in the formal model or not.
RA: **the system manages a set of registered user. This is not a requirement, right? This is the description description of the system.**

NF: OK for example RQ- 6 and 7. This is required. A user can only have a user can, yeah, register users. Yep,

SH: around 5 hours. I must say that this one is probably you know we we probably will put a question mark on that because you know the notion of owner and purchase or you know is something that so the two type ownership.
Register user is Env

RA: So in everyone's book these are environment EE and we rather than functional requirements. So yeah, yeah, yeah, depend on how need to buy that. There are two type of ownership, So what are they? You have to include them here. Yeah, the owner must own a property.

Here SH points that the owner can be derived from the set, dom of ownership is owner.

SH: Again, it's gonna be user not enough. I cannot say user not on. Well, you know it. It seemed like you know the the owner here is actually, you know kind of derivable from the ownership relationship. So if you look at the ownership relationship clearly you see that your that your who actually had the owner and then the requirement seeks. We REQ-6 challenged it. If you have percentage, but if you go for the simplest system is a different story. A user can register an account with the system directly. Yeah. So when you say register an account with the system directly, all of this could be misleading. Yeah, because it does. It means that you have account there. I worry about representing account or you could you could you could just simply say. I, I, I users should be able to register with the system. The system managed the set of registered users. So yeah, this is the description of the system in part. Partial description manager set up property. Again

Here feedback of tool of that help to write a SRS

NF: this is I can, I can help you realise this. I was just thinking maybe **Moscow** would be a good tool to explain what things went in the abstraction and what things got excluded from the abstraction for the complexity. What do you think

Commented [MA7]: 3

RH: Well, my student use it, yeah. Uh, I don't have any experience of using that. So I must say that Moscow is must shoot. Yeah. Could. Yeah. So prioritise your requirement, flashing your faulty

NF: Yeah actually I mean if you have an example that would be useful too and I will help her to rewrite yeah, this requirement.

MA: Moscow is prioritisation.

NF: Yes, Yeah, yeah, yeah. We should have put You have, can, won't have. Yeah. And as I said, you can't have. Maybe you can't achieve this amazing abstraction that has all the complexity that you need. So you put the prioritisation and all of the thing in the must have must be in the abstraction.

RA: Well what I found it useful maybe SH has a different experience but for a system. So if you remember in deploy with over the ***cruise control*** we had a lot of heated discussion and yeah the result was so many years ago we were involved in a project, big project and one of the case study was about cruise control. Cruise control is a system in cars that allow you see the speed in motorways and then without pressing the accelerated the card will continue until you

you break or something you put your your feet on break or something. So the company that was partner in the project given us a specification like this one few 100 pages of specification and **John Lemon** was there and he he said why should I need to to look at all so this can you tell me in a sentence what the system does or few sentences. So here you have to have a high level description of the system. So what? **What is the purpose of this system**? In this country we call it Land Registry. I don't know what it's called. This is representation of Land Registry. When authorised these that they have ownership of property can can can sell that property to someone that wants to to buy so that that high level description give me stay focused state of mind. So this is about Land Registry, about ownership, about users, few concepts you know buyers and sellers and then I can I can lease my requirement in an abstract way. So rather than having a partial description like this. So this system is not about only managing users, it's about Land Registry. And one thing it, it will involve a lot of register now users that they have ownership and some others that they are registered but they they don't have perhaps ownership at the moment or they might have if they are first time buyer they don't if they are selling other properties they have And then it is about linking each of us just the user that has a property should should be linked to the property and then it's about advertising and selling and transferring ownership. So few clear requirements.

Commented [MA8]: 4

NF: Awesome.

RA: Yeah, so here, So for example in **requirement 8** you say the system manages is set up property. The system managers are set up users. So I might find these contradictory because you haven't given me the high level specification of the system. If you sentences, uh, all properties should be so not all properties. All the properties known in the system should be on by some registered users. So and and so so in. In Arabic it is normal to use multiple terms, but in technical this could be two things. Yeah could be confusing. So the the property can be sold to owners to another statement to purchases. If if you are going for the simple system. So each property has one owner one purchase, right? So don't say other owners and or purchases. So this is the specification of the more complex system that you mentioned. Can be exchanged before. So again, this is the property information can be exchanged. How do you model this? How do you model this in your system? You don't include the requirement that you don't model in your system.

SH: Must be one to model that you'll put the information, yeah? Anyway, no, don't waste time. Continue reading this, I'll help her. And then you have a yeah, so this decide. So to summarise, decide with a clear concise specification of the system. So this is a this is representation of Land Registry system. In a Land Registry system, we have registered users that they can be owners of properties and then they can put forward their properties for selling and a registered user can can act or can be a buyer or purchaser. Use one single term buyer or purchaser, not both of them. If a property is put forward for selling, a purchaser can request purchasing that property and then the ownership can change at some stage. OK, so this has all the high level stuff.

MM: OK, what's that mean?

Here is good comments

NF: There's a method in software engineering software, software of prototyping by. Basically, you have one stakeholder and you use the stakeholder to reiterate and create the software. Do you mind if she worked with her to work on a set of property of the requirement she comes to you? Maybe some, maybe not. At the same time, Yeah, just say hey, can I have a quick look at the requirements and then once she has like OK, I have a feedback on them, then she can start to build her abstraction. Yes. OK,

RA: Do you think it's so much for your time?

SH: Yeah, I just realised that now this is very interesting and a lot of you know when we discussed you know a lot of interesting things about your complexity. So with the system itself to most of these kind of complexity came from the system itself. It's not because of you know of the the modelling or anything like that. You know some of these things is actually very tricky to to realise. You know the kind of thing like you know you can buy the share of the other owner so mean that you know they're both, you know trying to owner their own and buy the same property at the same time and things like that. And what are the kind of you know, challenge the the safety constraint that you want to put there for example. It's not only that you know you have the set of you know ohh owner and they try just try to rearrange the

the percentage and they are all regularly buyer in general and you know and then sell them at the same time of the same property. So yeah just try to how to displane that. OK. So yeah so there's a lot of interesting things you know and and I understand that there's a token is actually the the ultimate new implementation detail that that that you know that is my worry.

RA: This is why I thought maybe if she she she worked with a simplified version of the system might be more realistic

SH: . I mean I I can see you know the way how, how how to to to model this. So it's a token. It's a a good way to represent her. Well, I mean you're talking certainly you know the implementation implementation of the ownership issue. Yes, right.

RA: So so when you start you start with the functional requirement that I told you and then you, you think about security aspect. So what is the main security requirement of this system? No one who is the true owner of a property should be able to put forward a property for sale and selling, right? OK, this is the main you might have others security requirements, but let's concentrate on this. OK, so how do you establish then the the question is, so that is your security requirement. Then the question is how do we establish that they claimed person is the true owner of the property and how you incorporate this in the main operation of the system. And one way as you mentioned or as I mentioned earlier, you call it certificate, token or whatever is that you have an authority source that issue tokens. So you acquire token and then you use that token for the purpose of the exchange.

Commented [MA9]: 2

MM: how do you model that that that this one, you know the formal method this is it the certificate.

RA: How do you model the authenticated user? So maybe you come up with a simplest version. So someone claim ownership and you divide it to fake ownership and through ownerships, and then you refine these by OK, someone asking for a token. And then obviously you have to introduce the organisation that issued A token and then now you have the issue of valid token or valid token misused or or invalid token. So you have this concept, I mean there's a lot of it is further away. This is why I don't go to much of beacon. When we have your clean functional requirement then we will have the chance to suggest how you incorporate safety, security in high level and then how you refine the security to become a real protocol. OK so for security like like functional requirement you have a a high level description right? And the high level description here is that the system should be able to identify authorised users from unauthorised users. OK, this is the higher one, but how you do it in reality is is quite complex type in in the examples that we use for teaching in my MSC module and I think still some uses. There is an example from Michael so about access to a building in a very high level specification says people either register or unregister. When they register they should be either inside or outside. Initially we decide there are outside and then bring the example from Michael Butler, the registered user. Yeah. So and then when they move in and out, we have simple operation. But even that model after that fuel level, it's very high level. So security still is not incorporated in a clear way. Then you might say OK people, they have card or token and then acquire cards card is valid for or CARD is valid for a while. But like I said to him, so

Commented [MA10]: 3

SH: I must say that there's a lot of interesting because yeah, the more when we discuss about it, the more I realise that there is not even though you have token, right, I mean you you would certainly say I want to sell general half of my token rather than I want to sell the whole token. How do you do that? You know, she might need to go for an ideal system. Yeah, that has one ownership only because multiple ownership bring a lot of complexity, but that's the funDMENTAL of it in the main idea moment that this is her final year and she's not. So if she was starting from year one before monetary. Yeah, yeah, yes,. Cautious about them. And I know so umm, how much time it takes with Mohammed abstruction. So we spend one year getting through iteration of refinement. Also make it simple, like only one owner. I think. Yeah it's safer for me. So each each user, owner, owner just one aged only other one.

Bibliography

Raymond Abdulai. Is Land Title Registration the Answer to Insecure and Uncertain Property Rights in sub-Saharan Africa. 2006.

Mark A Abramson and Therese L Morin. *E-government 2003*. Rowman & Littlefield, 2003.

Jean-Raymond Abrial. *Modeling in Event-B: system and software engineering*. Cambridge University Press, 2010.

Jean-Raymond Abrial, Michael Butler, Stefan Hallerstede, Thai Son Hoang, Farhad Mehta, and Laurent Voisin. Rodin: an open toolset for modelling and reasoning in event-b. *International journal on software tools for technology transfer*, 12(6):447–466, 2010.

ACFE. Association of Certified Fraud Examiners - Fraud 101. URL https://www.acfe.com/fraud-101.aspx.

ACFE. Association of Certified Fraud Examiners. Technical report, Report to The Nations on Occupational Fraud And Abuse., 2002.

Fawaz Alasmari. *An Institutional Analysis of State-Market Relations in the Saudi Arabian Housing System: A Case Study of Riyadh*. PhD thesis, The University of Sydney Faculty, 2019.

Ali Alomar. *Registration systems and Assessment of the Implementation of Cadastral Registration System in Kingdom of Saudi Arabia, the First Cadastral District in Huraymila Governorate (case study)*. PhD thesis, King Saud University, 2011.

Aanchal Anand, Matthew McKibbin, and Frank Pichel. Colored Coins: Bitcoin, Blockchain, and Land Administration. *Annual World Bank Conference on Land and Poverty*, 2016.

M. Teresa Anguera, Angel Blanco-Villaseñor, José Luis Losada, Pedro Sánchez-Algarra, and Anthony J. Onwuegbuzie. Revisiting the difference between mixed methods and multimethods: Is it all in the name? *Quality and Quantity*, 52(6):2757–2770, nov 2018. ISSN 15737845. doi: 10.1007/s11135-018-0700-2.

Khaled Bachour, Richard Wetzel, Martin Flintham, Trung Dong Huynh, Tom A Rodden, and Luc Moreau. Provenance for the People: An HCI Perspective on the W3C PROV Standard through an Online Game. pages 1–10, 2015.

Gordon Baxter and Ian Sommerville. Socio-technical systems: From design methods to systems engineering. *Interacting with computers*, 23(1):4–17, 2011.

Mark Charles Bechtold. *From desert to destiny: Saudi organizational leadership within the Saudi Arabian cultural context*. PhD thesis, Fielding Graduate University, 2012.

Raquel Benbunan-Fich and Arturo Castellanos. Digitization of land records: From paper to blockchain. 2018.

Aliaksandr Birukou, Enrico Blanzieri, Paolo Giorgini, and Fausto Giunchiglia. A formal definition of culture.

Robert Bogdan and Sari Knopp Biklen. *Qualitative research for education*. Allyn & Bacon Boston, MA, 1997.

T. F. Booth, E. A. Gould, and P. A. Nuttall. Structure and morphogenesis of Dugbe virus (Bunyaviridae, Nairovirus) studied by immunogold electron microscopy of ultrathin cryosections. *Virus Research*, 21(3):199–212, 1991. ISSN 01681702. doi: 10.1016/0168-1702(91)90033-R.

Richard E Boyatzis. *Transforming qualitative information: Thematic analysis and code development*. sage, 1998.

Virginia Braun and Victoria Clarke. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2):77–101, 2006. ISSN 1478-0895.

Gabriel Brennan. Defining Title Registration. In *The Impact of eConveyancing on Title Registration*, pages 115–151. Springer International Publishing, Cham, 2015.

Peter Buneman, Sanjeev Khanna, and Wang-Chiew Tan. Why and Where: A Characterization of Data Provenance. In G. Goos, J. Hartmanis, and J. van Leeuwen, editors, *Database Theory*, pages 316–330. Springer, 2001. ISBN 3-540-41456-8.

Michael Burrows, Martin Abadi, and Roger Michael Needham. A logic of authentication. *Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences*, 426(1871):233–271, 1989.

Michael Butler, Michael Leuschel, Stéphane Lo Presti, and Phillip Turner. The use of formal methods in the analysis of trust (position paper). In *Trust Management: Second International Conference, iTrust 2004, Oxford, UK, March 29-April 1, 2004. Proceedings 2*, pages 333–339. Springer, 2004.

Victor R Basili1 Gianluigi Caldiera and H Dieter Rombach. The goal question metric approach. *Encyclopedia of software engineering*, pages 528–532, 1994.

Lemuria Carter and Jolien Ubacht. Blockchain applications in government. *Proceedings of the 19th Annual International Conference on Digital Government Research Governance in the Data Age*, (September):1–2, 2018.

James Cheney, Laura Chiticariu, and Wang-Chiew Tan. Provenance in Databases: Why, How, and Where. *Foundations and Trends in Databases*, 1(4):379–474, 2009. ISSN 1931-7883. doi: 10.1561/1900000006.

Edmund M Clarke and Jeannette M Wing. Formal methods: State of the art and future directions. *ACM Computing Surveys (CSUR)*, 28(4):626–643, 1996.

William L. Cleveland and Martin Bunton. *A history of the Modern Middle East*, volume 31. 4th edition, 2009. ISBN 0813343747. doi: 10.5860/choice.31-6219.

CNN. Georgia Expands Project to Secure Land Titles on the Bitcoin Blockchain, 2017. URL https://www.ccn.com/republic-of-georgia-expands-project-to-secure-land-titles-on-the-bitcoin-blockchain/.

CoinDesk. Blockchain Land Registry Tech Gets Test in Brazil, 2019.

John Creswell. *Qualitative inquiry and research design: Choosing among five approaches*. 2007. ISBN 978-1-4129-1607-3 (pbk.).

John W. Creswell. *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. Pearson, 4th edition, 2012. ISBN 9780131367395.

John W Creswell and J David Creswell. *Research Design*. SAGE Publications, 5 edition, nov 2017. ISBN 9781506386690.

Charles T Cullen, Peter B Hirtle, David Levy, Clifford A Lynch, and Jeff Rothenberg. *Authenticity in a Digital Environment*. Council on Library and Information Resource, 2000.

Klaus W Deininger et al. *Land policies for growth and poverty reduction*. World Bank Publications, 2003.

Norman K Denzin and Yvonna S Lincoln. *SAGE Handbook of Qualitative Research*. SAGE Publications, 5 edition, jan 2017. ISBN 9781506365442.

Dana Dghaym, Michael Poppleton, and Colin Snook. Diagram-led formal modelling using iuml-b for hybrid ertms level 3. In *Abstract State Machines, Alloy, B, TLA, VDM, and Z: 6th International Conference, ABZ 2018, Southampton, UK, June 5–8, 2018, Proceedings 6*, pages 338–352. Springer, 2018.

Dana Dghaym, Thai Son Hoang, Stephen R Turnock, Michael Butler, Jon Downes, and Ben Pritchard. An stpa-based formal composition framework for trustworthy autonomous maritime systems. *Safety science*, 136:105139, 2021.

Georg Eder. Digital transformation: Blockchain and land titles. OECD Global Anti-Corruption & Integrity Forum, 2019.

Esther Eijk. Sharia and National Law in Saudi Arabia. In Jan Michiel Otto, editor, *Sharia Incorporated : A Comparative Overview of the Legal Systems of Twelve Muslim Countries in Past and Present*. LeIden Universioty Press, 2010. ISBN 978 90 8728 057 4.

Nawfal Fadhel, Federico Lombardi, Leonardo Aniello, Andrea Margheri, and Vladimiro Sassone. Towards a semantic modelling for threat analysis of IoT applications: a case study on transactive energy. pages 22 (6 pp.)–22 (6 pp.), 2019.

Nawfal F Fadhel, Richard M Crowder, and Gary B Wills. Provenance in the Additive Manufacturing Process. *IFAC-PapersOnLine*, 48(3):2345–2350, 2015. ISSN 24058963. doi: 10.1016/j.ifacol.2015.06.438. URL https://linkinghub.elsevier.com/retrieve/pii/S2405896315006771.

Gershon Feder and Akihiko Nishio. The benefits of land registration and titling: Economic and social perspectives. *Land Use Policy*, 15(1):25–43, 1998. ISSN 02648377. doi: 10.1016/S0264-8377(97)00039-2.

Arlene Fink. *How to conduct in-person interviews for surveys*, volume 5. Sage, 2003a.

Arlene Fink. *How to ask survey questions*, volume 1. Sage, 2003b.

Martin Fowler. *UML distilled: a brief guide to the standard object modeling language*. Addison-Wesley Professional, 2004.

Denis Galligan. *Law in modern society*. OUP Oxford, 2006.

Nurul Imtiaz Abd Gani, Mohan Rathakrishnan, and Hariharan N. Krishnasamy. A pilot test for establishing validity and reliability of qualitative interview in the blended learning English proficiency course. *Journal of Critical Reviews*, 7(5):140–143, 2020. ISSN 23945125. doi: 10.31838/jcr.07.05.23.

Nata Goderdzishvili, Eka Gordadze, and Nikoloz Gagnidze. Georgia's blockchain-powered property registration: Never blocked, always secured: Ownership data kept best! In *Proceedings of the 11th International Conference on Theory and Practice of Electronic Governance*, pages 673–675, 2018.

Nahid Golafshani. Understanding reliability and validity in qualitative research. *The qualitative report*, 8(4):597–607, 2003.

GovInsider. Estonia using Blockchain to secure health records: Blockchain's public sector use goes beyond payments, 2019. URL https://govinsider.asia/innovation/estonia-using-blockchain-to-secure-health-records/.

Jeffrey O Grady. *System requirements analysis*. Elsevier, 2010.

Jennifer C Greene. Preserving distinctions within the multimethod and mixed methods research merger. In *The Oxford handbook of multimethod and mixed methods research inquiry*. 2015.

Lynden Griggs, Rod Thomas, Rouhshi Low, and James Scheibner. Blockchains, trust and land administration–the return of historical provenance. *Trust and Land Administration–The Return of Historical Provenance*, 6, 2017.

Hassan Hamza Hajrah. *Public land distribution in Saudi Arabia*. PhD thesis, University of Durham, 1974.

Aurora Harley. Ux expert reviews. *URL: https://www. nngroup. com/articles/ux-expert-reviews*, 2018.

Adam Hayes. The socio-technological lives of bitcoin. *Theory, Culture & Society*, 36(4): 49–72, 2019.

Jo Henssen. Basic principles of the main cadastral systems in the world. In *Proceedings of the one day seminar held during the Annual Meeting of Commission*, volume 7, 1995.

Melanie Herschel, Ralf Diestelkämper, and Houssem Ben Lahmar. A survey on provenance: What for? what form? what from? *The VLDB Journal*, 26(6):881–906, 2017.

Thai Son Hoang. An introduction to the event-b modelling method. *Industrial Deployment of System Engineering Methods*, pages 211–236, 2013.

Bob Hodge, Robert Hodge, Robert Ian Vere Hodge, and Gunther R Kress. *Social semiotics*. Cornell University Press, 1988.

Geert Hoftede, Gert Jan Hofstede, and Michael Minkov. *Cultures and organizations: software of the mind: intercultural cooperation and its importance for survival*. McGraw-Hill, 2010.

Hilary J Holz, Anne Applin, Bruria Haberman, Donald Joyce, Helen Purchase, and Catherine Reed. Research methods in computing: What are they, and how should we teach them? In *Working group reports on ITiCSE on Innovation and technology in computer science education*, pages 96–114. 2006.

Anthony M Honoré. Ownership. In *Readings in the Philosophy of Law*, pages 563–564. Routledge, 2013.

International Council on Archives. International Standard Archival Description (General). Technical report, Paris, 1994.

International Standards Organization. ISO 15489.1 Records Management Part 1: General. Technical report, ISO, Geneva, 2001. URL https://www.iso.org/standard/62542.html.

Hanna Kallio, Anna-Maija Pietilä, Martin Johnson, and Mari Kangasniemi. Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of advanced nursing*, 72(12):2954–2965, 2016.

Cleverence Kombe, Majuto Manyilizu, and Aloys Mvuma. Design of Land Administration and Title Registration Model Based on Blockchain Technology. *Journal of Information Engineering and Applications*, 7(1), 2017. ISSN 2225-0506.

Heiko Koziolek. Goal, question, metric. In *Dependability metrics*, pages 39–42. Springer, 2008.

Debasish Kundu. Blockchain and trust in a smart city. *Environment and Urbanization ASIA*, 10(1):31–43, 2019.

Cara Lapointe and Lara Fishbane. The blockchain ethical design framework. *Innovations: Technology, Governance, Globalization*, 12(3-4):50–71, 2019.

Dean Leffingwell. Calculating the return on investment from more effective requirements managament. *American Programmer*, 10(4):13–16, 1997.

Victoria L Lemieux. Provenance: Past, Present and Future in Interdisciplinary and Multidisciplinary Perspective. In *Building Trust in Information*. 2016a. doi: 10.1007/978-3-319-40226-0_1.

Victoria L Lemieux. Blockchain and distributed ledgers as trusted recordkeeping systems. In *Future technologies conference (FTC)*, volume 2017, 2017.

Victoria Louise Lemieux. Blockchain technology for recordkeeping : help or hype? *Social Sciences and Humanities Research Council of Canada.*, 1(October), 2016b.

Victoria Louise Lemieux. Trusting records: is Blockchain technology the answer? *Records Management Journal*, 26(2):110–139, 2016c. ISSN 09565698. doi: 10.1108/RMJ-12-2015-0042.

Michael Leuschel and Michael Butler. Prob: an automated analysis toolset for the b method. *International Journal on Software Tools for Technology Transfer*, 10:185–203, 2008.

Martin Maguire and Nigel Bevan. User requirements analysis. In *IFIP World Computer Congress, TC 13*, pages 133–148. Springer, 2002.

Joseph Alex Maxwell. *Qualitative Research Design: An Interactive Approach*. Sage Publications, Inc., 1996.

JD McLaughlin and SE Nichols. Resource management: the land administration and cadastral systems component. *Surveying and Mapping*, 49(2):77–85, 1989.

Nicola McMeekin, Olivia Wu, Evi Germeni, and Andrew Briggs. How methodological frameworks are being developed: evidence from a scoping review. *BMC medical research methodology*, 20(1):1–9, 2020.

Ministry of Justice. MoJ's History, 2018. URL https://www.moj.gov.sa/English/Ministry/Pages/MOJHistory.aspx.

Paolo Missier. The lifecycle of provenance metadata and its associated challenges and opportunities. In *Building Trust in Information*, pages 127–137. Springer, 2016.

Paolo Missier, Khalid Belhajjame, and James Cheney. The w3c prov family of specifications for modelling provenance metadata. In *Proceedings of the 16th International Conference on Extending Database Technology*, pages 773–776, 2013.

Luc Moreau et al. The foundations for provenance on the web. *Foundations and Trends® in Web Science*, 2(2–3):99–241, 2010.

Monera Nahedh. *The sedentarization of a Bedouin community in Saudi Arabia*. PhD thesis, University of Leeds, 1989.

Satoshi Nakamoto. Bitcoin: A Peer-to-Peer Electronic Cash System. *White paper*, 2008. URL www.bitcoin.org.

NASA. What is formal methods?, 2023. URL https://shemesh.larc.nasa.gov/fm/fm-what.html.

National Archives and Records Administration. Blockchain White Paper National Archives and Records Administration. Technical report, 2019.

Nick Szabo. Smart Contracts: Building Blocks for Digital Markets. Technical report, 1996.

Jakob Nielsen. Usability engineering at a discount. In *Proceedings of the third international conference on human-computer interaction on Designing and using human-computer interfaces and knowledge based systems (2nd ed.)*, pages 394–401, 1989.

Benedikt Notheisen, Jacob Benjamin Cholewa, and Arun Prasad Shanmugam. Trading real-world assets on blockchain. *Business & Information Systems Engineering*, 59(6): 425–440, 2017.

Sabine Mertens Oishi. *How to conduct in-person interviews for surveys*, volume 5. Sage, 2003.

Svein Ølnes and Arild Jansen. Blockchain technology as infrastructure in public sector: an analytical framework. In *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*, pages 1–10, 2018.

Tope Omitola, Nicholas Gibbins, and Nigel Shadbolt. Provenance in Linked Data Integration. 2010.

Steve Omohundro. Cryptocurrencies, smart contracts, and artificial intelligence. *AI Matters*, 1(2):19–21, 2014. doi: 10.1145/2685328.2685334.

Jeff Patton and Peter Economy. *User story mapping: discover the whole story, build the right product*. " O'Reilly Media, Inc.", 2014.

Morgen E Peck. Blockchain world-do you need a blockchain? this chart will tell you if the technology can solve your problem. *IEEE Spectrum*, 54(10):38–60, 2017.

Beatriz Pérez, Julio Rubio, and Carlos Sáenz-Adán. A systematic review of provenance systems. *Knowledge and Information Systems*, 57(3):495–543, 2018.

Michael Pidd. *Tools for Thinking; Modelling in Management Science*. John Wiley and Sons Ltd, 2nd edition, 2003. ISBN 0-470-84795-6.

John P. Powelson. *The story of land: a world history of land tenure and agrarian reform*. The Lincoln Institute of Land Policy, USA, 1988. ISBN 0-89946-218-9.

Ratish J Punnoose, Robert C Armstrong, Matthew H Wong, and Mayo Jackson. Survey of existing tools for formal verification. Technical report, Sandia National Lab.(SNL-CA), Livermore, CA (United States), 2014.

Uzair Akbar Raja. Empirical studies of requirements validation techniques. In *2009 2nd International Conference on Computer, Control and Communication*, pages 1–9, 2009. doi: 10.1109/IC4.2009.4909209.

Stroie Elena Ramona. Advantages and Disadvantages of Quantitative and Qualitative Information Risk Approaches. *Chinese Business Review*, 10(12):1106–1110, dec 2011. ISSN 15371506. doi: 10.17265/1537-1506/2011.12.002.

Ridwan. Land Ownership Reform in Islam. *Asian Social Science*, 15(2):164, Jan 2019. ISSN 1911-2025.

Marten Risius; and Kai Spohrer. A Blockchain Research Framework What We (don't) Know, Where We Go from Here, and How We Will Get There. 59(6):385–409, 2017.

F Rizal Batubara, Jolien Ubacht, and Marijn Janssen. Unraveling transparency and accountability in blockchain. In *Proceedings of the 20th Annual International Conference on Digital Government Research*, pages 204–213, 2019.

Oliver C Robinson. Sampling in Interview-Based Qualitative Research: A Theoretical and Practical Guide. *Qualitative Research in Psychology*, 11(1):25–41, 2014. ISSN 1478-0895. doi: 10.1080/14780887.2013.801543. URL https://www.tandfonline.com/action/journalInformation?journalCode=uqrp20.

Markus Roggenbach, Antonio Cerone, Bernd-Holger Schlingloff, Gerardo Schneider, and Siraj Ahmed Shaikh. *Formal methods for software engineering*, pages 1–46. Springer International Publishing, Cham, 2022.

Kathryn Roulston. Data analysis and theorizing as ideology. *Qualitative research*, 1(3): 279–302, 2001.

Frances Ryan, Michael Coughlan, and Patricia Cronin. Interviewing in qualitative research: The one-to-one interview. *International Journal of Therapy and Rehabilitation*, 16 (6):309–314, jun 2009. ISSN 1741-1645. URL http://www.magonlinelibrary.com/doi/10.12968/ijtr.2009.16.6.42433.

S. Kejriwal and S. Mahajan. Blockchain in commercial real estate The future is here ! *Deloitte Center for Financial Services,New York*, 2017.

Kęstutis Sabaliauskas and Aidas Petrošius. Land and Property Administration Reform in Lithuania. In Thea Hilhorst and Frederic; Meunier, editors, *How Innovations in Land Administration Reform Improve on Doing Business: Cases from Lithuania, the Republic of Korea, Rwanda and the United Kingdom*, chapter 3. International Bank for Reconstruction and Development / The World Bank, 2015.

Mar Yah Said, Michael Butler, and Colin Snook. A method of refinement in uml-b. *Software & Systems Modeling*, 14(4):1557–1580, 2015.

Siraj Sait and Hilary Lim. *Land, Law and Islam Property and Human Rights in the Muslim World*. 2006. ISBN 9783319564753.

Siraj Sait and Britta Peters. *Islamic Principles and Land Opportunities for Engagement*. 2011.

Neil J Salkind. *Encyclopedia of research design*, volume 1. sage, 2010.

Outi Salo and Pekka Abrahamsson. An iterative improvement process for agile software development. *Software Process: Improvement and Practice*, 12(1):81–100, 2007.

Mark Saunders, Philip Lewis, and Adrian Thornhill. *Research Methods for Business Students*, volume 4. 4th edition, 2007. ISBN 9780273701484. doi: 10.1017/S0016756800135770.

J. E. Scholtens. Double Sales. *South African Law Journal*, 70, 1953.

Frederik Schwerter and Florian Zimmermann. Determinants of trust: The role of personal experiences. *Games and Economic Behavior*, 122:413–425, 2020. ISSN 0899-8256. doi: https://doi.org/10.1016/j.geb.2020.05.002. URL https://www.sciencedirect.com/science/article/pii/S0899825620300671.

Jeremy Scott, Stavros Marcou, and Charbel Sabeh. The Land Titles System and Practice in the Kingdom of Saudi Arabia, 2019.

Qiuyun Shang and Allison Price. A blockchain-based land titling project in the republic of georgia: Rebuilding public trust and lessons for future pilot projects. *Innovations: Technology, Governance, Globalization*, 12(3-4):72–78, 2019.

Mary Shaw. Prospects for an engineering discipline of software. *IEEE Software*, 7(6): 15–24, 1990.

Christina Silver and Ann Lewins. *Using software in qualitative research: A step-by-step guide*. Sage, 2014.

David Silverman. *Doing Qualitative Research*. SAGE Publications, London, 5th edition, 2017.

Smart Dubai. Blockchain Dubai, Dubai Blockchain Strategy, Smart Dubai, 2020. URL https://www.smartdubai.ae/initiatives/blockchain.

Colin Snook. iuml-b statemachines. 2014. URL https://eprints.soton.ac.uk/365301/.

Colin Snook and Michael Butler. Uml-b: Formal modeling and design aided by uml. *ACM Transactions on Software Engineering and Methodology (TOSEM)*, 15(1):92–122, 2006.

H Squires, J Chilcott, R Akehurst, J Burr, and MP Kelly. A framework for developing the structure of public health economic models. *Value in Health: the Journal of the International Society for Pharmacoeconomics and Outcomes Research*, 19(5):588–601, 2016.

Kurt C Stange and Benjamin F Crabtree. Publishing Multimethod Research THE POTENTIAL AND THE PROBLEM. *ANNALS OF FAMILY MEDICINE WWW.ANNFAMMED.ORG*, 4:292–294, 2006. doi: 10.1370/afm.615. URL http://www.annfammed.org/cgi/content/full/4/4/292.

Miroslav Stefanović, Sonja Ristić, Darko Stefanović, Marko Bojkić, and Dorde Pržulj. Possible applications of smart contracts in land administration. In *2018 26th Telecommunications Forum (TELFOR)*, pages 420–425. IEEE, 2018.

Nick Szabo. Secure Property Titles with Owner Authority. *Nakamoto Institute*, pages 1–5, 1998. URL https://nakamotoinstitute.org/secure-property-titles/.

Testbed. The Land Registry in the blockchain-testbed. Technical report, 2017.

Vinay Thakur, M. N. Doja, Yogesh K. Dwivedi, Tanvir Ahmad, and Ganesh Khadanga. Land records on Blockchain for implementation of Land Titling in India. *International Journal of Information Management*, (April):0–1, 2019. ISSN 02684012. doi: 10.1016/j.ijinfomgt.2019.04.013.

The World Bank. Electronic Government and Governance: Lessons for Argentina Paper. Technical report, 2002. URL www.cristal.gov.ar.

Marinos Themistocleous. Blockchain technology and land registry. *Cyprus Review*, 30 (2):195–202, Sep 2018. ISSN 25478974.

Marinos Themistocleous, Kypros Stefanou, Christos Megapanos, and Elias Iosif. To chain or not to chain? A case from energy sector. In *Lecture Notes in Business Information Processing*, volume 341, pages 31–37. Springer Verlag, 2019. ISBN 9783030113940. doi: 10.1007/978-3-030-11395-7_3.

Edward C Tomlinson, Andrew K Schnackenberg, David Dawley, and Steven R Ash. Revisiting the trustworthiness–trust relationship: exploring the differential predictors of cognition-and affect-based trust. *Journal of Organizational Behavior*, 41(6):535–550, 2020.

Abdulvahit Torun. Hierarchical Blockchain Architecture for a Relaxed Hegemony on Cadastre Data Management and Update: A Case Study for Turkey. *UCTEA International Geographical Information Systems Congress*, pages 15–18, 2017.

Daniel W. Turner. Qualitative interview design: A practical guide for novice investigators. *Qualitative Report*, 15(3):754–760, 2010. ISSN 10520147.

UNECE. Land administration guidelines. With special reference to countries in transition. Technical report, Geneva, Switzerland, 1996.

Bernardes Vasquez, Zevenbergen Luciana, Dimo JaapTodorovski, and Bastiaan Philip Reydon. Modeling The Complex Land Administration in Brazil. *Geospatial information for a smarter life and environmental resilience*, 2019.

Colin C Venters, Jim Austin, Charlie E Dibsdale, Vania Dimitrova, Karim Djemame, Martyn Fletcher, Sarah Fores, Stephen Hobson, Lydia Lau, John McAvoy, Alison Marshall, Paul Townend, Nick Taylor, Valentina Viduto, David E Webster, and Jie Xu. *Provenance for Sensemaking*, 2014.

Frank E. Vogel. *Islamic Law and Legal System: Studies of Saudi Arabia*, volume 8. Brill, 2000. doi: 10.2307/3087557.

Jacob Vos, Christiaan Lemmen, and Bert Beentjes. Blockchain-Based Land Administration Feasible, Illusory or a Panacea? *Annual World Bank Conference on Land and Poverty*, (March):1–27, 2017. ISSN 0953-8984. doi: 10.1088/0953-8984/19/29/295202.

Jeremy Waldron. Property and Ownership. In Edward N. Zalta and Uri Nodelman, editors, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, Fall 2023 edition, 2023.

Michael R. Welch, Roberto E. N. Rivera, Brian P. Conway, Jennifer Yonkoski, Paul M. Lupton, and Russell Giancola. Determinants and Consequences of Social Trust. *Sociological Inquiry*, 75(4):453–473, Nov 2005. ISSN 0038-0245.

Ashley Wheat, Simon Attfield, and Robert Fields. Analytic Provenance and Distributed Sensemaking. pages 151–161. 2016. doi: 10.1007/978-3-319-40226-0_10.

Ian Williamson, Stig Enemark, Abbas Rajabifard, and Jude Wallace. Land Administration for Sustainable Development. pages 11–16, 2010.

World Wide Web Consortium. An Overview of the PROV Family of Documents, 2013. URL https://www.w3.org/TR/2013/NOTE-prov-overview-20130430/.

Balkiz Yapicioglu and Rebecca Leshinsky. Blockchain as a tool for land rights: ownership of land in Cyprus. *Journal of Property, Planning and Environmental Law*, 12(2): 171–182, apr 2020. ISSN 25149407.

Yesser. Proggram Definition, 2019. URL https://www.yesser.gov.sa/EN/ProgramDefinition/Pages/Overview.aspx.

Mete Yildiz. E-government research: Reviewing the literature, limitations, and ways forward. *Government Information Quarterly*, 24(3):646–665, Jul 2007. ISSN 0740624X. doi: 10.1016/j.giq.2007.01.002.

Jaap Zevenbergen. *Systems of Land Registration Aspects and Effects*. NCG, Nederlandse Commissie voor Geodesie, Netherlands Geodetic Commission, Delft, The Netherlands, 2002. ISBN 9061322774.

Jaap Zevenbergen. A Systems Approach to Land Registration and Cadastre. *Nordic Journal of Surveying and Real Estate Research*, 1, 2004.

Jianying Zhou and Dieter Gollmann. Evidence and non-repudiation. *Journal of Network and Computer Applications*, 20(3):267–281, Jul 1997. ISSN 10848045. doi: 10.1006/jnca.1997.0056.